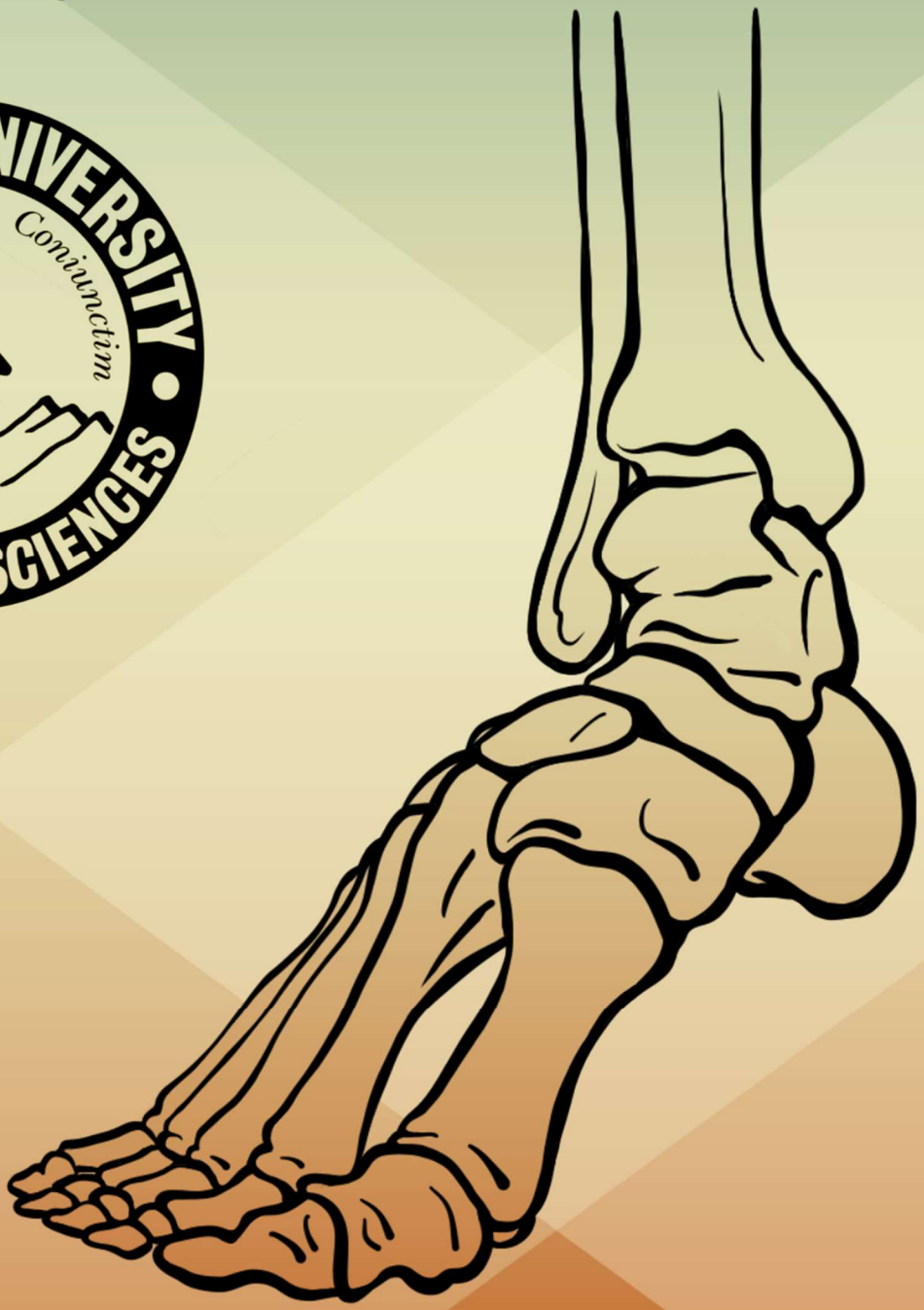
EXTREMITAS

Journal of Lower Limb Medicine



Vol. 8 June 2021

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EXTREMITAS
Journal of Lower Limb Medicine

In Memoriam

Dr. David Shofler, DPM, MSHS

August 6, 1980 - May 10, 2021

Dr. Vicki Wedel, PhD

December 20, 1974 - May 15, 2021

This year our college mourns the loss of two beloved professors. During their years at Western University of Health Sciences, both Dr. Shofler and Dr. Wedel were a source of guidance and touched the lives of everyone who had the good fortune to know them. Both had an immense love for mentoring and teaching students, and their impact extends well beyond the classroom.

This edition of Extremitas Journal is dedicated to their memory.

Letter from the Editor in Chief

Dear Readers,

In a year of challenges brought on by the COVID-19 Pandemic, this year's publication is a reflection of resilience of all who contributed to making this edition possible. Students, faculty and administrators have adapted to the demands of remote learning while also enduring personal losses.

This year, we received a record number of submissions from our students, despite these challenges. We commend them for their curiosity, effort, and dedication to honing their research and analytical skills. In this edition, you will find a wide range of topics affecting podiatric medicine today, from surgery and sports medicine to wound care and new issues brought on by the pandemic. This collection of work is a testament to the variety and quality that the *Extremitas Journal* continues to offer every year.

This invaluable opportunity for student research would not be possible without our supporters. We express deep gratitude to our sponsors, whose generosity helps cover the costs of producing this journal, and to the faculty, librarians, and administrators who have facilitated our team's efforts this year. A special thank you to Dean Satterfield and Dr. Shapiro, who have both provided their guidance and encouragement over the years for this student-run endeavor.

Last, but not least, I want to thank my colleagues on the *Extremitas* team whose many hours of meticulous review and comprehensive feedback continues to uphold the high standards of this journal. I could not have found fulfillment in my role without the assistance of my senior editor and the valuable perspectives offered by each editor. For their dedication to this effort, I am tremendously grateful and proud of what we accomplished together.

It is with great pleasure that we present to you the 8th edition *of Extremitas Journal of Lower Limb Medicine.*

Sincerely,

Faiza Zahid

Editor-In-Chief
Faiza Zahid
DPM Candidate 2022

"Two there are who are never satisfied – the lover of the world, and the lover of knowledge."
- Rumi

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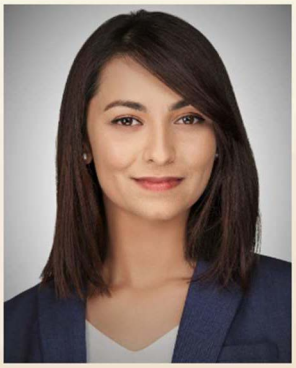

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REFLECTIONS FROM THE TEAM

"It has been truly an honor to be a part of Extremitas for these past couple of years. I hope that everyone who reads our journal can appreciate all the hard work the authors and editors put into making it. I want to say thank you to the team, Dr. Shapiro, and all of our sponsors for making it all possible."

Dy Chin, DPM Candidate 2022

"This year has been nothing short of awesome! It taught me how awesome of a student body that we have at Western. I have loved working with the Extremitas team and learning the importance of teamwork."

Alex Barney, DPM Candidate 2022

"It was really great to work with the wonderful Extremitas team and it was a rewarding experience to see the wide breadth of work from our student body. Thank you to everyone who supported this edition of Extremitas."

Adam Chan, DPM Candidate 2022

"Thank you to everyone who supported the 2021 edition of Extremitas! Despite all the challenges of this year, I'm grateful for the opportunity to work with this team."

Lawrence Chang, DPM Candidate 2022

"Being a part of the Extremitas team this year has been a blessing. It was an honor to learn from unique individuals with bright minds. I am proud of what we have accomplished this past year as a team. I am excited to see how we continue to grow as future DPMs."

Justin Luu, DPM Candidate 2022

"Serving on the editorial team for Extremitas this year has been an incredible opportunity that has furthered my passion for podiatric medicine. I am truly grateful to all involved in the production of this year's journal, especially Dr. Shapiro, our sponsors, and our outstanding team of editors."

Michael Amedeo, DPM Candidate 2023

"It was a privilege to work with such a great editing team on Extremitas this year! The experience taught me the importance of research writing in the scope of lower extremity medicine. Thank you to the authors and sponsors for this year's publication."

Nathan Fischer, DPM Candidate 2023

"In a time when medical science feels especially important, I am honored to have the opportunity to review such great works from this year's authors. Special thank you to our leadership and sponsorship for making this journal possible."

Aleksa Martin, DPM Candidate 2023

Table of Contents

INFECTIOUS DISEASE AND WOUND CARE:

COVID-19 PANDEMIC:

PAIN MANAGEMENT AND REHABILITATION:

SURGERY AND SPORTS MEDICINE

ORIGINAL RESEARCH

The Use of Bone Void Fillers in Diabetic Foot Infections: A look at PMMA and Hydroxyapatite with Calcium Sulfate.

Garrett Wireman A.T.C., B.S., Adam Chan M.S., B.S., and Spencer Sterling B.S.

ABSTRACT

Objective: Diabetic foot ulcers and infections leading to osteomyelitis have posed a challenge to surgeons to eradicate the infection. Comorbidities associated with diabetes such as peripheral arterial disease can limit the antibiotic concentration in vital areas such as the lower extremity. This study seeks to review the use of bone fillers and their use in local osteomyelitis and diabetic foot infections.

Methods: This literature review utilized the PubMed search engine to query the MEDLINE journal database. Query terms included "polymethylmethacrylate AND antibiotics AND osteomyelitis", "hydroxyapatite AND antibiotics AND osteomyelitis", "(diabetic foot infection OR diabetic foot ulcer) AND bone filler AND osteomyelitis".

Results: The mid-20th century saw the rise of polymethylmethacrylate (PMMA) as a mechanism to better secure hip prosthetics. PMMA soon after was used as a medium for local antibiotic use in osteomyelitis cases. During the 1990's synthetic bone composite, hydroxyapatite with calcium sulfate (HACS) was gaining ground as a medium for local diabetic foot infections. PMMA beads with antibiotics were shown to eliminate infections in 90.4% of feet while HACS eliminated infections in 90.0% of feet.

Conclusion: PMMA and HACS have similar efficacy in removing the presence of infection in osteomyelitis. However, HACS use has advantages over the use of PMMA. HACS does not need to be removed after placement as is all-natural composite that the body uses for osseous formation. Antibiotic use of HACS remains in the tissue for a much longer time with higher concentrations compared to that of PMMA. Both PMMA and HACS therapy are effective adjunctive treatments for osteomyelitis.

Introduction

Among diabetic patients, nearly 6% are affected with a diabetic foot ulcer (DFU) and an additional 25% may develop an ulcer in their lifetime.[1] Vascular disease and foot deformities in combination with peripheral neuropathy are the major risk factors for developing a DFU. Because of these complications, the risk of a lower limb amputation is approximately fifteen times greater in a diabetic patient than in a non-diabetic patient.[2]

One consequence of DFUs that often lead to lower limb amputations in the diabetic patient is the increased prevalence of infections. These can present as infections of the skin, muscle, or bone. In diabetics, chronic bone infections, or osteomyelitis, are most commonly seen. The primary cause in this population is the contiguous spread from tissue to tissue traveling in a superficial to deep direction of travel.[3] Infections of bone progresses via the following: (1) inflammatory destruction, (2) necrosis of bone, (3) new bone formation.[4] However, these infections progress from acute to chronic status without clearing due to the complications of vascular insufficiency and diminished immunocompetence.[5] Biofilm formation is a common complication in chronic osteomyelitis. Biofilms first begin to form as the bacterial colony encapsulates itself in a matrix of polysaccharides and extracellular matrix that help it to avoid the immune system.[6,7] In addition, biofilms are associated with a lower metabolism of the bacteria within leading to lower effectiveness of antibiotic treatment.[7]

Typically, a surgical and medical approach is warranted as treatment for chronic osteomyelitis. Medically, this includes a regimen of antibiotics, with a preference to those with a higher diffusion into bone. However, biofilm formation has a diminished response to antibiotic treatment. As such, both a medical and surgical approach has been warranted and has been shown to have increased healing rate when combined[8]. Current modalities to address chronic osteomyelitis include multiple steps. Commonly, surgery is used to resect unviable bone as well as any infected soft tissue.[5,9] To reduce the risk of recurrence, aggressive soft tissue resection of surrounding tissue is employed. Intraoperative anaerobic, aerobic, and fungal cultures of surrounding tissues may help to

spare tissue while preventing recurrence. Following resection, multiple techniques are employed to resolve any dead space. Dependent on the goals of surgery, the techniques range from maneuvering soft tissues and bone to the use synthetic bone substitutes with or without loaded with antibiotics.

Synthetic materials offer the opportunity to introduce high concentrations of antibiotics as well as resolve any dead space caused by removal of infected tissues and bone. The materials can be introduced as cement for prosthetic joints, as bone grafts, or as free-standing beads.[10] The properties of the materials have benefits based on the rate the antibiotics are able to be absorbed locally while also avoiding many of the systemic side effects.[11,12] Given the advantages compared to the current standard of care of surgical resection and systemic antibiotics, this review will explore two examples of these synthetic materials in the treatment of osteomyelitis.

The first example, polymethylmethacrylate (PMMA) has been used in medicine since the mid 20 century. PMMA is known to have been first used in 1951 by Schnebel as a mechanism to better secure the placement of a stem hip arthroplasty prosthetic. Shortly after, Charnley, in 1960 used the same mechanism to secure a double hip prosthetic. The first published use of PMMA in anchoring of prosthetic devices was in 1988.[13] However, its synergistic use with antibiotics was originally described by Buchholz and Engelbrecht in 1970 for use in hip arthroplasties.[14] Klemm of Germany worked off of Buchholz and Engelbrecht, by applying these principles of PMMA with antibiotics to debrided osteomyelitis debridement that had dead space. His original trial results were not as prosperous as reasons as "lack of drainage, limited formation of granulation tissue, and difficulty in removal of the cement plug". Klemm found better results early in the 1970's after PMMA loaded with gentamicin was placed on surgical wire, allowing for future removal. PMMA loaded with antibiotics has now been used routinely in the neck, abdominal, colorectal, and vascular surgery[14]. PMMA has wide use acceptance due to its properties. It acts as a transmitter of force and stress from the prosthetic to the osseous tissue while not engaging in a primary chemical bond.[13]

Methods

This literature review utilized the PubMed search engine to query the MEDLINE journal database. Query terms included "polymethylmethacrylate AND antibiotics AND osteomyelitis", "hydroxyapatite AND antibiotics AND osteomyelitis", "(diabetic foot infection OR diabetic foot ulcer) AND bone filler AND osteomyelitis". The results of these queries yielded publications that provided background information to begin our review.

Results

Polymethylmethacrylate

Antibiotic laden PMMA is commonly introduced as either a cement for prosthetic joint replacement, or as beads of varying size.[10] Dependent on cultured organisms, multiple antibiotics may be used locally to tackle the infection. Unlike systemic antibiotic use, PMMA can provide high concentrations with few to no side effects. Studies have found that the localized concentration of antibiotics are able to reach local levels of 20-200 mg/ml, multiple times higher than the minimum inhibitory concentration[15,16]. Studies have also demonstrated that systemic levels of the antibiotics range from 0.4 ug/ml to 2ug/ml, well below any risk of adverse effects.[17]

Antibiotics used with PMMA are limited due to needing to withstand up to 100 c temperature during the exothermic reaction of creating the PMMA.[10,18] When antibiotics are introduced, the stability of the structure is weakened, but this may not be an issue due to low demand for strength in certain areas of the foot.[19-21]

Schade and Roukis performed a retrospective observational study where they used an aggressive irrigation and debridement protocol combined with antibiotic-loaded PMMA in foot and ankle patients with soft tissue and osseous infections. A total of 36 feet and ankles were studied from 35 patients. Before PMMA bead implantation, all patients had a confirmed infection. After removal of the beads, 73 cultures were obtained. 66 showed no bacterial growth while 7 were positive for bacterial growth (9.6%). The most common organism was found to be methicillin-resistant Staphylococcus aureus. They found that antibiotic-loaded PMMA beads was a good adjunctive therapy.[13]

Hydroxyapatite with calcium sulfate

Hydroxyapatite with calcium sulfate has become an alternative to PMMA. Calcium sulfate alone has a known toxicity when used as an allograft alternative, but the addition of hydroxyapatite is shown to reduce the toxicity.[22] Calcium sulfate with hydroxyapatite dissolves at different rates, allowing for a porous scaffolding that allows for vasculature and bone remodeling.[23] Compared to PMMA, the osteoconduction and dissolvability of the materials eliminates the need for a secondary procedure for a possible immunocompromised patient.[24]

Calcium sulfate with Hydroxyapatite is osteoconductive with easy use of injection and molding the product, allowing for recreation of osseous architecture and support.[25,26] This material more compatible for a wider use of antibiotics to be used in a variety of delivery methods, from an allograft alternative to beads. A recent study by Rauschmann et al demonstrated that efficacy of the material was increased by adding the antibiotics after the material had been sterilized to prevent possible interference of the antibiotic with sterilization techniques.[27] The dissolution properties of the two mixed substances allows for faster and greater amounts of local antibiotic, four times higher concentrations than with PMMA.[28] Rauschmann, et al demonstrated that when iohexol is added to the hydroxyapatite with calcium sulphate that not only can heat stable antibiotics can be used but also heat unstable antibiotics.[29] High levels of antibiotics can be added without losing any structural integrity to the materials, unlike PMMA.[30,31]

Niazi conducted a retrospective study of 70 patients. The 70 patients were graded on the Texas Grade for diabetic foot ulcerations and osteomyelitis, all were graded either in 3B or 3D. The aim of the study was to evaluate the outcomes of these 70 patients treated with normal osteomyelitis management with debridement and irrigation along with "adjuvant local antibiotic loaded bio composite" use. The author used Cerament G the manufactured form of calcium sulphate/hydroxyapatite loaded with antibiotics. Within the operating room, multiple bone cultures were accessed for empiric antibiotic use in the Cerament G.[7]

Of the seventy patients, fourteen had peripheral vascular disease and nine had charcot neuropathy. Location of ulcer and infection varied with the majority having forefoot involvement, at 62%. Hindfoot was involved 33% with midfoot having 5% involvement. Fifty-three of the seventy patients acquired polymicrobial infections where *Staphylococcus aureus* had the highest occurrence. Follow up with patients was until either the ulcer healed, or the infection was completely void. The average follow-up time was 10 months. Complete terminations of infections occurred in sixty-three of seventy patients, a success rate of 90%. Seven patients did not have successful long-term outcomes, with five of these resulting in below knee amputations. These seven non healing patients had multiple comorbidities contributed to the poor outcome.[7]

Discussion

Diabetic Ulcer infections of soft tissue and osteomyelitis have been a challenge to the medical practitioners due to individual case complexity and avoidance of recurring infections. With the gold standard of care for osteomyelitis being surgical debridement and antibiotics being compared with the adjunctive treatment of localized induction of antibiotics via synthesized beads, there is a marked increase in the efficacy. Even with the limitations of the effect of the antibiotics on structure or antibiotic choice, the benefits of PMMA in its antibiotic formulation have been demonstrated.[13]

With the introduction of hydroxyapatite with calcium sulfate, many of the disadvantages to using PMMA are abated. With its properties of being osteoconductive, pliable, and having antibiotics imbedded after sterilization make hydroxyapatite with calcium sulfate more adaptable to more situations while also broadening the choice of antibiotic employed.[7]

Conclusion

This review explores the efficacy and outcome benefits of both PMMA and hydroxyapatite in its use in the treatment of osteomyelitis. One area that has not been explored are some of the cost or charge of these therapies. Although the cost/benefit has not been shown, the effectiveness and outcomes of the adjunctive therapies remain clear. Both PMMA and HACS therapy are effective treatments for osteomyelitis.

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Honey, I shrunk the Ulcers: The Effectiveness of Honey Based Alternative Interventions as Adjunctive Therapy for the Treatment of Diabetic Wounds

Parth Patel, B.S.

ABSTRACT

Objective: To discuss the current research on the properties of honey in implementation of diabetic wound care.
Methods: Various studies were analyzed with respect to healing potential, biochemical effects, and statistical validity. Multiple internationally and locally based research studies and articles are cross referenced to provide the scope of current knowledge and to discuss content gaps. Databases include Google Scholar, Wiley, and Elsevier.
Results: Honey use on wounds, whether in diabetic patients or mice models, was either better than or comparable to conventional treatments in multiple studies. Other studies, although validating the positive effect of honey toward healing, argue in favor of the necessity for higher-powered studies without any bias. Honey may have bacteriostatic and bactericidal features due to its hyperosmotic and acidic nature. Curcumin may be an important additive to honey for use in wound care due to its pro-angiogenic and anti-inflammatory nature.
Conclusion: The effectiveness of honey as an alternative intervention for treatment of diabetic wounds shows promise. Further higher-powered studies are needed comparing honey against turmeric-honey and conventional methods of treatment.

Introduction

Diabetic wound care is increasingly in demand given projected cases increasing to 366 million by 2030[1]. Hyperglycemia induced by diabetes mellitus has a detrimental effect on wound healing and closure.[2] Wound healing consists of three phases: Phase 1 as inflammatory, phase 2 as proliferative, and phase 3 as regenerative. The inflammatory stage marks the production of cytokines, mediators of inflammation, and growth factors. Recruitment of fibroblasts occurs in the second stage while ECM buildup occurs in the final stage.[3] Wound chronicity may stem from the 1st stage, suggesting prolonged inflammation as the culprit to non-healing wounds.[1] Wound beds are known to host polymicrobial populations, with greater variability of species in chronic wounds.[4]

Diabetic patients have significantly higher levels of free radicals due to the formation of advanced glycation end products, which in turn drive an increased level of inflammatory cytokines such as TNF-a and IL-1.[5] Patients with non-healing wounds also have higher levels of matrix metalloproteinases that limit growth factor efficacy via reactive oxygen metabolites and break down ECM needed to create essential scaffolding for healing tissue.[5]

Conventional wound dressing comprises of iodine and gauze, while functional dressing includes hydrocolloid materials forming a gel with liquid presence.[6] Other formulations that have been used in wound are silver nitrate, hydrogen peroxide alone, silver sulfadiazine, and neomycin.[7]

Honey use for wound healing can be traced to the Edwin Smith Papyrus about 3500 years ago. It is hypothesized to promote angiogenesis and healthy granulation from its ability to generate hydrogen peroxide at small concentrations.[4, 8] Honey has shown bactericidal and bacteriostatic properties against gram positive, gram negative, aerobic, and anaerobic bacteria. The biochemical composition of honey includes a variety of enzymes, phenols, flavonoids, carotenoids, Maillard reaction products, kynurenic acid, B vitamins, ascorbic acid, and trace amounts of elements including Mg, Zn, Fe, Cu, Se, F and Si.[9] Thus, research on the efficacy of honey on wound closure can prove to be important - if not for the measure of success, then rather insight on future treatments and compositions drawn from nature.

Methods

Articles including case series, pilot studies, randomized clinical trials, systematic reviews, and

meta-analyses are discussed in order to provide insight on current research conducted on the efficacy of honey as a possible treatment for diabetic ulceration. Databases used included Google Scholar, Wile, and Elsevier. Key phrases screened included "Diabetic wound care", "Honey use for diabetic wound care", "Alternative treatments for wound closure", and "Treatments for diabetic wound care". Emphasis is placed on the degree of wound contraction, rate of healing, time of healing, antibacterial properties, and comparison to conventionally accepted treatments.

Results

Kotian et. al studied the cellular mechanisms with regards to honey and wound healing in mice models. Excision wound modeling showed 44.3 ± 9.6% wound contraction at 8 days in comparison to 33.4 ± 5.1 % with control groups (Untreated). Honey treated wounds showed 90.6 ± 1.8% contraction by day 16 verses 87.9 ± 0.6 % with control ($P<0.01$). Increased rate of epithelialization was also significantly higher in honey treated wounds in comparison to control as well. Il-1 beta activity was significantly increased in the honey treated groups verses control. Both control and honey treated groups showed diminished IL-1 beta activity at day 16.[3]

In a study conducted by Acharya et. al comparing Saline + petroleum, honey + turmeric ([1:10]), and honey alone on the effect of wound healing in 2018-2020, the honey and turmeric combination resulted in significantly faster wound contraction than petroleum and saline ($p<0.0001$) and a much better improvement than honey alone ($P = 0.02$). The patient population included 33 diabetic foot ulcers, 6 venous ulcers, and 26 bed sores. Turmeric + Honey treated patients also reportedly had less foul odor as compared to other groups. At 8 weeks, Honey Turmeric treated wounds showed an average of 94.11% contraction with 2.58 cm of linear closure as compared to honey verses saline + petroleum jelly at 75.75%/1.74 cm and 25%/0.45cm, respectively.[1]

In a similar study, Kahn et al concluded turmeric paste showed 68.8% wound healing as compared to honey pasted at 62.45% against the diabetic control in mice after 6 days, followed by complete closure for both treatments in 9 days ($P<0.05$). Mice were diabetically induced via Alloxan monohydrate intra-peritoneal injection. Honey paste included 1:1 wild Apisflorea honey and petroleum jelly while turmeric paste included 1:1 turmeric liquid extract and petroleum jelly. By day 9, near 100% wound healing was achieved in all groups but diabetic control (untreated).[2]

A prospective study by Shukrimi et al. compared the efficacy of honey for Wagner grade 2 diabetic ulcers against 10% povidone iodine with normal saline in 30 patients with mean age 52.1. The honey treated group showed earlier healing at 14.4 days compared to 15.4 days with iodine and saline, suggesting honey as a possible alternative option. The honey treated group resulted in negative cultures for staphylococcus and streptococcus, however showed persistent infection for *Bacteroides* and *Enterococcus.*[10]

In a case series study by Gethin et. al, eight patients with leg ulceration aged 22-83 who had no signs of improvement in the previous four weeks are treated with Manuka honey. Initial size of wounds were 5.62 cm^2 with final area of 2.25 cm^2 on average showing a mean reduction of 54.8% by the end of the study. Pain improvement and odor elimination were among the other outcomes seen in all patients. Interestingly, arterial wounds of the leg were least responsive to this treatment, showing little change in wound size. Acute wounds showed the most improvement. Two patients reported mild stinging after each treatment.[4]

A randomized controlled double-blind study by Ingle et al. that compared honey and IntraSite gel showed no statistical difference with respect to average healing duration or wound size. 27% of patients treated with honey experienced itching, while 10% experienced pain. 31% of patients reported itching after IntraSite gel application, with no reports of pain.[11]

A randomized clinical trial studying the effectiveness of honey incorporated dressing by Jull et. al reported no significant improvement as compared to usual care at 12 weeks' time. The study included a total of 368 participants with 187 given honey and the remaining 181 standard care. Complete healing was achieved in 55.6% of honey treated and 49.7% standard care patients ($P = 0.258$).[8]

Another pilot randomized control trial by Tsang et. al. compared Manuka honey against nanocrystalline silver and conventional methods. Although not statistically significant, DFU's in patients treated with honey had 21% better healing

potential in comparison to conventional paraffin. The honey group showed 86.24% wound healing as compared to 76.9% with paraffin gauze. The study also found the most common microorganism was *Klebsiella* and *Staphylococcus* in the Manuka honey treatment group and paraffin cohort, respectively.[5]

Kamaratos et al conducted a prospective randomized, controlled, and double blinded study to analyze the efficacy of Manuka honey impregnated dressings on diabetic foot ulcers. This study consisted of 63 Caucasian T2DM patients with either treated by Manuka honey dressings (Medihoney) or conventional measures (Saline with Gauze). Mean time to healing was 31 ± 4 days for Medihoney versus 43 ± 3 days for the conventional group. Initial labs taken from wound swabs showed mixed growth in 71.5% patients, 7.9% with pseudomonas, 15.8% with *E.coli*, 3.2% with MRSA, and 1.6% with *Proteus*. 78.13 % of the Medihoney treated patients had sterile wounds by the first week with further 21.87% within the next four weeks. 35.5% of conventionally treated patients had sterile ulcers by the first week with a further 64.5% achieving sterility within six weeks.[12]

Misirlioglu et al studied the effectiveness of honey impregnated gauze against paraffin gauze and hydrocolloid dressing on time of healing and infection occurrence in patients post-split thickness graft procedures. They concluded a statistically significant rate of epithelialization for honey laden gauze when compared with paraffin gauze by 3 days however found no significant difference between honey and hydrocolloid dressing. The study also found an earlier rate of epithelialization for honey against saline soaked gauze, with honey gauze having an average earlier time frame by 4.1 days.[13]

A systematic review by Moore et al. followed seven studies with total N = 264 on honey usage in wound dressing where 167 received honey treatment and 151 received other treatments such as amniotic membrane. They found at 1 week, 58% of honey treated patients spanning these studies showed significant healing compared 19% of conventionally treated patients. However, the overall conclusion was the quality of study among those included were limited at best and possibly influenced by bias.[14]

Another systematic review conducted by Sharma et al analyzed 20 preclinical and 25 clinical studies on the antidiabetic effects of honey. They reported overall inconclusive findings in aggregate due to poor design, limitations, N values, and variability in honey source. They however did find 7 studies showed manuka honey as cost effective and beneficial for diabetic ulcer and wound healing.[9]

Finally, a meta-analysis conducted by Wang et al. investigated the effectiveness of honey dressing on wound healing and bacterial clearance rate/time. Five studies with 616 patients in aggregate produced results that showed positive correlation between honey dressing and greater wound healing ($P<0.01$; OR 1.85). Two other RCT studies were compared, and data suggested increased rates of bacterial clearance and earlier time of clearance with honey treated wounds as compared to traditional methods ($P<0.01$). All 5 observational studies in this meta-analysis was confirmed to show honey could increase healing rate and decrease time while also mitigating risk for amputation.[6]

Discussion

Current or previously tried treatments have benefits, but not without risk. Silver nitrate used on hyper granulated tissue may cause skin discoloration and is detrimental to epithelial health.[7] Povidone Iodine is cytotoxic to wound healing leukocytes, keratinocytes, and fibroblasts and has also been reported to be inactivated exudative fluid.[7] It may also cause contact dermatitis in healthy tissue when treatment is prolonged. Hydrogen peroxide alone may cause air emboli, is cytotoxic towards fibroblasts, and limits circulation.[7] Silver sulfadiazine cream is ineffective for exudative wounds and may be harmful to keratinocytes and fibroblasts.[7] Both Povidone Iodine and Silver sulfadiazine are not recommended during pregnancy.[7] Neomycin is known to cause ototoxicity, nephrotoxicity, and hypersensitivity.[7] Given these risks, the prospect of honey as a useful component to wound healing in diabetics may be beneficial.

Agreement on the degree of success and potential of honey as treatment for diabetic foot wounds seems to be in debate, yet hopeful. Many studies analyzed either show positive effects of honey on wound healing or no significant difference when compared to conventional methods. Either outcome can be deemed beneficial for the prospect of honey in wound care. Although some studies show beneficial findings of honey on wound health, they remain

inconclusive due to protocol issues such as design, variable source of honey, and bias.

The study by Jull et. al contradicts the optimistic outcomes of the other studies, attributing the discrepancy as a result of possible publication bias [8]. Jull et al also notes a funnel plot analysis shows no positive results, suggesting underpowered studies had been reporting positive outcomes based on chance alone. Another hypothesis the authors denote is the overwhelming number of acute wounds in the trials may have skewed results. They found 13 of 18 trials used to compare results had small sample sizes, with 75% of all other trials consisting of acute wound treatment.

Another such case is apparent in the systematic review by Moore et al. However, despite some concerns with protocol and study tangibility, there seemed to be encouraging data produced that attest toward honey usage. A particular point discussed was the high osmolarity of honey as a possible explanation for benefit. Conditions of high osmolarity have been shown to greatly effect infection treatment via mitigation of bacterial growth and initialization of healing. Honey may be a sterile and effective medium to achieve this. Hyperosmolar sugar paste has already been proven more effective when compared to antiseptics in animal models.[14]

Similarly, Misirlioglu et al also elucidates the physical properties of honey itself may play the largest role in the results produced. They believe the hypertonic nature of honey may decrease edema and simultaneously nourish the wound site due to high sugar content.[13] Honey's increased osmolarity results in fluid absorptions from interstitial tissue, which may have a positive effect on local lymphatic drainage.[10, 15] The osmotic pressure of honey is about 105 atm and may inhibit bacterial growth and concurrent high viscosity may serve as a barrier to new infection.[6]

Given the initial swab results of the DFU's followed by the time frame to reach sterility in the study by Kamaratos et al, honey seems to display antimicrobial properties. The authors suggest it is the physical properties of honey, such as hyperosmolarity and acidity, may be the key factor to this.[12]

Honey has a pH of 3.2-4.5, which can explain its inhibition on protease and thereby facilitate increased matrix production.[12, 7] Chronic non healing leg ulcers are alkaline in nature, and a lower PH would inactivate proteases and by effect fortify ECM.[12] The acidity may also release more oxygen into the wound ecosystem, further aiding healing.[6, 7] The PH of honey is largely due to gluconic acid.[7] This may greatly contribute to the antibiotic properties seen on experimentation. The acidity is also thought to increase levels of oxygen released from hemoglobin to subsequently promote granulation and healing.[7]

It is also known that diluted honey can produce hydrogen peroxide, which in turn can stimulate a cascade of macrophages, upregulate VEGF, and promote fibroblast proliferation while simultaneously protecting against oxidation.[12] Naturally occurring hydrogen peroxide has an effect of chemical debridement on wound beds.[13] Hydrogen peroxide (H_2O_2) in honey is produced as a result of glucose oxidase secreted by the hypopharyngeal gland of bees.[7] Levels of Hydrogen peroxide are far below toxic as they are 1:1000 the concentration in antiseptics used in clinical settings.[7] H_2O_2 has also been shown increase fibroblast growth in in vitro studies and stimulate angiogenesis in vivo.[7]

Curcumin efficacy on wound healing in conjunction with and against honey was studied in two of the aforementioned studied. The joint action of honey with curcumin seems to be a byproduct of combined antioxidant properties and hydrophobicity. Curcumin is hydrophobic in nature and has low solubility in acidic environments. However, its degradation is greatly increase under alkaline conditions, suggesting stability in acidic environments.[16] This would suggest a synergistic relationship between the two as the acidity of honey could serve to stabilize the molecular structure of curcumin. Curcumin can attenuate lipid peroxide levels and increase superoxide dismutase, catalase, and glutathione peroxidase.[17] Curcumin acts as a free radical scavenger, thereby decreasing levels of oxidation and diminishing the inflammatory response through direct inhibition of NF-kB.[2] This suggests an intrinsic antioxidant property that can improve wound healing capacity. Curcumin has also been shown to improve wound maturation and collagenation in rat models.[17] It has been shown to increase the rate of re-epithelialization and vascularization, attract fibroblasts to the wound site and have antibiotic properties.[1] In conjunction with honey, the effects can be greatly increased given proper timing and understanding of the stages of wound healing.

Honey has also been used to treated cachexia induced wounds stemming from chemotherapeutic drugs such as vincristine in pediatric patients.[15] This decubitus ulceration was caused by peripheral nephropathy from treatment, not unlike that seen in uncontrolled diabetes.[15]

The antibiotic effect of honey may be another avenue usage in wound care. Honey diluted to as little as 5% showed bactericidal aptitude against MRSA, VRE, and Pseudomonas.[15] Manuka honey itself has been shown to work against MRSA via cell cycle arrest and Pseudomonas via lysis.[12] Additionally, honey stimulates mitosis of B and T Lymphocytes and promote neutrophil phagocytosis.[6] Glucose in honey may also explain the lessening of malodor as bacteria supplement it to create lactic acid rather than ammonia and sulfate compounds via amino acid breakdown.[7] Lastly, unprocessed honey has also been shown to inhibit Gram (+) and gram (–) organisms.[13]

Limitations to honey use in diabatic wound care may include pricing, wide range of bee species, specific plants pollinated, allergies and initial hesitance. Honey may be less effective, or even have a negative effect on chronic wounds. TNF-a and IL-1B are already overexpressed in venous ulcers and chronic wounds, in which case honey could impede healing by increasing the concentrations further.[8] Methylglyoxal, an antibacterial constituent of Manuka Honey, can react with amino acid residues on collagen and create advanced glycation end products (AGEs) – subsequently inhibiting wound repair.[12]

Conclusion

Overall, honey can prove to be an effective mode of treatment for diabetic wounds due to its physical properties such as hyperosmolarity and acidity, intrinsic biochemical composition, and bacteriostatic nature. This benefit could be compounded further by the addition of curcumin. Detailed blinded and high-powered studies need to be completed that account for the exact type of honey, minimal effective concentration, efficacy amongst different diabetic populations, and healing. Further research is needed.

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A Review of Recent Advancements in Negative Pressure Wound Therapy with Irrigation in the Treatment of Diabetic Foot Wounds

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ABSTRACT

Objective: This paper will review the recent advancements in negative pressure wound therapy (NPWT) with irrigation in the treatment of lower extremity wounds and explore the pertinence of these findings in the treatment of diabetic foot wounds.

Methods: A literature search was performed on the Pumerantz Library, PubMed, and Google Scholar to identify recent articles that discussed NPWT with irrigation and its utility in treating infected lower extremity wounds. The terms used in this search were "negative pressure wound therapy with irrigation," "negative pressure wound therapy with instillation," "diabetes," and "diabetic foot wound."

Results: NPWT therapy has been integral in treatment plans for diabetic foot wounds. New studies into NPWT with irrigation reveal that it may be more effective at reducing bacteria and promoting wound healing. These studies particularly focus on the possible benefits of using different solutions, variations in the NPWT device placement, and stress the overall need for larger studies into NPWT with simultaneous irrigation.

Conclusion: NPWT therapy with irrigation is effective at treating infected diabetic foot wounds in theory and on a case-by-case basis. However, these results have yet to be reinforced by a large, robust trial.

Introduction

According to the CDC, in 2017, approximately 23 million adults in America were living with diabetes.[1] As this number grows, so does the prevalence of diabetic foot wounds. The occurrence of foot ulcers, just one type of foot wound, in diabetics is approximately 19 – 34%.[2] Foot wounds are susceptible to infection and are the most common cause of hospitalization and amputation in diabetic patients.[3] Diabetes also significantly complicates the healing process for foot wounds, especially when coupled with other signs of the disease such as neuropathy, poor circulation, and compromised skin integrity. The result is an increased healing time and progression to severe infection.

NPWT is an important tool in the approach to the treatment of diabetic foot wounds. This therapy involves the installation of a vacuum over a sealed wound dressing to draw out debris and pull the wound together to stimulate healing. A study comparing NPWT to advanced moist wound therapy, an alternative conventional therapy, in the treatment of diabetic foot ulcers demonstrated that 43.2% of patients using NPWT achieved complete closure compared to the alternative treatment at 28.9%.[4] These findings are supported by a study on the use of NPWT for partial diabetic foot amputations in which more patients treated using NPWT healed at 56% of 77 patients compared to the control at 39%.[5] NPWT with simultaneous irrigation is a variation of NPWT that builds on the success of traditional NPWT and is being investigated to more effectively treat infected diabetic foot wounds.

The high percentage of Americans living with diabetes highlights the need for improvements to NPWT systems to improve their efficacy in the treatment of infected diabetic foot wounds. NPWT with irrigation has been demonstrated to decrease the wound bioburden in a porcine model more effectively than NPWT alone.[6] Another study using gel models of complex wounds showed that NPWT with irrigation could also provide a steady flow of antiseptic to the tissue beds of complicated wounds.[7] NPWT with irrigation therefore has the potential to contribute important advancements in the treatment of diabetic foot wounds. This paper will look at recent studies that advance the existing clinical understanding of NPWT with irrigation in the treatment of diabetic foot wounds.

Methods

Pumerantz Library, PubMed, and Google Scholar were used to identify publications. Key words used to identify articles of interest included: "negative pressure wound therapy with irrigation," "negative pressure wound therapy with instillation," "diabetes," and "diabetic foot wound." Papers written with a focus on NPWT with irrigation as the primary method of wound healing were included. Articles that were more than 5 years old were excluded to maintain a focus on the most current advancements. Several important articles on NPWT research that were conducted out of the 5-year time frame were included to underscore NPWT as an important advancement in wound care. Studies that did not focus specifically on results from the treatment of diabetic foot wounds were also

included due to the important advancements being studied in the current literature.

Results

In a benchtop study, Davis et al. used a clear synthetic ballistic gel as a model to assess whether NPWT with simultaneous irrigation is able to deliver irrigation solution throughout a simulated wound bed. Deionized water with blue food coloring was used to represent irrigation solution. The solution was administered to a complex wound bed model at 100 cc/minute then visualized through the transparent ballistic gel. The ability of the irrigation solution to cover the wound was assessed visually. Researchers determined that even in gel models with undermining and tunneling, NPWT with simultaneous irrigation achieved effective distribution throughout the wound bed.[7] Additional studies in the current literature analyze how the results from the model developed by Davis et al. translate to patient-based studies.

An open prospective study by Ludolph et al. assessed 267 patients with chronic infected wounds treated with surgical debridement and NPWT with computer-controlled irrigation. This study found that the treatment significantly reduced the bacterial load in various chronic infected wounds. Swabs from each patients' wounds were taken and analyzed for changes in the bacterial load over time. Each wound was treated with NPWT with instillation of 0.4 mg/1 mL of polihexanide (Lavasept ®, B. Braun Medical AG, Germany). Instillation volumes for each patient were set according to the dimensions of the wound and dwell time was set to 20 minutes. Cycles were repeated every 2 hours and pressure was designated to be -125 mm Hg. In 111 of the patients who underwent a minimum of 4 operations, a swab of the wound was collected at the first and fourth operation. When compared, researchers discovered the mean amount of bacteria showed a significant ($P < 0.001$) decrease of 65% between the two operations.[8] Alterations in the application of NPWT devices to infected wounds were tested in a subsequent study involving sub-flap placement of an NPWT device.

A retrospective study by Kurlander et al. assessed a novel flap plus sub-flap irrigation technique with NPWT for infected extremity wounds. This study looked at 8 patients over a mean follow-up time of 21 months who had reconstructive surgery for infected extremity wounds and were treated with this surgical variation of NPWT with irrigation. The technique involved tubing for the irrigation placed under the flap insert, with the foam sponge placed superficial to edges. The pressure of the NPWT device was set to -100 mmHg and delivered 50 mL of 0.5% sodium hypochlorite solution every 4 hours with 15 minutes of soak time. Two patients experienced delayed wound healing however, there were no post-reconstruction infections. There were also no total or partial flap losses.[9] Additional studies on a larger scale compared to that of Kurlander et al. compared traditional NPWT against NPWT with irrigation.

In a 150 subject, 16-week, prospective randomized clinical study, Lavery et al. compared wound healing using traditional NPWT to NPWT with simultaneous 0.1% polyhexanide-betaine irrigation. Diabetic patients with moderate or severe foot infections were treated using the Cardinal Health PRO Therapy NPWT system. The devices were set to 125 mm Hg continuous pressure and with solution administered at 30 cc per hour. Wound closure was defined as total epithelialization of the wound and no dehiscence or drainage. The result was that there were no statistical differences in wound characteristics, treatments, or outcomes between the two evenly split groups, one receiving traditional NPWT and the other receiving NPWT with irrigation. One notable outcome of the therapies analyzed however, was wound dehiscence of surgically closed wounds which occurred in 78.0% of patients treated with traditional NPWT compared to 63.4% of patients treated with NPWT with irrigation ($p = 0.08$). Another notable outcome of the therapies was median time to heal, which was 42.0 days for patients who received NPWT with irrigation while for those treated with traditional NPWT, time to heal was 51.0 days (Log rank (Mantel-Cox) $p = 0.24$).[10]

In a 90 patient, 12-week prospective randomized clinical study, Davis et al. further compared wound healing for complex foot wounds using NPWT with simultaneous irrigation to two traditional NPWT devices (KCI VAC Ulta, San Antonio, TX and Cardinal Health, PRO, Dublin, OH). In this study, devices were set to deliver 125 mmHg of continuous pressure and patients using irrigation received saline irrigation administered at 15mL per hour. Davis et al. determined that NPWT with simultaneous irrigation did not yield any statistically significant differences in outcome for diabetic patients with moderate to severe infections. Although not statistically significant, one notable result for wound healing for NPWT with simultaneous irrigation was a 63.3% wound healing rate compared to 50.0% for the Cardinal Health, PRO and 46.7% for the KCI, VAC Ulta ($p = 0.39$). Additionally, NPWT with irrigation demonstrated 83.3% surgical wound closure compared to the Cardinal Health and KCI devices at 80.0% and 63.3%, respectively ($p = 0.15$).[11]

Discussion

The recent advancements in NPWT with irrigation show that this therapy can be used to irrigate a complex wound, reduce bioburden in infected

wounds and reduce post-reconstruction infection.[7,8,9] Many of the studies also emphasized the need to investigate other aspects of NPWT with irrigation thoroughly or to increase the number of subjects studied. Ultimately, recent advancements in NPWT with irrigation demonstrate the importance of this therapy as an evolution of traditional NPWT that may be better suited to treating diabetic foot wounds.

Davis et al.'s visualization of the wound bed coverage achieved using NPWT with irrigation has significant implications for understanding how this therapy can improve on traditional NPWT. One of the main implications is that irrigation solution can reach tunneling and undermining in complex wounds, possibly resulting in decreased wound bioburden. Another major implication is that debris can be removed from the wound bed, possibly allowing for stimulation of granulation tissue.[7] While the ballistic gel used to mimic a wound used in this study is not a perfect substitute for a real diabetic foot wound, the understanding of how this therapy works in a model helps to explain results from other recent clinical studies.

The results from the prospective study conducted by Ludolph et al. goes on to support the conclusions made from Davis et al.'s model. They show that NPWT with irrigation can cause a significant decrease in the bacterial load in chronic infected wounds. A decrease in wound bioburden is significant because bacteria are often capable of forming biofilms which are resistant to removal with antibiotics. A decrease in bacteria also helps to prevent reinfection, which could complicate treatment and delay healing. Researchers in this study also noted that NPWT with irrigation appeared to increase granulation tissue in the wound bed compared to wounds treated with traditional NPWT. The increase in granulation tissue is notable as a sign of wound healing. While this study provided promising results for the use of NPWT with irrigation in a variety of wounds, it was conducted on wounds of varying etiologies and therefore did not draw its conclusions solely from infected diabetic foot wounds. Photographs of some of the wounds however show that several lower extremity wounds were treated in this study and therefore a future study with a similar or larger test group size of purely diabetic foot wounds treated using NPWT with irrigation may yield similar results.[8] The control over wound bioburden demonstrated through NPWT with irrigation by Ludolph et al. is crucial in the treatment of diabetic foot wounds, particularly in the post-reconstructive patient as demonstrated in next study.

The retrospective study of a flap plus sub-flap irrigation with NPWT by Kurlander et al. demonstrated that a flap plus sub-flap irrigation was effective in treating patients who were at high risk of infection. This newly developed irrigation technique placed the irrigation tubing beneath the flap as opposed to the traditional location superficial to the wound. 4 out of the 8 patients analyzed in this study had diabetes and all wounds were primarily traumatic. Therefore, although not all the patients in the study had diabetic foot wounds, the end result of no post-reconstruction infections speaks to the utility of NPWT with irrigation in the treatment of diabetics with extremity injuries that are prone to infection.[9] While Kurlander et al. focused on a variation in installation of the NPWT with irrigation device, other studies compared NPWT with irrigation to older forms of NPWT.

Lavery et al.'s study of NPWT with irrigation using 0.1% polyhexanide-betaine solution versus traditional NPWT in the treatment of diabetic foot wounds was robust in design but did not demonstrate statistical significance between the treatments. This was despite some notable but ultimately statistically irrelevant findings that NPWT with irrigation was able to reduce healing time on average when used on diabetic foot wounds. This study mentioned that the study population may have been limited in number and in diversity as it was conducted at a single site in a relatively socioeconomically homogenous population in the United States. While no statistically significant findings definitely elevated NPWT with irrigation over traditional NPWT in this study, it is worthwhile to conduct additional investigations with more diverse populations, with more subjects, at more hospital sites to investigate the results of this study.[10]

An additional study by Davis et al. further explored the benefits of NPWT with irrigation compared to older forms of NPWT in their prospective clinical study of two types of traditional NPWT and NPWT with irrigation also did not yield statistically significant results in the use of NPWT with irrigation using saline for the treatment of diabetic foot wounds. Ultimately, there were no notable findings in this study however the small number of patients studied and their relatively homogenous socioeconomic background may have limited the results. Therefore, this study would also benefit from being expanded to more hospital sites and among more diverse populations. The future of NPWT with irrigation in the treatment of diabetic foot wounds is therefore likely to benefit from greater investigation in basic questions such as the type of procedure used to install the device, the optimum settings for the treatment of diabetic foot wounds, and the type of solution that is most effective.[11]

Conclusion

In the midst of a diabetes health crisis in the United States, research in advancements of NPWT with irrigation represents an opportunity to build on the existing framework of NPWT. Diabetic foot wounds often take longer to heal and are, therefore, at greater risk of infection. A system such as NPWT with irrigation that decreases bacterial growth and promotes faster wound healing, therefore, is a powerful therapy and has the potential to save lives. The research into models, techniques, and the precise benefit that NPWT with irrigation can provide will drive its widespread adoption into diabetic foot wound care. Before this can happen, additional large and diverse randomized clinical studies must be conducted to investigate promising potential advancements on this subject.

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Understanding the Role of Hyperbaric Oxygen Therapy for the Treatment of Lower Extremity Diabetic Ulcers

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ABSTRACT

Objective: To evaluate the efficacy of Hyperbaric oxygen therapy (HBOT) on lower extremity diabetic ulcers and its effects on ulcer healing, size, and amputation.

Methods: A literature search was done using PubMed in order to discover several articles that discussed the studies that were conducted on HBOT and its effects on diabetic foot ulcers. Keywords such as "Hyperbaric oxygen therapy" and "diabetic foot ulcers" were utilized to find the articles used in this paper.

Results: In a study testing diabetic foot ulcer area progression, it was found that ulcer size decreased by 100% in 5 out of 8 patients in comparison to the control group where there was 95% healing in 2 out of 8 patients at 6 months follow up from treatment with HBOT. Another study looking at the effects of HBOT on healing of diabetic foot ulcers found that 25 out of 48 patients who underwent HBOT had complete healing of their ulcer. A study discussing the outcome of HBOT in decreasing likelihood of amputation found that out of 35 patients being treated with systemic hyperbaric oxygen therapy (s-HBOT), 3 underwent major amputation.

Conclusion: HBOT is used as adjunctive treatment to traditional treatment for diabetic lower extremity ulcers. However, studies have shown that HBOT is effective in treatment of the diabetic ulcers. Research should continue to explore the efficacy of HBOT in reducing amputation risks for patients with diabetic lower extremity ulcers in order to get more coherent data.

Introduction

Hyperbaric oxygen therapy is a treatment process in which the patient is enclosed in a chamber with 100% oxygen filled air while exposed to increased atmospheric pressure.[1] This process involves patients inhaling pure oxygen which can assist in treating medical conditions such as non-healing diabetic foot ulcers, vision loss, varicose veins, and gangrene.[1]

Patients with prolonged diabetes develop neuropathy leading to decreased ability to sense pain or sensation in the foot due to nerve damage. Peripheral vascular disease can further worsen the problem by reducing the body's ability to heal and increase the risk of infection leading to diabetic foot ulcers.[2] It has been estimated that 15%-25% of people with diabetes mellitus will develop some type of diabetic foot ulcer sometime in their lifetime.[3]

HBOT has been shown to ameliorate wound tissue hypoxia, enhancing perfusion, decreasing edema, down regulating inflammatory cytokines, promoting fibroblast proliferation, increasing collagen production and aid in angiogenesis.[4] HBOT is controversial in its effectiveness to treat diabetic foot ulcers and reducing the risk of amputations but the studies show mixed results. However, the majority of the studies show that HBOT can be helpful if used with conventional treatments. This article will focus on how HBOT decreases both the risk of amputation and the ulcer size for people who suffer from diabetic foot ulcers.

Methods

A PubMed search was conducted with the keywords "Hyperbaric oxygen therapy" and "diabetic foot ulcers". Primary literature was searched that determined the effect of hyperbaric oxygen therapy on diabetic foot ulcers and its effectiveness in decreasing the occurrence of amputation. Publication language was restricted to English and there were no limitations on publication date.

Results

Diabetic ulcer area progression

A double-blind randomized trial completed by A. Abidia et al. demonstrated the effects of HBOT on decreasing ulcer size in a group of 18 participants with diabetic ischemic non-healing lower-extremity ulcers.[5] The participants were split up into two groups; one group that received hyperbaric 100% O_2 and the

other that received hyperbaric air. One participant from the treatment group left due to personal reasons and another from the control group left due to a serious vascular complication. Results obtained from this study are seen in Table 1.[5] The ulcer size and depth in the treatment group were measured to be 12-823 mm^2 and 0.5-4mm^2 respectively. The size and depth of ulcers in the control group were measured to be 18-866 mm^2 and 0.5-4 mm^2 respectively. The decrease of the ulcer at 6 weeks follow-up in the treatment group was 34-100 mm^2. 5 out of 8 of the patients had a 100% decrease in their ulcer size. In comparison to the control group which was (-29)-100 mm^2; 1 out of 8 of the patients had a 52% decrease in their ulcer size. At 6 months follow up the decrease in size was 100% for 5 out of 8 of the patients in the treatment group and 95% for 2 out of 8 patients in the control group.[5]

Group	Treatment	Control	*p* value
Ulcer size (mm^2)*	106 (12–823)	78 (18–866)	NS
Ulcer depth (mm)*	2.3 (0.5–4)	1.6 (0.5–4)	NS
Wagner Grade I	0	1	NS
Wagner Grade II	8	7	NS
Signs of infection	3/8	2/8	NS
Ulcer duration (months)	6 (2–18)	9 (3–60)	NS
Ulcers healed:			
At 6 weeks	5/8	1/8	NS
At 6 months	5/8	2/8	NS
At one year	5/8	0/8	$p = 0.026$
Reduction in ulcer size			
At 6 weeks	100% (34–100)	52% ((−29)–100)	$p = 0.027$
At 6 months	100% ((−206)–100)	95% (0–100)	NS
Major amputation	1	1	NS
Minor amputation	1	0	NS

* Results as median and (range).

Table 1*. Ulcer size reduction and healing for Treatment group (HBOT) and Control group over the span of 12 months.*

Diabetic Ulcer Healing

Magnus Löndahl et al. conducted a randomized, single-center, double-blinded, placebo-controlled clinical trial reporting the outcomes of HBOT in facilitating healing of chronic foot ulcers in patients with diabetes.[6] The study included ninety-four patients with Wagner grade 2,3 and 4 ulcers which have persisted for >3 months. Wagner system is used to classify the severity of diabetic foot ulcers from the grade of 0 to 5. Grade 0 is no ulcer but possible hyperkeratosis, grade 1 is a superficial ulcer, grade 2 is a deep ulcer, grade 3 is an ulcer with involvement of the bone, grade 4 is an ulcer with localized gangrene and grade 5 is an ulcer with gangrene involving the whole foot.[7] A group of 94 patients was split up into 2 groups; The HBOT group had 49 patients and the placebo group had 45 patients.[6] Fifty-four patients completed all of the 40 treatments, 75 completed >35 treatments, 9 patients completed <10 treatments and 10 patients completed 14-28 treatments.[6] Out of the 94 patients, 75 completed the study due to various reasons. After 1 year follow up, complete healing of the ulcer was attained in 37 patients.[6] In the HBOT group, 25/48 patients were completely healed in comparison to the placebo group where 12/42 patients were completely healed.[6]

Major Amputation

A randomized study accomplished by Ezio Fagla et al. evaluated the efficacy of systemic HBOT or HBOT in decreasing amputation rate in diabetic patients with critical foot ulcers.[8] 70 subjects were hospitalized and underwent diagnostic and therapeutic protocols. One patient refused treatment and one patient died of an acute stroke six days after admission. Out of the 70 subjects, 35 patients were treated with s-HBOT and 33 patients were part of the control. The 35 patients who were treated attended an average of 38 sessions.[8] In the s-HBOT group three patients experienced major amputation; one being above the knee (AKA) and two being below the knee (BKA).[7] In the non-s-HBOT group 11 subjects underwent major amputation; 4 AKA and 7 BKA. The difference is statistically significant.[8]

Discussion

HBOT has great potential in treating lower extremity ulcers due to its effect on decreasing ulcer size, healing the ulcers and decreasing the likelihood of amputation in diabetic patients with lower extremity ulcers. [9] Oxygen is found in the blood in two forms, attached to hemoglobin or dissolved in plasma. While HBOT may not increase the amount of oxygen bound to hemoglobin, it can increase the amount of oxygen dissolved in the plasma. [9] Breathing in room air allows for a person to saturate their hemoglobin up to 97%, therefore an increase in oxygen level and pressure will not significantly escalate the oxygen delivered to hemoglobin. [9] Even if HBOT increased oxyhemoglobin, the reduced perfusion, hypoxia or lack of blood vessels at the site of injury would prevent

oxygen from reaching the tissues. [9] Nonetheless, even poorly perfused injuries can acquire oxygen through hyperoxygenated plasma.[9]

As discussed above, HBOT allowed for diabetic ulcer healing, wound size reduction and decreased risk of major amputation. [9] These outcomes were due the ability of hyperoxygenated plasma to decrease ischemic effect, increase in production of nitric oxide, growth factors, cytokines to allow for promotion of cellular proliferation. [9] In addition, increased collagen synthesis allowed for enhanced bactericidal effects. [9]

HBOT is effective at ameliorating lower extremity diabetic ulcers; however, it is not a gold standard in treating such wounds. [9] HBOT should not exceed more than two hours due to potential side effects such as lung damage, tympanic membrane rupture, and oxygen poisoning. [9] The reason why HBOT is not used for every patient depends on the patient's health. [9] The most common complication is barotrauma, the inability to equalize the pressure as the pressure inside the chamber is above the average room pressure due to 100% oxygen air. [9] Barotrauma typically affects the middle ear of the patient which is one of the reasons why patients with diabetic lower extremity foot ulcers are not recommended for HBOT.[9] With further research, HBOT can be utilized more as an adjunct therapy in treating diabetic foot ulcers.

Conclusion

Prolonged diabetes mellitus causes peripheral nerve damage which leads to lack of sensation in the foot. Foot injuries can occur without the patient realizing it, leading to ulcers. HBOT is a treatment option for patients with diabetic foot ulcers. The patient is placed in a chamber with 100% oxygen while atmospheric pressure is increased. HBOT usage may be controversial in its effectiveness to help patients with diabetic foot ulcers but studies that were conducted in this article showed that HBOT is helpful in diabetic ulcer healing, reducing the ulcer size, and can help reduce the risk of amputation. Based on the results, physicians can use HBOT in conjunction with other treatment options to heal serious diabetic ulcers and to prevent major amputation. Future research of HBOT should focus more on its link to decrease amputation risk in patients with diabetic lower extremity ulcers as there has not been a lot of studies done for that aspect of HBOT.

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Ultrasound Guided Endovenous Thermal Ablation versus Vein Stripping Surgery for the Treatment of Varicose Vein Disease

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Abstract:

Objective: Varicose vein disease is hard to treat due its natural complexity. Over the years, there have been multiple attempts at exploring the best way to treat varicose vein. The goal of this paper is to compare and contrast the traditional vein stripping surgery to ultrasound guided endovenous thermal ablation for the treatment of varicose vein disease.

Methods: Relevant research articles on venous ulcers were found via the PubMed, National Institute of Heath databases, Wolters Kluwer Health databases, the Korean Journal Internal Medicine, Ontario Health Technology Assessment Series, the Journal of American College Certified Wound Specialists, the Indian Dermatol Online Journal, and Cochrane databases.

Results: On average, the vein stripping group spent 11.2 days in the hospital post-operatively, while the thermal ablation group spent 7.1 days. Vein stripping group also reported a higher complication rate, with 36 patients presenting with saphenous nerve injury, 1 with deep vein thrombosis, and 2 with superficial phlebitis. On the other hand, the thermal ablation group reported 11 cases of saphenous nerve injury and 15 superficial phlebitis.

Conclusion: When comparing ultrasound-guided endovenous thermal ablation to the traditional vein stripping technique, the research found that thermal ablation is ideal due to lower cost, fast healing, decreased revascularization, less time spent in the hospital, a lower complication rate, and a quicker return to work.

Introduction

There are two categories of veins in the body: those of the deep system and those of the superficial system.[1] The superficial system anastomoses with the deep system at the saphenopopliteal and saphenofemoral junctions, as well as through perforating veins. The saphenopopliteal junction joins the small saphenous vein from the superficial system to the popliteal vein from the deep system.[2] The saphenofemoral junction joins the great saphenous vein from the superficial system to the femoral vein from the deep system.[1,2]

The blood flows unidirectionally against gravity and is controlled by valves. Due to gravity, valvular insufficiency results in venous reflux and retrograde blood flow back to the lower extremities. Over time, varicosities of the superficial venous system result in bulging veins and chronic venous insufficiency symptoms such as leg pain, itching, burning, cramping, restlessness, corona phlebectatica, and hyperpigmentation.[2,3]

Physical exam findings include diminished +1/3 dorsalis pedis and posterior tibial pulses on the affected foot and in some cases edema at the ankle due to fluid build-up. Aside from the physical exam, doppler ultrasound is used as a confirmative diagnostic tool.[2] A venous reflux time of greater than 500 milliseconds on venous duplex ultrasound indicates insufficiency and is used to diagnose for varicose vein disease.[2,4] Severe cases of varicose vein disease lead to a buildup of pressure of the vein at the lower leg and ankle, potentially resulting in ulceration.[2]

A CEAP (clinical, etiology, anatomy, and pathophysiology) classification is utilized in addition to the physical exam to determine the stages varicose vein disease. C0 through C6 classifications denote no venous disease, telangiectasia, varicose vein, edema associated with varicose vein disease, dermatosclerosis or atrophie blanche associated with varicose vein disease, healed venous ulcer, and active venous ulcer respectively.[1,2,3,4,5]

The first line therapy in treating varicose vein disease is conservative compression therapy with 30-40 mmHg compression therapy. However, graduated compression stockings, leg elevation, and exercises are temporizing measures and serve to mitigate but not eliminate the patient's symptoms. As a result, the veins will continue to bulge, leading to a worsening progression of symptoms. The most definitive treatment of refluxing vein is with ablation techniques or through surgical excision

Vein surgery is also known as vein stripping.[1,2] Patients are prepped in a supine position and sedated under general anesthesia. Limbs are cleaned with chlorhexidine gluconate solutions. The refluxing veins and its perforating branches are removed from the leg.[1]

A more modern treatment modality used to treat varicose vein includes the use of endovenous thermal ablation (EVTA) procedures.[1] The two most common types of EVTAs are endovenous laser therapy (ELT) and radiofrequency ablation (RFA). ELT uses a 1470 nm diode laser fiber to heat and disintegrate the refluxing veins.[2,3] RFA uses radio

waves to heat the vein. Both procedures are done under ultrasound guidance.[1,2,4]

Once the refluxing vein has been treated through either vein stripping or endovenous thermal ablation, blood will redirect to healthy veins, and symptoms will slowly regress. The purpose of the paper is to compare and contrast the traditional vein stripping surgery to ultrasound guided endovenous thermal ablation for the treatment of varicose vein disease.

Methods

Relevant research articles for endovenous thermal ablation for varicose vein disease from 2009-2020 were identified via the PubMed, National Institute of Heath databases, Wolters Kluwer Health databases, the Korean Journal Internal Medicine, Ontario Health Technology Assessment Series, the Journal of American College Certified Wound Specialists, the Indian Dermatol Online Journal, and Cochrane databases. Inclusion criteria included patients who are 18 years or older, C4 CEAP classification for varicose vein of the lower extremity and have refluxed GSV and its perforated branches with 500 milliseconds or greater. Exclusions in the study included patients who were younger than 18, history of vein stripping or surgery, normal vein that refluxed less than 500 milliseconds, non-venous ulcers, and systemic diseases.

Results

Liu et al. had a retrospective cohort study which consisted of 200 patients that underwent endovenous thermal ablation with compression and 120 patients that underwent vein stripping with compression for the treatment of varicose vein disease with an active ulcer. Patients were seen again after one month, six months, and 12 months postoperatively for evaluation. Out of the total of 120 patients who underwent vein stripping with compression, 69 had an ulcer on the medial malleolus, 15 on the lateral malleolus, and 36 on the calcaneus. From the total 200 patients that underwent endovenous thermal ablation with compression, 122 had an ulcer on the medial malleolus, 20 on the lateral malleolus, and 58 on the calcaneus area.[6] The average time spent in the hospital post-operatively for the vein stripping with compression group was 11.2 days with a standard deviation of 8.1 days, while the average for endovenous ablation with compression group was 7.1 days with a standard deviation of 1.6 days. In regard to post-op complications, 36 reported with saphenous nerve injury, 1 with deep vein thrombosis, 2 with superficial phlebitis for those that underwent vein stripping. For those that underwent endovenous ablation with compression, 11 reported with saphenous nerve injury, 1 with deep vein thrombosis, and 15 with superficial phlebitis. The average ulcer healing time for vein stripping is 2.3 months with a standard deviation of 2.4 months. However, endovenous thermal ablation with compression led to a healing time of 1.7 months with a standard deviation of 1.7 months.[6]

A study was also done by Ontario Health Technology Assessment Series and consisted of a randomized control trial to compare between the two types of endovenous thermal ablation, endovenous laser treatment (ELT) and radiofrequency ablation (RFA) to surgery. The average rate of returning to work for RFA and ELT was one week, with a standard deviation of 2 days, while the average for surgery is 2 weeks with a standard deviation of 2 weeks. Pain scores were evaluated using a 100 nm visual analogue scale post-operatively after 3 and 10 days. This study showed that scores for RFA were significantly lower when compared to ELT and surgery.[7]

An additional study by Ontario Health Technology Assessment Series combined 22 cohort studies that consisted of a total of 10,883 patients to compare the outcome of ELT versus vein stripping. These studies found that ELT, when compared to vein stripping, led to an average return to work time of 4 days versus 17 days. Major adverse events occurred more often in vein stripping, at an incidence of 1.8% compared to 0.4% for ELT. Neovascularization was found to be greater in surgery than ELT post operatively. Patients who underwent ELT were brought back for ultrasound evaluation every 3 months to determine venous closure. The average time for vein to be completely closed and disintegrated from the body was 6.4 months post operatively.[8]

In a study by Recek, 57% of 100 cases with vein stripping showed revascularization after 6 years post-op. On the other hand, only 3.5% of 509 ELT cases after 12 months post op showed revascularization and 5.6% over 5 years post-op. For RFA, 13% of the 104 cases exhibited revascularization after 4 years post-op. All procedures were performed without ligating or ablating the incompetent saphenofemoral junction (SFJ) or the saphenopopliteal junction (SPJ) (reflux time >500 milliseconds).[9]

Discussion

Most research suggest conservative modalities for first-line therapies for varicose vein patients because it is claimed to be effective in reducing lower extremity edema. In actuality, conservative treatments generally fail to address the underlying condition in a varicose vein patient, leading to chronic symptoms. In a symptomatic

patient, vein valves become insufficient, causing an inferior reflux of blood into the lower extremities. Excessive blood contributes to increased pressure build-up, prominently at the malleolar areas, which may lead to ulceration. Surgical treatment remains the definitive method of treatment through the removal of refluxing veins and redirection of blood flow to healthy veins.[2]

Liu et al. concluded that endovenous thermal ablation with compression is preferred over vein stripping with compression for varicose vein disease treatment due to shorter hospital stay and lower rate of saphenous nerve complication. Superficial phlebitis is not considered a major complication as it resolves on its own over a few weeks or may be treated with NSAID, warm compress plus graduated compression stockings.[6] The thermal energy from laser fiber caused a minor burn in 6 patients but resolved within a week. The likelihood of getting burnt reduced significantly when the power was reduced from 14 W to 10 W. However, the use of tumescent anesthesia perivenous to the ablating vein can greatly reduce burn by creating a heat sink to allow better transmission of heat, reducing the chance of injury.[2] Since there are over 20 miles of vein in the lower extremities, removal of superficial veins through surgery or thermal ablation does not change the overall blood circulation as blood is being redirected to other branches, bypassing the non-functional, and refluxing veins.[5]

The additional 22 cohort studies done by Ontario Health Technology Assessment Series confirm that endovenous thermal ablation, ELT, is superior to vein stripping surgery due to faster return to duty time and lower rate of occurred adverse events. Neovascularization of veins post operatively indicates recurrence of varicose vein disease by damaging valves in healthy veins. Previous studies by Recek provide data that ELT has a lower rate of developing ulcers due to severe varicose vein disease compared to vein stripping surgeries.[8]

Even though the thermal ablation technique has proven superior over vein stripping surgery, a careful assessment must be considered due to potential risks and complications. The most common complication to thermal ablation is superficial phlebitis; however, the conditions are mild and resolve on its own over time. Deep vein thrombosis (DVT) is a serious complication that can result due to thermal ablation.[10] If not discovered, an acute venous thrombosis can break loose from the vein, causing a pulmonary embolism (PE). Clots in the lungs are hazardous and can lead to death.[10] As a result, patients are advised to walk immediately after the procedure and are instructed to follow up within 3 days to check for DVT. Some patients complain of pain that lasted months post-operatively. However, everyone tolerates pain differently.[10]

Conclusion

A careful assessment of each technique is necessary due to the natural complexity of varicose vein disease. Overall, the data suggests that endovenous thermal ablation may be better than vein stripping surgery for the treatment of varicose vein disease. Results have shown endovenous thermal ablation takes significantly less time, performs in an outpatient setting, and requires local anesthetic agents. While the risk of infection post-op exists, it is not significant. Other risks include a feeling of tightness in the lower extremities, which, according to Liu et al., can take up to an average of 6 months post-operatively to subside.[7] However, further studies with a longer follow-up time are crucial to fully appreciate the potential revascularization that leads to the recurrent varicose vein disease and eventual development of a venous ulcer.

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A Comparative Study on COVID-19 Toes and Chilblains

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ABSTRACT

Objective: This study aims to investigate and compare the clinical and pathologic characteristics of "COVID-19 toes" and chilblains.

Methods: A literature review was conducted of peer-reviewed publications regarding "COVID-19 Toes" through PubMed, Science Direct, and the Journal of Advanced Academics (JOAA) from patients reports made between April 2020 to January 2021. Search terms included: COVID-19 toes, COVID-19 chilblains, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and COVID acral lesions. Background information on chilblains was obtained using the following search terms: primary (idiopathic) chilblains, secondary chilblains, and perniosis.

Results: COVID-19 chilblains, or "COVID-19 Toes," is a newly emerging classification of chilblain-like lesions. This condition is commonly observed in adolescents and young adults. Recent literature reports an asymmetrical presentation of COVID-19 chilblains mainly in the feet, which may be accompanied by pruritus or pain. It may present in warm springtime weather, unlike primary (idiopathic) chilblains that are associated with cold weather exposure.

Conclusion: As the COVID-19 pandemic remains rapidly evolving, more cases of COVID-19 chilblains continue to be reported. While COVID-19 chilblains are distinct from primary or secondary chilblains, this condition is still not well characterized in a clinical setting. Clinicians are encouraged to continue to look for updates regarding the knowledge and treatment of skin manifestations of COVID-19.

Introduction

Coronavirus disease (COVID-19) is caused by the infection of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and commonly results in respiratory illness. People infected with SARS-CoV-2 can experience a large range of symptoms, from minor to severe complications and critical illness.[1] Although it predominantly affects the respiratory system, COVID-19 has been documented to impact many different systems in the body, from the central nervous system to the integumentary system.[1,2] Throughout the pandemic, there have been many patient reports worldwide that describe different skin manifestations in suspected or confirmed COVID-19 patients, one of which includes chilblains.[1,3-5]

Perniosis, or chilblains, is typically an inflammatory response to vascular ischemia from vasoconstriction due to prolonged cold exposure. Chilblains present as symmetrically distributed edematous nodules, macules, or papules on the dorsal toes or fingers. Appearance can range from erythematous to violaceous, and in severe cases, can display blistering and ulceration. This condition can often present with pruritus, pain, or a burning sensation.[1,3] Chilblains often occur in winter weather within 12-14 hours of cold exposure. Acute chilblains may resolve within 1-3 weeks, whereas chronic chilblains may occur in longer episodes extending beyond the cold season, or as recurrent episodes of acute chilblains.

A 2020 study by Casas et al. showed that chilblains make up approximately 19% of these COVID-related skin manifestations.[6] Chilblains are typically categorized into groups of primary (idiopathic) and secondary chilblains. However, a recently emerging group is the "COVID-19 chilblains," also known as "COVID Toes." These acral cutaneous lesions are observed on the feet in children and young adults with COVID-19.[1,3-7]

If a patient is suspected of COVID-19 chilblains, a complete physical examination and reviews of past medical, travel, and family history are conducted. If testing is available, patients often are required to complete a nasopharyngeal swab and/or serology testing for the presence of SARS-Cov-2. However, a negative result for COVID-19 RT-PCR or antibody testing should be approached with caution due to the test's well-documented inaccuracy.[3] In a 2020 report made by Landa et al., some patients with chilblain-like lesions did not undergo COVID-19 testing. However, these patients were suspected to have COVID-19 due to their geographic location, where there was high risk for the virus.[5]

Currently, the COVID-19 pandemic continues to spread throughout populations around the world. As reports of COVID-19 chilblains increase, we obtain a better understanding of the condition's incidence rate, clinical presentation, and pathogenesis. In this review, we present the pathologic and clinical characteristics of COVID-19 chilblains, or COVID Toes, seen in patients with confirmed or suspected COVID-19.

Methods

A review of current literature regarding "COVID-19 toes" was conducted through keyword

searches on the medical journal search engines, PubMed, Science Direct, and the Journal of Advanced Academics (JOAA). Search terms included: COVID-19 toes, COVID-19 chilblains, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and COVID acral lesions. We reviewed articles published between April 2020 to January 2021 that focused on COVID-19 skin manifestations. Background information on chilblains was obtained using the following search terms: primary (idiopathic) chilblains, secondary chilblains, and perniosis.

Results

Epidemiology

Chilblains are classified into primary (idiopathic) and secondary chilblains. This condition is often observed in women and the elderly. Primary chilblains are commonly seen in children and adolescents. Secondary chilblains are common in older adult patients, with an average age of 40 years.[3] By contrast, COVID-19 chilblains are frequently observed in adolescents and young adults. A report made in France by Hubiche et al. found that the median age of 40 patients with COVID-19 chilblains was 22 years.[8] A report by Piccolo et al. made in Italy of 63 patients found the median age was 14 years.[9]

Pathogenesis

The pathogenesis of COVID-19 chilblains remains largely unknown, but it differs from that of primary and secondary chilblains. They are thought to be induced by ischemic lesions implicated in COVID-19, whereas primary chilblains are diagnosed due to exclusion. Secondary chilblains are seen in lupus erythematosus, rare monogenic autoinflammatory diseases, and diseases that exacerbate vasoconstriction-induced ischemia.[3]

COVID-19 lesions also differ from primary and secondary chilblains in that they may be created due to thrombotic microvascular insults as a result of complement activation and pro-coagulation.[10] The presence of microthrombi has been highlighted in 3 cases of probable COVID-19 and could contribute to the altered coagulation seen in those with severe COVID-19.[11,13] There is also evidence of deposits of immunoglobulins and C3 on dermal vessels in addition to swollen endothelial cells and fibrin deposits within the wall of dermal venules. These findings lead researchers to believe that there is vascular involvement in the genesis of chilblain-like lesions.[13]

Clinical Presentation

In contrast to idiopathic and secondary chilblains, there are notable differences in the presentation of COVID-19 chilblains. Ladha et al. reported an asymmetrical involvement of mainly the feet, which can be accompanied by pruritus or pain. COVID-19 chilblains have shown to have a late onset in the course of infection, with a mean duration of 12.7 days. Conversely, idiopathic chilblains can onset within 12-14 hours of exposure and can last up to 3 weeks. Chilblains associated with COVID-19 have also been reported to present in warm springtime weather, unlike idiopathic chilblains which occur in response to cold weather exposure.[3]

Differential Diagnosis of Chilblains

Factor	Primary (Idiopathic)	Secondary	COVID-19
Age	Children	Adult: Mean age of ~40 years	Adolescent and young adult
Duration	1-3 weeks	Recurrent episodes of several weeks	12.7 days (mean)
Caused by cold weather	Yes	Yes, but can extend beyond cold season	No, warm springtime
Appearance	Symmetrically distributed, edematous, erythematous to violaceous macules, papules, or nodules	Symmetrically distributed, edematous, erythematous to violaceous macules, papules, or nodules Ulceration and blisters occasionally	Asymmetrical appearance
Location	Dorsal toes or fingers Less common: heels, nose, ears	Dorsal toes or fingers Less common: heels, nose, ears	Dorsal toes, heels Rare: both hand and foot involvement
Related Symptoms	Pain, pruritus, burning sensation	Pain, pruritus, burning sensation	Pain and pruritus

Table 1: *Comparison between clinical characteristics of primary (idiopathic), secondary, and COVID-19 chilblains.*

Histopathology

Primary chilblains have a nonspecific histopathology. The findings have shown to find a nonspecific infiltrate that extends through the dermis associated with edema. It may be concentrated in a perieccrine distribution and have necrotic keratinocytes in the dermis.[12] In contrast, COVID-19 chilblains have been reported to have a superficial and deep lichenoid lymphocytic infiltrate and basal

vacuolar changes, similar to chilblains lupus. This has led clinicians to believe that the condition may be activated through the Type I IFN pathway, as seen in lupus.

In an immunohistochemical study of 17 COVID-19 cases by Kanitakis et al., the most common epidermal changes (71%) were deep horizontal zones of parakeratosis within the horny layer. About half of these were caused by preceding bullae and scattered necrotic or apoptotic keratinocytes. In 82% of the cases, there was erythrocyte extravasation. 76% had papillary dermis edema, causing the formation of subepidermal pseudobullae.[13] The direct immunofluorescence exam result was positive in 14 of the 17 cases. In those 14 cases, vascular deposits of Immunoglobulin M (IgM), Immunoglobulin A (IgA), and complement component 3 (C3) were seen in 9, 5, and 5 cases, respectively. The remaining cases were negative or showed nonspecific findings.[13]

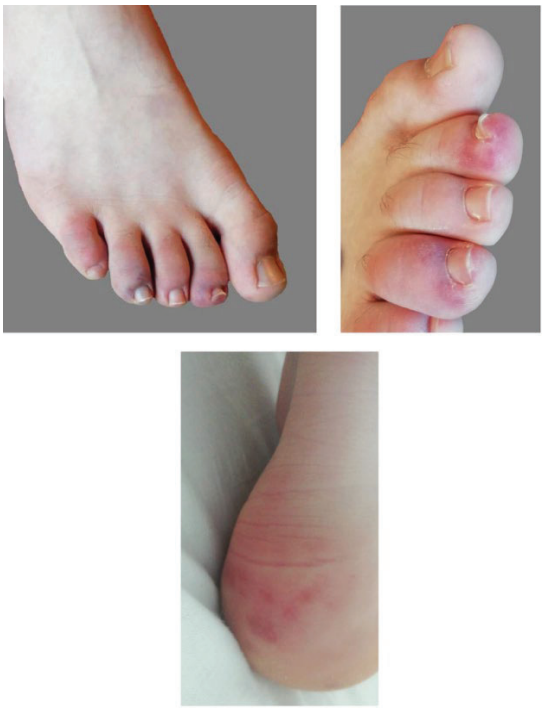

Figure 1: *Clinical images of chilblain-like lesions on the toes and heel of a patient during the COVID-19 pandemic.*[5]

Discussion

Treatments used in primary and secondary chilblains may be modified for the treatment of COVID-19 chilblains. These include avoidance of cold exposure, evaluation of vasoconstrictor substances (nicotine products and psychostimulants), and the usage of topical corticosteroids. Patients with presumed COVID-19 chilblains are encouraged to abide by public health guidance to undergo SARS-CoV-2 testing and self-quarantine.[3]

The pathogenesis of COVID-19 chilblains remains unknown. This condition is similar to what is seen in primary and secondary chilblains; however, it differs in its triggers. This disease is a result of thrombotic microvascular insults caused by the complement system and pro-coagulation. Primary chilblains, however, have a nonspecific histopathology with the most common reporting being dermal infiltrate with associated edema. Other common findings include spongiosis, deep perieccrine inflammation, basal layer vacuolization, and necrotic keratinocytes.[14] This creates a distinction from idiopathic and secondary chilblains, displaying a link to COVID-19. While conducting direct immunofluorescence exam results on COVID-positive patients, there were also vascular deposits of IgM, IgA, and C3.[13]

The clinical significance of this newly emerging class of chilblains is still to be determined. It is still not well understood if skin manifestations indicate severity of the disease, and this may only be confirmed with extensive cutaneous documentation in as many COVID patients as possible.[15] Increased awareness and the ability to differentiate COVID-19 chilblains from those of the primary or secondary groups may improve detection and treatment of the disease.

There were several limitations in this literature review. The main limitation was the inability to include all populations affected by the disease, with the pandemic spanning throughout the world. Additionally, as the pandemic began to surge internationally, the increasingly high number of affected patients limited the ability to test each case. Thus, not all patients were accompanied with a laboratory confirmed COVID result, and negative results should be interpreted with caution since chilblains are observed to be a later manifestation. Another limitation is the inadequate understanding of the disease's clinical characteristics, especially regarding skin manifestations.

Conclusion

As the COVID-19 pandemic remains rapidly evolving, more new cases of COVID-19 chilblains continue to be reported. While these chilblains are distinct from primary or secondary chilblains, this condition is still not well characterized in a clinical setting. Clinicians are encouraged to continue to look for updates regarding the knowledge and treatment of skin manifestations of COVID-19.

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Changes in Diabetic Foot Care During the COVID-19 Pandemic: A Literature Review

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ABSTRACT

Objective: To present a review of the impacts on diabetic foot ulcer management during the COVID-19 pandemic and consequent adaptations to care.

Methods: Various studies are analyzed with attention to diabetic foot care, both before and during the COVID-19 pandemic, and implemented changes for providing appropriate care. Multiple internationally based research studies and articles are cross referenced to provide the scope of current knowledge and discuss content gaps. Databases include Google Scholar, Wiley, and Elsevier.

Results: The interruption to caring for diabetic foot wounds was found to have increased adverse outcomes from studies conducted early in the pandemic and required adaptation to currently existing algorithms for care. Delays in wound care as a result of the pandemic were demonstrated to increase adverse outcomes and further emphasize the importance of appropriate and timely care.

Conclusion: Few statistical studies exist on the impacts of DFU wound care during the COVID-19 pandemic, and these studies draw their conclusion based on a small sample size and short-term follow-ups. Hence, there is not sufficient data to conclude whether this new wound care system has negative or positive outcomes on patients with DFUs.

Keywords: wound care, diabetic foot, diabetic foot ulcer, telehealth, telemedicine, COVID-19 pandemic.

Introduction

The ongoing COVID-19 pandemic has seen over 110 million confirmed cases and over 2.4 million deaths worldwide as of February 2021.[1] This pandemic has disrupted the healthcare system across multiple specialties and forced changes in the management of various chronic health conditions. Type 2 diabetes, an established risk factor for severe COVID-19 manifestations, complicates the traditional approach to individuals with diabetic foot ulcers (DFUs).

Prior to the pandemic, the approach to diabetic wound care involved a "healing at any cost" approach which utilized any hospital or procedural interventions that could improve or speed up wound healing.[2] During the pandemic, the risks of COVID-19 exposure to DFU patients in the hospital setting have prompted a new triage approach that identifies critical cases that need urgent intervention and stable cases that can utilize telehealth visits.[2, 3]

Using this triage system alleviates the burden on the healthcare system and limits patients from COVID-19 exposure, but there are challenges with this new system as well. For some DFU patients, limiting in-person visits can present with poor compliance and an increased risk of infections, hospitalization, amputations, and death.[4] For other patients, a lack in technological literacy and equipment needed for effective telehealth correspondence may present a challenge.[5] In both instances, delays in wound care can result in further stress on the patient and poor wound healing outcomes. This purpose of this paper is to present a rapid review on recent literature analyzing the impacts of the pandemic on DFU outcomes and newly implemented changes in approach to managing DFUs.

Methods

A rapid review of related literature articles was analyzed from various databases: Google Scholar, Wiley, and Elsevier. Keywords were used to narrow down the literature searches, and the time frame for published articles was set from 2009-2020. Two studies were identified from 2020 and considered management of 387 patients from two countries (China and Italy) impacted during the COVID-19 pandemic. Three studies ranging from 2009-2012, considered management prior to COVID-19 for relative comparison. One study on telehealth DFU care prior to COVID-19 was used to assess the effects of telehealth on DFU outcomes. A rapid literature review was chosen for this paper, because of the need to hasten the acquisition of relevant evidence to applied in the current health care crisis.

Results

A study by Liu et al. was conducted on the impact of the COVID-19 pandemic on patients with DFUs during the first trimester of 2020. Two groups of patients with DFUs were studied, a group of 44 patients during the COVID pandemic in 2020 and a pre-COVID group from 2019 of 87 patients. There was a statistically significant difference between the 2020 group and 2019 in terms of presenting with

severe DFU infections on initial presentation (p-value < 0.001). 52.3% of the 2020 group and 20.7% of the 2019 presented with severe infections on initial presentation. The median number of days from when patients reported the onset of their DFU to when the patient received medical care was also significant (p-value = 0.024) at 75 days for the 2020 group and 45 days for the 2019 group. Additionally, the median interval from outpatient to hospital admission was 3 days for the 2020 group and 7 days for the 2019 group. Inpatients had a median duration of stay were similar for both groups at 10 days for the 2020 group and 9 days for the 2019 group. Overall, the 2020 group had a significantly higher prevalence for gangrene (p-value = 0.009) at 64% versus 29% for the 2019 group and percentage of patients who required amputation (p-value = 0.001) at 60% versus 18% for the 2019 group.[6]

Meloni et al. conducted a study on the outcome of DFUs managed with a triage pathway designed for the COVID-19 pandemic (February to April 2020). This study consisted of 154 patients with DFUs of which 58.7% had severely complicated DFUs, 21% had complicated DFUs, and 20.3% had uncomplicated DFUs. All these DFUs patients also had at least one comorbidity, including but not limited to various cardiac and vascular diseases and end stage renal disease. It is not reported whether these comorbidities occurred before or during the COVID-19 pandemic. 106 of the 154 patients had regular in person follow ups. Of the remaining patients 45 received wound care management via telemedicine and three were lost to follow up. After at least one month of regular follow ups, 27.1% of patients' DFUs healed and 1.9% had major amputation due to untreatable limb ischemia. No data from before the COVID-19 pandemic was included.[3]

A retrospective cohort study, which observed patients pre-COVID from 2009-2011, by Smith-Strom et al. investigated whether DFU severity and duration before treatment could predict healing time. 45.7% of the 105 patients' DFUs healed and 36.2% had amputations. The remaining patients either died before ulcer healing or were lost to follow up. Of the patients with who waited 0-13 days before being referred to wound care, 50% had less severe ulcers while 16% had highly severe ulcers. Of the patients who waited 52 days or more for wound care, 34.9% had highly severe ulcers. The association between a shorter duration from ulcer onset to wound care referral and less severe DFUs as well as longer duration and highly severe DFUs was significant (p-value = 0.042).[7]

In terms of recurrence of DFUs, Ndosi et al. conducted a prospective observational study from 2011-2013 on the 12-month clinical outcomes of infected DFU. 45.5% of the 250 DFU patients were healed in 12 months. Median ulcer healing time was 4.5 months. Ulcer recurrence was reported in 9.6% of healed patients (p-value = 0.0217).[8] A retrospective cohort study by Fournier et al. from 2013-2019 also studied DFU recurrence rates. 37.1% of DFU patients had ulcer recurrence at 6 months after initial ulcer healing and 54.4% at 12 months of the 85 DFU patients in this study. It was found that DFU recurrence at 6 months was statistically significant based on multivariate analysis with an odds ratio of 4.77 and 95% confidence interval of 1.02 to 22.21. DFU recurrence at 12 months also statistically significant with an odds ratio of 9.25 and confidence interval of 1.02 to 22.21.[9]

A randomized controlled trial by Rasmussen et al. was conducted on the outcomes of DFUs which were managed via telemedical monitoring versus standard in person wound care. 193 patients were part of the telehealth group and 181 in the control group of standard in person wound care. The median time period for this study was 74 days for the telehealth group and 91 for the control. It was found that there was no significant difference (p-value = 0.42) in healing outcome between the telehealth group and controls as they experienced complete healing of DFUs during the study at 72% and 73% respectively.[10]

Discussion

Currently, there have not been many studies collecting data on the impacts of the COVID-19 pandemic on DFU. The few studies which have been done suggest that there is a negative impact on wound care or a lack of data to draw any significant conclusions.[3, 6] Results from studies done before the COVID-19 pandemic have also suggested the necessity for longer term studies.

Limitations in the studies include small sample sizes and data represented from very few geographic locations. Between the only studies found on DFU outcomes during the COVID-19 pandemic, Liu et al. and Meloni et al., there were only 285 total patients who participated. Additionally, each of these studies only drew data from a single location. Liu et al. only had data from patients in Sir Run Run Shaw Hospital in China and Meloni et al. from the Diabetic Foot Unit at the University of Tor Vergata in Italy.[3, 6] Additionally, Meloni et al. did not report any data prior to the COVID-19 pandemic for comparison.[3]

Smith-Strom et al. suggested a significant association between longer wait times for DFU care and more severe ulcers.[7] It was seen by Liu et al. that during the COVID-19 pandemic, the duration of time from patients reporting ulcer onset to receiving care for said ulcer was significantly longer than pre-pandemic times. It was also noted that there was a greater percentage of severe DFU on initial

presentation in patients seen during the COVID-19 pandemic. Liu et al. also reported a significantly higher prevalence of gangrene and amputation and suggests this is due to delayed diagnosis and treatment of DFUs.[6] Likely a reason the COVID-19 pandemic could negatively impact the outcome of DFU is because of longer wait times for wound care.

Oropallo et al. suggests telehealth platforms have been widely used to avoid having in person patient visits while maintain regular wound care follow ups virtually with the advent of COVID-19.[11] Rasmussen et al. even found there to be no significant differences in DFU outcomes in terms of healing between telehealth and standard management of DFUs.[10] Though this may resolve the issue of longer wait times for wound care during the COVID-19 pandemic, there are limitations to telehealth. Bondini et al. points out videos and photographs, though the main form of visual communication in telehealth, are not sufficient for assessing the progression of wounds. Telehealth relies mainly on the ability of patients to communicate their symptoms and relay this information to healthcare providers virtually. With a majority of chronic wound patients over 60 years old, these patients may not have the technological literacy needed to successfully communicate with providers.[7]

The "management track" of the COVID-19 pandemic, where patients are triaged by severity of wound into managing DFUs with minimal contact with healthcare providers, have yet to be proven as effective "treatment pathway" of pre-COVID times, where "healing at any cost" was the basis of wound care.[3,12] Liu et al. even suggests that this triaging model during the COVID-19 pandemic has led to increased DFU severity due to patients not being treated as soon as pre-COVID times and patients attempting to avoid and distance themselves from others by putting off seeing healthcare providers.[6]

Both Ndosi et al. and Fournier et al. found that after initial DFUs have healed, the likelihood of recurrence was significant.[8, 9] However, there has yet to be any studies done on recurrence of DFUs in patients who developed and were treated during the COVID-19 pandemic. Furthermore, this brings up the question of what the long-term effects may be of treating DFUs using new models of care designed for minimalizing person-to-person contact.

Conclusion

At this time, the effects of the COVID-19 pandemic on the outcome of diabetic foot ulcers are not completely known. The delays in seeking wound care during the pandemic demonstrate the importance of timely management of DFUs and have also prompted new approaches to monitoring and intervention for patients at the highest risk. While the shift to telehealth allows regular monitoring for lower risk DFU patients, future studies are needed to understand any limitations of triaging care with this approach. Further, long term studies will also be needed to completely understand the impacts of the COVID-19 pandemic on DFU patient outcomes.

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Using Nerve Block Therapy for Pain Management Following Foot and Ankle Surgeries

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ABSTRACT

Objective: The goal of this paper is to review adjunctive lower extremity nerve block therapy in conjunction with opioids for pain management after foot and ankle surgeries and its potential to decrease the amount of opioids necessary to achieve satisfactory pain control.

Methods: Retrospective and prospective randomized double-blind placebo-controlled studies were collected from search engines such as PubMed and ScienceDirect from December 26, 2018 through December 4, 2020.

Results: Nerve block therapy has shown to be an effective analgesic for postoperative pain management. In a randomized double-blind placebo-controlled study, 80% of the patients receiving ropivacaine did not require a single oral opioid tablet during their infusion. Patients reported average rest pain as less than 1 on a scale of 1 to 10. Another prospective, randomized double-blind placebo-controlled study demonstrated that all patients who received nerve block therapy were able to achieve a pain score of zero immediately postoperatively. A third double-blind, randomized, placebo-controlled study found 100% of their placebo group to require opioid analgesics as opposed to 40% of patients who received bupivacaine. Patients in the bupivacaine infusion group reported a higher rate of complete satisfaction with their postoperative pain management (90% versus 10%) during the follow-up assessment period.

Conclusion: Nerve block therapy is a sensible treatment option for postoperative pain management. Patients who received treatment reported lower pain scores and opioid usage while reporting higher levels of satisfaction with their pain management. Adverse effects are significantly of lower risk relative to those of opioid therapy.

Introduction

Opioids have been a valuable treatment option for many patients struggling with both acute and chronic pain management. However, its side effects of addiction, respiratory depression, nausea, vomiting, and constipation are drawbacks to opioid therapy. The opioid crisis is responsible for numerous cases of death in the United States. According to the Centers for Disease Control and Prevention, over 70,000 deaths occurred in the United States in the year 2017; this number has increased by 9.6% from the previous year.[1] However, about 40% of patients undergoing same day orthopedic surgeries still report moderate to severe pain postoperatively.[2] The opioid epidemic is in part, due to a lack of effective alternatives to pain management.

Lower extremity nerve blocks have demonstrated efficacy for the management of acute pain postoperatively, where opioids have been traditionally the primary treatment option. Nerve block therapy limits postoperative pain by decreasing the nociceptive input and subsequent hyperexcitability of the nerve.[3] Continuous lower extremity nerve block can be administered via an adjustable or non-adjustable perineural catheter at a steady infusion rate. Nerve block therapy allows for prolonged analgesia postoperatively, where patients would otherwise be extending their hospital admission for traditional intravenous opioid therapy.[4] This review aims to review peripheral nerve block as a viable adjunctive treatment option for postoperative pain management and its potential to decrease the amount of opioids necessary to achieve satisfactory pain control.

Methods

Retrospective and prospective randomized double-blind placebo-controlled studies were collected from search engines such as PubMed and ScienceDirect from December 26, 2018 through December 4, 2020 using the keywords: popliteal nerve block, local anesthesia, opioid crisis, opioid addiction, foot and ankle surgery. Nerve block studies were selected for the article. Any articles that were not specific to the lower extremity were excluded. Any sources before the year 1997 were excluded to ensure that most recent data collected is targeted on the topic.

Results

Ilfeld et al. conducted a randomized double-blind placebo-controlled study involving 30 patients to investigate the effectiveness of a popliteal sciatic nerve block in postoperative pain management. The

surgeries included various lower extremity procedures, including achilles repair, ankle ORIF, hammertoe correction, and subtalar fusion. Patients were discharged with a popliteal sciatic catheter *in situ* with a reservoir containing 550ml of solution. Continuous infusion of 8ml/h was begun with a 2ml patient-controlled bolus available every 20 minutes. Catheters were removed in the evening of the second postoperative day. Half of the patients received ropivacaine, while the other half received saline as a placebo. They found that patients in the ropivacaine infusion group had markedly fewer sleep disturbances and less pain and opioid use.[5] The popliteal sciatic perineural catheter used was an adjustable at-home pump that allowed for patients to control their local anesthetic bolus dosing as needed. The catheter decreased postoperative baseline pain for patients, and 80% of the patients receiving ropivacaine did not require a single oral opioid tablet during their infusion. Patients also reported average rest pain as less than 1 on a scale of 1 to 10, with 10 representing the most severe pain.[5]

Another recent prospective, randomized double-blind placebo-controlled study conducted by Bjorn et al. discussed the efficacy of a saphenous nerve block as an analgesic for major ankle surgery. The surgeries in this study included total ankle arthroplasty, ankle arthrodesis, subtalar arthrodesis, and triple arthrodesis. Patients were asked to score their pain on the numerical rating scale (NRS) from 0 to 10, with 10 representing the most severe pain. Pain scores were evaluated at 30, 40, 60, 75, 90, 105 and 120 minutes postoperatively. All 18 patients experiencing pain from the saphenous nerve territory in the anteromedial ankle region reported significant clinical pain within the first 30 minutes after surgery. All patients who reported NRS greater than 3 had a rescue saphenous nerve block performed, and all of those patients reported reduction of pain score to 0.[6] This study has shown that a supplemental saphenous nerve block will also reduce patients' pain experience after a major ankle surgery.[6]

White et al. also conducted a double-blind, randomized, placebo-controlled study on sciatic nerve block therapy. Twenty-four patients either received bupivacaine or placebo infusions after undergoing various surgeries, including bunionectomies, hammertoe corrections, and ankle surgeries. Four patients had their catheters dislodged before their discharge from the hospital and were therefore excluded from the experiment. While all of the patients receiving placebo required oral opioids postoperatively, only 40% of the patients who received bupivacaine required adjunct opioid therapy. Furthermore, all ten of the patients in the placebo group required overnight hospitalization, as opposed to six of the ten patients in the bupivacaine infusion group.[6] The bupivacaine infusion group patients were also able to achieve lower postoperative pain scores on a verbal rating scale (0-10) than the placebo group, and reported a higher rate of complete satisfaction with their postoperative pain management (90% versus 10%) during the follow-up assessment period.[7]

Discussion

These studies have shown that nerve block therapy is highly effective for decreasing acute pain postoperatively. Patients receiving nerve block therapy throughout the studies consistently expressed higher rates of satisfaction and decreased pain scores and rates of adjunctive opioid therapy. Of the three studies reviewed, only one of them experienced complications. Four of the patients in the study conducted by White et al. required a modification in their procedures in order to properly secure their catheter in the popliteal fossa and were eliminated from their results.

Pearce and Hamilton included infection, hematoma, nerve injury, and systemic toxicity as potential side effects of regional anesthesia. However, they concluded that the risk of nerve injury may result from accidental intraneural as opposed to perineural injection and systemic toxicity from dosing miscalculations.[8] A prospective study by Auroy et al. of 21,278 patients receiving peripheral nerve blocks found 3 cardiac arrests, 16 seizures and 4 cases of neurological damage.[9] These statistics complement the lack of complications encountered in the above mentioned randomized double-blind placebo-controlled studies. Nerve blocks present their own set of side effects but are still relatively safe when compared to the risks of opioid therapy, as there have been over 70,000 opioid related deaths in the United States in the year 2017.[1]

Conclusion

The opioid crisis is multifaceted and is in part due to the lack of alternative treatment options.

Peripheral nerve block therapy is a viable alternative that does not present the risks of abuse and sedation. Patients who received peripheral nerve block therapy in adjunct to opioids reported fewer sleep disturbances, less pain, and less opioid use than patients who solely used opioids for postoperative pain management. Patients also reported a higher level of overall satisfaction with their pain management. Adverse effects of peripheral nerve blocks are of significantly lower risk than those of opioid therapy. Thus, peripheral nerve blocks are an excellent adjunctive treatment option for treating postoperative pain and can help reduce the amount of opioids taken for postoperative patients.

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Assessment of First Ray Length and Mobility and its Relationship to Metatarsalgia: A Literature Review

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Abstract:

Objective: Metatarsalgia is a common disease experienced with lower extremity injuries. A common causative factor includes pathology of the first ray. The purpose of this literature review was to assess the efficacy of the studies encompassing the following two questions:

1. Is there a positive correlation between the length of the first ray and the progression of metatarsalgia?
2. Is there a positive correlation between the mobility of the first ray and the progression of metatarsalgia?

Methods: Studies included in this review were held to criteria matching the study of metatarsalgia relating to first ray abnormalities in relation to biomechanics. The study focused on the development of metatarsalgia due to improper biomechanics resulting from either congenital abnormalities or musculoskeletal imbalances not derived from surgical interventions. As a literature review correlating data from multiple studies on possible causation of metatarsalgia, only studies that were peer reviewed were used. Studies collected were then cross referenced to find support from other peer reviewed sources. Individual case studies did not meet these criteria and were also excluded.

Results: The relative length of the first ray and progression of metatarsalgia is shown in a multitude of studies. However, opposing research also exists showing no positive correlation. Literature review also showed an overall consensus amongst studies that first ray hypermobility, and subsequent elevated first metatarsal (M1), were contributing factors to the progression of metatarsalgia.

Conclusions: Due to lack of support against mobility as a lead indicator for metatarsalgia, our conclusion leans toward abnormalities in first ray mobility as the primary indicator of symptom development towards metatarsalgia. Studies of gait biomechanics lend support to the hypotheses of biomechanical compensatory mechanisms leading to normal strike force and weight transfer. However, our research also shows a strong correlation linking first ray mobility and first ray length, indicating that abnormalities in first ray length may be a leading cause to first ray mobility issues. This follow up question can be addressed in subsequent follow up studies.

Introduction

The significance of first ray pathology in correlation to metatarsalgia has been debated in the field of orthopedics for decades. Greisberg et al. asserts his findings that “those with metatarsalgia symptoms had a significantly greater first ray mobility suggesting a mechanism by which load can be transferred from the first to lesser metatarsals.” By discussing the inherent length of the first ray in the developing foot, its effects of first ray mobility and the correlation of developed length as a precursor to symptoms such as hallux valgus and gastrocnemius recession, these characteristics are shown to lead to the multiple types of associated metatarsalgia.[1] The most frequent correlations linked to symptoms of metatarsalgia all linked to abnormal first ray mobility and abnormal first ray length.[1-4]

Background

Metatarsalgia is pain in the forefoot beneath one or more metatarsal heads. According to Besse, and supported by Walker, metatarsalgia pain most likely arises from a variety of factors including mechanical abnormalities, congenital anomalies, and/or iatrogenic factors that induce overloading of the forefoot.[2,5] Patient evaluations for metatarsalgia tend to reveal gastrocnemius recession, fixed equinus of the foot, hallux valgus, a physically shortened first metatarsal (M1), pes cavus, metatarsal malunion, or even a history of a neurological disorder such as Charcot-Marie-Tooth disease which involves the loss of muscle tissue.[2] All of these conditions will contribute to an increased plantar pressure on the forefoot to some degree. The change in length and mobility of M1 and how it relates to the onset of metatarsalgia is the focus of the research discussed here.

Biomechanics

During gait, the metatarsal head should be able to contact the ground via plantarflexion, but if shortened, one should have increased plantarflexion of that specific metatarsal in order to compensate.

Increased plantarflexion of M1 along with increased maximal peak pressure has been noted as a contributor to metatarsalgia.[1] It is important to note that increased plantarflexion does not relate to increased hypermobility, which is considered a different pathology. Increased hypermobility discusses an *elevated*, but not shortened, first ray.

Types of metatarsalgia

Primary metatarsalgia occurs as a result of anatomical abnormalities of the metatarsals, secondary metatarsalgia is caused by pathologies that indirectly increase pressure on the forefoot.[2]

Propulsive metatarsalgia in which pain is present during the propulsion phase of gait. Another type is static metatarsalgia in which pain is present during the midstance phase of gait, but this type of pathology is not directly due to the length of M1, rather, it is exclusively involved with M1 hypermobility, specifically metatarsal elevation.[2]

Methods

Studies included in this review were held to criteria matching the study of metatarsalgia relating to first ray abnormalities in relation to biomechanics. Greisberg et al was chosen for their study on first ray mobility.[1] Slulitel et al and Walker met the criteria in their study of first ray length and congenital abnormalities[1,5], while Besse mirrored the studies on first ray length in addition to discussing musculoskeletal abnormalities such as equinus of the gastrocnemius.[2] The studies further discussed in the sections below provided quantitative data that allowed for unbiased comparison. The focus was specified to the first ray, therefore studies with direct inclusion of abnormalities of rays 2-5 did not match criteria and were subsequently excluded. The area of focus also included biomechanics under normal circumstances of development, therefore studies including metatarsalgia due to surgical interventions were also excluded.

Data

Maestro's "Forefoot Morphotype Study and Planning Method for Forefoot Osteotomy"[4] and Besse's "Metatarsalgia"[2] studied normal metatarsal position with even weight distribution using radiographic measurement of 40 subjects. In their study, data showed optimal foot morphology where the average center of the Fourth metatarsal head (M4) is in line with the lateral sesamoid bone (SL) of the First metatarsal (M1). The SL-M4 line became the baseline for subsequent length measurements of the tops of the M1 to M5 heads. Of the 40 participants, Maestro 2003 showed optimal weight distribution occurred when the tops of M1, M2, M3, M4 and M5 heads were 13.5mm, 17mm, 14mm, 7mm and -6mm from the SL-M4 line respectively with and average variation of ±2mm. Besse 2017 made claims that larger deviations from these numbers decreased foot stability during movement and increased risk of developing metatarsalgia.[4]

In contrast, Kaipel's research in "Metatarsal Length does not Correlate with Maximal Peak Pressure with Maximal Force" claimed no correlation between length and pathology progression. Kaipel prospectively followed groups of 46 and 45 patients with and without metatarsalgia, respectively. Subjects underwent weight-bearing radiography and dynamic pedobarography to evaluate pressures under first, second, and third metatarsal heads. Extrapolated data showed a correlation coefficient $r < 0.13$, in which the relative length of the first and third metatarsals did not relate to the maximal peak pressure and force under the respective metatarsal heads.[6]

Slullitel in "Effect of First Ray Insufficiency and Metatarsal Index on Metatarsalgia in Hallux Valgus", performed a cross-sectional study of 121 subjects with non-arthritic hallux valgus to identify clinical and demographic factors that contribute to primary metatarsalgia. Logistical regression provided data within a 95% CI, that showed 84 of the 121 subjects presenting with metatarsalgia had one or more of the following causative factors: toe deformities (OR 2.6), gastrocnemius shortening (OR 5.8), abnormal metatarsal index (OR 0.3) and weight (OR 2.5).

Greisberg in "First Ray Mobility Increase in Patients With Metatarsalgia."[3] utilized a proprietary method to measure first ray mobility of 352 patients, 64 of which presented with transfer metatarsalgia. Those with symptoms had greater first ray mobility with an average of 9mm (compared to the 7mm of the asymptomatic group) as well as greater M1 elevation with an average of 5mm (compared to the 3mm of the

asymptomatic group).

Discussion

Data between studies showed a discrepancy in regard to the correlation between M1 length and symptoms of metatarsalgia. Maestro et. al.[4] showed positive correlation, while Greisberg et. al.[3] showed no correlation. Further research showed support for both hypotheses with Besse[2] and Walker[5], respectively.

Gresiberg and Walker both, however, provided data from studies testing biomechanics that also supported positive correlation between first ray mobility and metatarsalgia.

With biomechanics of first ray as the most supported causative link, consideration should include patient history including factors but not limited to areas like activities of daily living, occupation, height, weight, and exercise habits, It is also important to note that metatarsalgia is a multifactorial pathology, meaning that there are other biomechanical influences that could contribute to its onset. Slullitel[1] also found a positive correlation between the length of M1 and metatarsalgia, however, the length abnormality was an indirect cause, more so affecting first ray anatomical structure through the development of hallux valgus. This sentiment was also mentioned by other authors listed in the data section above. Slullitel also found other influencing pathologies in conjunction with hallux valgus that could contribute to metatarsalgia such as gastrocnemius recession, Achilles shortening, and/or lesser toe deformities.[1]

Hallux valgus therefore, becomes an important pathology and precursor to metatarsalgia to note in regards to the length of the first metatarsal. In a healthy foot, the angle between the hallux and proximal phalanx should be less than twenty degrees; if larger than twenty degrees, then it is considered to be hallux valgus.[1] The mechanism for which the medial forefoot can effectively distribute weight is altered, thus putting the lesser metatarsals at risk for excessive pressure upon weight-bearing positions during gait. This was validated in a study done by Yavuz et al. as he found that hallux valgus patients had increases in the plantar pressure of the lateral forefoot.[7]

Gastrocnemius recession and subsequent Achilles shortening is another extrinsic pathology that may contribute to the onset of metatarsalgia due to indirect overloading of the lesser metatarsals. These pathologies are specifically important during the normal gait cycle, where weight distribution transitions from rear to forefoot as body mass is propelled forward. The specific portion where weight transfers over the ankle is called the “ankle rocker”, which is said to be “controlled by the eccentric contraction of the gastrocnemius muscles.”[2] If there is shortening of the gastrocnemius, the foot is in a perpetual plantarflexed position. This causes weight distribution that is chronically distributed to the forefoot, excessively loading the metatarsals. Performing a physical test aimed at measuring gastrocnemius tightness, such as the Silfverskiold test used by Besse[2] can help further differentiate potential causes of the patient’s metatarsalgia.

Understanding causative factors leads to better understanding of potential treatment options.[5] Walker discussed potential treatment options, both conservative and surgical. Walker, alongside Greisberg, both show support for prophylactic measures which has become more feasible with the development of various means of measurement such as the calculation of first ray mobility.[3,5] One such method of measurement developed is discussed below and has been utilized in a multitude of studies, including the studies discussed here, as a means to procure precise quantitative data.

Kim developed the Eulji Medical Center device (EMC) as a means to calculate first ray range of motion.[8] Greisberg et al. also developed a variation of the EMC that contributes supporting data to the efficacy of measurement. The device allows us to consistently measure the vertical motion of the first ray with respect to the lesser metatarsals on both the dorsal and plantar surfaces. Prior to this device, physicians utilized subjective measurements that left room for error in data recorded. Considering data from Maestro, showing the difference between normal and abnormal ranges to be measurements as small as ±2 mm, it could be reasoned that the margin of error in assessment needs to be minimal.

Due to abnormalities in areas of the body that undergo such repetitive trauma involved in the gait cycle, the person will experience distress in the form of metatarsalgia. This is significant because with the

advancement of objective and reliable devices, we can treat patients before trouble arises, now knowing that there is a relationship between the two.

Conclusion

Metatarsalgia is a common disease experienced by many due to repetitive trauma through ambulation. Better understanding of its causes can lead to improved prophylactic measures. The studies reviewed show a positive correlation between abnormalities in mobility of the first ray and the progression of metatarsalgia, with data supporting a possible association with abnormalities in first ray length leading to abnormal mobility. Future studies can be designed to further detail how first ray length affects mobility as well as other associated structures, such as tarsometatarsal joints, that are connected to the first ray.

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Comparison of The Different Treatment Modalities of Plantar Fasciitis, Both Conservative and Surgical, With an Emphasis on Novel Therapies

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ABSTRACT

Objective: Plantar fasciitis is one of the most common inflammatory conditions, affecting more than 1 million people a year. The goal of this review is to compare different treatment methods, both conservative and surgical, in terms of effectiveness and postoperative healing time as well as compare the effectiveness and postoperative healing time of traditional treatment methods to novel ones.

Methods: A literature review of comparative and clinically based articles was conducted to evaluate and analyze the effectiveness of the various treatment methodologies. The different approaches were analyzed against each other in their respective categories. One novel treatment approach was introduced to each category, conservative or surgical.

Results: Extracorporeal shockwave therapy (ESWT) has been shown to have an equivalent visual analog scale (VAS) and heel tenderness index (HTI) scores as taping; however, ESWT has increased foot functionality index (FFI) scores. Percutaneous radiofrequency microtenotomy yields a shorter operative time and faster postoperative recovery time.

Conclusion: Novel methods, such as extracorporeal shockwave therapy (ESWT) and percutaneous radiofrequency microtenotomy, are as effective as traditional treatments. These novel conservative and surgical treatments, respectively, have a faster recovery period, increased functionality, lower complication rates, and increased patient satisfaction.

Introduction

Heel pain is one of the most common complaints that patients present with to a foot and ankle clinic[1]. Plantar fasciitis is an inflammatory condition that involves degeneration of the plantar fascia and affects about 1 million Americans annually.[2,3] Patients often present with heel pain and tightness after waking up in the morning, often improving with exercise[4]. It is often due to repetitive motion to the area, causing substantial tensile stress.[5] Plantar fasciitis is present in patients with a sedentary lifestyle as well as athletes, especially runners, making it the most common cause of heel pain.[4,5] While often self-limiting, the self-resolution time of 6-18 months can be a cause of frustration for many patients, leading them to seek care.[6] Both conservative and surgical therapies are available to treat plantar fasciitis.[4]

Many conservative therapies like rest, corticosteroids, stretching, sham-taping, load-bearing exercises, and physical therapy are initially recommended.[4] While these treatments address the pain and inflammation, they often do not help correct the posture of the foot which may have led to plantar fasciitis.[5]

Low-dye taping helps patients with overpronation by bringing the subtalar joint axis back to the neutral position and reducing the excessive medial force.[5] When conservative treatment does not help resolve the pain, surgical treatment may be implemented. Surgery is usually conducted if the patient does not find relief of symptoms 6-12 months after conservative therapy.[7] Two types of surgeries are common for treating recalcitrant plantar fasciitis: a complete or partial fascia release or a gastrocnemius release.[7] They can be done both as an open surgery or endoscopically, with an open partial fasciotomy being the treatment of choice.[7] While these traditional options are available, novel treatments are on the rise.

A novel conservative treatment is extracorporeal shock wave therapy (orthotripsy). A study done on a rabbit model demonstrated that shockwave therapy can induce the release of proliferating factors such as eNOS (endothelial, VEGF (vascular endothelial growth factor), and PCNA (proliferating cell nuclear antigen).[8] These factors help promote the growth of blood vessels at the tendon-bone junction of the Achilles tendons of the rabbits.[8]

A fairly modern surgical procedure for recalcitrant plantar fasciitis is radiofrequency microtenotomy.[3] In this procedure, microincisions are made along the area of interest to stimulate growth factors such as VEGF and FGF (fibroblast growth factor).[7] This promotes angiogenesis and the eventual revascularization of the area, leading to healing of the

degenerated area.[7]

This review aims to compare current treatment modalities with novel treatments in terms of efficacy, impact on the quality of life, and, when applicable, postoperative recovery time.

Results

Conservative Treatments

Three conservative taping techniques have been previously used to treat plantar fasciitis. The first specific conservative treatment that could be used to treat plantar fasciitis is low-dye taping. Low-dye taping helps improve the posture of the foot by reducing excessive pronation.[5] A study by Park shows that applying low-dye taping is more effective in treating plantar fasciitis in comparison to conservative physiotherapy.[5] Low-dye taping was shown to improve stability and reduce pain in a patient that has plantar fasciitis.[5] Another conservative treatment that could be used to treat plantar fasciitis is calcaneal taping. A study by Hyland describes the potential use of calcaneal taping for pain relief, as well as a forerunner to orthotics.[9] The calcaneal taping technique is unique in that it is not directly placed on the arch as support. Instead, it is used to invert the heel and raise it medially longitudinally. The third form of taping modality is sham taping. Sham taping is a type of technique that attempts to reduce plantar fasciitis without accounting for the position of the calcaneus.[9]

Calcaneal taping has been shown to be more effective than stretching ($p= 0.006$) and sham taping ($p=<0.001$) when evaluating for posttreatment pain and the visual analog scale (VAS).[9] However, low-dye taping is superior to calcaneal taping in the treatment of plantar fasciitis in terms of increasing the range of motion of the foot and decreasing pain.[10]

Another conservative treatment that could be used to treat plantar fasciitis is extracorporeal shock wave therapy, or ESWT (orthotripsy). ESWT is a type of sonication characterized by different types of pressure originally used for breaking up kidney stones in the 1980s and its use has since expanded to include musculoskeletal conditions.[11,12] The mechanism of ESWT is yet to be fully understood, but it is thought to provide anti-inflammatory relief and promote neovascularization.[13] A study by Alvarez et al. shows that there was a positive correlation to the ESWT in patients that were experiencing constant heel pain that lasted >6 months.[14]

In a study done to compare the efficacy of low-dye taping and ESWT, it was found that there was no significant difference between ESWT plus low-dye taping, ESWT plus sham-taping (another type of traditional conservative therapy), and ESWT alone.[15] They found that during the 4-week follow-up, there was no significant difference in VAS, and heel tenderness index (HTI) between the three groups.[15] However, the foot functionality and pain were improved in the group undergoing treatment with ESWT with adjunctive low-dye taping therapy as compared with ESWT alone ($p= 0.042$).[15] FFT and pain were also improved when comparing ESWT plus low-dye taping and ESWT plus sham-taping ($p=0.027$), showing that low-dye taping is a preferred method for banding treatment.[15]

Surgical Treatments

When plantar fasciitis symptoms continue beyond 6-12 months with no relief from conservative methods, surgical treatments may be considered.[13] An open partial fasciotomy, in which the medial third of the fascia is removed, is the conventional approach with the least risks.[13] However, complications can arise from these procedures, particularly iatrogenic flat foot, lateral column overload, and loss of the windlass effect.[16] Endoscopic plantar fasciotomy is performed via insertion of a slotted cannula through a stab section over the medial glabrous junction.[17] An incision is then made transversely on the medial one-third of the fascia and is then followed by irrigation of the wound.[17] In a study by Tomczak et al., which also factored in heel spur resection for open fasciotomies, when factoring in age, sex, and symptoms before the surgery, results showed that patients who underwent the endoscopic plantar fasciotomy were able to return to work 55 days before patients who underwent an open fasciotomy.[18]

A fairly new treatment for the therapy of recalcitrant plantar fasciitis is radiofrequency microtenotomy, also known as bipolar radiofrequency microdebridement.[7] This treatment is based on the concept that plantar fasciitis is due to chronic degeneration because of hypertrophy of fibroblasts, absence of inflammatory cells, avascular areas within the tissue, and disorganization of collagen fibers.[7] Radiofrequency microtenotomy aims to revascularize the tissue by promoting angiogenesis through the stimulation of growth factors.[7] It can be done percutaneously or via an open procedure, but an open

procedure is usually more effective.[2,7,17] This treatment particularly targets the areas of maximal discomfort.[2,7] A study by Chou et al. compared the efficacy of radiofrequency microtenotomy to plantar fasciotomy.[2] They concluded that there was no significant difference between the two procedures in terms of functionality, symptom reduction, or patient satisfaction.[2] However, there was a slight reduction in complication rate for the patients who underwent the radiofrequency microtenotomy procedure only (7.3%) as compared to a plantar fasciotomy (11%) and a combination of the two (33%), but this was not statistically significant ($p=0.069$).[2] While this study did not distinguish between an open, endoscopic, or percutaneous plantar fasciotomy, a study done by Wang et al. compared an endoscopic plantar fasciotomy and an open radiofrequency microtenotomy.[17] At 3 months post-operatively, it was found that patients who had the endoscopic plantar fasciotomy procedure progressed to be functionally better with an improved pain score than those who underwent the open radiofrequency microtenotomy.[17] However, at the one-year postoperative follow-up, patients in both groups had similar outcomes, concluding that both procedures were equivalent.[17] This early improvement for the endoscopic procedure could be due to the minimally invasive aspect of the procedure as well as the nerve degeneration that takes place in the radiofrequency microtenotomy procedure, which occurs until 60 days postoperatively, with recovery happening at around 90 days postoperatively.[17] Yuan et al. concluded that while the symptoms improved in patients who underwent either procedure, those who underwent the percutaneous radiofrequency microtenotomy benefitted from a shorter operative time and a faster postoperative recovery time.[1]

Discussion

There are many treatment modalities for plantar fasciitis. Conservative therapies are often the starting point for the treatment of plantar fasciitis. Taping is frequently employed in the treatment of plantar fasciitis. Although taping, specifically low-dye taping, is equivalent to ESWT in terms of VAS and HTI, it is significantly cheaper and can use as little as 4 pieces of tape to address both pain and functionality.[9] The lower cost of the treatment could be a factor for patients when deciding the treatment route.

While ESWT has equivalent VAS and HTI scores to taping, it does have significantly higher FFI scores. This could lead to an improved return to work and athletic activities. Patients may also prefer ESWT because it is minimally invasive and has a low side effect profile.[15]

In about 90% of patients, conservative therapy seems to provide relief of symptoms.[18] While the mainstay surgical treatment is an open fascia tenotomy, this may have issues such as a larger wound, longer recovery period, and possible postoperative complex regional pain syndrome.[1] However, newer procedures have made advancements in the postoperative outcomes of patients. Endoscopic fascia tenotomy yields fewer complications with a similar outcome as an open fascia tenotomy. Patients who underwent an endoscopic procedure also had an earlier return to work.[18] While both procedures were equally as effective in relieving symptoms, a faster return to work might have a greater impact on patient satisfaction. Nonetheless, since both of them require patients to be non-weight bearing for longer periods, they can result in complications such as venous thromboembolic disease.[7] Radiofrequency microtenotomy, a novel procedure, seems to be a viable option for treating plantar fasciitis. It was first reported in the treatment of the myocardium to promote regeneration in patients with cardiac failure and has since been applied to treat various ailments, including plantar fasciits.[1,7] Percutaneous radiofrequency microtenotomy has been shown to be as effective as an open fascia release. There were no significant differences in VAS scores and both had similar curative effects. However, a percutaneous radiofrequency microtenotomy has a shorter operative time and postoperative recovery period.[1] This could be due to a more straightforward operative method.[1]

Conclusion

Novel treatments, both conservative and surgical, have shown to be as effective as their traditional counterparts.[17] Additionally, they lead to better patient satisfaction and a faster recovery time.[18] ESWT is comparable to low-dye taping. Since both low-dye taping and ESWT have shown equal patient satisfaction scores and improvement of plantar fasciitis, it is ultimately the decision of the clinician to choose the best treatment for the patient. In terms of surgical treatment for recalcitrant plantar fasciitis,

percutaneous radiofrequency microtenotomy has shown to be better in terms of patient satisfaction and should be considered over plantar fasciotomy.

A faster postoperative recovery period after a percutaneous radiofrequency microtenotomy could also lead to earlier weight-bearing and faster return to work, compensating for any economical losses during this time.[17,18]

This subject of plantar fasciitis management warrants further inspection into which combination of treatments work best together, whether they are surgical or conservative. Further research is also warranted to investigate which populations would benefit the most from these treatments.

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Functional Electrical Stimulation in Treatment of Drop Foot: A Review of Current Literature

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ABSTRACT

Objective: The aim of this article is to review the potential efficacy of the use of Functional Electrical Stimulation as an alternative to Ankle-Foot Orthoses for the treatment of Drop Foot and gait irregularities following cerebrovascular accident.

Methods: A literature review was performed using the online databases of PubMed, GoogleScholar, and Wiley Online Library to gather relevant research articles, as well as to direct any trends or patterns that deal with the specific area of research related to Functional Electrical Stimulation, Ankle-Foot Orthoses, and Drop Foot.

Results: Current research supports the use of **t**he Ankle Foot Orthosis as the standard of care in the treatment of drop foot, with a meta-analysis by Tyson et al. demonstrating a statistically significant improvement in gait biomechanics and joint kinematics in stroke patients. However, multiple studies show that Functional Electrical Stimulation is also able to improve gait by activating anterior leg muscles to induce dorsiflexion. However, there is a lack of standardized measurements of the exact changes in biomechanics that this gait improvement works by in current Functional Electrical Stimulation studies.

Conclusion: Functional Electrical Stimulation has the potential to be a safe and effective alternative to Ankle-Foot Orthoses in the treatment of post-stroke drop foot. Both treatments show equivalent benefits in the areas of gait speed and therapeutic effects, but with Functional Electrical Stimulation users consistently giving higher ratings of user satisfaction and improvements in quality of life. There are some obstacles, but still many directions that are open to further investigation.

Introduction

Foot drop is a common gait abnormality seen in patients following a stroke, and can lead to other gait abnormalities and compensatory movements such as slower walking speed, heel catch, and risk of tripping or falling.[1,2] As a result, many patients display a decreased quality of life.[3] Concluding analysis suggests that ankle-foot orthoses (AFO) has a dependable success-rate, with years' worth of evidence-based research supporting the use of this conventional drop foot intervention.[4] Recent research introduces another method of foot and ankle therapy which uses stimulation of the peripheral nerves in the lower extremity to facilitate the dorsiflexor muscles' pre-established motion. Functional electrical stimulation (FES) is a therapy which can utilize an external device to stimulate the motor nerves by electrodes, either applied transcutaneously or implanted via surgery.[7] Both interventions show improvement in gait, demonstrating their efficacy in the treatment of drop foot in stroke patients.[5,6] Studies show that they also both may demonstrate an improvement in patients' gait after a period of long-term use that persists even when the device is not being used at the time of testing.[1]

Due to this apparent equivalence between the two interventions, it may ostensibly seem that there is no benefit of one modality over the other. This seems to be the prevalent attitude, as there is currently no reimbursement currently provided in the United States for the usage of FES in the treatment of drop foot, as AFOs are already the more well-established method and require less money to produce.[7]

Further research needs to be done in order to see if they are truly equal or if one is superior to the other in terms of minimizing compensatory movement patterns or improving gait in a way better applicable to patient's goals and tasks.[1]

Methods

Data extraction was performed using online resources such as PubMed, GoogleScholar, and Wiley Online Library to identify research articles with information related to the use of FES in the treatment of drop foot. Articles and papers were identified using search terms such as "neurorehabilitation", "foot drop", "functional electrical stimulation", "gait", and "ankle foot orthosis", and from there were chosen as they pertained to the purpose of this review.

Background

A cerebrovascular accident, also known as a stroke, occurs when blood supply is lost or reduced to part of the brain, resulting in the damage to or death of brain tissue in that area. In the United States alone, approximately 795,000 people have a stroke each year, resulting in the patient's death or disability.[8] A common disability seen post-stroke is a gait

abnormality known as drop foot, which affects about 20% of stroke survivors.[5,9]

Drop foot is a neurodegenerative disorder that causes weakness of certain muscle groups in the lower extremity, mainly those in the anterior compartment of the leg, resulting in the inability to dorsiflex the foot at the ankle joint, which leads to an outcome of mechanical and functional abnormality of the foot.[5] In the case of stroke patients, drop foot arises from a lesion to the upper motor neuron (UMN) that innervates the dorsiflexor muscles of the leg and foot. This can lead to deviations from the normal walking pattern as well as chronic changes in muscle architecture, as the muscle tissue atrophies from disuse and becomes infiltrated with adipose and fibrous tissues.[10] Due to the importance of dorsiflexion in normal gait patterns, drop foot can lead to further complications such as slower walking speed, heel catch, and an increased risk of tripping or falling due to catching the foot on objects.[1,2]

The traditional treatment method for drop foot has been the use of an Ankle Foot Orthosis (AFOs), which accommodates the lack of strength in the anterior tibial muscles by maintaining the ankle in a rigidly locked 90° position.[11] Modern day therapies have been introduced to address neural disabilities, such as the recent advancement of Functional Electrical Stimulation (FES), which has gained attention in lower extremity care.[9] FES was initially used in the treatment of different neuromuscular diseases, but the majority of professionals now use it as an alternative treatment for drop foot, utilizing low-level electrical impulses to stimulate paralyzed or damaged muscles in set intervals. This ultimately helps to improve muscle function by re-establishing communication through nerve stimulation.[11]

Results

Ankle Foot Orthosis

The AFO is currently considered the standard of care in the management of drop foot.[6] A meta-analysis conducted by Tyson et al. used a pool of twenty trials with 314 total participants, looking at the use of AFOs in managing drop foot in stroke survivors. From their research, they concluded that AFOs have a beneficial impact in regards to improving certain aspects of patients' gait biomechanics. Patients using an AFO demonstrate statistically significant improvements in ankle joint kinematics ($p<0.00001$-0.00002), in ability to bear weight on the affected leg in stance phase ($p<0.0001$-0.01), and in a minimized energy cost during gait ($p=0.004$).[4]

A comparison of seven random control trials by Prenton et al. also showed that patients showed improvement in gait even without the AFO after a training period, referred to as the therapeutic effect, as measured by an increase in walking speed with a 10 m gait test.[1]

Functional Electrical Stimulation

Muscles are normally activated by input from the motor cortex of the brain through nerve pathways. However, if some part of this pathway is damaged or interrupted, the muscles will no longer be able to activate properly, resulting in their weakness or paralysis. In the case of a stroke, the motor cortex is damaged and thus, the brain is unable to generate the normal signal to the muscle. The aim of FES is to directly stimulate the anterior muscles of the leg using electrical impulses to motor nerves applied externally by a device, thereby bypassing the pathway from the brain to the muscle.[7] Due to this, an increase in dorsiflexion is an improvement common with FES in drop foot. However, a literature review by Gil-Castillo et al. concluded that there is still a lack of understanding on any exact changes in lower extremity kinematics with FES because there is a high amount of variability in timing of the stimulation and in practical application of FES devices.[12] However, it has been consistently demonstrated that there are positive improvements in gait with FES. In a study conducted by Stein et al., walking speed was measured by 10 m Figure-8 test and a statistically significant increase was noted after a 3 month period, with an increase of 5.0% with the FES on ($p<0.003$) and 17.8% with FES off ($p<0.005$).[6]

As mentioned previously, the FES device can be triggered to send the electrical pulse by a few different methods: a pressure sensor on the bottom of the user's heel, a tilt sensor, or a hand switch that the user manually activates.[1,3] No matter which method is used, the goal in each case is to activate the muscles to dorsiflex the ankle once the affected foot leaves the ground, and deactivate once the heel of the affected side makes contact with the ground again.[7] In this way, the anterior muscle groups would be stimulated and activated at the same point that they would be in normal gait, creating a walking pattern that more closely approximates that of the patient pre-stroke.[5]

FES also varies in the placement of the electrodes used, either to the surface of the skin by transcutaneous FES (tsFES) or surgically positioned around the nerves by semi implantable FES (siFES).[7,13] In a study performed by Martin et al., it was demonstrated that patients statistically improved their walking speed in both the siFES group ($p<0.0001$) and tsFES group ($p=0.0001$), as measured by a 20 m gait-test, but with those in the siFES group show greater improvement ($p<0.0001$). However, in a short Quality of Life survey conducted on patients in the same study, the majority

of participants in both groups indicated satisfaction with the treatment, with 96% of participants reporting improvements in outcome measures such as mobility, social participation, and quality of life.[5]

A study by Berenpas et al. also examined applicability of FES in improving mobility in terms of obstacle avoidance, by comparing patients with FES and AFO and having them walk on a treadmill with objects occasionally dropped in front of the affected leg. They demonstrated that both tsFES and siFES show comparable improvement in obstacle avoidance when compared to AFO use ($p=0.04$).[2]

Discussion

Orthotic Effect of FES versus AFO

FES primarily stimulates the common peroneal nerve to ultimately invigorate the tibialis anterior muscle to achieve dorsiflexion at the ankle during the swing phase of gait, allowing the foot to clear the floor. The improvements in gait due to this stimulation by the FES device is referred to as the orthotic effect, named in part due to its similarity in function to that of an AFO.[6] It has repeatedly been shown that improvements in gait ability parameters such as maximum gait speed, perceived mobility, functional exercise capacity, and other motor function tests are comparable between these two modalities.[1,5,7] However, FES demonstrates a greater benefit over AFO in more challenging tasks such as obstacle avoidance, which require faster changes in adaptation of stride or gait in order to avoid tripping over an object. This may be in part due to the greater freedom of movement and increased dorsiflexion available with FES compared to an AFO, which keeps the ankle locked in a rigid position.[2]

Therapeutic Effect of FES versus AFO

In addition to the orthotic effect of FES, it has also been documented that some patients who use FES demonstrate improvements in voluntary dorsiflexion of the ankle when the device is off and therefore not stimulating these muscles, a phenomenon referred to as the therapeutic effect.[3,6] Several mechanisms have been proposed to explain the therapeutic effect of FES: that the increased usage of muscles due to facilitation of movement allows for positive changes in the muscle tissue itself, that the contraction of muscles pushes out swelling from the affected area while increasing blood and oxygen supply, and increase in neuroplasticity leading to changes in the organization of the cortex.[1,5,7,11] It had generally been believed that this therapeutic effect was specific to the FES. However, a meta-analysis by Prenton et al. revealed that long-term users of AFOs demonstrated an equivalent therapeutic effect and patients showed improvement when their gait was tested while not using an AFO after having previously used an AFO.[1] However, it was acknowledged by Prenton et al. that although the magnitude of these therapeutic effects were comparable within a controlled laboratory setting, there was not enough data in the studies examined to determine whether the mechanism of the therapeutic effect was the same or whether these therapeutic effects could equally be applied to a range of different environmental conditions or more complex tasks in patients' activities of daily living.[1]

Plantarflexion Enhancement with FES

Several studies have shown or discussed the importance of plantarflexion in gait. This has been explained as one of the downsides of AFOs, as the ankle is kept locked in a position and is allowed neither to dorsiflex nor plantarflex.[2] In many cases, the loss of neuromuscular control is due not just to drop foot, but additionally from resulting spasms in the plantarflexor muscles.[14,15] As one of the issues raised with both AFOs and FES as a treatment for drop foot is the inability to replicate the natural movement patterns of gait, the stimulation of other muscle groups in addition to dorsiflexor muscles is a natural progression for future research.[3] Although studies specifically investigating stimulation of both dorsiflexor and plantar flexor muscles has been limited so far, it has been shown to have greater improvements in gait when compared to FES of dorsiflexor muscles alone.[15]

Interestingly, stimulation of the common peroneal nerve by FES may lead to better propulsion of the body weight by the plantar flexor muscles even without direct stimulation of the muscle group through the tibial nerve.[16] This better utilization of the plantar flexors was one possible hypothesis given to explain the greater improvement that FES users had compared to AFO users in measures of obstacle avoidance and reduced time needed to complete an obstacle course This suggests that FES patients may better be able to handle more complex tasks associated with activities of daily living, such as navigating different environments.[2]

Disadvantages of AFO

Another important thing to note when comparing the two interventions is that each has their own disadvantages in addition to their benefits and these should also be taken into account when discussing their usage.

When considering AFOs, the mechanism itself can serve as a disadvantage as holding the ankle rigidly in a 90° angle over long periods of time, as the device is intended to do, causes the muscles to stiffen up. As this progresses, it can lead to contractures of the muscles of the leg and foot, especially the plantar flexor muscles.[5,6]

As the AFO only holds the ankle in position, this does not affect other joints. As drop foot tends to be only one symptom of stroke, if the motor weakness extends to other muscles such as the hip flexors, then an AFO may not be sufficient.[5] This could also be said for the conventional 2-channel peroneal nerve stimulator, as it is meant primarily to target the dorsiflexor muscles of the leg. However, it has been shown that FES also may result in enhanced plantarflexor activity and that long-term use of FES may also impact the muscle architecture of other muscles not directly stimulated, such as the rectus femoris.[10,16]

It has also been documented by several studies that some complaints have been made about inconvenience of using AFOs due to the size and weight of the device, and the fact that it is difficult to conceal underneath clothing. Patients have noted these when surveyed on user satisfaction as to why FES devices are often preferred, also indicated in a study by Stein et al that showed increased rates of dropout in the AFO group versus the FES group.[3,5,6,7]

Disadvantages of FES

One major disadvantage preventing the more widespread use of FES for use in drop foot is monetary cost. As stated previously, the orthotic effect of AFO and FES have many gait parameters that show equivalent measures of improvement.[1,6,7] As this is the primary goal of both interventions, it is generally considered by regulatory bodies that the two are equal, and as FES is a more complex device and therefore more expensive to manufacture, reimbursement has generally not been provided so far for use in stroke patients.[7] One advantage that has been demonstrated by multiple studies is that improvements in gait have the potential to continue without the use of the FES device.[3,5,7,9,11,14] This therapeutic effect has been shown inconsistently and requires greater characterization as to the factors that influence an FES user's status as a responder or non-responder to therapeutic effects.[9,11] It could also be shown that therapeutic effects are seen in both AFO and FES users, although this also warrants further investigation as the mechanism is still unknown in either case and so may be different in a way that one may be more clinically relevant or better applicable to improving patient's quality of life.[1,2]

In addition, each type of FES device has its own disadvantages. The use of tsFES may cause irritation to the skin at the application site of the electrode, which could lead to dermatological issues including blistering, rash, and contact dermatitis.[5,17] As drop foot is often not seen alone in stroke patients, and other motor impairments may be present, setting up the tsFES device and applying the electrodes may not be realistic, especially as they must be applied with each use.[5] This may lead to inconsistent practice and training with the tsFES over the long-term and may help to explain why the therapeutic effect was larger in siFES versus tsFES.[5,9,18]

One study showed that patients who may not tolerate tsFES may be able to use siFES without pain.[13] Some patients may not find siFES appealing due to the fact that it requires surgery in order to position the electrodes at specific points around the nerves.[18] As with any surgery, there were potential complications associated with siFES, as documented in the study conducted by Martin et al, but these were noted to be relatively rare, including hematoma, lymphedema, deficit in wound healing, infection, and accidental damage to the peroneal nerve.[5]

Conclusion

In closing, FES has shown promise as an alternative treatment to the widely accepted AFO in the treatment of drop foot in stroke victims. AFOs have long been used as the standard of care, with users demonstrating consistent increases in gait speed and lower extremity kinematics during the gait cycle.[4] It has repeatedly been shown that FES shows equivalent improvement in gait speed by stimulating the peroneal nerve to activate dorsiflexor muscles, but with additional therapeutic effects being shown by some patients maintaining improvements in gait after long-term usage of FES, even when the muscles are not being stimulated, potentially by facilitating cortical neuroplasticity.[3,6,7,11] Although it has since been shown that there is evidence of similar degree of therapeutic effects with the use of AFOs as in the use of FES, it remains to be seen by what mechanism - functional recovery or compensation - this occurs in AFOs and whether these effects translate into patients' particular environments and activities of daily living.[1,2] Future studies should work to further characterize the kinematic implications of FES in the gait cycles so that these improvements can be directly compared.

Currently, AFOs remain the traditional treatment for drop foot, with several significant barriers preventing widespread use of FES for drop foot. However, there are many potential advantages that FES may have over AFOs that should be considered and many avenues that warrant further exploration.

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Radiofrequency Therapy for the Treatment of Morton's Neuroma: A Review

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ABSTRACT

Objective: Morton's neuroma is a fairly common cause of lower limb pain, primarily affecting middle-aged women. Radiofrequency therapy is a novel treatment for Morton's neuroma that shows promise in pain management. No previous literature exists comparing the two different methods of radiofrequency treatment, pulsed radio frequency versus continuous radiofrequency. The purpose of this review is to examine and compare the outcomes of the different radiofrequency therapies in the treatment of Morton's Neuroma.

Methods: A literature review was conducted, querying PubMed and Google Scholar. Search terms included "Morton's Neuroma," "Radiofrequency Treatment," "Pulsed Radiofrequency," and "Continuous Radiofrequency." Papers that required a fee or case reports were excluded.

Results: All studies reviewed showed a decrease in pain after radiofrequency therapy. Deniz et al. examined the effects of pulsed radiofrequency therapy, with 60% of patients reporting a 50% or more decrease in pain levels following treatment. A study examining continuous radiofrequency therapy by Shah et al. comparatively showed 71.4% of neuromas reporting a 50% or more decrease in pain levels. Masala et al. reported a total mean pain reduction of 76.7% following continuous radiofrequency treatment.

Conclusion: Both pulsed and continuous radiofrequency therapy showed promising results for pain management of Morton's neuroma, and proved their efficacy and safety. Continuous radiofrequency therapy seems to have slightly better results in terms of level of pain reduction. More research needs to be conducted in order to further study the long-term benefits of each treatment.

Introduction

Morton's neuroma is a painful degenerative neuropathy that can cause pain and significant discomfort.[1] This condition is a common cause of forefoot pain, especially in women.[2] It is clinically presented by fibrosis most frequently in the second or third digital nerves in the forefoot.[3] Several treatments to reduce the pain levels associated with this painful neuroma are available. Radiofrequency therapy is a novel treatment showing potential in terms of pain reduction in addition to little to no side effects. Two different radiofrequency methods are currently used for treatment of Morton's neuroma, pulsed radiofrequency therapy and continuous radiofrequency therapy. In this review, the different radiofrequency treatments will be examined and compared to determine which radiofrequency therapy has a more favorable outcome, in terms of safety and efficacy, when treating Morton's Neuroma.

Epidemiology

The exact incidence of Morton's neuroma is unknown but is thought to be a common cause of forefoot pain.[4] Morton's neuroma is five times more common in women than men, with the mean age at presentation of symptoms being 50 years.[5] It is commonly seen in athletes, mainly those involved in activities that cause repetitive trauma to the metatarsals, such as runners and dancers. Individuals with foot deformities, such as bunions, high arches, or flatfeet, are at a higher risk of developing Morton's neuroma. Other risk factors include wearing tight shoes and high heeled footwear, which accounts for the higher incidence in women as compared to men.[6]

Diagnostics & Treatment

Symptoms of Morton's neuroma include a sharp, burning like pain in the ball of the forefoot; patients may describe the sensation as having a pebble in the shoe while walking.[7] Diagnosis is primarily made using a history and physical exam in patients presenting symptoms, but imaging methods such as ultrasound and MRI are useful in confirming the diagnosis.[4] There are a variety of treatments available, with the ultimate goal of treatment being pain relief. Initial treatment is usually conservative, such as modifications to footwear, rest, or use of special orthotic devices. Further, infiltrative treatment includes local anesthetics and steroid or alcohol injections.[8] If conservative treatments are not effective, surgical interventions may be required.[9]

Radiofrequency Therapy

Radiofrequency therapy is an infiltrative, non-surgical option that may look appealing for those who have been unsuccessful with conservative treatment. Radiofrequency treatment uses radio waves and heat on the nerve to cause neural ablation or destruction of nerve.[10] Continuous radiofrequency therapy produces a high-frequency, high-temperature

(above 70°C) electric current to the target tissue, with the intention of being neurodestructive.[11] On the other hand, pulsed radiofrequency is a minimally or non-neurodestructive and less painful technique,[12] that is characterized by the lower temperature of its electrical current and high-voltage bursts, with the target tissue never exceeding 42°C.[10] The exact mechanism in providing pain relief by pulsed radiofrequency treatment is not known, but this technique has been successful in treating a variety of conditions involving chronic pain.[13] Both techniques are relatively novel treatments, and there are no known studies comparing the two. The objective of this review is to compare continuous radiofrequency therapy to pulsed radiofrequency therapy for the treatment of Morton's neuroma. Analyzing efficacy of the treatment, improved function while walking, and safety of each treatment are factors that will be taken into account when comparing the different types of therapy.

Methods

Studies were drawn from PubMed and Google scholar using the search terms "Morton's Neuroma," "Radiofrequency Treatment," "Pulsed Radiofrequency," and "Continuous Radiofrequency." A total of four studies published between 2011 to 2019 were selected and reviewed. Studies were selected based on their objectives, similarity in mean age groups, and similarity in female to male ratio. Papers that required a fee and case reports were excluded.

Results

Pulsed Radiofrequency Treatment

In 2011, Karaman et al. designed a retrospective study to examine the effects of pulsed radiofrequency therapy on decreasing lower limb pain, specifically in patients with osteoarthritis suffering from chronic knee pain. In this study, 31 patients underwent pulsed radiofrequency therapy performed at 42°C for 15 minutes, under anesthetic. Patients pain levels were assessed using a VAS (visual analogue scale) score, from 0 being the least amount of pain to 10 being the most severe pain imaginable. The mean VAS scores of the patients before treatment was 6.1 ± 0.9 and decreased to 3.9 ± 1.9 one month after treatment. During the six month follow up, patients reported a mean VAS score of 4.1 ± 1.9. A minimum decrease of 2 points in the VAS score was reported by 64.5% of patients, and 35.5% of patients reported over a 50% decrease in pain. No complications were reported during the procedure or in the follow-ups.[14]

In 2015, Deniz et al. used an open-label study to analyze the effectiveness of pulsed radiofrequency therapy in Morton's neuroma. In a study with 20 patients, pulsed radiofrequency therapy was performed at 42°C for 300 seconds, under anesthetic. Patients pain levels were assessed before treatment and after a six-month follow-up, using a numerical rating scale of 0-10. The mean pain score of patients was 7.16 ± 0.26 before the procedure, and 3.36 ± 0.54 six months after the procedure ($p < 0.0001$) showing about a 53% mean decrease in pain. After the six month follow up, 90% of patients reported a decrease in pain level. Successful pain control was determined by a reduction of pain of 50% or more. 60% of patients reported successful pain control. All patients had expressed pain in walking, as well as footwear restrictions before treatment, but only 20% of patients reported to experience this pain after therapy. In terms of safety, no permanent complications were reported.[10]

Continuous Radiofrequency Treatment

In 2017, Masala et al. conducted a retrospective study to examine the effectiveness of continuous radiofrequency in patients suffering from chronic pain due to Morton's neuroma. Ultrasound-guided continuous radiofrequency therapy was performed on 52 patients, with one cycle of 90 seconds at a temperature of 85°C. A VAS score and Foot Health Status Questionnaire (FHSQ) was given before and after the procedure. Pain intensity during walking was assessed using VAS with a range of 0-10. The FHSQ measured foot health, on a scale from 0-100, 0 being the poorest state of health and 100 being the ideal state of foot health. The VAS score for pain during walking before the procedure was 9 ± 0.9, and seven days following the procedure was 3.7 ± 1.1, showing a significant reduction in pain while walking ($p < 0.005$). During the two month follow up, the mean VAS score was 2.1± 0.9 ($p < 0.05$) and 1.7 ± 0.8 after six months ($p=0.005$). Patient's FHSQ answers showed an improvement in foot health seven days after the procedure, with a mean score of 71 ± 17, compared to the mean score of 36 ± 21 prior to the procedure. The mean FHSQ scores during the six month follow up was 75 ± 22. A one year follow up was conducted, where the mean VAS increased to 2.1 ±1.7 ($p < 0.005$) , and the mean FHSQ score decreased to 73 ± 20 ($p < 0.005$). 98% of patients were able to use normal shoes and resume activities within two days of treatment. One patient decided to undergo surgical excision after treatment, and five patients requested another radiofrequency treatment as their pain reappeared during the one year follow up. No patients developed serious complications.[15]

In 2019, Shah et al. assessed the efficacy and safety of ultrasound-guided radiofrequency ablation for Morton's neuroma. 18 patients underwent continuous radiofrequency treatment. Between 3-10 one-minute cycles of radiofrequency therapy were applied at a temperature of 80°C (the number of cycles

depended on the size of the neuroma). A VAS score, Foot and Ankle Questionnaire, and patient satisfaction was used to assess patient outcome. VAS scores of each patient were taken before the treatment, eight weeks post-treatment, and between six to eight months post treatment. The median VAS scores pre-procedure compared to after the procedure showed a significant decrease, with the median VAS score being 8 pre-operation and dropping to 3 about eight weeks after operation ($p < 0.001$), demonstrating a median pain decrease of 62.5% . The median VAS score dropped further after the eight month follow up, to 1 ($p= 0.008$). 71.4% of neuromas showed a 50% or greater improvement in VAS pain score during the eight month follow up. A total of 89% of patients after six to eight months self-reported to have either a satisfactory, good, or excellent outcome. No significant adverse effects were seen during the procedure or reported in the follow up. However, one patient who reported excellent treatment said they experienced new, painless twitching in their second toe since the procedure.[16]

Discussion

Several limitations were seen in the studies. Two of the studies, Deniz et al. and Shah et al., had relatively smaller (20 and 18 patients respectively) as compared to the group studied in Masala et al. (52 patients). The follow up period was not standardized across the studies, with Masala et al. showing the highest follow up period at one year. Other limitations include different clinical settings and different study types (open label versus retrospective). In addition, only one study was found examining pulsed radiofrequency specifically for treatment of Morton's neuroma.

In each study, the patients had already tried conservative treatments for Morton's neuroma before choosing to proceed with radiofrequency treatment. Conservative methods, such as avoiding heeled, tight shoes, alcohol or steroid injections, or orthotic devices alone are often not enough to relieve pain. In one study, only 41% of patients found that conservative treatment alone relieved pain.[17] Surgical treatment is a method for pain management caused by Morton's neuroma, through either surgical excision of the lesion or nerve decompression. While these procedures are generally successful in terms of pain reduction, surgical treatment comes with risks such as hematoma, stump neuroma, and deep space abbess.[15] In addition, there is often a recovery period associated with surgery that some patients may wish to avoid.

Radiofrequency therapy, in comparison, is minimally invasive, efficient, and in all studies showed no complications or long-term adverse effects. In this sense, it is a promising treatment for those who have been unsuccessful with conservative treatments but do not wish to risk the complications or undergo a recovery period through surgery. However, radiofrequency treatment for Morton's neuroma is a relatively novel technique and needs to be further studied.

Pulsed Radiofrequency therapy is ideal in that it allows for pain management for Morton's neuroma with minimal destruction to the nerve and tissue.[17] It is not clear how pulsed radiofrequency reduces pain, but there are several theories, such as it altering the transmission of pain signals through a pathway involving c-Fos.[19] In Karaman et al., pulsed radiofrequency showed a decrease in pain in patients suffering chronic knee pain related to osteoarthritis. All of the patients in the study had not responded to more conservative treatments (physical therapy, analgesic drugs), but pulsed radiofrequency was successful in decreasing the mean pain score by a total of 2.0 ± 1.4 points after the last follow-up. No adverse effects, such as hemorrhage or infection, were reported during or after treatment. This study confirmed the safety and efficacy of pulsed radiofrequency in treating lower limb pain.[14]

In Deniz et al., pulsed radiofrequency showed to be successful in pain reduction for 90% of the patients suffering from Morton's neuroma, and 80% of patients felt comfort while walking after the treatment. No permanent complications were involved, making this treatment an appealing choice for those who prefer the treatment to be minimally neurodestructive. Due to the lower temperature of the therapy (42°C compared to 80°C or more in continuous radiofrequency therapy) this method may be less painful as well.[10] However, this is only one study, and it is important for more research to be done regarding pulsed radiofrequency therapy for treatment of Morton's neuroma.

Continuous radiofrequency therapy showed promising results as well. Shah et al. showed a total of 89% of patients reporting excellent, satisfactory, or good results after treatment. Compared to the study Deniz et al. conducted, we can see that in both cases a similar percentage of satisfaction with the procedure was reported (89% versus 90%). Karaman et al., Deniz et al., and Shah et al. all conducted studies that measured the percentages of patients who felt a decrease in pain by 50% or more. In this case, continuous frequency treatment showed better results (71.4% from Shah et al. versus 60% from Deniz et al. and 35.5% from Karaman et al).[10,14,16] None of these studies reported significant adverse effects. One patient in the study conducted by Shah et al. did report a painless twitching sensation in their left toe after the procedure; the cause for this is unknown.

Masala et al. were able to demonstrate the effects of continuous radiofrequency therapy in a larger study, with a longer follow up period (one year) compared to the studies conducted by Karaman et al., Deniz et al., and Shah et al. This is useful in understanding the long-term benefits of this treatment. The mean VAS score assessing the intensity of pain decreased by about 81% six months after the procedure as compared to before the procedure. However, during the one year follow up patients reported a slightly increased mean VAS score, with a pain reduction of approximately 76.7% as compared to before the procedure. Mean foot health score increased by about 52% six months after the procedure as compared to before the operation and decreased slightly to about 50.6% during the one year follow up. No patients developed any complications. However, during the one year follow up, about 10% of patients felt the reappearance of pain and requested a repeat treatment.[15] This study showed success in that 98% of patients could resume activities only two days after treatment, with a high level of average pain reduction at 76.7% during the one year follow up. It is important to note the slight decrease in average pain reduction during the one year follow up as compared to the six month follow up, as well as the slight decrease in foot health of patients during this time. This may indicate that continuous radiofrequency therapy, while initially successful, should be examined in more long-term studies.

Conclusion

Both pulsed radiofrequency and continuous radiofrequency have proven to be successful for pain management of Morton's Neuroma. However, the studies examining continuous radiofrequency therapy reported higher percentages in terms of level of pain reduction. Both techniques have shown no significant adverse effects or complications. The nature of the therapies and the mechanisms by which they relieve pain differ, but they produce similar results in terms of efficacy and safety. Overall, more research needs to be done to examine the long-term outcomes of both pulsed and continuous radiofrequency therapy.

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The Use of Cannabis for the Relief of Peripheral Neuropathic Pain of the Lower Extremity

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ABSTRACT

Objective: Neuropathic pain is the most reported symptom among patients diagnosed with Peripheral Neuropathy, with other symptoms including loss of sensations and weakness when ambulating. The objective of this study will focus on the efficacy of cannabis use for the relief of peripheral neuropathic pain.

Methods: A literature search was conducted on the PubMed and Google Scholar databases to retrieve articles relating to cannabis use for the relief of peripheral neuropathic pain. Twelve articles were found to be appropriate for the study.

Results: The study supports cannabis as an analgesic therapy for peripheral neuropathic pain. With its ability to alleviate pain it also has its list of side effects such as an impairment in learning, memory, and psychomotor speed, feeling of psychosis, uncontrollable cough, throat irritation, headache, dizziness, fatigue, and a decline in attention and memory.

Conclusions: The use of cannabis should be considered as an adjunctive treatment for peripheral neuropathic pain, as it is found to be effective in alleviating neuropathic pain. Cannabis has also been found to be useful in alleviating pain when first-line pharmacotherapies were no longer effective in patients. Physicians must conduct a complete physical and mental examination of their patients and have knowledge of the current literature about cannabis before prescribing cannabis to their patients.

Introduction

Peripheral Neuropathy

Peripheral neuropathies include a number of disorders of the peripheral nervous system that present in different patterns.[1] The pattern mostly seen in clinics is the Distal Sensory Polyneuropathy (DSP) pattern.[1] DSP contains loss of sensation, pain, and weakness when walking that causes gait instability, and foot ulcerations which may eventually lead to amputation.[1] Other patterns of peripheral neuropathies are Mononeuritis Multiplex where many individual nerves are injured which shows symptoms of a spotted pattern of injury.[1] Polyradiculopathy is another pattern of peripheral neuropathy that causes weakness and numbness in the proximal and distal limbs.[1]

Peripheral neuropathies can be described based on the size of the nerves and type of nerve fiber affected. Small diameter, myelinated and unmyelinated fibers are responsible for thermal and mechanical pain and damage to these fibers causes a burning sensation, tingling, electric shock, increased sensitivity to painful and non-painful stimuli.[1] Medium and large myelinated sensory fibers are responsible for vibrations and body positioning awareness and injury to these fibers can cause numbness, imbalance, distal weakness and atrophy. [1]

Pain is the most reported symptom from patients suffering from peripheral neuropathy. In patients with diabetic neuropathy 20-30% of patients said that neuropathic pain was the most disabling symptom.[1] Causes of peripheral neuropathy can be related to uncontrolled diabetes mellitus, long-term alcohol use, chemotherapy, Human Immunodeficiency Virus, autoimmune diseases and metal toxicity.[2]

This disease can severely decrease one's quality of life and may have some emotional and cognitive effects.[2] Drug therapy that is currently being used in clinics to combat neuropathic pain are tricyclic antidepressants, anticonvulsants, and serotonin-norepinephrine reuptake inhibitors.[1] The only 2 drugs approved by the United States Food and Drug Administration (USFDA) to treat diabetic neuropathic pain are Duloxetine and Pregabalin which are a serotonin-norepinephrine reuptake inhibitors and anticonvulsant, respectively.[1] The side effects of Duloxetine range from nauseas, diarrhea, fatigue, sexual side effects, mild increases in blood pressure, diaphoresis, tachycardia, tremors, and anxiety.[3] Pregabalin has similar side effects as Duloxetine with a higher emphasis on its potential for abuse due to its euphoric or "high" feeling when used in excess.[4]

Alternative remedies for peripheral neuropathy have gained popularity.[1] These alternative solutions are physical therapy, acupuncture, herbal medications, chiropractic manipulation and meditation.[1] A study conducted by Callaghan and Feldman found that in 180 patients with peripheral neuropathy 43% of those patients admitted to experimenting with alternative medicine for their peripheral neuropathic pain.[5]

Cannabis

Cannabis, like many other drugs and medicine, can be taken by inhalation, orally, or topically. Cannabis has been used in various ways in the medical field for pain control, inflammation, sleep disorders, epilepsy, anorexia, schizophrenia and other conditions.[2] There are over 80 known phytocannabinoids and the 2 main components within these strains are Δ9-Tetrahydrocannabinol (THC) and Cannabidiol (CBD).[2]

Modesto-Lowe et al. state that THC is the component in cannabis that is the primary psychoactive component, and is responsible for relaxation, altered perception, increased sensation, increased sexual desire, and impaired sense of time and space.[6] They also state that CBD has a non-psychoactive effect and is responsible for anti-inflammatory and antioxidant; Its main responsibility is to reduce pain and inflammation.[6]

When a nerve is injured, neurons along that nociceptive pathway become sensitive and reactive. There is an increase of sensation to pain in these nerve endings.[6] Cannabis is thought to reduce this pain by inhibiting nociceptive pathways in the dorsal horn of the spinal cord and in the ascending spinothalamic cord.[6]

Endocannabinoid System

The human body has a cannabinoid system that regulates and helps maintain the balance of the central nervous system.[6] It is responsible for transmitting pain in the nociceptive pathway. The two main endogenous cannabinoids are anandamide and 2-arachidonoylglycerol. They are made in the central nervous system and they target the G protein coupled CB1 receptor, which is found on the peripheral system, that inhibits pain.[6] They also target the G protein coupled CB2 receptors, that are found in immune cells, that slow down the release of nociceptive agents.[6] CB1 receptors are involved with movement, memory, and pain signals whereas CB2 receptors help alleviate inflammation, allodynia, and hyperalgesia.[6]

Methods

A literature search was conducted on the PubMed and Google Scholar databases to retrieve articles relating to cannabis use for the relief of peripheral neuropathic pain. When searching the databases keywords used were cannabis, peripheral neuropathy, neuropathic pain, neuropathy, marijuana, alternative medicine, weed, THC, CBD, foot pain, ankle pain, tingling, podiatry. Twelve articles were found to be appropriate for the study.

Results

Wilsey et al. conducted a double-blinded placebo-controlled study that observed the effects of cannabis in 38 patients with peripheral neuropathic pain.[7] The study consisted of 3 groups. One group was assigned to inhale cannabis with 7% THC, another group with 3.5% THC, and a placebo group. Participants were instructed to take 2 puffs to begin, 3 puffs the next hour, and 4 puffs the next hour. Pain intensity was measured every minute using the Visual Analog Scale (VAS). It was found that the 2 groups of cannabis with THC content each had a -.0085 pain reduction on the VAS compared to the placebo, which had a -.0040 pain reduction.[7] Some of the complaints from the group assigned the cannabis with 7% THC were, that they experienced impairment with learning, memory and psychomotor speed.[7]

Ellis et al. conducted a double-blind placebo-controlled study that looked at the effects of cannabis in 28 HIV patients with neuropathic pain, who were no longer responsive to at least 2 other analgesic drugs.[8] This study consisted of 2 groups. One group was assigned to inhale cannabis with the potency ranging from 1-8% THC and the second was the placebo group. Treatment was weekly and the doses of cannabis were adjusted based on the tolerance of the participant. The overall consensus from the patients was that they admitted to an overall reduction in pain caused by neuropathy. Ellis et al. state that of the 28 patients, 46% had an average of 3.3 points in pain reduction from the baseline of 11, which was the mean pain intensity of the 2 groups measured pre-treatment with the Descriptor Differential Scale (DDS).[8] Some side effects mentioned by the patients were having the feeling of psychosis and an uncontrollable cough that resolved after cessation of the study.[8]

Ware et al. conducted a randomized crossover study that looked at the effectiveness of cannabis use with 21 patients that were suffering from neuropathic pain following a traumatic event or surgery.[9] The 21 patients were all tested for different potency of cannabis from 0%, 2.5%, 6% and 9.4% THC, for 14 days each (14 days with 0% THC, 14 days with 2.5% THC, etc.). For the 14-day periods patients were assigned to inhale 25mg of cannabis 3 times daily for the first 5 days with the last 9 days of cannabis-free cleansing. The patient's average pain intensity was measured daily. The study also looked at the patient’s mood, sleep, and quality of life. From the study patients reported that the use of cannabis with 9.4% THC had a significant decrease in pain and they experienced better sleep. The use of 9.4% THC cannabis caused an average pain to decrease from 6.1 to 5.4. Ware et al. study also concluded that as the potency of THC increased there was also an increase

of adverse effects ranging from throat irritations, burning sensation, headache, dizziness, and fatigue.[9]

Wilsey et al. again conducted a double-blind placebo-controlled study in 2013 that looked at the effects of cannabis on central and peripheral neuropathic pain in patients who were resistant to first-line pharmacotherapies.[10] The study consisted of 3 groups. One group was assigned cannabis with 3.5% THC, another with 1.3% THC, and the placebo group. It was found that 26% of the patients in the placebo group reported a decrease in pain, whereas the groups assigned to 1.3% and 3.5% THC had a 57% and 61% decrease in pain intensity, respectively.[10] There was no significant difference between the 2 groups containing THC content. Patients admitted to some psychoactive effects, but symptoms reversed at the conclusion of the study.[10]

Wallace et al. conducted a randomized, double-blind, placebo-controlled crossover study looking at the effects of cannabis on 16 patients suffering from diabetic peripheral neuropathy.[11] All 16 patients stated to have had neuropathic pain in the lower extremity for at least 6 months. Randomly the 16 patients were given a single inhalation dose of cannabis with 1%, 4%, 7% THC or the placebo. From the study it was found that all groups containing THC content had the lowest score of pain intensity compared to the placebo group, with the 7% THC group having the most analgesic effect.[11] Patients stated that they experienced a decline in attention and memory.[11]

Discussion

From the studies mentioned, there is a consensus that cannabis is effective in alleviating pain caused by peripheral neuropathy. It was also found that cannabis was beneficial in patients suffering from neuropathic pain, who were no longer responsive to first-line pharmacotherapies.[8] Cannabis may have been successful in alleviating some physical sensory pain but there were complaints from patients involved in the studies. Side-effects mentioned by patients ranged from impairment in learning, memory, and psychomotor speed, feeling of psychosis, uncontrollable cough, throat irritations, headache, dizziness, fatigue, and a decline in attention and memory. Inhalation of cannabis or inhalation of any tobacco product long-term can have some negative respiratory effects and also run the risk of dependence and addiction.[12] The use of cannabis for peripheral neuropathic pain should be taken with caution as any other drug therapy.

Despite studies supporting the analgesic benefits of cannabis for peripheral neuropathic pain, additional studies should be conducted. These additional studies should investigate the effectiveness of cannabis for neuropathic pain administered in other routes such as oral, topical, or intravenously. The studies mentioned were all conducted with inhalation as the route of administration. An analysis of other routes of administration, their side effects, and duration of drug action would be beneficial in providing options for patients who prefer not to inhale cannabis. Another potential study that should be conducted should investigate a solution to minimize the list of side effects associated with cannabis use.

Conclusion

The use of cannabis should be considered as an adjunctive treatment for neuropathic pain. Recent studies have found the use of cannabis very effective in alleviating neuropathic pain. Cannabis has also been found to be useful in alleviating pain when first-line pharmacotherapies were no longer effective in patients. Physicians must conduct a physical and mental examination of their patients, have knowledge of the current literature on cannabis, and use it as guidance for the prescription of cannabis, for the relief of peripheral neuropathic pain.

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A Review on the Effects of Dance interventions on Motor Function of those with Parkinson's Disease

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ABSTRACT

Objective: To perform a literature review on current findings in the effectiveness of dance-therapy to improve the motor functions and balance in those with Parkinson's Disease.

Methods: Suitable and applicable articles regarding dance rehabilitation for Parkinson's Disease patients were analyzed. Keywords searched included 'dance therapy with Parkinson's' and 'Parkinson's Disease.' Articles were obtained utilizing the search engines PubMed, NCBI, and the Western University of Health Sciences Pumerantz Library databases.

Results: The analyzed studies revealed that dance interventions in patients with Parkinson's Disease improved aspects of motor function, revealed in tests such as the timed up-and-go test, 6-minute walking test, and the walking kinematics of self-selected speed.

Conclusion: The analysis of literature shows that dance rehabilitation can improve motor and balance functions in patients with Parkinson's Disease. However, further research is required to consider dance therapy an effective form of rehabilitation.

Introduction

A neurological disease that influences the motor function of those affected is Parkinson's Disease (PD). Gait, balance, and motor function are most notably affected, ultimately impacting the quality of life for these patients.[1]

Parkinson's Disease is the second most common neurodegenerative disease, following Alzheimer's Disease. [1] Current research indicates that the pathology of PD is characterized by changes of the activity of dopaminergic cells located in the substantia nigra, a part of the basal ganglia of the midbrain. The cardinal motor symptoms of PD include rigidity, bradykinesia, tremor, postural instability, and alterations in gait patterns.[2] The alterations in gait are directly caused by cognitive deficits such as time and spatial perception loss and alterations in balance, consequently decreasing step length and cadence.[3] Thus, gait recovery is an essential part in the rehabilitation of those that are affected.

According to the National Institute on Aging (NIA), the current interventions for Parkinson's Disease are physical and occupational therapy for motor dysfunction, specifically for gait. Abbruzzese et al. (2015) reports that the current physical therapy rehabilitation includes stretching, muscle strength training, balance training, postural exercises, and treadmill training. Occupational therapy includes therapy to help motor and sensory function to relearn skills needed for daily life such as hair grooming, cooking, and housecleaning. However, there is no general agreement among physicians on what the optimal form of therapy for PD patients.[7]

While there have been some improvements with gait and balance when practicing traditional forms of rehabilitation, gait remains significantly impaired when comparing those affected by PD and healthy adults. In a study on post-stroke patients with similar motor symptoms that completed traditional forms of gait and balance training, patients displayed a 45% decreased cadence when compared to healthy adults of the same age group.[8] It is evident that new forms of rehabilitation for gait and balance are essential. Recently, there is an elevated interest in the arts for rehabilitation especially with dance as it seems to be adapted to both the cognitive and motor deficits of those affected by PD.[9] Dance is a prominent form of the performing arts that utilizes the whole body to move in synchrony with music. With this rhythmic stimulation, dance is a promising tool to treat the physical and psychological deficits with PD. The purpose of this review is to analyze the current literature for the effectiveness of dance rehabilitation to improve motor function.

Methods

Relevant and current research were found using PubMed, NCBI, and the Western University Pumerantz Library database. Keywords such as "dance rehabilitation, and "Parkinson's Disease," were utilized when searching for relevant literature.

Results

After review of the 15 articles of current literature regarding dance therapy, 4 primary resources were included in this review. Most notable results that highlight the benefits of dance therapy as well as possible downfalls are reported in Allen et al. (2017), Hashimoto et al. (2015), Delabary et al. (2018), and Romenets et al. (2015). While 3 of 4 articles exhibited

the potential of dance as useful therapy, Romenets et al. (2015) indicated there were no benefits with dance interventions on the motor severity of Parkinson's Disease.

Allen et al. (2017) utilized the Unified Parkinson's Disease Rating Scale (UPDRS-III), Berg Balance Scale (BBS), 6-Minute Walking Test (6MWT), and Dynamic Gait Index (DGI). Notable results were found using the 6-Minute Walking Test in which the patient walks for 6 minutes and the distance walked in those 6 minutes is measured in minutes and the Dynamic Gait Index in which 9 different parameters are used to assess the gait of a patient and then scored out of 24. Results were measured pre-intervention and after 3 weeks of high-volume Adapted Tango rehabilitation. In the 6MWT, participants walked an average 28.83 meters more than before intervention and the Dynamic Gait Index increased 1-6 points after intervention.

Delabary et al. (2018) assessed functional mobility and spatiotemporal parameters with those diagnosed with Parkinson's Disease by comparing traditional rehab techniques and dance interventions using Brazilian dance. 18 participants were divided among two groups - walking group and a dance group. Rehab occurred twice a week for an hour, for 12 weeks. Before interventions, the Unified Parkinson's Disease Rating Scale (UPDRS-III), a test which measures the motor difficulties of patients with Parkinson's, was utilized. For those affected by Parkinson's Disease, the greater the motor injury, the higher the score on the UPDRS-III. After the 12 week period, parameters were assessed by using the timed-up-and-go test (TUG), 6-minute walking test (6MWT), walking kinematics of self-selected speed (SSS), and fast speed (FS). Delabary et al. (2018) reported that the walking group and dance therapy group improved significantly in TUG test and FS and the results favored dance rehabilitation in the 6 MWT, with an improvement of an average of 40 meters more than the walking group. Spatiotemporal parameters were improved in the dance therapy group and in the FS test swing phase time decreased in the dance group.

Similarly, Hashimoto et al. (2015) studied participants on their motor functions after dance interventions. 46 participants were randomly assigned to three possible groups – dance group, PD exercise group, and a control group. Motor functions were assessed using the Timed Up-and-Go (TUG) test and Berg Balance Scale (BBS). After comparing results from before interventions and after interventions, the dance group showed significant improvement in the TUG test and BBS.

In Romenets et al. (2015), UPDRS-III was utilized to report motor function for a group utilizing partnered tango intervention and a control self-directed exercise group. The primary outcome was to measure the overall motor severity and the secondary outcome measured other motor elements such as balance, cognition, fatigue, and quality of life. It is reported that there was no difference between groups regarding the primary-intention-to-treat analysis and there was no clear difference between the two groups of study. Nonetheless, it was reported that participants preferred tango dance interventions and found it more enjoyable. It is also reported that dance intervention may improve secondary aspects of motor ability such as balance, functional mobility, and may also improve cognition.[9]

Discussion

The main purpose of this literature is to analyze the possibility of dance interventions for those with Parkinson's Disease.

There is optimism that dance interventions in therapy could provide an enjoyable yet effective form of rehabilitation for these patients.[14] Of the articles included in this study, 3 of them indicated that dance therapy improved the motor functions of those diagnosed with PD. Hashimoto et al. (2015) and Delabary et al. (2018) compared traditional physical therapy to dance intervention and found motor functions such as balance, gait, and spatiotemporal parameters improved, specifically in the TUG test in which the patient is asked to stand from a seated position, walk a certain distance, turn around and return to a seated position and the time it takes for the patient to finish is recorded. This test is indicative of a patient's postural stability, gait, stride length, and sway, which are all important in motor function and autonomy. Thus, dance therapy presents as a promising possibility for motor improvement. Some other parameters that are being explored are the effects of dance therapy in other aspects, including its benefits to treat depression and social skills.

Opposing results were found in the study by Romenets et al. (2015) in which there were no differences found in the comparison of dance intervention and the control self-directed exercise group. However, it is reported that many of the participants dropped from the study, therefore results should be interpreted with caution.

Traditional forms of physical therapy include cardiovascular warm-up activities, stretching exercises, strengthening exercises, functional, gait and balance training, recreational games, and relaxation exercises.[13] Ciortea et al. (2019) studied the improvement of gait function using traditional interventions of physical therapy and reported that after interventions, there were no significant improvements in the 6-minute walking test. Allen et al. (2017) and Delabary et al. (2018) also utilized the

6MWT to evaluate dance interventions. However, in comparison to Ciortea et al. (2019) it was reported that patients using dance therapy improved in the 6MWT, indicating dance interventions may have a better efficacy in comparison to traditional physical therapy.

Nonetheless, more research is required in order for dance therapy to be considered as a possible therapy for PD patients. All of the articles included in this study contained small sample sizes, producing low statistical power. A complication presented in the analysis was the discontinued participation over time, where patients stopped attending dance therapy for unknown reasons, reducing sample size further.

Due to the recency of the study of dance interventions as a secondary form of medicine to those diagnosed with PD, the number of primary articles available regarding these studies were very limited, thus restricting the sample size of the literature analyzes. Protocols to assess the motor function of patients did not include enough detail, making it challenging to understand the procedure for dance therapy groups. Mainly, the frequency and type of intervention were included in the studies. There was also a lack of continuity in the types of dance interventions proposed in the study such as tango or Brazilian dance which can pose a problem when finding the optimal form of dance for rehab.

An additional drawback not mentioned in the included literature is the feasibility of conducting dance therapy sessions. If dance therapy were to be included in the standard of care for PD patients, questions arise such as: who would conduct the sessions, where would it take place, would patients agree to dance therapy and be compliant, and adverse outcomes such as falling.

Dance interventions show promise in improving cognitive and motor functions of those with neurodegenerative disorders of Parkinson's disease. However, additional scientific studies must occur in order to integrate dance therapy in the treatment plans of patients.

Conclusion

Parkinson's Disease is amongst the neurogenic diseases with a consequence of loss in motor function, especially in gait function. Although traditional methods of gait and motor training have improved for those with PD, the gap of gait function between healthy individuals and those affected still remains broad. The need for a new form of intervention is evidently needed for motor rehabilitation. The use of dance interventions has shown to improve gait function for those affected, however, it is still unknown how the mechanism of these dance interventions improve gait function and more research is needed to effectively evaluate the use of dance interventions in PD patients.

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Podiatric Interventions for Fall Prevention in Elderly Populations

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ABSTRACT

Objectives: The purpose of this review is to discuss a variety of podiatric interventions that aid in preventing falls in the elderly population.

Methods*:* A PubMed search was conducted on relevant research pertaining to fall prevention in elderly populations through podiatric interventions. In this review, seven studies from the years 2006-2019 were identified and utilized.

Results: Through various randomized controlled trials, retrospective cohort studies, surveys, and systematic reviews, it has been found that podiatric interventions including proper footwear, custom made ankle foot orthoses, and foot and ankle exercises not only decreased the incidence of falls in the elderly population but also decreased fear of falling, increased levels of physical activity, and improved quality of life.

Conclusion: In conclusion, it was found that podiatric interventions, including ankle foot orthoses and foot and ankle exercises, have a strong likelihood of being effective in preventing falls in elderly populations.

Introduction

Every year, fractures and falls contribute largely to not only morbidity but also health care cost in the United States.[1] It has been suggested that the fear of falling has a larger impact on the perceived quality of life and morbidity than the falls themselves or their sequelae.[1] In 2005, a population-based survey published by the *Karger Journals* of Gerontology studied the factors that affect fall prevalence in elderly populations in South Australia. It was found that about 30% of community-dwelling adults experienced falls throughout 2004.[2] In a study published in 1981 by *The Oxford Academic Journal*, Prudham et. al. conducted a survey of the prevalence of falls in a population of 2,793 adults over the age of 65, which reported that the average prevalence rate of falls annually was 28%.[3] It has been found that elders at high fall risk have a lower quality of life and more comorbidities. It was found that when compared to the population of non-fallers, fallers have more frequent contact with their primary care physician, higher rates of mobility issues, higher risk of strokes and heart disease, and more episodes of vertigo and fainting.[3] The elderly who have experienced falls have also shown higher evidence of cognitive impairment.[3]

Inappropriate footwear can also increase the risk of falls in the elderly population.[4] In addition, it has been found that foot and ankle complications may increase the risk of falling in elderly populations. There was a higher prevalence of foot pain in the population of fallers than non-fallers.[5] Fallers also experienced decreased strength in toe plantarflexion, severe hallux valgus deformity, increased likelihood of disabling foot pain, and decreased plantar tactile sensitivity.[6]

Due to the vast foot and ankle complications that increase fall risk, podiatric interventions are being developed to combat this issue, especially within the elderly population. Healthcare professionals are starting to prescribe custom footwear interventions in both the healthy elderly populations along with the elderly population with increased fall risk to improve dynamic balance and gait.[4] Patient education regarding fall prevention has also shown to be effective in reducing falls by 36% in the group receiving podiatric interventions. It has been shown that receiving podiatric interventions can improve ankle strength, range of motion, and balance, therefore preventing falls.[4]

The objective of this study is to highlight podiatric interventions for fall prevention in elderly populations to reduce the large burden that this problem has on the elderly and society as a whole.

Methods

A PubMed search was conducted on relevant research pertaining to podiatric interventions to prevent falls in elderly populations. Seven studies from the years 2006-2019 were identified and included in this review. Some phrases that were used for our search included: elderly population, fall prevention, balance, podiatric interventions, orthoses, and gait. Studies that combined non-podiatric interventions with podiatric interventions were excluded. Studies that mentioned alternative interventions such as acupuncture were also excluded. In addition, articles that mentioned podiatric interventions for improving gait and balance but did not explicitly mention their effects on fall prevention were also excluded.

Results

In a 2011 article published by the *British Medical Journal*, Spink et al. conducted a randomized control study recording the number of falls in 305 elderly participants.[7] The participants were divided into an intervention group of 147 participants and a control group of 149 participants. The intervention group received orthoses, footwear, subsidy for

footwear, foot and ankle exercises, fall prevention booklet education, and routine podiatry care for 12 months.[7] The control group only received routine podiatry care for 12 months. A total of 264 falls occurred during this randomized study; the intervention group had 103, and the control group 161.[7] The number of falls per person per year was 1.06 in the control group and 0.67 for the intervention group. Overall findings show a 36% reduction in fall rates using interventions of education, footwear, and orthoses (incidence rate ratio 0.64, 95% confidence interval 0.45 to 0.91, P=0.01).[7]

In a 2019 study conducted by Noah et al., the effect of wearing balance orthotics for 4 months on balance and mobility within a cohort of community-living elderly adults was measured. In this study, the experimental group's mobility and balance were evaluated before wearing custom foot orthoses, which were strategically weighted and fitted to combat loss of balance, and after the four-month period of wearing balance orthotics.[8] The 24 participants in this study all had limited mobility, measured by a Short Physical Performance Battery (SPPB) of between 4 and 9 out of 12 points maximum.[8] The SPPB score is a good indicator of predicting the risk of decline in activities of daily living, hospitalization rates, and mortality rates. An SPPB score of under 9 indicates a two-fold increase in developing new impairments to activities of daily living and hospital readmission rates. An SPPB score increase of 1 point indicates a 14% reduction in hospital readmission rates.[8] The balance orthotics were worn for 4 hours each day in 2-hour increments, 2 times a day for 2 hours each. The post-test assessments were conducted after the four-month period and at least eight hours after the removal of the balance orthotics. It was found that after the four-month period, the Short Physical Performance Battery improved by 1.3 points (P = 0.001), and the functional gait assessment improved by 2.6 points (P = 0.001).[8] A Wilcoxon Signed Rank Test indicated that the 5-time sit-to-stand test improved significantly between pre-test and post-test by 7.4 seconds (P = 0.002), and the tandem stance test times showed no changes between pre-test and post-test.[8]

In the REFORM study, a randomized controlled trial conducted by Corbacho et al. in 2016, 1,010 participants were randomized to either receive podiatric interventions or to remain as a control group.[9] The podiatric interventions consisted of foot and ankle exercises, orthoses, new footwear if needed, and patient education in the form of either a fall prevention pamphlet or the usual needed podiatric treatment with a fall prevention pamphlet. The primary outcome measured was the self-reported incidence of falls within 12 months after receiving the interventions. Secondary outcomes included fear of falling, participants reporting multiple falls, Geriatric Depression Scale, foot pain, quality of life, and cost-effectiveness of the interventions. In the intervention group, there was a very small non-significant reduction of incidence of fall rates (incidence rate ratio of 0.88; p=0.016).[9] However, a fewer number of participants had experienced a fall, as the incidence decreased from 54.9% to 49.7% (p = 0.05).[9] The incidence of experiencing two or more falls also decreased from 34.6% to 27.6% (p=0.01).[9] The incidence of foot pain, however, increased in the intervention group.[9] This study also found that the intervention was more costly but also more effective and had an increase in quality adjusted life years (QALYs).[9]

In support of the use of podiatric interventions for fall prevention, a 2018 randomized control trial was executed by Wang et al. In this study, 44 adults aged 65 years and older with a fear of falling were randomly assigned into a control group or an intervention group. The adults within the intervention group received a pair of walking shoes as well as bilateral custom-made ankle foot orthoses on postural stability whereas the adults in the control group only received a pair of walking shoes.[10] A significant difference was found in postural sway, ankle sway, center of mass (COM) sway in mediolateral (ML) direction with the use of ankle foot orthoses (AFO) in a 6 month follow-up (p=0.004–0.040).[10] The balance, levels of physical activity, and fear of falling were measured at the beginning of the treatment and after six months.[10] The fear of falling was measured by the Falls Efficacy Scale-International (FES-I). At baseline, there was no significant difference between the control group and the intervention group. In the control group, the 6 month follow-up showed no significant changes in the fear of falling and levels of physical activity when compared to baseline (p=0.122-0.894).[10] In the intervention group, the 6 month follow-up showed significantly reduced hip, ankle, and center of mass sways when compared to the control group (p = 0.005-0.040).[10] There was also an increase in the number of walking bouts when compared to the baseline levels (p=0.440), showing an increase in the physical activity levels.[10] The fear of falling measured with the FES-I was also reduced significantly (p=0.036).[10]

In a 2013 study conducted by Menz et al. published in the *Oxford Academic Journals of Gerontology*, a survey regarding older people's perceptions of multifaceted podiatric medical interventions for fall prevention was performed. In this study, 153 patients received podiatric interventions which consisted of at-home foot and ankle exercises, assistance when purchasing footwear, and foot orthoses.[5] Six months after the interventions, the

participants were asked to state their perception of the intervention's benefit on balance, foot and ankle strength, the difficulty of the program, and their satisfaction with the orthotics and footwear that was given.[5] Of the 153 patients that received podiatric interventions, 87.6% of them (134 patients) followed through with the follow-up assessment and the survey questionnaire.[5] It was found that the majority of the patients found improvements in their balance (62.7%), as well as foot and ankle strength (74.6%).[5] In the study conducted by Menz et al., 86.6% of participants, had noted the level of difficulty of the exercises to be "just right", and 92.6% of patients had reported that they were either somewhat or very satisfied with the footwear provided. It was also reported that 81.6% of participants were somewhat or very satisfied with the orthoses provided.[5]

In a systematic review and meta-analysis conducted by Wylie et al. in 2019, the podiatric interventions used to prevent falls in elderly populations were analyzed.[11] In this review, randomized or quasi-randomized controlled trials depicting podiatric interventions in populations of elderly people over the age of 60 were considered.[11] Nine studies met the inclusion criteria. In this study, podiatric interventions with only a single component did not depict a significant decrease in fall rates.[11] In multifaceted podiatric interventions, the fall rate ratio was reduced to 0.73 from the normal falls rate ratio of 0.77, showing an improvement in fall rates when multifaceted podiatric interventions were utilized.[11]

Discussion

The results were consistent with the findings of past studies presenting that podiatric interventions are an effective resource for fall prevention in elderly populations, many of the subjective resources that were asked retrospectively are vulnerable to recall bias such as those found in Menz et al. study.[5] Corbacho et al.'s REFORM study brings up the possibility of dilution as control patients also received podiatric care and fall prevention overall causing a lower power.[9]

The strength in the effectiveness of podiatric interventions is still underpowered.[11] Steps have been taken to begin the support for the use of podiatric interventions in fall preventions of elderly patients, but larger studies are yet to be done. A consensus has been made solidifying the potential interest in podiatric interventions. However, it is relevant for future studies to determine the most effective podiatric intervention in fall prevention from conservative foot and ankle exercises, AFO, and possible invasive surgeries. Further, the addition of the most cost-effective method with the additional QALYs should be taken into consideration in these future endeavors especially when considering the age of the population.

populations. This was seen in a study conducted by Wang et al., which related the significance in improved balance to the increased ankle support provided from AFOs.[10] Wang et al. further interpreted that the increased proprioception is derived from the open gauntlet style of the AFO which increases the contact area with the foot and the shin.[10] In addition, the Wylie et al. meta-analysis included foot and ankle exercises as a form of podiatry interventions that have shown positive protective effects against falls.[11] In agreement with Wylie et al. assessment, Spink et al. suggested the reason for this reduced fall incidence is due to the increased foot and ankle strength and range of motion which eventually lead to increased balance, walking speed, and functional movement.[7]

As for subjective findings of the participants, Menz et al. reported increased rates of subjective balance and ankle and foot strength. Menz et al. attributed these as a reflection of improvements in exhibited ankle eversion strength, postural sway, and maximum balance range when compared to the control.[5] This study emphasized the increased rates of satisfaction of those with footwear (92.3%) and foot orthoses (81.6%) during the trial.[5]

However, this benefit comes with a price. In the REFORM study, Corbacho et al. reported that costs £19,494 for every additional QALY gained, however finally concluding that podiatric interventions could present on average a cost-effective resource of NHS.[9]

Some notable limitations found within the studies reported were limitations to particular groups within the elderly populations. In the Noah et al. study, the group was limited to elderly patients with progressive neurological issues, which reduces the external reliability of its findings.[8] Within elderly

Conclusion

In conclusion, the literature indicates that podiatric interventions, AFOs, and exercises have a strong potential for fall prevention in elderly populations. AFOs increase ankle support via increased contact area, therefore increasing total stability of the foot and ankle.[10] Exercises increase stability and speed via increased ankle and foot muscle strength and range of motion.[5, 7, 9, 11] Subjective findings showed elderly individuals who received podiatric interventions showed increased rates of satisfaction, confidence, and decreased fear of falling when compared to individuals who did not receive those interventions.[5] Limitations, such as cost, recall bias, and small underpowered studies, have been noted within the studies which point to the need for further research to elucidate the true effectiveness of such interventions.

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Efficacy of Extracorporeal Shockwave Therapy (ESWT) on the Treatment of Knee Osteoarthritis

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ABSTRACT

Objective: Conservative, nonpharmacologic management of patients with knee osteoarthritis is fundamental for effective symptom relief and management of functional limitations and overall quality of life. Extracorporeal shockwave therapy (ESWT) has emerged to be effective in the treatment of musculoskeletal disorders such as epicondylitis, plantar fasciitis, nonunion and delayed fracture healing, and in recent years, knee osteoarthritis. The goal of this paper is to review current literature to assess the efficacy of ESWT as a treatment for knee osteoarthritis.

Methods: The BIOSIS, Embase, and PubMed databases were used to access articles using the key search words "knee osteoarthritis" and "extracorporeal shockwave therapy." Inclusion criteria were limited to a patient population with knee osteoarthritis (Kellgren-Lawrence grade II or III) as well as research that compared the efficacy of ESWT using the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) scores. Only randomized controlled trials and those written in English were included. Five studies that met the inclusion criteria were included in this review.

Results: All five studies suggest that there is a statistically significant improvement in patients with knee osteoarthritis receiving ESWT compared to placebo based on the WOMAC score and two studies concluded that ESWT is superior to other treatment modalities such as kinesiotherapy (KIN) and platelet rich plasma (PRP) injections. Of the five studies, one concluded better outcomes with higher energy doses of ESWT compared with lower doses.

Conclusion: The use of ESWT should be considered in the management of knee osteoarthritis as it is effective in reducing the pain associated with this syndrome. It is noninvasive, safe with proper dosing, does not require hospitalization, and is relatively cheaper than other conservative and surgical options. However, the role of ESWT in the overall management of knee osteoarthritis still remains unclear. Further pilot studies are recommended to explore this option as a mainstay of treatment and whether or not it is effective in combination with conventional therapies.

Introduction

Arthritis is the inflammation of one or more joints often characterized by pain, swelling, and stiffness. Osteoarthritis is the most common form of degenerative arthritis with a global prevalence of 16%.[1] Although osteoarthritis can affect many joints, weight bearing joints such as the hip and knee joint are particularly susceptible due to the normal "wear-and-tear" and eventual degradation of the overlying protective cartilage. Loss of cartilage in these joints may cause joint space narrowing and the formation of bone spurs resulting in significant pain.[1]

Pain and inflammation that disrupt daily activities are common symptoms that encourage patients with knee osteoarthritis to seek medical attention. Knee osteoarthritis is a disabling condition associated with difficulties in rising from a seated position, climbing stairs, standing and walking. The management of early osteoarthritis is fundamental for effective symptom relief, management of reduced functional mobility (i.e., range of motion), and maintenance of quality of life while minimizing adverse effects from therapeutic measures.[1]

Management of knee osteoarthritis is dependent on the presentation and severity of the disease. As a general principle, mild presentations can

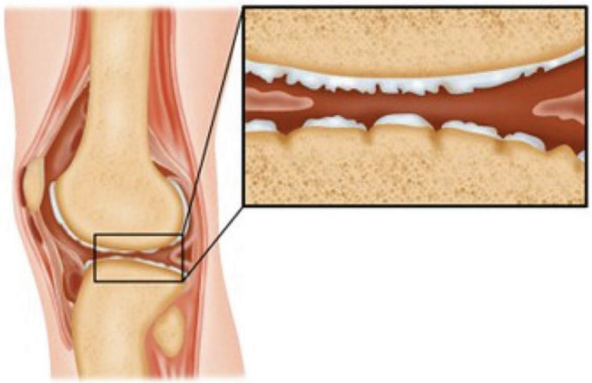

Figure 1: *Osteoarthritic knee with erosion, cartilage loss and joint space narrowing.*[2]

be treated with conservative, nonpharmacologic therapies such as stretching (quadriceps, hamstrings, calves, etc.) weight loss, strength training, and the use of assistive devices (e.g., canes and braces).[1] Pharmacologic therapy can be started in combination with or after a trial of nonpharmacologic interventions if satisfactory pain relief is not achieved with these measures alone. As per the 2010 Osteoarthritis Research Society International (OARSI) guidelines, this includes acetaminophen, capsaicin, duloxetine,

glucosamine and chondroitin sulfate, oral non-steroidal anti-inflammatory drugs (NSAIDs) and topical NSAIDs.[3] If conservative methods fail to provide pain relief, corticosteroid injections may be considered as well as more non-conservative methods such as surgery. Surgical options may include synovectomy, osteotomy and arthroplasty.[1]

In recent years, extracorporeal shockwave therapy (ESWT) has been utilized to reduce pain and improve function in those with knee osteoarthritis. ESWT is a noninvasive therapeutic modality whereby a generator conveys a sequence of single sonic pulses to specific target areas.[3] It was first used for the management of kidney stones, however its purpose has expanded to include treatment of various musculoskeletal disorders by incidental observation of an osteoblastic response pattern during animal studies in the late 1980s. These musculoskeletal conditions include epicondylitis, plantar fasciitis and nonunion or delayed fracture healing.[4] The benefits of the procedure is that it is noninvasive, has a low incidence of complications and does not require hospitalization. ESWT is effective in reducing pain, improving hip function, and preventing progression of avascular necrosis.[3] Veterinarians first began to use ESWT to treat equine knee osteoarthritis and several studies found that ESWT improved motor dysfunction and ameliorated pain in animals with osteoarthritis. These findings led to more research based on the effects of ESWT in humans.[5] The goal of this paper then is to assess the current literature regarding the clinical efficacy of ESWT on the treatment of human knee osteoarthritis.

Methods

The BIOSIS, Embase, and PubMed databases were used to access articles using the key search words "knee osteoarthritis" and "extracorporeal shockwave therapy." Inclusion criteria were limited to a patient population with knee osteoarthritis (Kellgren-Lawrence grade II or III) as well as research that compared the efficacy of ESWT using the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) scores. The Kellgren-Lawrence grading scale is a classification system (grades I, II, III, IV) used to describe radiographic findings consistent with osteoarthritis. Only randomized controlled trials and those written in English were included. Exclusion criteria omitted papers written prior to 2013. Of the many papers written on ESWT as a treatment for knee osteoarthritis, only five papers that fit the inclusion criteria stated above were included in this study.

Results

In a study conducted by Zhao et al. 2013, 70 patients with OA were randomized to receive placebo (n = 36) or ESWT (n = 34). The placebo group received shockwave at 0 mJ/mm2 weekly for four weeks at the patellofemoral and tibiofemoral borders of the knee. The ESWT group received 4000 pulses of shockwave at 0.25 mJ/mm2 at 6 Hz/s frequency weekly for four weeks in the same area. The effect of ESWT on knee osteoarthritis was assessed using a 10-cm visual analog scale (VAS) for pain, the Lequesne index for severity, and WOMAC index for disability and patient perception of the clinical severity of osteoarthritis. These evaluations were performed at baseline, and after 1, 4, and 12 weeks. Both groups showed reduced pain on movement as measured on VAS with greater decrease in pain with ESWT than with placebo in each period ($P < 0.01$). At 12 weeks, the mean VAS score decreased 3.73 points with ESWT whereas the mean VAS score decreased 1.14 points for placebo. Disability as measured by the Liquesene and WOMAC index significantly improved in the ESWT group. For the Lequesne index, at 12 weeks, the decrease in disability was almost 2.0 for the placebo group but 4.1 for the ESWT group ($P < 0.01$). Similarly, the mean change in WOMAC score after 12 weeks was 8.5 for the placebo group and 19.1 for the ESWT group ($P < 0.01$). Disability by patient perception of clinical severity was significantly better for the ESWT group than that for the placebo group. The mean change in patient perception at 12 weeks was 0.3 and 0.9, respectively ($P < 0.01$).[5]

In a separate study, Kim et al. 2015 built upon the results of Zhao et al. 2013 and investigated the dose-related effects of ESWT (at different total energy flux density [EFD]) in patients with knee osteoarthritis. 60 patients were randomly classified into two groups: group L, which was a low-energy group (n=30; 1,000 shocks/session; EFD 0.040 mJ/mm$_2$) and group M, which was a medium-energy group (n=30; 1,000 shocks/session; EFD 0.093 mJ/mm$_2$). For each group, 1,000 shock waves were delivered to the medial tibial plateau area weekly for 3 weeks. The main outcome measures were the VAS score, the Roles and Maudsley (RM) score, the WOMAC score, and the Lequesne index. Each assessment was performed at baseline and at 1, 4, and 12 weeks after ESWT. Compared to baseline, the VAS score significantly decreased with time, up to the 12-week follow-up for both groups ($P < 0.001$ for time effect, $P < 0.001$ for group-time interaction). There were also significant differences between the two groups at 1 week and 12 weeks ($P < 0.05$). Compared to baseline, the RM score significantly decreased with time, up to the 12-week follow-up, in both groups ($P < 0.001$ for time effect, $P < 0.005$ for group-time interaction); there were significant differences between the two groups at 1 week and 4 weeks ($P < 0.05$). Compared to baseline, the WOMAC score

significantly decreased with time, up to the 12-week follow-up, in both groups ($P < 0.001$ for time effect, $P < 0.001$ for group-time interaction). There were significant differences between the two groups at 4 weeks and 12 weeks ($P < 0.05$). Compared to baseline, the Lequesne index significantly decreased with time, up to the 12 week follow-up in both groups ($P < 0.001$ for time effect, $P < 0.001$ for group-time interaction). There were significant differences between the two groups at 12 weeks ($P < 0.05$).[4]

A 2017 study by Lizis et al. compared the effects of ESWT and kinesiotherapy (KIN) on the treatment of knee osteoarthritis. Forty participants, aged 40–75 with knee osteoarthritis were randomized to an ESWT (n = 20) or KIN (n = 20) treatment group. The ESWT underwent 5 shockwave sessions, one intervention weekly. They received 8000 pulses in total, which were applied at 0.4 mJ/mm2 at a frequency of 8 Hz/s at the patellofemoral and tibiofemoral borders of the knee. The KIN group also underwent 5 kinesiotherapy sessions, one intervention weekly. The kinesiotherapy program included: (1) warm-up and stretching (10 minutes) – global flexion- extension of the lower limb, alternated dorsal plantar flexion of the ankles, and stretching of the hamstrings; (2) strengthening (10 minutes) – is metric knee extensors: flex 0 degrees, isometric knee extensors: flex 60 degrees, isometric ham-strings: flex 60 degrees, and concentric-eccentric hip abductors and adductors; (3) functional task-oriented training (10 minutes) – get up and sit down, resistive knee extensor strengthening while sitting against Thera-Band, controlled bilateral knee flexion-extension while standing, bilateral knee flexion to 90 degrees while standing, climbing on a platform or a flight of stairs, walking backward on a slope and/or laterally while crossing the lower limbs, and walking in place with a large amplitude of hip and knee flexion and upper limb movements; (4) endurance (10 minutes) – walking and stationary cycling. Each treatment session did not exceed 40 minutes. Both groups completed 5 interventions for 5 weeks. Evaluations were performed at baseline and after treatment for perceived health using the WOMAC score and knee flexion/extension range of motion (ROM). Improvement as measured by the WOMAC score shows a significant difference favoring the ESWT group, regarding pain ($P < 0.001$), stiffness ($P = 0.018$), physical function ($P < 0.001$) and total score ($P < 0.000$) at 5 weeks (post-intervention). Regarding ROM, the improvement of extension and flexion in the affected knee was identified in the ESWT group, and only of flexion in the KIN group. The comparison between groups at week 5 (post-intervention), show a significant difference favoring the ESWT group regarding extension ($P = 0.015$) and flexion ($P < 0.000$).[6]

Whenzen et al. 2019 evaluated the effects of ESWT combined with knee joint cavity puncture injection of autologous platelet-rich plasma (PRP) on the treatment of knee osteoarthritis. 180 participants were randomly divided into 3 groups: Group A (n = 60) received knee joint cavity puncture injection of autologous PRP, Group B (n = 60) received ESWT, and Group C (n = 60) received knee joint cavity puncture injection of autologous PRP. Group A received 4 mL of PRP weekly for 5 weeks; Group B received 2,000 shocks/session at an EFD 0.20 mJ/mm2 weekly for 5 weeks; Group C received PRP followed by ESWT after a period of 10 minutes weekly for 5 weeks. Evaluations were made at baseline and after 1, 3, and 5 weeks using the VAS score, Lequesne Index score, WOMAC score, and ROM. With the prolongation of treatment time, the VAS score, Lequesne index score and WOMAC score gradually decreased ($P < 0.05$), but there was no statistically significant difference in the knee joint ROM ($P > 0.05$) for all 3 groups. Before treatment, there was no significant difference in VAS score, Lequesne index score, WOMAC score, and knee joint ROM among the three groups ($P > 0.05$). At 1, 3, and 5 weeks after treatment, the VAS, Lequesne index and WOMAC scores in Group C were significantly better ($P > 0.05$) than those in groups A and B, with Group B better than Group A. There was no statistically significant difference in degree of ROM ($P > 0.05$).[7]

Another study by Zhong et al. 2019 sought to test the efficacy of low-dose ESWT on osteoarthritic knee pain, lower limb function and cartilage alteration. 63 patients were randomized into either a placebo group or experimental group. Participants in the experimental group received low-dose ESWT once a week for 4 consecutive weeks for 2000 pulses/session of 8-Hz frequency at 2.5 bars of pneumatic pressure at the patellofemoral and tibiofemoral borders. The placebo group received sham shockwave therapy using the same ESWT protocol as the experimental group, but the air pressure was set at 0.2 bar. Knee pain and physical function were measured using VAS, WOMAC, and Lequesne index scores at baseline and at 5 and 12 weeks. Cartilage alteration was measured analyzing the transverse relaxation time (T2) mapping. The VAS score, WOMAC, and Lequesne index of the ESWT group were significantly better than those of the placebo group at 5 and 12 weeks ($P < 0.05$). Both groups showed improvement in pain and disability scores over the 12-week follow-up period ($P < 0.05$). In terms of imaging results, there was no significant difference in T2 values between groups during the trial, although T2 values of the ESWT group at 12 weeks significantly increased compared to those at baseline ($P = 0.004$).[8]

Discussion

The studies reviewed in this paper have demonstrated that the use of ESWT is effective at reducing the symptoms associated with knee osteoarthritis. Zhao et al. found that ESWT is effective in reducing pain and improving knee function, doubling the results of placebo after the 12-week treatment. Symptoms were ameliorated with ESWT compared with those with placebo as measured using the Lequesne index and WOMAC. However, this study had limitations in that it did not address factors such as dose, intensity, or frequency that may influence the effect of ESWT on OA. Optimal treatment needs to be studied by comparing dosing intervals and energy flux densities.

Kim et al. expanded on the findings from the above study and found that higher energy flux densities show greater improvement in regard to relieving pain and restoring functional outcome compared to lower energy flux densities. However, there are limitations in this study. For example, the control group was not employed to exclude the placebo effect. Additionally, a small sample size was used and the evaluation period (12 weeks) was too short to fully assess the long term effectiveness of ESWT.

ESWT compared to other therapies such as KIN is more effective at improving the symptoms related to knee osteoarthritis based on the WOMAC score as well as improving ROM as studied by Lizis et al. However, this study also had its limitations in using a small sample size and the follow-up period was too short to confirm these findings.

The study by Su et al. found that the effect of ESWT combined with intra-articular autologous PRP injections was significantly better in reducing pain and improving function than that of a single treatment modality. But similar to the previous studies, the major limitation in this study is that the synergistic effect of ESWT and PRP injections cannot be definitively proven as the follow-up period (5 weeks) was too short to make this conclusion.

Zhong et al. found that a 4-week treatment of low-dose ESWT was superior to placebo for pain easement and functional improvement in patients with mild to moderate knee osteoarthritis but had some negative effects on articular cartilage. However, there were several limitations to this study. Patients had similar degrees of knee pain and radiographic knee osteoarthritic findings before treatment. Therefore it is ambiguous whether patients with higher levels of pain and more severe knee osteoarthritis would benefit from ESWT. In addition, high expectations and large placebo responses may influence the assessment of effect. Moreover, because only a small sample size was used, results may have been due to chance and the treatment period (3 months) was relatively short therefore the sustained effects remain unknown.

Conclusion

The use of ESWT should be considered in the management of knee osteoarthritis as it is effective in reducing the pain associated with this condition. It is noninvasive, safe with proper dosing, does not require hospitalization, and is relatively cheaper than other conservative and surgical options. However, the role of ESWT in the overall management of knee osteoarthritis still remains unclear. Further pilot studies are recommended to explore this option as a mainstay of treatment and whether or not it is effective in combination with conventional therapies.

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Open Repair versus Percutaneous Repair for Achilles Tendon Rupture

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ABSTRACT

Objective: To review the current literature on the two main Achilles tendon rupture treatments through open repair versus percutaneous repair.

Methods: Relevant research articles for open repair, percutaneous repair, and Achilles tendon rupture were found via the Bone Joint Research, BMC Musculoskeletal Disorder, Journal of Orthopaedic Surgery, International Journal of Surgery, European Journal of Orthopedic Surgery and Traumatology, Orthopaedic Journal of Sports Medicine, PubMed, and National Institute of Health databases. Eleven articles were analyzed and included in this review of Achilles tendon rupture treatments.

Results: Multiple studies revealed small sample sizes that reported miniscule statistical difference between the treatment of open repair versus percutaneous repair for Achilles tendon rupture. The two groups showed very similar values in plantar flexion strength, range of motion and single heel raise tests between the two groups. The group of patients that received the open repair treatment were shown to have greater incidence of deep wound infections, longer return to work, lower AOFAS score and wound complications. The group of patients treated with percutaneous treatment showed higher AOFAS score, no deep infections but did show a greater chance of sural nerve injury.

Conclusion: Controversy exists with surgical treatment outcomes of percutaneous vs. open repair for achilles tendon ruptures. The current literature leans more toward the percutaneous approach over open repair as the method of treatment best to treat Achilles tendon ruptures. The studies show minimally statistical differences in strength and range of motion postoperatively. However, the percutaneous approach has shown to be more beneficial in many different aspects such as faster return to work and Higher AOFAS score, which have the greatest outcome for the patients.

Introduction

The Achilles tendon connects the fused gastrocnemius and soleus muscle to the posterior calcaneus. Even though it is the strongest tendon in the human body, it is a common site of rupture. Achilles tendon ruptures occur more in men in their third or fourth decade of life, and are typically physically inactive. The incidence is 5.5-9.9 ruptures for every 100,000 people in North America and has been increasing, possibly due to increased sports activity.[1] Achilles tendon ruptures can be treated surgically or conservatively. Nonoperative treatment is not the mainstay treatment due to a high rate of recurrence.[1] Therefore, surgery is typically performed to prevent prolonged immobilization causing calf muscle weakness and early impaired ankle mobility seen in non-conservative treatment.[1] Open-repair and percutaneous repair are common procedures used to treat Achilles tendon ruptures. However, the best surgical treatment of Achilles tendon rupture remains controversial.[1,2]

In the Open-repair technique, a posterior-medial longitudinal incision is placed over the ruptured Achilles, followed by the ruptured ends being sewn together using various stitch patterns.[2,3] The procedure allows for direct visualization to aid in tendon realignment for optimal healing. Complications with open repair procedure include but are not limited to, impaired wound healing, increased risk of rerupture, increased scarring, and longer overall recovery time. Percutaneous repair includes smaller incisions that are fed by sutures that approximate the distal and proximal ends of the tendon together to ensure healing of the tendon.[4]

The goal of this study is to compare open repair and percutaneous procedures for Achilles tendon rupture repair, and to suggest which treatment is more effective.

Methods

Eleven relevant research articles to compare open repair and percutaneous repair for acute Achilles

tendon rupture from 2005-2020 were identified via the Bone Joint Research, BMC Musculoskeletal Disorder, Journal of Orthopaedic Surgery, International Journal of Surgery, European Journal of Orthopedic Surgery and Traumatology, Orthopaedic Journal of Sports Medicine, PubMed, and National Institute of Health databases. Inclusion criteria included patients with Achilles tendon rupture, surgical treatment with open repair or percutaneous repair, post-op outcome assessment with American Orthopedic Foot and Ankle Society (AOFAS) to monitor progress post-op, and Visual Analog Scale (VAS) scores for pain, Achilles Tendon Total Rupture score (ATRS) for outcomes in patients with acute rupture, retrospective study, prospective randomized study, and meta-analysis. Exclusions in the study included minors under the age of 18 with Achilles tendon rupture, opinions, commentary or review, and case reports.

Results

Karabinas et al. conducted a randomized controlled trial on a group of 34 patients, 15 of those had open surgical repair, and 19 had percutaneous repair. On average, it took patients in the open surgical repair group 7 weeks to return back to work, while it took 9 weeks for the percutaneous repair group. All patients from both groups were able to bear weight 8 weeks postoperatively.[5] It took roughly 5 months for patients from both groups to return to their previous activities. Only 1 patient from the open repair group experienced mild pain at the incision site. No other complications such as post-op infection, sural neuroma, or Achilles tendinitis were found in either group. Patients from the open repair group had an average 22 months follow-up and an average of 20 months follow up for the percutaneous group.[5]

Another randomized controlled trial conducted by Martins et al. analyzed 45 patients with Achilles tendon rupture between the age of 30 to 50. Out of the total, 46% suffered from professional activity, 38% from playing soccer, and 16% from other injuries.[6] Open surgery was performed on 25 patients, open surgery augmented with gastrocnemius fascia was performed on 5 patients, and percutaneous surgery was performed on 15 patients. The AOFAS mean score to monitor progress post-op was 100 for the percutaneous group, 92 for the open surgery, and 91 for the open surgery with gastrocnemius augmentation. The open surgery group had 3 patients with complications, 1 had sural nerve damage, 1 had post-op infection, and 1 with delayed healing. No complications were reported from the percutaneous group.[6]

A retrospective study by Lee at al. further investigate and compare between open repair and percutaneous repair for Achilles tendon rupture. The study included 30 patients, 12 were treated with ultrasound guided percutaneous repair and 18 were treated with the traditional open repair technique.[7] The AOFAS score for the ultrasound guided percutaneous repair group was 93.7, and 92.6 for open repair. The ATRS score was 90.7 for the percutaneous group and 89.3 for the open group. When performing the single heel raise test, the percutaneous group averaged 3.75, while the open surgery group averaged at 3.65. Analysis on calf circumference post-operatively found the percutaneous group to average around 15mm and 14.4 mm for the open group. In terms of recovered athletic ability, 3 patients from the percutaneous group reported to retain the same level, 4 patients reported a diminished level, 5 patients stopped all activities. From the open repair group, 5 patients retained, 7 patients reported a diminished level, 5 patients stopped all their activities, 1 never participated in any athletic activities.[7] Satisfaction level in terms of scarring on a scale of 1 to 10 was 9.9 for the percutaneous group and 7.1 for the open group. No complications were noted from the percutaneous group. However, 1 patient from the open group had to go through additional surgeries due to post-op infection and recurrent Achilles tendon rupture.[7]

A retrospective study conducted by Carmon et al. attempted to assess the long-term functional outcome for patients who underwent percutaneous repair. The study consists of 73 patients who were evaluated at 3 months, 6 months, 9 months, and again at 12 months post operatively. All surgeries were performed within 48 hours of the injury. The injury mechanism includes 62 patients who suffered from sport injuries, 8 from external force, and 3 from other activities of daily living. The main assessment used in the study is the ATRS (Achilles Tendon Total Rupture Score).[8] At 3 months follow up, the average ATRS score was 42.5. At 6 months, it was 73, 83 at 9 months and 89 at 12 months. The complication rate was 13.5% and those who developed complications had a lower ATRS score (18-34) at 3 months follow up. Only 1 patient experienced re-rupture at 8 weeks post-op, 2

had deep vein thrombosis, 1 developed adhesion, 4 with sural nerve injury, 2 had superficial infection, and 1 with prominent suture knot.[8]

A meta-analysis study conducted by Yang et al. investigated the difference between open repair vs percutaneous repair for Achilles tendon rupture. There were 815 patients that met criteria to be involved in the study from five randomized control trials and seven retrospective studies to meet the criteria for the study. The participants had to have an acute Achilles tendon rupture. 2- they were apart of randomized controlled trials or cohort studies comparing percutaneous versus open repair; 3- the studies that recorded the incidence of re-rupture, sural nerve injury, deep infection, deep vein thrombosis, AOFAS score and ankle range of motion.[9] The study concluded with evidence pointing to percutaneous repair is superior to open repair for treating Achilles tendon ruptures because it showed to have advantages in reducing deep infections, AOFAS scores and ankle range of motion. However, it was shown to more likely cause sural nerve injury, but the incidence of sural nerve injury can be avoided or reduced with the route percutaneous treatment.

A retrospective study was conducted by Henriquez et al which included 32 patients. Seventeen patients were treated with percutaneous repair and fifteen patients treated with open repair. The main function of the study was to compare 3 things. 1- function (ankle range of motion, muscle strength, single heel rise and return to work). 2- Cosmetics and 3- complications. The minimum follow up was 6 months postoperative state to a maximum of 48 months post-operative. The patients were evaluated for the following at follow up (1) ROM of the ankle joint: range of ankle dorsiflexion and plantar flexion; (2) length of scar; (3) time of surgery to return to work and sports; (4) cosmetic appearance of the scar by subjective evaluation of the patient as excellent, good, regular, or bad;(5) all complications of surgery.[1] They observed similar outcomes between the two treatment options. Patients treated with open repair muscle strength tended to be greater (147 N versus 120N). Both groups had similar ankle dorsiflexion (15°) and plantar flexion (40°). The mean time to return to work in the open repair treatment group was 3 months but had a maximum of 30 months to return to work contrary to the percutaneous group which returned to work in 2 months. One patient developed a deep wound complication that required surgical treatment.[1] In conclusion the percutaneous group was superior to the open repair treatment due to better cosmetic appearance, lower rate of wound complications and a shorter return to work time.

Discussion

The main complication associated with the percutaneous approach is sural nerve damage seen in 3%-18% of cases.[1] The percutaneous procedure is associated with improved healing time, less scarring, better wound healing, and overall better patient satisfaction. Both groups have shown similar results for plantar flexion strength, range of motion, and single heel rise tests, thus the best treatment remains controversial.[1]

Literature continually suggests that open repair and percutaneous repair provide better outcomes compared to non-operative treatment mainly based on longer recovery time and higher rerupture rates.[1] Furthermore, percutaneous repair has been shown to have less complications than open repair but not without its own drawbacks. A Meta-Analysis by Khan et al. consists of 800 patients across 12 different trials and studies conclude that percutaneous repair leads to a lower complication rate and lower rerupture rate compared to open repair.[10] Open repair was also noted to have increased risk of skin related damage and infection compared to percutaneous repair. Patient satisfaction is shown in a case series by Carmont et al. The 76 patient case series with a mean age of 45.5 showed an increased percentage in Achilles Total Tendon Rupture Score (ARTS) at 3-, 6-, 9- and 12-months post-op and reported either a good or excellent outcome after their percutaneous repair. Even though there is a higher patient satisfaction of percutaneous repair, the procedure comes with complications such as sural nerve damage and recurrence of rerupture.[8] A retrospective study by Henriquez et al. showed 10% of cases having a rerupture and sural nerve injury being reported in 3%-18% of patients.[1] However the Yang et al meta-analysis suggested a percutaneous procedure that avoids damage to the sural nerve. The post infection rate between the two procedures gives percutaneous repair another advantage over open repair, which saw up to 21% having a post-infection complication in a RCT of 33 patients.[2] Yang et al. suggested a lower overall complication rate of 9.7% vs 21% with percutaneous and open repair, respectively from a study of 237 patients.[2] The post-surgical scar

from either procedure played a role in patient satisfaction as well. Henriquez et al. described a mean scar length of 9.5 cm vs. 2.9 cm in a retrospective study.[1] Open repair has shown improved heel-lift test results and calf circumference in a 61-patient retrospective study by Wang et al. The study also showed a similar PROM in comparison with percutaneous repair.[4]

Data further support for percutaneous over open repair was provided in a randomized controlled trial conducted by Martins et al. The study concluded a higher AOFAS score and a lower complication rate for the percutaneous group.[6] Similarly, Lee et al. also concluded a higher AOFAS score, ATRS score, single heel raise score, and a lower complication rate for the percutaneous group.[7]

Carmon et al. conducted a retrospective study further to analyze the long-term functional outcome of percutaneous repair. The study found the ATRS score increases as time progresses, and the patient slowly returns to their daily living activities. However, those that developed complications had a significantly lower score initially and continued to increase at a much slower pace at 3, 6, 9, and 12-months post-op.[8]

The randomized control by Karabinas et al. showed no significant difference between the percutaneous group versus the open repair group except for the average time to return to work. On average, it took the percutaneous group 2 weeks longer.[5]

Conclusion

Despite the disadvantages of sural nerve injury and increased rerupture rates, percutaneous repair offers a less invasive surgical option for patients seeking a quicker recovery of a ruptured Achilles tendon. Percutaneous repair had quicker recovery time, less infections risk, and smaller, more cosmetically acceptable scars compared to open repair. The analysis of literature reviews is continually showing the benefit of percutaneous repair vs. open repair, even though more research is needed to be more conclusive due to a mainstay treatment remaining controversial.[1,2] Future studies should include a bigger sample size and a longer follow-up time to accurately determine the long-term effects of both methods.

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Clinical Outcome and Predictive Values of Transmetatarsal Amputations

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ABSTRACT

Objective: In particular cases of severe foot infection, transmetatarsal amputation (TMA) should not necessarily be looked upon as failure of care, but rather the most appropriate intervention for preventing more proximal spread of infection and persistent hospital stay. The purpose of this paper is to review current literature and assess the clinical outcome of TMA in diabetic and dysvascular patient populations. Associated comorbidities were examined for statistical significance in either complication or healing rate.

Methods: The BIOSIS, Embase, and PubMed databases were used to access articles. Inclusion criteria were limited to patient populations that have undergone TMA due to diabetes and other comorbidities. Only retrospective cohort studies and case studies written in English were included. Five papers that fit the inclusion criteria were included in this study.

Results: The five studies included in this review concluded that TMA with and without revascularization should be considered in the treatment of diabetic patients with severe forefoot ulceration and infection as it has lower morbidity and mortality rates compared to more proximal amputations. Risk factors for postoperative complications and reamputation rates following TMA were found to be having additional comorbidities such as peripheral arterial disease, osteomyelitis and end-stage renal disease (ESRD).

Conclusion: TMA is an effective procedure in the treatment of severe ulceration and infection in diabetic patients. When the forefoot is deemed nonviable, TMA allows for return to ambulation without postoperative complications. Precaution should be taken, however, in evaluating whether TMA would be an appropriate course of treatment in patients with additional comorbidities. Further studies are needed to create a systematic approach that would allow clinicians to evaluate whether a diabetic patient would benefit from TMA.

Introduction

In recent years, an increased attention has been placed on the alarming increase in the incidence of diabetes due to its serious and debilitating complications such as foot ulceration and subsequent infection. In particular cases of severe foot infection, amputation should not necessarily be looked upon as failure of care, but rather the most appropriate intervention for preventing more proximal spread of infection and persistent hospital stay. Development of a diabetic foot ulceration is often a multifactorial process; however, neuropathy and peripheral vascular disease are recognized as significant contributing factors.[1] Ulceration due to neuroischaemic causes account for a majority of diabetic cases that develop a soft tissue infection.[1] In circumstances where soft tissue infection is severe or where underlying bone is infected, amputation may be considered an appropriate line of treatment. Aggressive management of severe foot infection and ulceration can reduce the risk of more proximal amputation.

The aim in all cases of diabetic foot infection is to maintain foot function and preserve structure. However, in certain cases (e.g., soft tissue envelope has been lost or circulatory impairment has rendered the forefoot nonviable) a trans-metatarsal amputation (TMA) might be considered an appropriate option.[1] A TMA involves removal of the forefoot at the level of the metatarsal shafts with the aim of maximizing limb function.[2]

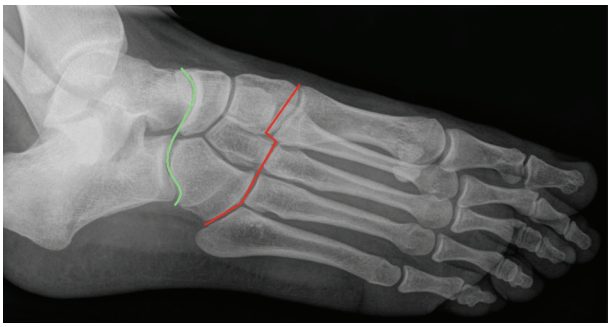

Figure 1: *Chopart's joint (green) and site of TMAs at Lisfranc's joint (red).*[3]

The goal of TMA is twofold: to adequately control forefoot infection or ischemia by removing all necrotic, ischemic, or infected tissue to a level that allows healing; and secondly, to maximize limb function by salvaging the midfoot and rearfoot, thus leaving a plantigrade platform on which the patient can adequately weight bear.[1] However, complications after this procedure are not uncommon. Complications include: more proximal amputation, postoperative infection, chronic stump ulceration, stump deformity, wound dehiscence, equinus, and calcaneus gait.[1] Despite its potential complications, TMA is

considered preferable to below-the-knee amputation (BKA) or above-the-knee amputation (AKA) because TMA allows a weight-bearing residuum to remain.[2] The purpose of this paper is to review current literature and assess the clinical outcome of TMA in diabetic and dysvascular patient populations. Associated comorbidities were examined for statistical significance in either complication or healing rate.

Methods

The BIOSIS, Embase, and PubMed databases were used to access articles using key search words such as "transmetatarsal amputation," "clinical/functional outcome," and "morbidity and mortality." Inclusion criteria were limited to patient populations that have undergone TMA due to diabetes and other comorbidities. Only retrospective cohort studies and case series written in English were included. Exclusion criteria omitted papers written prior to 2006. Of the papers written on the clinical outcomes of TMA, only five papers that fit the inclusion criteria stated above were included in this study.

Results

In a study conducted by Pollard et al. 2006, medical records were retrospectively reviewed for 90 patients (101 amputations) who underwent TMA due to diabetes and other comorbidities such as coronary artery disease (CAD), cerebral vascular accident (CVA), hypertension (HTN) or end-stage renal disease (ESRD). Indications for surgery were chronic forefoot ulceration, forefoot infection, forefoot gangrene, or a combination of these. Data was also collected to assess presence or absence of complications occurring after TMA. Complications were defined as mortality occurring less than 30 days postoperatively, stump infarction with or without more proximal amputation, postoperative infection, equinus or calcaneus gait, stump deformity in any of the three cardinal planes, wound dehiscence, and chronic stump ulceration. Uncomplicated outcome was defined as absence of all these complications and an ability to walk on the stump with a diabetic shoe and filler after a minimum follow-up at 6 months. A healed stump was achieved in 58 (57.4%) of the 101 amputations, including 49 (55.7%) of the 88 diabetic patients. Healing was achieved in 52.6% of patients preoperatively diagnosed with gangrene only, in 60% of patients preoperatively diagnosed with infection, in all patients preoperatively diagnosed with chronic ulceration alone, in 50% of patients with both gangrene and infection, and in 16 (44.4%) of the 36 patients preoperatively diagnosed with ESRD. A palpable pedal pulse was predictive of healing ($P = 0$ .0567). A healed stump was achieved in 24 (70.6%) of the 34 patients who had a palpable pedal pulse. Two patients died within 30 days, yielding a perioperative mortality rate of 1.98%. Both patients who died had ESRD, therefore ESRD was a statistically significant predictor of nonhealing ($P = 0.04$). A documented palpable pedal pulse was a statistically significant predictor for not requiring more proximal amputation ($P = 0$ .03). For 31 patients, stump infarction required more proximal amputation. Wound dehiscence was observed in 52 (51.5%) of the 101 amputations; for 29 (55.8%) of the 52 patients with wound dehiscence, a healed stump was achieved. Of 10 (9.9%) stump deformities, 2 required a more proximal amputation, and 1 died during the follow-up period. Thirty (53.6%) of 56 patients with a healed stump were independently mobile, and 26 (46.4%) of 56 patients with a healed stump required an assistive device. Postsurgical complications developed in 88 of the 101 patients, of whom 46 had a diagnosis of CAD, 83 had a diagnosis of HTN, 21 had a history of CVA, and 36 had ESRD. Of the 31 patients for whom more proximal amputation was required, 1 had a Lisfranc procedure, 2 had a Chopart procedure, 21 had BKA, and 7 had AKA. Postoperative wound infection developed in 19 of the 101 patients and was successfully treated with oral antibiotic agents and local wound care. No calcaneus or equinus gait had developed in any patient with a healed stump when last seen.[4]

In a separate study, McCallum et al. 2012 retrospectively studied 11 patient logs (12 amputations) who underwent TMA between June 2006 and December 2011. Of the cohort studied, there was a 0% mortality rate and only 1 patient required further BKA due to peripheral vascular disease (PVD). However, the patient with PVD achieved successful wound healing and had one episode of further ulceration, which required surgical debridement. The amputation site subsequently healed and remained intact for 5 weeks after debridement. One patient following TMA suffered further ulceration due to development of equinovarus deformity following TMA. Overall, 81% of the patients included in this retrospective study had a history of diabetes. However, this was not a significant predictor of mortality perioperatively.[5]

A 2016 study by Mandolfino et al. retrospectively reviewed the medical records of 394 patients (218 amputations) between January 2008 and January 2013 who had a severe foot infection with and without gangrene in a diabetic population. Five patients were lost to follow-up. The remaining 213 patients were monitored until they reached a clinical status of wound healing, major amputation, or death. Revascularization was performed combined with TMA. A good outcome included time to wound healing, a history of no additional procedures,

ambulatory status postoperatively and independent living status. Perioperative complications were defined within 30 days after amputation. TMAs were closed in 135 (62%) and open in 83 (38%) cases. In 130 patients of the closed group, 102 (7%) healed, 28 (21%) underwent additional procedures, 8 (6%) had a major amputation, 6 (4.6%) died. In the open group, 83 patients, 38 (45%) healed, 45 (54%) underwent additional procedures, 19 (22%) have had a major amputation, 12 (14%) died. An overall good functional outcome at hospital discharge after TMA was obtained by 38% of patients ambulating independently, 43% with assistance and 60% were discharged to home. Patients who underwent closed amputation were more likely to ambulate without assistance than those with open amputation.[6]

Another study by Zhang et al. 2019 sought to evaluate the clinical outcome of TMA without revascularization in a diabetic population. The records of 102 diabetic patients between July 2012 to December 2016 who were not candidates to receive revascularization because of severe comorbidity, non-ambulatory status, inadequate blood flow, patient's refusal or other conditions not accepted by vascular surgeons were included. These patients were followed up for a mean period of 38 months to observe wound healing, AKA and death. Of the 97 patients who fit the inclusion criteria, 63 (64.9%) had primary wound healing after an average of 8 months. Patients with serum albumin <30 g/l and with an ABI <0.7 had lower wound healing rates. Of the 97 patients included, 16 (16.5%) patients underwent AKA and the median interval was 13 months after TMA. The cause of higher level amputation was expanded infection, critical ischemia, adipose tissue liquefaction or stump infarction. All patients who received AKA had an ABI <0.90. There were 26 (26.8%) patients who died during the duration of this study with one due to severe foot ulceration infection.[7]

Botek et al. 2017 sought to examine the five year mortality rate of those who underwent TMA compared to BKA as well as the presence of comorbidities in patients requiring TMA. The records of 129 patients who underwent TMA at Cleveland Clinic between 2009 and 2011 were retrospectively reviewed. Comorbidities included diabetes (79%), HTN (90%), PVD (53%), CAD (36%), previous foot amputation (30%), neuropathy (68%), and renal disease (45%). The majority of patients had neuropathy (68.2%), HTN (89.9%) and PVD (52.7%). Only 29.5% of patients had prior limb amputations. Thirty-one patients (24.03%) had higher amputations after TMA, including 26 BKAs and 5 AKAs. After TMA, 102 patients ambulated (79.1%). This study found that following TMA procedure, there is a 39% 5-year mortality rate compared to 40%-82% after BKA.[8]

Discussion

Multiple studies have demonstrated that the clinical outcomes of TMA are without complications in certain patient populations, therefore TMA should be considered only as a treatment option in diabetic patients with chronic foot ulceration and infection. Pollard et al. found that there is no statistically significant difference in healing rates among diabetic versus nondiabetic patients. Instead, those with ESRD as a comorbidity had a statistically significant effect on healing postoperatively. Additionally, a palpable pedal pulse was a clinically significant predictor of healing. However, there were limitations in this study. For example, in patients without a palpable pedal pulse, methods of noninvasive diagnostic evaluation varied. This varied assessment of pedal perfusion made it difficult to find correlations with healing potential after TMA. Of the demographics and types of comorbidities studied, hypertension, CVA, and a history of CAD failed to reach statistical significance as predictors of healing after TMA.

McCallum et al. found that diabetes was not shown to be a significant predictor of perioperative 30-day mortality. However, there are limitations in this study. For example, the number of patients (n = 11) was relatively small compared to the other studies included in this review. Additionally, the evaluation period was not definitively identified to fully assess the long term effects of TMA on morbidity and mortality.

In the study by Mandolfino et al., it was found that re-ampuation rates were significantly impacted by the presence of comorbidities such as severe PAD and osteomyelitis. However, the limitation of this study is that the average follow-up period (15 months) was relatively short to identify additional morbidities associated with TMA aside from ambulation status at discharge and re-amputation rates.

Diabetic patients who are not candidates for revascularization undergoing TMA could achieve a satisfactory wound healing rate with a multidisciplinary treatment as studied by Zhang et al. This study also concluded that ABI and serum albumin levels are significant predictors of wound healing. However, there were multiple limitations to this study. For example, it was a single-center observational study thereby inevitably prone to selection bias. Secondly, the sample size (n = 97) was small to make an assessment of adequate wound healing.

Botek et al. found that there is a statistically significant difference in mortality between those patient populations receiving TMA or BKA, with a

higher mortality rate in BKA. However, a limitation of this study is that the selection criteria was too broad to make any definitive conclusions regarding the overall effect of comorbidities on TMA. The patient population of this study included patients with multiple disease processes; thus, correlations were made between the effects of multiple comorbidities on TMA instead of direct causations.

Conclusion

TMA is an effective procedure in the treatment of severe ulceration and infection in diabetic patients. When the forefoot is deemed nonviable, TMA allows for return to ambulation without postoperative complications if deemed appropriate for certain populations. TMA, however, does not come without risk and caution should be taken in evaluating whether TMA would be an appropriate course of treatment in patients with additional comorbidities. Further studies are needed to create a systematic approach that would allow clinicians to evaluate whether a diabetic patient would benefit from TMA using predictive clinical laboratory values already studied in current literature.

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A Review of the Effective Use of Ultrasound in Podiatric Medicine and Surgery

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ABSTRACT

Objective: This paper will demonstrate the various ways that ultrasound is being studied and effectively applied to support its expanded use in podiatric medicine and surgery.

Methods: JAPMA and NIH online databases were used to select eight articles for this review. Keywords used include "ultrasound, foot", "ultrasound, ankle", "ultrasound, podiatry", "ultrasound, MRI", "ultrasound, vascular, foot" and other similar terminology. Articles were omitted if they were published before 2006, were not in English, and did not grant free access to the full article.

Results: Varaki et al. concluded that Duplex ultrasound is the gold standard imaging modality for diagnosing peripheral vascular disease in the lower extremity. Rehmani et al. demonstrated the complementary role of ultrasound and MRI in the current treatment of lower extremity pathologies experienced by elite ballet dancers. Pastides et al. found that in the diagnosis of Morton's neuroma, MRI and ultrasound had statistically insignificant differences in sensitivity. Iborra-Marcos et al. utilized ultrasound in the surgical resection of the transverse intermetatarsal ligament. 98.1% of the patients improved postoperatively and none of the patients had a postoperative infection. Rettedel et al., DeLuca et al., and Argerakis et al. found no significant differences in inter-rater reliability when reading ultrasound images. Harish et al. utilized ultrasound imaging to correctly diagnose patients with plantar heel pain who were previously clinically diagnosed with plantar fasciitis. They found that 47 of 175 imaged feet were incorrectly diagnosed with plantar fasciitis.

Conclusion: There are several benefits to ultrasound: it is safe, inexpensive, and time efficient. With continued research and thorough device training, ultrasound can be effectively applied to a wider range of areas in podiatric medicine and surgery.

Introduction

In the United States, the use of ultrasound is still considered an adjunctive imaging modality, with radiographs and MRI often being the gold standard.[1] Ultrasound has the potential to become equally important in the field of podiatry. Ultrasound is considered non-invasive, inexpensive, and can be done in the office with a quick turnaround time for diagnosis and patient relief. Increased research in the application of ultrasound has led to innovations in ultrasound equipment, such as the high-frequency linear array transducer. This allows for greater spatial resolution of certain soft tissue anatomical structures.[2] Recent research and development in ultrasound technology also shows promising new applications for ultrasound beyond its current mainstay use as an accessory imaging modality to classically gold standard imaging like MRI and radiography. This paper will discuss and assess contemporary ultrasound applications to explore their potential effectiveness in podiatric medicine.

Nazarian examined 10 advantages that ultrasound can provide in medicine.[1] Of those 10 advantages, the following apply to podiatric medicine. Ultrasound is not contraindicated like several other imaging modalities.[1] Ultrasound can provide dynamic evaluation of patients and movement of the probe to the localized area of pain can provide better diagnostics.[1] Ultrasound can provide doppler information.[1] This information can then be used in a variety of ways such as improving the confidence of a diagnosis by providing information about a patient's pain. Finally, ultrasound is a better imaging modality for guiding therapeutic interventions.[1]

Siddle et al. reported that in the podiatric care setting, ultrasound is most commonly used for vascular imaging and as an injection guidance tool.[3] Nair and Sahoo discussed the benefits of ultrasound guided injections for plantar fasciitis treatment.[4] Varaki et al. concluded that ultrasound is the gold standard imaging modality in the treatment and diagnosis of peripheral vascular disease and chronic venous insufficiency.[5] As these applications are thoroughly researched methods in the field, articles discussing these topics will not be included as evidence for the effectiveness of novel ultrasound applications in podiatric medicine.

This paper will discuss the advantages that ultrasound can provide with the aim to identify and evaluate novel ultrasound methodologies that can be applied in the podiatric setting.

Methods

The NIH and JAPMA online databases were utilized to obtain eight articles. Keyword phrases that were input into the databases include "ultrasound,

foot", "ultrasound, podiatry", "ultrasound, ankle", " ultrasound, MRI", "ultrasound, vascular, foot" and similar variations. Articles discussing ultrasound for injection guidance were omitted, as this is already a thoroughly discussed ultrasound methodology in the field. Only free, full access, articles that were in English were selected for this paper. Articles that were published before 2006 were not considered.

Results

Varaki et al. conducted a review of imaging modalities used to evaluate vascular function in the lower extremity.[5] They reported on the use of plethysmography, ultrasound, pulse wave velocity, vascular optical tomographic imaging, polymer based sensors, and blood pressure measurement methods in the diagnostic assessment of peripheral vascular disease. There are many different types of ultrasound methodologies. Varaki et al. investigated B-mode, continuous wave, pulsed wave Doppler, and duplex ultrasound methodologies.[5] B-mode Doppler ultrasound can be used to evaluate the diameter of large veins and was compared to venography studies in evaluating the presence of deep vein thrombosis. One study with 145 patients found a 94% sensitivity and 100% specificity when comparing B-mode Doppler ultrasound with venography to detect deep vein thrombosis.[5] A different study compared the efficacy of B-mode Doppler ultrasound to venography in discriminating between acute and chronic deep vein thrombosis and found that they agreed 93% of the time.[5] One study with 100 patients reported that Doppler ultrasound had a greater specificity and sensitivity in diagnosing arterial occlusion and stenosis than angiography.[5] Color Doppler ultrasound was compared to angiography in a study evaluating for arterial occlusion and stenosis in 100 legs of 51 patients.[5] Color Doppler ultrasound had a 95% sensitivity and 99% specificity for arterial occlusion and 92% sensitivity and 97% specificity for stenosis.[5] Varaki et al. acknowledged a potential drawback to ultrasound is that it can be operator dependent.[5] Furthermore, they claimed that ultrasound is not an appropriate imaging modality when patients have ulceration or calcified arteries.[5] Despite these limitations, Varaki et al. name Duplex ultrasound as the gold standard in peripheral vascular disease evaluation.[5]

Rehmani et al. focused on the complementary role of ultrasound and MRI in examining elite ballet dancers.[6] This paper discussed injuries of the entire lower extremity. For the purposes of this review, the focus will be on the foot and ankle with an emphasis on imaging and treatment for Morton's neuroma (MN), Lisfranc injuries, and plantar fasciitis. In this review, the physicians used a low depth linear probe, L12-15MHz, and the common needle used for ultrasound guided injections was a 1.5 inch 25 gauge needle.[6] This is a review article based on cases that were carried out at a single institution and does not include any specific recommendations for treatment techniques. When discussing MN the study found that both MRI and ultrasound are important in diagnosis and treatment.[6] MN viewed on MRI is commonly visualized in the coronal plane and short axis view at the metatarsal heads and appears as a hypointense mass that is "'tear drop'-shaped".[6] In comparison, when viewing MN on ultrasound the probe is placed proximal to the metatarsal heads to view the intermetatarsal spaces. A positive image will show a hypoechoic, well-circumscribed, oval mass that can appear nodular.[6] Dynamic ultrasound can make the MN appear more prominent by plantarflexing the ankle and compressing or palpating the affected area with the probe can reproduce symptoms. Upon treatment, ultrasound can be used as a guidance tool to ensure the proper placement of the steroid injection to surround the neuroma.[6]

When comparing Lisfranc injuries, diagnostic imaging included computed tomography (CT), MRI, and ultrasound. CT has the ability to show any fractures not originally seen on radiographs and can demonstrate any widening of 2 mm or more between the medial cuneiform and second metatarsal base.[6] MRI can be used to further evaluate the integrity of the Lisfranc ligament complex, particularly the plantar and dorsal aspects.[6] Ultrasound was used to evaluate any avulsion fractures and has limited use for this injury.[6] Treatment options for Lisfranc injuries did not include the use of ultrasound guided techniques. Imaging for plantar fasciitis also included the use of MRI and ultrasound. In MRI, the plantar fascia appears thickened (>5mm) and may show edema of the adjacent calcaneal bone marrow.[6] On T2 weighted MRI, tears will appear hyperintense.[6] On ultrasound the plantar fascia will appear thickened, with increased blood flow at the calcaneal origin, however tears will appear hypoechoic.[6] The treatment options noted for plantar fasciitis include conservative management and ultrasound guided therapies with corticosteroid injections. It is noted that injection therapy, particularly with corticosteroids, can increase the risk for plantar aponeurosis rupture.[6] Ultrasound guided injection techniques increase the accuracy of where and how injections are placed. [6]

Pastides et al. conducted a retrospective study of the clinical and diagnostic imaging that was carried out prior to patients undergoing surgical excision of Morton's Neuroma(s).[7] The study followed 36 patients and the removal of 43 MNs all performed by a single surgical team.[7] These patients underwent history and clinical examinations and imaging, including MRI and

ultrasound. The aim of this study was to determine how accurate clinical assessment and diagnostic imaging is in relation to operative findings in patients who required surgical treatment. Of the patients in the study, 13 received MRI only (1 patient had ultrasound followed by MRI), 28 received ultrasound only (2 ultrasounds were performed on 1 patient), and 3 received MRI and ultrasound.[7] All patients had history and clinical examinations including Mulder's click test, where the metatarsal heads are compressed and the examiner assesses for a "click" that is heard or felt, and a Tinel-Hoffman sign, where the examiner taps above the webbed spaces of the foot in an attempt to elicit symptoms.[7] Pastides et al. found that the history and clinical exam was most sensitive (98%, 42/43), ultrasound was found to be 90% sensitive (28/31) and MRI was found to be 88% sensitive (14/16).[7] The limitations noted regarding ultrasound included that it is operator dependent and does not accurately visualize neighboring structures.[7] As evidenced, one patient underwent an additional ultrasound conducted by a second musculoskeletal radiologist after a negative ultrasound but continued clinical suspicion. An advantage to ultrasound was the ability to combine the imaging with clinical examination, for instance the Mulder's click test, and to be able to dynamically image the location of pain.[7] The limitations noted for MRI were the cost and the duration of time.[7] However, the benefits noted the ability to duplicate the static image that could be reviewed by a team of physicians and was not operator dependent.[7] Pastides et al. concluded that ultrasound and MRI imaging were not required in the accurate diagnosis of MN unless the history and clinical examination is inconclusive or multiple locations for neuromas are suspected.[7]

Iborra-Marcos et al. assessed the use of ultrasound as a guiding tool in the surgical resection of the transverse intermetatarsal ligament (TIML) in the treatment of MN.[8] Resection of the TIML can also be performed as an open endoscopic surgery. The ultrasound guided surgical resection of the TIML to decompress a MN was proposed with the aim of improved patient outcomes due to less trauma, decreased pain and discomfort, decreased infection, and decreased recovery time.[8] The surgical technique was first performed on 20 cadavers to ensure patient safety.[8] The study then moved to 56 live patients.[8] The ultrasound used was a 8-17 MHz linear transducer with Needle Vision Plus software.[8] Long axis ultrasound examination of the dorsal foot was used to locate the MN, the interosseous muscle, and the TIML.[8] One podiatric surgeon then widened the entry point of the injection site while another held the ultrasound steady, keeping the TIML and MN in view.[8] The TIML was then cut and a blunt dissector was used to ensure the TIML had been completely resected.[8] The 56 patients were followed at 1,3,6, and 12 months following the procedure.[8] The American Orthopaedic Foot and Ankle Society (AOFAS) and Visual Analog Scale (VAS) were used to evaluate function and pain of the patients both before and after the procedure.[8] 54 of the 56 patients in the study reported improved pain and function at 3 months and continued to improve through 12 months.[8] No patients in the study acquired a post-operative infection.[8] 98.1% of the patients improved following the ultrasound guided surgical technique.[8] 1.9% of the patients did not improve and required further surgery.[8] By comparison, the endoscopic approach showed positive outcomes in 91.3% of patients.[8] The ultrasound guided technique improved upon recovery time and postoperative infection rates when compared to the endoscopic technique.[8] The ultrasound guided technique also uniquely allows the provider to operate on both feet during a single surgery.[8]

Rettedal et al. evaluated the reliability of ultrasound in obtaining consistent measurements of the dorsal Lisfranc ligament (DLL) in healthy subjects.[9] Based on previous research, it was determined that by visualizing the DLL, the integrity of the inter-osseous segment of the Lisfranc ligament can be concluded.[9] The study was performed bilaterally on 50 subjects, 25 male and 25 female, (n=100).[9] For each subject the average age (24.74 years), weight (75.3 Kg), height (173.9 cm), foot length (25.4 cm), and foot width (9.5cm) was recorded.[9] The Siemens SONOLINE Antares Ultrasound Imaging System with a 10.0 MHz linear array transducer was used.[9] The ultrasound images were saved digitally to determine the length in each trial.[9] Trials were conducted in three stress loads and two angles of abduction.[9] These included non-weight bearing, bipedal stance, and single leg stance at either 0° or 15° foot abduction.[9] An in house seated calf raise position apparatus was created to simulate stress conditions that could be loaded with weight plates.[9] Foot print markings were also created at 0° or 15° abduction to ensure correct foot placement.[9] Measurements in all six orientations were then taken using a randomized protocol for each subject.[9] Randomized sets of twenty subjects were asked to return at least 24 hours later to be measured again.[9] The measurements obtained were compared within the session with the single rater (intra-rater), between two sessions with the same rater (intra-rater comparison) and between two sessions with different raters (inter-rater comparison).[9] Both raters were podiatric medical students who underwent 40 hours of ultrasound training prior to the collection.[9] The average overall intraclass correlation coefficient (ICC) decreased from within session intra-rater reliability ICC (0.889, n=100), to the between session intra-rater reliability

ICC (0.747, n=40), and the between session inter-rater reliability ICC (0.685, n=40).[9] Rettedal et al. suggested that these small differences can be attributed to examiner training and that similarly trained examiners would produce more reliable results.[9]

DeLuca et al. utilized ultrasound to identify the dorsal Lisfranc ligament (DLL) in 18 cadaveric right feet.[10] Sonosite and ImageJ machines with a 6-13 MHz linear array were used. Immediately after ultrasound imaging, the foot was dissected and the measurements of DLL length, thickness, and dorsal joint space were compared.[10] DLL length was significantly different between ultrasound and dissection measurements, with ultrasound showing a smaller length.[10] Ultrasound evaluation of the mean dorsal joint space was significantly larger than measured on dissection.[10] Ultrasound evaluation of DLL thickness was significantly larger than on dissection.[10] There was no significant difference in measurements between the two types of ultrasound technologies for any of the measurements.[10] For these reasons, DeLuca et al. concluded that ultrasound can appropriately be used to visualize trauma to the DLL, however it is not the most appropriate imaging modality for obtaining DLL dimensions.[10]

Harish et al. assessed the use of ultrasound in identifying and measuring the superomedial part of the spring ligament (SMSL) in cadaveric and asymptomatic participants.[11] A Siemens Antares scanner with a high-resolution linear array transducer of 5-13 MHz was used for SMSL evaluation in four cadavers.[11] After ultrasonographic identification of the SMSL, the structure was injected with 0.1% methylene blue dye.[11] A foot and ankle trained orthopedic surgeon dissected the cadavers, observing that the injection and ultrasound had properly identified the SMSL in all four specimens.[11] A GE Logiq 9 scanner with a high-frequency linear array transducer of 5-12 MHz was used to compare the SMSL characteristics and visualization in 40 asymptomatic participants bilaterally.[11] Visualization in SMSL scores using the ultrasound were rated as good in 92.5%, intermediate in 6.25%, and poor in 1.25%.[11] In these calculations, right and left ligaments were evaluated separately, with a total of 80 SMSL evaluations from the 40 participants.[11] Harish et al. obtained comparable ultrasound-obtained SMSL measurements to MRI-obtained measurements with a mean value of 3 mm and 3.2 mm respectively.[11]

Argerakis et al. conducted a retrospective review of ultrasound used in etiological evaluation in 143 patients presenting with unilateral or bilateral heel pain and clinically diagnosed with plantar fasciitis.[2] An iU22 scanner and a high-frequency linear phased array transducer was used by a board-certified radiologist to collect and interpret the ultrasound images.[2] Then, a different board-certified radiologist also interpreted the imaging.[2] Through randomized selection of 30 images, there was 100% inter-rater reliability between the two radiologists.[2] Ultrasound imaging of the 175 feet demonstrated heel pain etiologies of 128 feet with plantar fasciitis and 47 without plantar fasciitis.[2] Notable findings include: 90 feet had fibromas, 27 of the 47 feet without plantar fasciitis had one or more fibroma, 11 feet negative for plantar fasciitis and fibroma showed no abnormalities, and 9 feet negative for plantar fasciitis and fibroma showed other anatomical pathologies.[2]

Discussion

In reviewing these articles, it can be seen that there are several benefits to expanding the use of ultrasound in podiatric medicine beyond its current complementary use with MRI, in vascular imaging, and in guided injections.[1,2,8-11] Varaki et al. referenced many articles in support of their claim that Duplex ultrasound is the gold standard imaging modality for diagnosing peripheral vascular disease.[5]

Rehmani et al. demonstrated the relationship between ultrasound and MRI and presented the advantages and disadvantages of both and how they can be used together in diagnosis and treatment.[6] Although MRI is best for viewing joints and deep structures including bone and cartilage, ultrasound is a better option for imaging superficial structures.[6] This is especially applicable to the foot where many superficial structures are implicated in various pathologies. This article supports the further use of ultrasound alongside MRI to help with dynamic evaluation leading to diagnosis and ultrasound guided therapies, including ultrasound guided injections. Using this technique allows physicians to place medication, such as corticosteroids, more precisely and can reduce complications, such as ruptures of the plantar aponeurosis or tendons.[6]

Pastides et al. found that when comparing MRI and ultrasound in the diagnosis of MN the difference in sensitivities was not statistically significant.[7] When analyzing the differences, ultrasound was noted to be more cost effective and provided for dynamic evaluation of patients.[7] The main drawback to ultrasound is that it is operator dependent in comparison to MRI which creates a reproducible, static image.[7] This was the main benefit of MRI, although the imaging is costly and more time consuming.[7] These are factors physicians consider when ordering imaging.

When applied to the surgical aspect of podiatric medicine, ultrasound proved to be an important guiding tool.[8] Iborra-Marcos et al. found that ultrasound guided resection of the TIML improved the surgical outcome compared to the

standard endoscopic technique.[8] They reported that no patients who underwent the ultrasound guided resection surgery acquired a postoperative infection and all but two patients required further surgical treatment.[8] As postoperative infections and complications are always a significant concern of surgical procedures, there is a need for continued research in the utilization of ultrasound to enhance surgical techniques.

A common argument against using ultrasound, as described by Pastides et al., Varaki et al. and Rehmani et al., is that there is poor inter-rater reliability between different technicians and that differences can arise between different hospitals and clinics.[5-7] However the opposite was true in three of the reviewed articles.[2,9,10] Argerakis et al. found no differences in diagnostic evaluation of heel pain using ultrasound between two highly skilled radiologists.[2] DeLuca et al. found no statistically significant difference in DLL measurements between types of ultrasound machines.[10] Rettedel et al. found statistically insignificant variations in measurements of the DLL.[9] The technicians in this study were students, and they attributed these slight variations to their limited experience.[9] This provides evidence to suggest that with thorough and uniform training, podiatrists can use ultrasound to obtain immediate and definitive evaluations of presenting pathologies.

Conclusion

Ultrasound is an underutilized imaging modality that has several applications in podiatric medicine. Ultrasound is inexpensive, portable, and time efficient. Most importantly, it is non-invasive and not contraindicated in many patient populations. Ultrasound should be utilized in a broader scope in podiatric medicine beyond its popular application in vascular imaging and ultrasound guided injections. Continued research should be conducted to explore the vast possibilities of ultrasound application and training in the podiatric care setting.

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Optimal Surgical Approaches to Adult Hallux Valgus Deformity: Chevron vs. Scarf Osteotomies

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ABSTRACT

Objective: To compare and contrast first metatarsal corrective procedures, Chevron and Scarf osteotomies, for the management of adult hallux valgus.

Methods: Relevant research articles were compiled from PubMed listing, detailing and comparing the surgical procedures to each other for the treatment of adult hallux valgus.

Results: Postoperative corrections for hallux valgus angle (HVA) and intermetatarsal angle (IMA) were slightly higher for Scarf than for Chevron osteotomies, but these differences were not statistically significant, with the exception of a modified Chevron osteotomy. Benefits, complication rates, and patient satisfaction were also not statistically significant between the two osteotomies. Chevron was noted to have a higher recurrence rate (13%) when compared to Scarf (0%).

Conclusion: In terms of efficacy, both treatments work well for the management of adult hallux valgus. Though there are no statistically significant differences between the two for benefits and risk rates, their implications of use are based on the severity of the hallux valgus deformity and patient status. Chevron is more commonly used and a first choice because it is a simpler and less time demanding procedure to perform, useful for early treatment of mild hallux valgus. Scarf is a more complex procedure and should be used in moderate to severe hallux valgus for greater correction.

Introduction

Hallux abducto valgus deformity (HAV) or bunion, is a first ray deformity that involves deviation of the hallux in the transverse plane away from the midsagittal line of the body.[1] This creates a bony protrusion of the metatarsal head on the medial side of the foot, affecting placement in shoes, appearance, biomechanics, gait, and lifestyle. Radiographically, hallux valgus has an increased intermetatarsal angle (IMA) greater than or equal to 8°, and an increased hallux valgus angle (HVA) greater than or equal to 15°. HAV is a common foot deformity that has a higher prevalence in women and older patients, affecting an average of 23% of adults aged 18-65 and 35.7% of older adults aged over 65.[2] Conservative treatment is the first step of management for HAV, especially for mild cases, as surgery can lead to complications, overcorrection, or both. This includes the use of NSAIDs, orthotics, shoe modifications, etc. For more severe cases where conservative treatment is not enough for management of the deformity, operative treatments are considered. The goals of surgical correction are to restore and maintain first ray stability and function, and provide painless full range of motion.[1] In general, a larger intermetatarsal angle (IMA) indicates osteotomies to be done more proximally. This is diagnostic for procedure selection based on severity of the deformity, in addition to the patient's medical and social history.[1]

Using IMA as an indicator in addition to gross appearance of the bunion, there are two surgical procedures that are commonly used for correction of HAV: Chevron (Austin) osteotomy and Scarf osteotomy. A Chevron osteotomy is a distal osteotomy of the first metatarsal that creates a V-shaped cut to the shaft of the metatarsal head laterally.[3] The Chevron osteotomy is a stable procedure that utilizes internal fixation with screws,[3] and can also be modified for multi planar correction.[1] A Scarf osteotomy is a diaphyseal osteotomy of the first metatarsal that is characterized by a distal cut from the dorsal cortex, a long horizontal cut along the long axis, and a proximal cut from the plantar cortex.[1] This creates a "Z" shaped cut that is also stable.

Chevron and Scarf osteotomies are both first metatarsal corrective procedures for hallux valgus.[4] However, Chevron is used for mild hallux valgus indicated with an IMA < 15°, while Scarf is used for moderate to severe hallux valgus indicated with an IMA < 20°.[3] Normally, IMA is less than 8°, and both osteotomies are used to reduce the increased IMA and HVA from the deformity. In relation to each other, Scarf is done proximally at the diaphysis of the first metatarsal while Chevron is done distally at the first metatarsal head. This follows the general rule of Scarf being done for a larger IMA and more severe cases of hallux valgus.

The purpose of this article is to compare and contrast the indications for and complications of the Chevron and Scarf osteotomies for the management of adult hallux valgus. These specific osteotomies were chosen because they are the more common head and base procedures used by surgeons for hallux valgus. By understanding the underlying mechanisms behind

these procedures, patients can receive optimal treatment suited for them with minimal complications.

Methods

Relevant articles were found through PubMed relating to surgical approaches toward adult HAV deformities. Sources were then selected based on emphasis to Chevron and Scarf osteotomies. The articles were used to compare and contrast views toward the two surgical procedures, and their indications and complications. Search terms included "adult hallux valgus surgery" and "adult hallux valgus Chevron vs. Scarf osteotomies." Additional keywords for the search of articles in the PubMed database included "hallux valgus," "Chevron," "Scarf," "bunion," and "Chevron versus Scarf." Exclusions of articles were dependent on whether they discussed only conservative treatment, inconclusive data, and any personal, monetary, or affiliated bias that would skew data.

Results

In a randomized control trial conducted by Deenik et al., the Scarf and Chevron osteotomies were directly compared using a treatment group for each in a randomized clinical trial of 83 patients between the years of 1999 and 2001. Postoperatively, Chevron showed an improvement in the hallux valgus angle (HVA) by a mean of 13.1° ± 7.0° while Scarf showed an improvement of the angle by a mean of 10.9° ± 7.2° (p=0.13). For IMA correction, Chevron showed an improvement by a mean of 3.1° ± 2.7° while Scarf showed an improvement by a mean of 3.1° ± 2.9° (p=0.97).[5] It was also noted that Chevron took a mean operation time of 24 minutes ± 5.8 minutes while Scarf took 29 minutes ± 6.7 minutes. In terms of complications from the respective treatments, 3 patients in the Chevron group developed partial metatarsal head necrosis while 4 patients in the Scarf group developed grade I complex regional pain syndrome.[5]

In another study by Elshazly et al., a prospective randomized controlled comparative trial of the two treatments was conducted. Forty-eight cases were divided where 21 patients were treated by Scarf osteotomy, 22 were treated by Chevron osteotomy, and 5 were missed during follow-up. For all cases, the average age was 36 years old and follow up time averaged 25.9 months. The mean operative time for the Scarf osteotomy was 69 minutes ± 8.38 minutes compared to 63 minutes ± 8.36 minutes for the Chevron osteotomy (p=0.86). For the amount of radiological correction postoperatively, there was improvement in IMA from Chevron by a mean of 11.27° ± 3.41° and from Scarf by a mean of 9.24° ± 5.22° (p=0.14). HVA also showed improvement postoperatively from Chevron by a mean of 23.64° ± 12.86° and from Scarf by a mean of 24.71° ± 11.96° (p=0.78). The American College of Foot and Ankle Surgeons (ACFAS) scoring scale was also used to measure patient satisfaction. The study found that the average ACFAS score change in percentage postoperatively was 69.1% for the Chevron procedure and 57.5% for the Scarf procedure (p=0.29). In terms of complications, both Scarf and Chevron groups had one case each for superficial infection and wound dehiscence. Chevron was the only procedure to have one case of recurrence.[6]

In another randomized control trial in 2016, Mahadevan et al. compared the Chevron osteotomy to the Scarf osteotomy for HAV deformity correction. The trial saw 84 patients, 46 patients for the Chevron group and 38 for the Scarf group. Preoperatively, IMA for the modified Chevron group was 15.2° ± 3.1° while Scarf was 14.3° ± 2.9° (p=0.214). Postoperatively, IMA for Chevron was corrected to a mean of 5.8° ± 2.5° while Scarf was corrected to a mean of 6.9° ± 2.8° (p=0.045). HVA preoperatively had 32.3° ± 8.3° for Chevron and 29.5° ± 7.6° for Scarf (p=0.118), while postoperative correction was to a mean of 14.3° ± 7.4° for Chevron and 13.0° ± 7.6° for Scarf (p=0.374). Patient satisfaction using the Manchester Oxford Foot Questionnaire (MOxFQ) provided preoperative scores of 49.8 ± 18.5 for Chevron and 47.0 ± 16.2 for Scarf (p=0.495), while postoperative scores were 12.6 ± 19.0 for Chevron and 10.2 ± 15.0 for Scarf (p=0.545). Both Chevron and Scarf osteotomies saw one complication of hallux varus.[7]

A comparative study of Scarf vs. Chevron osteotomy by Vopat et al. found 70 patients that were eligible for the study. Fifty-two patients had a Scarf osteotomy performed while the remaining 18 had the extended Chevron osteotomy. The amount of angle correction provided by extended Chevron and Scarf for HVA was 30.3° and 31.4° respectively (p=0.7295). This study used two different techniques to measure IMA corrections for both osteotomies: Nestor and Miller techniques. Correction of IMA using Nester changed the angle by 10.8° for Chevron and 11.2° for Scarf (p=0.5980), while using the Miller technique changed the angle by 8.8° for Chevron and 8.9° for Scarf (p=0.9169). Overall complications included symptomatic hardware indicating removal in four patients and one case of superficial infection.[8]

Fakoor et al. published a retrospective cohort study of 44 patients with hallux valgus deformity, treated surgically from 2010 to 2013, that was done for the comparison of clinical outcomes between Scarf and Chevron osteotomies. In this study, the mean amount of HVA correction was 16.17° ± 3.7° for Chevron and 18° ± 2.1° for Scarf (p=0.42), while the

mean amount of IMA correction was 4.5° ± 2.4° for Chevron and 6.3° ± 1.9° for Scarf (p=0.79).[9] Postoperative results of patients showed that recurrence of hallux valgus from using Chevron was 13% while from using Scarf was 0%.[9]

Discussion

In the randomized control trial by Deenik et al., it was shown postoperatively that both the Chevron and Scarf procedures showed significant improvements in the HVA and IMA correction, but the differences between the corrections of both treatments were not statistically significant as HVA had a p-value of 0.13 and IMA with a p-value of 0.97. Even though both procedures offer similar benefits, there is a 5 minute difference in favor of Chevron for the mean operation time as Chevron took a mean of 24 minutes while Scarf took a mean of 29 minutes to complete. In terms of complications, osteonecrosis of the metatarsal head in Chevron osteotomies can be attributed to lateral release, periosteal stripping, and the osteotomy itself.[5] Patients who received the Scarf osteotomy developed grade I complex regional pain syndrome which may be attributed to the more extensive approach of the procedure.[5]

In the randomized controlled comparative trial of the two treatments conducted by Elshazly et al., clinical postoperative outcomes for IMA (p=0.14) and HVA (p=0.78) correction showed no statistical significance between the two treatments. Though there was a 6 minute difference in favor of Chevron, the mean operation times for both treatments are also not statistically different (p=0.86). The change in average ACFAS score showed higher patient satisfaction for Chevron (69.1%) compared to that of Scarf (57.5%),[6] but the difference in scores was also not statistically significant (p=0.29). For complications, both Scarf and Chevron groups had similar cases of superficial infection and wound dehiscence,[6] which are risks of many invasive procedures. When compared to Scarf, Chevron's additional risk of recurrence of the hallux valgus deformity can be attributed to its distal site of correction and simplicity of the procedure. Overall, there is not much to differentiate as both osteotomies provide similar correction and clinical improvements. Thus, there was a subjective difference in the study for the surgeons performing both surgeries who favored Chevron due to its simplicity and shorter operation time.[6]

In the randomized control trial by Mahadevan et al. comparing the two osteotomies for HAV deformity correction, there was no statistical significance in hallux valgus angle preoperatively (p=0.118) and postoperatively (p=0.374). Patient satisfaction using the Manchester Oxford Foot Questionnaire was also not statistically significant for the two osteotomies preoperatively (p=0.495) and postoperatively (p=0.545). There was, however, statistical significance between the two osteotomies in regards to the postoperative IMA (p=0.045). This difference and magnitude of IMA correction in the Chevron group is unlike the difference in IMA correction of the previously mentioned studies. This presence of statistical significance can be attributed to the Chevron osteotomy being a modified version of the traditional method. The study states that the modified Chevron in this study produces an extended plantarflexed first ray, which increased the surface contact area to provide improved stability and greater displacement for correction. The plantar cut also avoided the distal metaphyseal flare, reducing the likelihood of the plantar vessels to the metatarsal head to be damaged, thus reducing the risk of osteonecrosis.[7] The modified Chevron potentially accounts for deficiencies of the traditional method by reducing the risk of osteonecrosis as seen as a complication from previous studies. With a greater magnitude of correction than Scarf and a reduction of risks, the modified Chevron appears favorable in this study and in general for hallux valgus deformities. Deciding the use of a modified Chevron should be weighed based on the patient's status and past medical history. For the complication of hallux varus from both osteotomies in the study, this deformity can occur from overcorrection of hallux valgus.

In the comparative study of Scarf vs. Chevron osteotomy by Vopat et al., there was no statistical significance in regards to the amount of correction for HVA (p=0.7295) and IMA using both Nestor (p=0.5980) and Miller (p=0.9169) techniques. The Nestor technique represents the first metatarsal axis by drawing a line through the center of the metatarsal head and proximal shaft, while the Miller technique defines the first metatarsal axis with a line drawn from the center of the metatarsal head through the center of the base of the first metatarsal.[8] Thus, the techniques switch the endpoint and shift the location of the first metatarsal axis. As seen from the results, the Miller technique in both osteotomies provides even less of a difference for correction than the Nestor technique. Regardless of technique, the amount of correction and benefits of both osteotomies are similar. Risks in this study were minimal. It is noted from the study however that the worst complication from Chevron is avascular necrosis of the metatarsal head, which is seen as a complication in previous studies. Aside from Scarf being more difficult to perform, malunion is a complication from more proximal osteotomies.[8] Though different forms of risks are involved, the rates of them occurring is similar between both procedures. A meta-analysis by Ma et al. determining the optimal surgery for the

correction of HAV deformity states that there was no significant difference in complication rates between Chevron and Scarf groups (p=0.3938).[10] Thus, the study concludes that Chevron is favored due to it being less technically demanding than Scarf.[10]

In the retrospective cohort study by Fakoor et al., no statistical significance was seen again for HAV correction (p=0.42) and IMA correction (p=0.79) between the two osteotomies. It was noted though that Chevron (13%) has a higher recurrence rate than Scarf (0%). This could be due to Chevron being a more distal osteotomy that provides slightly less correction than Scarf. Thus, the study concludes that using Scarf results in better correction and patient satisfaction than Chevron for a moderate hallux valgus deformity.[9] Providing more correction with no risk of recurrence provides an incentive for surgeons to use Scarf instead of Chevron.

Conclusion

Osteotomies, specifically Chevron and Scarf, are corrective procedures used to manipulate bone structure for the improvement of angles in the hallux valgus deformity. Overall, it is seen that the two surgeries have no statistically significant differences for benefits and complication rates. Both procedures offer a significant amount of correction and their implications of use are based on the severity of hallux valgus and status of the patient. Chevron osteotomies are the more commonly used method for milder cases of hallux valgus as they are simpler procedures and take less time to perform. This is preferable for the surgeon and would offer less errors during the operation. Chevron, however, has the risks of recurrence and avascular necrosis of the metatarsal head, unless a modified Chevron is performed which would offer greater correction and reduction of risks. In the case of a moderate to severe hallux valgus deformity, the Scarf osteotomy is preferred for the patient and should be used for greater correction of angles with no risk of recurrence. Scarf osteotomies can pose the risk of malunion and grade I complex regional pain syndrome, but these can be resolved or avoided with proper weight bearing of the patient and planning of the surgeon.

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Current Studies for Optimal Exercise Induced Calf Hypertrophy

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ABSTRACT

Objective: To study the current research shown to induce calf hypertrophy.

Methods: Research on triceps surae muscle hypertrophy from varying exercise regimens is presented. Databases include google scholar and Wiley.

Results: The intrinsic anatomy and composition of the triceps surae can individually impact hypertrophy potential. Stretch based regimens can be equally as effective as resistance-based training for the gastrocnemius muscles. Loading may not be relevant to calf muscle hypertrophy while foot positioning has been shown to target individual heads of the gastrocnemius. Concentric and eccentric resistance exercises are also shown to be effective in older men.

Conclusion: Calf muscle hypertrophy is achievable through consistency, progressive overload, repetition until failure, and proper protein intake.

Introduction

A common belief amongst gym attendees is calf muscle hypertrophy while training with resistance is much more difficult when compared to other muscle groups of the body – leading to an imbalanced appearance of a well-developed upper body and a lesser developed lower body.[1] Understanding the anatomy of the calf muscles, or triceps surae, is imperative when investigating why this commonly held belief may exist. The calf muscles consist of the soleus, lateral head, and medial head of the gastrocnemius. The gastrocnemius muscle complex crosses the ankle and the knee.[2]

The gastrocnemius muscle is a bipennate muscle with tendons contributing to the Achilles tendon, resulting in two heads sharing unequal loads during conventional resistance training.[3] The lateral head of the gastrocnemius has a more oblique attachment as compared to the linear attachment of the medial head of the gastrocnemius (MG).[3] Thus, the MG undergoes greater load based on anatomical position and results in increased changes in mass. The lateral gastrocnemius (LG) is able to dissipate a larger percentage of torque due to its oblique nature.[3] Experimental findings suggest the soleal muscle is much more resistant to changes when undergoing resistance training despite using large amounts of glycogen.[1] The soleus may be relatively unresponsive to resistance training due to already being chronically trained as the main plantar flexor.[1] It is also notable to discuss the different fiber types in muscles.

Type 1 muscle fibers are generally thought to be endurance oriented, with high capacity against fatigue.[4] Type two fibers achieve higher peak tension with low tolerance and fatigue much faster.[4] Most muscles are a mix of the two. The soleus is almost entirely made of Type one fibers as its main role is posture regulation while standing.[4] Schoenfeld et al. has shown a lower potential for hypertrophy in soleus muscles when compared to other muscles due their predominance of Type 1 fibers.[4] This may explain the difficulty commonly experienced by individuals attempting to increase calf mass.

Progressive muscle overload produces stress on that leads to eventual growth as a form of adaptation, otherwise known as hypertrophy. Unsurprisingly, lack of stimulation can lead to attenuation or atrophy.[5] Repeated stress in the form of resistance training can change the length of muscular fascicles, pennation angles, and overall size. This requires a load with enough mass to stress the muscle beyond normal use.[3] The lengths of fascicles in muscles increase through the addition of sarcomeres in series at the muscle tendon junction.[3] Fascicle length and muscle size are closely correlated.[3] The purpose of this study is to elucidate current research with respect to exercise induced calf hypertrophy.

Methods

Articles related to calf hypertrophy are analyzed and discussed in order to provide insight on current research conducted that may explain ways to significantly increase mass as a result of training. Databases used included Google Scholar and Wiley online library. Key phrases screened included “calf hypertrophy”, “triceps surae”, “calf resistance training”, “gastrocnemius hypertrophy”, and “soleus hypertrophy”. Emphasis is placed on the degree of muscle hypertrophy versus specific exercise regimen completed. Each exercise regimen is explained in detail as done in the individual studies chosen for review.

Results

Muscle Protein Synthesis

A study by Trappe et. al recruited 8 males of average age 27 and had them complete an exercise regimen including standing, bent knee, and seated calf

presses with heel rise at 4 sets by 15 repetitions. Protein synthesis studies were immediately taken to measure soleal activation for muscle growth and repair. Protein synthesis was found to be 200% lower than comparable exercises with the vastus lateralis muscle.[1, 4] RNA content in muscles 2 days post stretch training showed a 250% in ribosomal RNA concentration.[5]

Stretch Training

Simpson et al. presents stretch training as a way to change gastrocnemius structure through the lengthening of fascicles, attenuation of pennation angles, and increased density.[3] The training involved 21 males at average age 22 with similar height and build (physique), of which 10 served as controls with strength training alone. The 11 remaining subjects had been assigned stretch training on their dominant legs. Training included static passive stretch exercises five times a week for a total duration of six weeks. Each player was given 2 days rest every five days. Sessions began with 3 minutes of two leg hops followed by 15 calf raises at body weight.[3]

Using a leg press machine, hips were oriented at 90 degrees, and the press was loaded to 20% of maximal voluntary contraction. This translated to about 7.2 kg per volunteer and was increased 5% each week thereafter. When ready, the volunteer was instructed to remove his dominant leg and relax his plantar flexor muscles in order to allow maximum safe dorsiflexion, and thus, stretch of the calf muscles for 3 minutes. At three minutes, the dominant leg was used to place press back into safety position. The volunteers were then given .25 grams per kilogram weight of whey isolate protein mixed with water. This continued for 6 weeks. At the end of 6 weeks, ankle flexibility and range of motion were increased ($P<0.01$). Both heads of the gastrocnemius had significantly longer fascicular lengths by week 6, especially with the LG as compared to the MG. The pennation angle of the LG decreased by 8.7% and increased for the MG by 4.9%. Muscle thickness increased by 5.6% for both.[3]

Heavy vs. Light Load

Schoenfeld et al. studied longitudinal adaptation for strength and hypertrophy in calf muscles between light weight-load and heavy weight-load plantarflexion exercises. Light weight was subjective to each participant and was measured as a load sustainable for 20-30 repetitions. Similarly, heavy weights were loads sustainable for only 6-10 repetitions. The study involved 30 male volunteers with an average age of 22.5 years. Participants underwent strength testing for baseline as well as a familiarization schedule for three consecutive days with 3 sets of repetitions staggered from 5-10-15 increasing.[4]

Resistance training then occurred the week following for the next 8 weeks. Light and heavy exercise orders were staggered among testing groups; however, each subject was to complete both heavy and light training for the same workout. Exercises included straight-leg calf raises with heavy and light weight as well as bent leg calf raises with both weight types. Participants followed a strict regimen of four sets each exercise with 90 seconds rest in between sets and 3-minute rests during transition to other exercises.[4]

All participants performed each set to failure. Weights were changed as needed to ensure maximum number of repetitions. Each motion included concentric contraction followed by 2 seconds of eccentric contraction. Twenty-four grams of whey isolate protein were administered on training days. Muscle growth with respect to heavy versus light workout was insignificant, as was isometric strength. The researchers found no discernable difference between light and heavy training on gastrocnemius and soleus muscles. All calf muscles showed significantly increased growth despite training load. The lateral gastrocnemius showed greater growth when compared to the medial head and soleus. For light weight exercises the soleus, MH gastrocnemius, and LH gastrocnemius showed growth of 1.3 ± 1.4 mm, 1.5 ± 1.3, 2.1 ± 1.4mm for heavy weights and 1.5 ± 1.3, 1.8 ± 1.6, and 2.3 ± 2.2 mm, respectively.[4]

Foot Positioning

Nunes et al. studied the effects of foot position on gastrocnemius growth when subjected to progressive resistance training. Positions included rectus, valgus, and varus. Thickness was measured with ultrasound. The study included 22 males with ages ranged 18-35, all without chronic illness or deformity. The regimen consisted of training three times per week for nine weeks unilaterally with a seated horizontal press machine. Step wise training was implemented starting with 3 sets x 20-25 repetitions per leg to maximum ROM for the first three weeks followed by 4 sets x 20-25 thereafter. Sets were alternated between legs where only one was trained per set. Rest time was one minute to 90 seconds between sets. Each repetition was broken down to 1 second in the concentric phase, 1 second at peak concentric phase, and 2 seconds in eccentric phase; participants were told to squeeze the muscle and push close to failure by the last 3 repetitions. Weight was increased by 5-10% depending on repetitions completed before near failure. To test varus and valgus positioning, feet were pointed outward or inward 45 degrees. Outward foot positioning resulted in significantly larger hypertrophy for the medial head of

gastrocnemius with average increases of 0.69 cm/8.4% ($p<0.05$). Similarly, inward foot positioning showed significant gain for the lateral head with an average growth of 0.58 cm/9.1% of thickness ($p<0.05$).[2]

Older Age groups

Ferri et al. conducted a similar study with 16 men aged 65-81 years, who underwent resistance training 3 days per week for a total of 16 weeks using seated calf machines and leg press machines. Warm up training consisted of cycling for 10 minutes at 50% maximal heart rate followed by 20 contractions of target muscles at 30% one-rep max. Each individual completed one set at 50% one-rep maximum that increased to 80% within four weeks. Each rep consisted of concentric phase of 2 seconds followed by eccentric phase of three seconds. Triceps surae cross sectional area increased an average of 5 % ($P<0.001$).[6]

Discussion

The studies reviewed in this paper each conducted a different method to test viability for increasing calf muscle size. Investigations were specific to stretch based muscle training, load based training, or positional based training. The two other studies included investigation on the biochemical reasoning for difficulty of calf growth hypertrophy and training in older population groups. This differentiates from the overwhelmingly young population group used in a majority of these studies. All studies resulted in significant hypertrophy of either the gastrocnemius, soleus, or both.

Simpson et. al noted that the MG showed immediate adaption while LG adaptation was delayed. However, the changes in the pennation angles of both heads seemed to come closer in value. This may indicate that increased hypertrophy can be achieved through stretching loads in place of resistance training which traditionally results in growth from muscle damage and regeneration.[3] Stretch has been shown to significantly stimulate the synthesis of muscle proteins and growth via addition of sarcomeres in series. Stretch exercises with concurrent resistant training can show significant hypertrophic gain. The overall findings seem to suggest that the pennation angle of both heads in the gastrocnemius could be manipulated to achieve maximum torque on each muscle in tandem. This study also placed more focus on the pennation angle and reported hypertrophy as a mean of both heads of the gastrocnemius rather than separately.

The study conducted by Schoenfeld et al. suggested no discernable difference between heavy and light weight training. The heads of the gastrocnemius are more dynamic rather than static, meaning greater effectiveness for sudden bursts of increased force production.[4] It has been previously hypothesized that in order to achieve maximum growth, muscles with dominance of type 1 fibers require light loads with high repetitions while type 2 based muscles require heavy loads and low repetitions.[4] However, the data from this study reports otherwise. Interestingly, this study was the only one to include a familiarization schedule to limit the effect of soreness on data.

The findings of Nunez et al. are unsurprising when considering the vector of force and physical loads depending on it in response to foot position. Outward and inward positioning have greater affects on oppositely located heads of the gastrocnemius, which can be explained by greater torque placed on each. However, as the foot positioning could lead to inversion and eversion, the peroneal and anterior muscles of the leg may have been involved with load bearing and possibly limited the full extent of hypertrophy.

Ferri et al planned the exercise regimen aslow repetition high resistance training at one set was shown to be equally as effective as multiple sets in previous studies. This was also optimal risk mitigating protocol in an older population. However, they also implemented aerobic conditioning as a warmup. Conversely, previous research has shown completing resistance exercises concurrently with aerobic exercise can limit strength gains by impairing muscle fiber growth.[7] This disruption in growth is more specific to Type 1 muscle fiber hypertrophy.[7] Aerobic exercise, , when done concurrently with resistance exercise, can completely stop muscle growth with higher concentrations of type one fibers due to diminished satellite cell response.[7] This could have possibly limited the true hypertrophy potential of the calves.

A majority of the studies included young men who were healthy and inexperienced in calf muscle training. This may explain the success as subject started at their true baselines. There could also have been marked improvement in terms of sample size, thus leading to higher powered studies. No women were included in the studies.

Conclusion

The intrinsic anatomy and composition of the triceps surae can individually impact hypertrophy potential. Stretch based regimens can be equally as effective as resistance-based training for the gastrocnemius muscles. Loading may not be relevant to calf muscle hypertrophy while foot positioning has been shown to target individual heads of the gastrocnemius. Concentric and eccentric resistance exercises is also shown to be effective in older men.

Overall, it seems consistency, progressive overload, and repetitions until failure can lead to increased calf growth. Future studies could include all confirmed findings into one study with multiple subject groups assigned to each method and separate groups assigned to multiple against a control. Wider age ranges could be used as well as both genders.

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Open Wound vs. Arthroscopic Broström-Gould Methods for Lateral Ankle Ligament Sprains: A Comparison

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ABSTRACT

Objective: The goal of this article is to determine whether the open wound or arthroscopic Broström-Gould (BG) procedure is more beneficial to the patient.

Methods: Data was analyzed that included both treatment methods. The various studies chosen had data on both arthroscopic Broström-Gould and open Broström-Gould procedures. The AOFAS, VAS, and Karlsson scores were utilized to assess fair comparison of the procedures.

Results: The study concluded that both open and arthroscopic Broström-Gould repair of the ATFL result in similar functional outcomes when comparing the AOFAS, VAS, and Karlsson scores. Arthroscopic, however, has an advantage over open surgery through the following: earlier return to daily activity, lower risk of iatrogenic complications and simultaneous repair of intra-articular pathologies.

Conclusion: The research and studies analyzed indicated variable differences in efficacy and post-operative recovery between the Arthroscopic Broström-Gould Procedure and the open wound Broström-Gould procedures, slightly favoring the arthroscopic method for better efficacy and recovery times.

Introduction

An acute ankle sprain is one of the most common lower extremity injuries sustained by athletes.[1] Up to 85% of these cases involve the stretching or tear of the anterior talofibular ligament (ATFL). This ligament originates on the fibula (lateral malleolus) and attaches to the antero-lateral talus. In cases where the ATFL or other surrounding ligaments are injured, treatment options vary. The method of care is typically determined by the grade of the sprain.

The West Point Sprain Grading System grades ankle sprains based on the following criteria: tearing, swelling, joint instability, and weight bearing [ability].[2] Grade I sprains are the least severe where ligaments are stretched without macroscopic tearing, little to no edema, and no mechanical instability in the joint.[1] A grade III sprain is the most severe, where the ligament is fully ruptured with swelling, hemorrhage, tenderness, loss of function, and instability. Grade I and II ankle sprains have been proven to heal through non-surgical measures such as ice, stabilization, compression, physical therapy, and rest. Total ruptures of the ankle ligaments [Grade III] sprains are repaired through differing surgical procedures if conservative treatment options have been exhausted.[3]

An athlete with a grade I or II sprain may also undergo surgery if the ankle incurs multiple ankle sprains or does not have the ability to maintain a rectus position over the course of a year. This is defined as chronic lateral ankle instability (CLAI). If an ankle presents with CLAI and conservative methods have failed, the patient will most likely undergo surgical treatment.[4] A test to confirm CLAI is the anterior drawer test.[5] This test is performed by stabilizing the anterior tibia, while simultaneously cupping the calcaneus and moving it anteriorly. A positive test is noted if there is excessive movement of the foot on the ankle joint. This is defined as a mechanical deficit, while a functional deficit is due to a neuromuscular injury.[6]

One commonly used method for repairing a torn ATFL is the Broström-Gould (BG) procedure. The Broström-Gould technique is the gold standard for repairing a ruptured ATFL and is done by repairing the ATFL while also using the inferior extensor retinaculum to protect it. This procedure can be performed via open or arthroscopic manipulation. Open Broström-Gould procedures require full exposure of the ankle joint by incision and are expected to result in full healing for the ruptured ligaments. In an arthroscopic procedure, a small opening of 1 cm. is cut that the scope then is inserted into, while in the open procedure a larger incision of 4 cm. is used to visualize the ankle.[7] Each procedure contains benefits and risks for the overall healing of the ankle ligaments, and multiple studies have

documented these factors in attempts to establish one method as superior to the other. The purpose of this study is to compare and contrast these two procedures.

Methods

This study utilized a variety of studies on the topic and analyzed data on the different treatment methods, respectively. The NCBI database was used to help determine which papers were most relevant to our article. A search including the words "Arthroscopic Broström-Gould" and "Broström-Gould" were used. Non-clinical results were excluded, along with articles that did not include both procedures.

Different rating systems were utilized in the various studies to assess clinical status of the patients. Among these was the AOFAS score, the VAS score, and the Karlsson score.

The American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-hindfoot score is a rating system used for evaluation of the clinical status of the ankle-hindfoot. The score assesses patient pain, and physicians assess alignment. A patient can get a score between 0-100, with a healthy ankle receiving a 100. A healthy ankle is one that can bear weight without any discomfort. The score is useful in assessing the ankle, subtalar, talonavicular, and calcaneocuboid joint levels. The AOFAS score can then be helpful in planning for fractures, arthroplasty, arthrodesis, and instability procedures.[8]

The Visual Analog Score (VAS) is used to determine pain intensity experienced by patients. It consists of a line, approximately 10-15 cm in length, with the left side signifying no pain with a smiling face image and the right side signifying the worst pain ever with a frowning face image.[8]

The Karlsson score assesses ankle function. Patients answer a series of questions and get a score from 0-90. A fully functional ankle, one able to allow movement without pain or discomfort, would receive a score of 90.[9]

Results

In 2019, Song et al. published a clinical guideline on the surgical treatment of lateral ankle instability, with a specific section about arthroscopic versus open wound BG procedure.[4] Song et al. mentioned four distinct articles with a total of 207 cases that showed no significant difference in AOFAS, VAS, and Karlsson scores. A total number of 97 arthroscopic Broström-Gould cases and 110 open Broström-Gould cases were retrospectively analyzed. These four studies were done by Rigby and Cottom, Yeo et al., Li et al., and Matsui et al.

Rigby and Cottom included cases of lateral ankle instability between 2009 and 2013, with MRI findings of disrupted lateral ankle ligament structures and failure of conservative treatment in their study. Statistical analysis showed no difference for VAS pain score, AOFAS score, or Karlsson-Peterson Score. However, patients with arthroscopy were able to weight-bear within 12 days compared to open wound procedure which was 22 days, with no significant difference in postoperative complications.[10]

Return to Daily Activity

D'Hooghe et. al gave recommendations to future studies, including consistent patient metrics and an adequate description of return to daily activity, which has been assessed in studies done by Xu et al., Feng at al., and Lopes et al. In multiple stages of the post-operative process, arthroscopic BG cases have shown to limit the post-operative healing period and allow athletes to return to sports faster. Xu et al.'s study described that the arthroscopic technique used a smaller incision and less subcutaneous dissection, shortening the bleeding and post-operative adhesion time when compared to open surgery.[14] Feng at al. described that the average postoperative hospital stay of 37 arthroscopic BG patients was 3.77 days, significantly less than the open BG counterparts.

Lastly, Lopes et al. stated athletes that underwent an arthroscopic ATFL repair or reconstruction returned to sports in a shorter amount of time compared to those with the open surgical repair.[4] However, D'Hooghe et al. had found the opposite result, where patients that had undergone open BG procedures returned to sports in 2.85 months versus arthroscopic cases returning in 3.795 months.[13] Larger, well designed studies should be further pursued to investigate the difference in return to play time of high-performing/professional athletes.

Lower Risk of Iatrogenic Complications

Furthermore, Lopes et al. mentioned that the risk of cutaneous, infectious and nerve complications in patients that underwent an arthroscopic ATFL repair with or without extensor retinaculum

advancement was lower as compared to open surgery.[4] For example, Lopes et al. confirmed that injury to the superficial fibular nerve occurred in 4.3% of patients included in the study, which was half of what other studies reported.[4] This is largely due to the small hole required in arthroscopic repair, utilizing an area of the ankle with less important structures that can be damaged. During arthroscopy, blood vessels near the ATFL are still intact compared to open surgery, allowing for improved vascularization and healing of the ATFL.[12] Arthroscopic technology is also able to achieve minimal cutaneous scarring, while having the same results as an open wound surgery.

Simultaneous Repair of Intra-Articular Pathologies

When patients present to the clinic with mechanical ankle instability, the trauma from the inciting event not only causes the lateral ligament to be damaged but may cause an inversion trauma as well.[16] The use of an anterior ankle arthroscopy enables the surgeon to visualize all intra-articular structures for simultaneous repair with the ATFL. Intra-articular pathologies that can be repaired include osteochondral defects, soft tissue injury, bony impingements, and arthrosis.[15] An example of this simultaneous repair was found by Song et al., where the AOFAS, VAS, and Karlsson scores showed no difference when performing an arthroscopic ATFL repair alone versus a procedure where an osteochondral lesion and ATFL were repaired simultaneously.[6]

Discussion

The collection of referenced studies identified multiple points of interest in analyzing the two methods of surgery. Notably, there is data that suggests that arthroscopic BG is the superior method of treatment. Zeng et al. reports a clear benefit in the technique of the procedure, with the arthroscopic maneuver requiring a smaller incision vs. open. There is also an improvement in the length of time studied patients were able to bear weight after the arthroscopic procedure, as reported by Rigby and Cottom. The difference is significant and should be considered when deciding which surgery to perform. It should be cautioned though that D'Hooghe et al. found opposing evidence in that sports players with an open wound surgery were able to weight-bear 1 month before those with arthroscopic procedures. In both cases, it should also be noted that a small sample size was again an issue, and future studies should be conducted with larger sample size to have more conclusive results.

Another perspective comes from D'Hooghe et al., where it is mentioned that the limitations in comparing the methods is due to minimal data on arthroscopic treatment, specifically patients' return to daily activity. D'Hooghe et al. includes recommendations for future studies to properly correct this issue. Implementing consistent patient metrics and an adequate description of return to daily activity to future studies would provide viable data to further compare the methods. Song et al. also mentions that the time to return to daily activity is still inconclusive due to limitations and conflicting data from D'Hooghe et al. and Matsui et al. This issue stemmed from a lack of published data on patients who underwent arthroscopic vs. open instability management. Furthermore, it would benefit future studies to include sufficient variety in their patient pool. Limiting the study and analysis to athletes, as conducted in all the above studies, could result in an incomplete image as to the overall effectiveness of each procedure. Athletes are likely to recover at faster rates than nonathletes due to athletes being in better shape physically and typically having faster access to care.[17]

Additionally, Lopes et al. highlights the increased number of complications in patients with open wound treated patients, providing further support for treating patients arthroscopically. Minimally invasive surgery like arthroscopic procedures is highly sought, preserving the aesthetic appearance while also providing improved functionality for the patient. It is within reason to assume that patients would prefer arthroscopic procedures due to the lessened risk of complications and aesthetic preservation of their ankle.

Lastly, a major benefit to arthroscopic surgery is found in Liszka et al. The ability for surgeons to perform simultaneous repair to ATFL tears and other defects, such as osteochondral defects, soft tissue injuries, and fractures, has many advantages. Surgeons can restore multiple damaged areas for the patient, which improves their overall health and satisfaction. It also decreases the probability of recurring injury and prevention of additional surgeries to the patient. Arthroscopic BG allows surgeons to discern a wider and more complete picture of the issues visible in their patient's ankle and

foot. As Lopes et al. and Liszka et al. state, there are benefits to arthroscopic procedures vs. open which lend them to being the preferred method of treatment.

After review of the studies, it can be determined that there are definitive differences between arthroscopic Broström-Gould vs. open wound Broström-Gould procedures that favor the arthroscopic technique. However, all articles mentioned showed no significant difference in postoperative surgical scores,[6,7,10,11] indicating either procedure may be used to treat chronic lateral ankle stability. The major benefits to arthroscopic techniques are evident in the shortened patient recovery time, the diminished risk of complications, and the ability to treat other foot and ankle abnormalities concurrently with ATFL repair. It is important to mention that some studies comparing the two procedures suffered from small sample sizes, and more studies containing larger samples would lead to a more conclusive result. Furthermore, longer term studies highlighting postoperative complications in arthroscopic BG cases would be helpful in improving the standard of care for ankle sprains, though arthroscopic techniques have only recently been discovered.

Conclusion

The aforementioned studies should influence providers to utilize the procedure that best suits the patient. The arthroscopic procedure provides equal efficacy to ATFL repair as the open Broström-Gould procedure, with the added benefits of earlier time to weight bear, lower iatrogenic risk, and the ability to simultaneously repair associated pathologies with the ankle sprain. Based on the studies published to date, there are more benefits to performing arthroscopic Broström-Gould versus an open Broström-Gould surgery, but larger, well-designed studies could improve the postoperative standard of care for patients.

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Navicular Stress Fractures: A Progressive Treatment Analysis

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ABSTRACT

Objective: To explore the treatment of navicular stress fractures and to use Saxena et al's navicular stress fracture classification system as the new standard of care.

Methods: A PubMed search was conducted on research related to surgical and conservative management of navicular stress fractures throughout a 40-year span. Return to activity (RTA) times were used to quantify the viability of each treatment modality.

Results: Currently, both conversative and surgical treatments have a success rate of over 90%. Both of these methods also have a RTA within 21 weeks, but surgical methods seem to allow athletes to return to their sport faster. These results were not always consistent, and it may be due to the lack of surgical vs nonsurgical protocol when treating NSF.

Conclusion: Open reduction internal fixation surgeries were the preferred method of fixing navicular stress fractures due to lower number of complications. However, research is inconclusive on whether conversative and surgical care differ in return to activity times. A defining protocol such as a classification system by Saxena et al should be implemented to standardize care.

Introduction

Although not as prevalent in the general population, the navicular stress fracture (NSF) is increasingly becoming one of the most diagnosed stress fractures in athletes.[1] Many of the athletes diagnosed with navicular stress fractures are sprinters or basketball players.[1] This type of stress fracture is more likely to occur with movement involving explosive or side to side movements.[2] Throughout time, stress fractures have been misdiagnosed because they are difficult to see on normal radiographs.[3] As new imaging technologies such as CT scans become available, physicians have been able to diagnose stress fractures much easier.[3] This has allowed physicians to better appreciate small fractures that would have otherwise been missed. This has led to better treatment methodologies that can be tailored to each patient.

To diagnose a navicular stress fracture (NSF) clinically, the first signs to look out for are dorsal midfoot and anterior ankle pain.[4] This sharp pain radiates to the arch and is exacerbated with explosive movements. Tenderness to palpation on the most dorsal aspect of the talonavicular joint, also referred to as the "N" spot (figure 1), is highly indicative of a navicular stress fracture.[5] When the NSF goes unnoticed, an altered gait may be observed due to the body compensating to offload the stress placed on the navicular.[6] In some instances, pain can be noticed while the patient is on the tips of their toes or when the patient is asked to hop.[3]

Imaging should be used to properly diagnose a navicular stress fracture. Plain radiographs are not intended to diagnose NSFs because it takes on average about 12 days for any bony resorption to show up on X-rays.[3] Radiographs may be used to rule out any other possible diagnosis. One of the most used modalities would be a bone scan.[4] A triple-phase bone scan may be used for possible suspicion of a NSF, but its lack of anatomical resolution to view the size and location would be extremely limiting for its use clinically.[3] MRI could be extremely useful if used early enough. MRI has extremely highly sensitivity and can show any early bone changes, joint effusions, or bone edema.[4] MRIs may show some stress reactions which occur right before stress fractures. The imaging modality of choice would be the CT scan.[3,4] It is highly sensitive; it can show the most precise location and size of the NSF. The CT scan is also used to classify an NSF.[5]

Figure 1*: The X illustrates the anatomical location of the "N" spot on the skeletal view of the foot. Tenderness to palpation is highly indicative of a navicular stress fracture.*

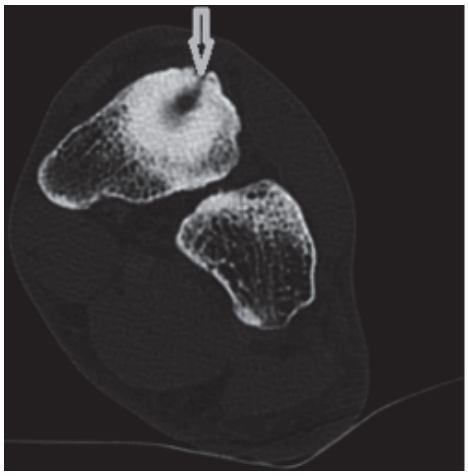

Figure 2: *Example of a Type 1 navicular stress fracture demonstrating a dorsal cortical break noted by the arrow.*[5]

To treat a navicular stress fracture adequately and consistently, Saxena et al created a classification system (table 1) that can be used to guide treatment modalities. Saxena et al stated that type 0.5 and 1 can be treated conservatively but types 2 and 3 should be treated surgically.[5] However, the classification guides, treatment plans, and optimal treatments have not been fully tested. A few different conservative and surgical treatments are compared to see what treatment modality has the fastest return to play.

Table 1
Navicular stress fracture classification

Type	Description
0.5	Stress reaction; signal change on MRI noted, but stress fracture not imaged on CT
1	Dorsal cortical fracture on coronal image
2	Fracture extends into navicular body on coronal image
3	Complete propagation of fracture to second cortex (medial, lateral or plantar) on coronal image

Table 1: *Classification system of the navicular stress fracture from Saxena et al (2017).*

Exploring the different types of treatment, both conservative and surgical, will regulate the standard of care for navicular stress fractures. This will also allow for a better prediction of the timeline of healing of the different types of navicular stress fractures and the mode of treatment. Athletes will have a better understanding of how long they must wait before they can return to play.

Methods

A PubMed search was conducted with the keywords "surgical treatments for navicular stress fractures" and "conservative treatments for navicular stress fractures." Studies that emphasized specific conservative and surgical treatments for athletes were chosen. Publication language was limited to English. There were no restrictions on publication date. Articles that focused primarily on military personnel or the general public were excluded from the study.

Results

Saxena et al, performed two early studies in which earlier return to activity was achieved using surgical treatment. In the first study the average patient age was 27.2 years (range, 17- 48 years). There were II elite athletes (competitive at the high school, college, or postcollegiate/professional level) and 11 recreational athletes.[7] Fourteen were involved in track or running-related sports.[7] In the earlier study, it was statistically different in which the athletes were able to return to activity in 12.4 weeks as opposed to 17.2 weeks when treated conservatively.[7] A later study was performed and found that although the surgical patients returned to activity sooner (14.8 weeks), it was not by much as conservative patients were able to return at around 16 weeks.[2] In the later study there were nineteen patients fulfilled the inclusion criterion. The 11 women and eight men had an average age of 24.7 ± 9.2 years.[2] Overall, when comparing 4 studies, the average return to activity when treated surgically was 16.4 weeks and when treated conservatively was 21.7 weeks. Both methods of treatment resulted in over 90% success rate and only varied by a few weeks.[2,6,8,9]

Torg et al mentioned 21 stress fractures of the navicular were examined and treated. The average length of follow up and return to activity was around 21 months.[10] There were ten patients who had partial and complete fractures of the navicular. These patients were treated by immobilization with a non-weight bearing cast for 6-8 weeks, and all of them were able to RTA in about 4 months without any complications.[10] There were two patients with a partial NSF were treated just by limited activity, and they continued to tolerate weight-bearing. Both healed, one at 4 months and the other at 7 months. There were four patients who were professional basketball players that were treated with a non-weight bearing cast (NWBC). These four patients experienced delayed healing and one of the patients experienced a refracture about 5 months after clinical healing.[10] Torg et al stated that 3 patients received surgery through open reduction and internal fixation.[10] After surgery they were placed in a NWBC for 6-8 weeks. All 3 of

the patients were able to RTA in 4 months. Towards the end of the study, those patients who had non-unions or delayed healing were treated with bone grafts with internal fixation, and they all had complete healing and were able to RTA in 5-7 months.[10]

A study by Khan et al compared 82 athletes with 86 clinical navicular stress fractures who were treated by either surgery or non-weight bearing cast.[11] All of these athletes were diagnosed using CT scan and were followed for about 33 months. Twenty-two patients were in a non-weight bearing cast for 6-8 weeks, 34 patients were told to limit activity but could continue ambulation as tolerated.[11] Fifteen patients underwent surgery. Nineteen of the 22 patients in a non-weight bearing cast were able to return to activity in 20 months, only 9 out of the 34 patients in the limited activity group returned to activity within 22 months, and 11 of the 15 patients in the surgery group returned to activity.[11]

Saxena et al did a relatively new study comparing 62 navicular stress fractures with 3 being type 0.5, 14 being type 1, 28 as type 2 and 17 of them were type 3.[5] Forty-five of them were in types 2 and 3 which would indicate of surgery. Additionally, two patients from the type 1 category were also treated surgically as Saxena et al concluded it would provide for less complications and a faster recovery time.[5] Saxena et al stated that a CT scan was performed initially in 38 patients and the findings led to a correct diagnosis of NSF 100% of the time. Comparatively, MRI was used as the initial study in 49 patients and only 35 of the patients were correctly diagnosed with NSF (71.4% sensitivity).[5]

Discussion

Navicular stress fractures can be treated effectively both surgically and conservatively with good clinical outcomes if one has a high index of suspicion. While the direct surgical approach is unclear with many surgeons using internal fixation with screws, patients were able to return to their sport in about 16 weeks.[7] This is about five weeks faster than if patients were treated conservatively. Surgical patients also did not report any complications after their operation. With the patients that were treated conservatively, there were many complications including malunions, delayed unions and refracturing the navicular. According to Mann et al, most prominent conservative treatment included using a non-weight bearing cast for 6-8 weeks.[12] This was the preferred method of fixation conservatively as it allowed for the least number of complications. Other conservative treatment modalities including electrostimulation led to more complications speculating on that fact that the navicular was not properly immobilized.[12] Further studies should delve deeper into comparing electrostimulation with a non-weight bearing cast versus just a non-weight bearing cast for optimal results.

Overall, there is conflicting evidence between studies. Where some studies provide results that are significantly different between surgical vs. conservative treatments, other studies show that there is not a difference between return to activity times. A unifying classification system that addresses treatment options should be the focus for treatment of NSF. The future of treating NSF resides in the use of Saxena's classification system. Properly diagnosing and treating NSF according to the classification system seems to yield faster and better outcomes for the patient. Similarly, using the appropriate imaging modality will yield to a faster diagnosis and faster treatment of NSF. Prompt diagnosis of navicular stress fractures should be the primary goal of the treating surgeon. When the navicular stress fracture is identified promptly and classified adequately, it should lead to better treatment outcomes for the patient.

This becomes increasingly evident in the Khan et al study. Due to the study being done in 1992, it fails to provide a basis of when and why surgery was indicated. The results indicate that NWBC immobilization is the treatment of choice for navicular stress fractures. This treatment compares favorably with surgical treatment for patients who present after failed weightbearing treatments.[11] Due to this, surgery may have been done in cases where it should not have been done by today's standards. If the same study was done in 2020, Saxena's classification system could have been used to further divide the 82 patients by the types of NSF they sustained. As more studies are being done to address a better standard of care for NSF, it should be done under Saxena's classification system.

As more cases are reported, there will be more prominent research done on the best treatment modalities for navicular stress fractures. Based on the studies, open reduction internal fixation (ORIF) was the preferred method of treatment as it has the fewest complications and an overall faster return to activity time. ORIF should only be used for navicular stress fractures that are considered types 2 and 3 through the Saxena classification system. Overall treatment of types 0.5 and 1 should remain nonsurgical.[7] Further study should address the comparative results between surgical treatment of type 1 versus conservative treatment of type 1 injuries.

Conclusion

A unifying basis for NSF should be the starting point for the care and treatment of navicular stress fractures. Throughout 40 years of studies, one could

not come to a consensus of the proper way to treat NSF. Both surgical and conversative methods are viable but an indication of either would lead to the most optimal treatment plan for the patient. As these fractures occur in athletes who are usually younger, the most optimal plans should be considered to prevent complications later in their life. The classification system proposed by Saxena et al is the most useful system a clinician can use because it addresses not only the severity of the fracture, but also, it provides information to the clinician as to which intervention provides the best outcome.

As the classification systems by Saxena et al gains more traction, it will allow for better treatment plans optimized for each individual patient. As stated, using the correct imaging modality such as the CT scan will also help diagnose and address the NSF in a timely manner. Further studies need to be conducted on the use of the classification system before an adequate conclusion can be made.

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Achilles Tendon Injury Epidemiology, Prognosis and Risk Factors in Elite Basketball Players: A Literature Review

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ABSTRACT

Objective: To summarize and incorporate the existing literature on the performance impacts, epidemiology, and risk factors of Achilles injuries.

Methods: A PubMed search was conducted with the keywords "Achilles Injury Basketball." The literature was searched for studies involving Achilles injuries that related to basketball players.

Results: Basketball is the most common activity associated with Achilles rupture when compared to soccer, football, volleyball and other sports. However, there is no significant risk related to BMI of athletes. There is a significant difference in level of baseline activity and risk of Achilles tendon rupture. Risk of injury does seem to increase with age, along with a more difficult path to returning to peak performance. Returning to the level of performance following an Achilles rupture is significantly difficult to achieve.

Conclusion: Following an Achilles tendon injury, there is an observed decrease in the number of games played and player performance, compared to prior to injury. Further study is needed to determine the impact of variables not accounted for in this review and how to better surgically repair these injuries so that patients have a better chance to return to an equivalent level of play prior to injury.

Introduction

For professional athletes in the National Basketball Association (NBA), game related injuries occur at a high rate and ankle injuries are incredibly common. While lateral ankle sprains have the highest injury rate, Achilles tendon ruptures can be particularly devastating for these athletes.[1] In 2019, nineteen players in the NBA suffered Achilles injuries, which led to 351 games missed. In comparison, over twice as many NBA players suffered back injuries in the same year and missed 232 games.[2]

Several studies have examined the negative effects of Achilles injuries on performance in athletes across multiple sports.[3,4] It has been demonstrated that it is difficult for athletes to return to their prior level of performance after an Achilles rupture. Other studies have explored possible risk factors and epidemiology of Achilles ruptures.[5] Also, different mechanisms of injuries and their frequencies have been investigated.[6]

The purpose of this study is to review the existing literature on the performance impacts, epidemiology, and risk factors of Achilles injuries.

Methods

A PubMed search was conducted with the keywords "Achilles Injury Basketball." The literature was searched for studies involving Achilles injuries that related to basketball players. A snowball approach was performed on the literature yielded from the PubMed search. Publication language was limited to English. There were no restrictions on publication date.

Results

Epidemiology and Risk Factors

Noback et al. performed a 2 -to-1 matched cohort study to analyze the risk factors associated with Achilles tendon rupture. A retrospective chart review of the normal population was performed on 93 Achilles tendon rupture patients who were subsequently age and sex matched to two individuals who presented with ankle sprains. To gain additional statistical relevance outside of what could be gleaned from a simple case series, a control group was used. To serve as the control group, ankle sprains were chosen due to the frequency of these complaints, making them readily available to be age and sex matched with Achilles tendon rupture patients. This study found that basketball was the most common activity associated with Achilles tendon rupture (42%), followed subsequently with soccer (8%), American football (5%), and racquet sports (4%). BMI between the control group (ankle sprains) and the Achilles tendon rupture group (27.77 and 26.66, respectively) was found to be statistically equivalent ($p=0.047$ and $p<0.001$) via two one-sided t-test. This study however did find a significant difference in level of baseline activity and risk of Achilles tendon rupture ($p=0.013$).

In 2009, Flood et al. conducted a retrospective epidemiological study on basketball and netball injuries via data collected from the National Hospital Morbidity Database using 'activity when injured' codes from July 2000 to June 2004. This study included 5,090 basketball related injuries. Achilles tendon rupture or injury (combined in the ICD - 10 - AM code) accounted for 381 (7.5%) of this larger

cohort. Of these Achilles tendon injuries the average age was at 35 years.[7]

A smaller set of epidemiological data for Achilles tendon ruptures was collected by Lemme et al. by using publicly available data on NBA players suffering Achilles tendon ruptures between 1970 and 2018. Variables that were collected on players with Achilles ruptures included age, position, body mass index (BMI), draft position, total games started, laterality of injury, and minutes played before injury. In total, this study identified forty-four Achilles tendon ruptures with the average age being 28.3 years, BMI averaging 25.6, and the Achilles rupture occurring at an average of 6.8 seasons into a players career. Lemme et al. also found there to be a significant difference between the positions of the players who were injured, with fourteen players being guards and 30 players identifying as forwards. Laterality was split evenly between injuries reported with 21 being left sided, 21 being right sided, and 2 were unable to be identified. When identifying the period of the season these injuries occurred in, this study split the season between off-season, pre-season, early, late, and postseason. Injury rate was highest in the early season with twelve of the forty-four injuries (27.3%) occurring then. Increases were also seen in pre-season and late season, which both accounted for 8 (18.2%) of the injuries apiece.

Prognosis and impact on performance

Amin et al. conducted a study charting performance outcomes after repair of a complete Achilles tendon rupture in NBA players. Data over a 23 year period were collected on 18 players with an Achilles tendon repair and compared against a control group of 11 players, which was calculated by power analysis to be the required sample size. To compare performance, player efficiency rating (PER) was used, which is a rating of a player's per minute productivity that is commonly used in NBA statistical analysis. The study found that 7 of the 18 players with a repaired Achilles never returned to play in the NBA. For those that did return to NBA competition, PER and minutes played after injury both declined. The differences were similar in both the first and second season after injury. When comparing these declines against the control group, they were found to be statistically significant. A final multiple logistic regression model was used that included PER 2 years before the index season and whether the athlete had undergone surgery or not. Both variables were statistically significant for if a player would return to NBA competition. The chances of returning to play after injury were increased by 18% for every 1-unit increase in the player's PER prior to injury. Therefore, those who had greater performance prior to injury were at less risk to lose their career.[4]

Trofa et al. charted the performance impacts of athletes returning to play after Achilles tendon rupture across several professional sports. When comparing between individual sports, it was found that NBA players were more significantly impacted. In the NBA, National Football League (NFL) and Major League Baseball (MLB), the games played per season, after injury, were significantly decreased. However, when comparing the leagues separately, it was found that only NBA players were significantly impacted in the number of games played 1 and 2 years following surgery ($P < 0.001$). NFL players played in fewer games for only the first season returning from injury, and no difference was noted in MLB players.[8]

Discussion

This study summarizes literature to determine the impact of Achilles tendon injuries on elite basketball athletes. Ankle injuries, in general, are extremely common in basketball, and Achilles tendon ruptures remain one of the most devastating injuries to these athletes.[1]

Multiple factors were identified regarding the epidemiology of Achilles tendon rupture injuries, including age, BMI, position played, and time in the season when the injury occurred. Flood and Harrison and Lemme et al. found that most Achilles tendon ruptures in elite basketball athletes occurred between the ages of 25 to 35 years old and players most often had a BMI of 25 to 27.[5,6] Injuries were most likely to occur in the early season and occurred most often to players who self-identified as forwards rather than guards.[6] Although these factors are important in gaining a full understanding of the epidemiology of Achilles tendon ruptures in elite basketball athletes, they did not influence a player's ability to return to the game following an injury. In fact, there was no difference in age, BMI, position, or time during the season the injury occurred between players that returned from injury and those that did not.[6,8]

However, on an individual basis, there were differences in the amount of games played and productivity, pre and post injury status, which was measured by the player's PER. In the players that returned from injury, the PER was significantly decreased compared to prior to injury.[4] Similar findings were noted when comparing NBA players to athletes in the NFL and MLB. NBA players who suffered an Achilles tendon rupture not only had a greater decrease in performance in the seasons following injury but also played in fewer games than they had prior.[8] This observation reveals that NBA players are generally more affected by Achilles tendon ruptures than are other athletes in different professional sports. Furthermore, it was determined that a surgical repair of this injury led to a significant

decrease in the odds of returning to professional play at all.[4]

This summary of literature has some limitations that affect the overall determinations. Most importantly, of the articles reviewed, few of them had information regarding the health of these players prior to injury. For example, the players that suffered an Achilles tendon rupture may have had a preexisting injury that made a rupture more likely to occur, or made the recovery harder to return from. It is also unknown whether these players were taking any medications that could increase the risk of tendinous injury such as steroids or fluoroquinolones.[6] When considering an NBA player's ability to return to professional play at a high level, it is also difficult to control for other factors such as the players emotional mindset, financial state, and family guidance, following the injury.

Fortunately, there were many strengths to these studies, including meticulous control of variables and exceptional measurements to determine the prognosis following injury.

Conclusion

Achilles tendon ruptures continue to be one of the most devastating injuries to professional athletes, and in particular, elite basketball athletes. Regardless of epidemiological variables, in elite basketball athletes, the injury negatively impacts games played and player performance, when compared to the professional career of the player prior to the injury. Further study is needed to determine the impact of variables not accounted for in the reviewed articles and how to better surgically repair these injuries to give these patients a better chance at return to a level of play equivalent to that of prior to injury.

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Postoperative Complications of Flatfoot Reconstruction

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ABSTRACT

Objective: The objective of this article is to present a review of current literature on the various complications of flatfoot reconstruction in both adults and children.

Methods: A literature search was done on JFAS, PubMed, and Google Scholar to retrieve several articles discussing post-surgical complications of flatfoot reconstruction. The JFAS, PubMed, and Google Scholar databases were utilized with the following search keywords: "flatfoot", "postoperative", "reconstruction", and "complications", and any articles published prior to the year 2010 were excluded.

Results: In the subtalararthroereisis study, the complications were mild discomfort, pain, and a superficial wound infection. In the lateral column calcaneal lengthening study, the complications were pain and non-union. The study involving the double calcaneal osteotomy mentioned pain, a superficial wound infection, and abnormal gait. The study regarding the effects of gastrocnemius recession and tendo-achilles lengthening mentioned complications that included neuritis of the sural nerve, a decrease in plantar flexor power, stiffness, and Achilles tendon rupture. The calcaneo-cuboid-cuneiform osteotomy and modified Kidner procedure study had a case of overcorrection. Lastly, the studies involving the medial displacement calcaneal osteotomy with posterior tibial tendon reconstruction and the combined talocalcaneal coalition resection, graft interposition, and subtalararthroereisis reported no complications.

Conclusion: There are a variety of surgical techniques involved with correcting flatfoot deformity, and with each technique, there are also different levels of possible complications. Future research should be conducted with larger sample sizes and a wider array of surgical procedures in order to find the best procedure with minimal surgical complications.

Introduction

Pes planus, or flatfoot, is a common foot deformity that can occur in both children and adults. While children tend to be born with flatfeet, adults acquire flatfoot deformity.[1] In fact, most cases of flatfoot deformity in adults are associated with posterior tibial tendon dysfunction due to the tendon being the primary dynamic stabilizer of the medial longitudinal arch.[2] The treatment of pes planus usually involves surgery since conservative treatment does not seem to help, with the exception of some mild cases.[3] Flatfoot deformity can correct on its own through normal continued growth prior to puberty, but for children, whose flatfeet do not resolve on their own, surgical treatment tends to be necessary if conservative treatment through physical therapy and orthoses do not alleviate symptoms.[1]

In the field of podiatric medicine, there have been many different methods of treating flatfoot deformity, most of which involve surgical correction. However, just as with any surgery, there should be a proper way to care for the foot post-surgery as to avoid complications as much as possible. For example, several ways to care for feet after flatfoot reconstruction include exercise or physical therapy, walking boots, supportive insoles, casts, and not bearing weight on the feet for a certain amount of time after surgery. There are many different complications that can arise postoperatively. These complications can include discomfort, pain, stiffness, decreased range of motion, inflammation, non-union, wound infections, abnormal gait, neuritis, tendon rupture, implant breakage, muscle spasms, joint effusions, stress fractures, misalignment, undercorrection, and overcorrection.

As with many foot-related deformities, there are a wide variety of surgical techniques out there for flatfoot reconstruction. This article focuses on several of these techniques, including subtalararthroereisis, lateral column calcaneal lengthening, double calcaneal osteotomy, medial displacement calcaneal osteotomy with posterior tibial tendon reconstruction, the effects of gastrocnemius recession and tendo-achilles lengthening, a combination of techniques involving talocalcaneal coalition resection, graft interposition, and subtalararthroereisis, and lastly, a calcaneo-cuboid-cuneiform osteotomy (triple C) with a modified Kidner procedure. This article aims to identify these different surgical techniques involved in correcting flatfoot deformity as well as the complications that may follow a particular treatment method.

Methods

A search of articles relating to postoperative complications of flatfoot reconstruction was conducted using JFAS, PubMed, and Google Scholar. Fifty articles were reviewed, and eleven articles were found to be appropriate for this study. The JFAS, PubMed, and Google Scholar databases were utilized with the following search keywords: "flatfoot", "postoperative", "reconstruction", and

"complications". Any articles published prior to the year 2010 were excluded. Articles were chosen if they presented any sort of complications after surgical flatfoot reconstruction.

Results

Subtalararthroereisis with interference screw

One way to correct pediatric flatfoot deformity is through an interference screw that can be used in a subtalararthroereisis implant procedure. Through this surgical procedure and the placement of this screw, the medial longitudinal arch is restored. This study by Hong et al involved 21 children, between the ages of 8 and 14 years old, and 39 of their affected feet. In 17 feet, the subtalararthroereisis was the only surgical operation performed, while additional surgical removals or transpositions were performed in the other 22 feet. Postoperatively, the most common complications were mild discomfort and pain of the sinus tarsus after long periods of weightbearing and walking. However, this problem resolved on its own. Another complication was superficial wound infection that also resolved on its own. In terms of fixation itself, there was no breakage of the interference screw or loosening of the interference screw noted.[1]

Lateral column calcaneal lengthening

An article by Yontar et al describes a study consisting of 18 adolescent and young adult patients with 21 affected feet. All patients underwent lateral column calcaneal lengthening under general anesthesia. Patients also underwent other surgical operations, if necessary, due to any remaining deformity or accessory bones. Complications that occurred were pain at the osteotomy site related to an implant, which resolved after removal of said implant, and a non-union of the allograft used in the lateral column calcaneal lengthening procedure. However, because the patient with the non-union was asymptomatic, there were no surgical interventions performed, and the patient was still happy with the results.[4]

Double calcaneal osteotomy

A retrospective study that involved 13 adolescent and young adult patients from 10 to 18 years old was conducted, and the operative technique involved a double calcaneal osteotomy. This technique consisted of several other surgical techniques such as the percutaneous Hoke method, the posterior calcaneal osteotomy, and the Evans osteotomy. This technique also involved fixations with small plates and titanium alloy compressive hollow screws. Plates and screws were removed one year post-surgery. In terms of complications, two patients felt pain on the lateral side of the foot, but this was resolved once plates and screws were removed. Another patient had a superficial infection at the incision site, which resolved after taking antibiotics. However, this patient was left with abnormal gait that improved after systematic rehabilitation.[5]

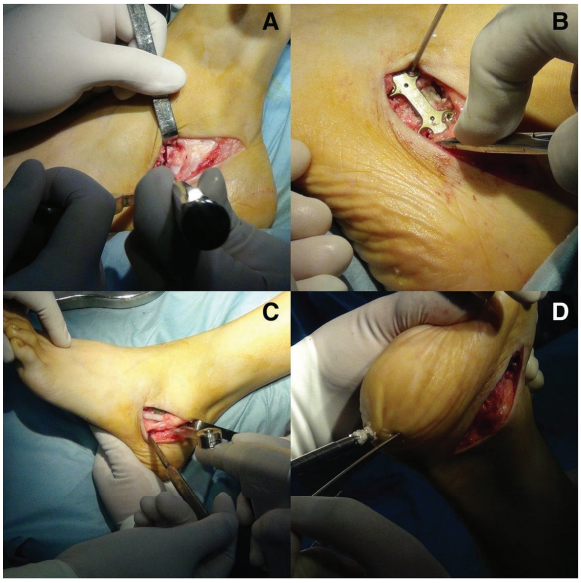

Figure 1: *Intraoperative photos. The Evans osteotomy (a). The fixation of Evans osteotomy (b). The posterior calcaneal osteotomy (c). The fixation of calcaneal osteotomy (d).*[5]

Medial displacement calcaneal osteotomy with posterior tibial tendon reconstruction

The most common surgical techniques used to correct flatfoot deformity has been medial displacement calcaneal osteotomy combined with posterior tibial tendon reconstruction. A study by Cao et al involved 16 patients ranging from 18 to 64 years old with 21 feet who underwent this common combination of flatfoot reconstruction. Physical therapy was utilized if full range of motion was not seen after 3 months post-surgery. Otherwise, according to the study, no complications or infections were present posteroperatively.[6]

Gastrocnemius recession and tendo-achilles lengthening

When performing flatfoot reconstruction, it is important to improve the range of motion of the ankle as well as plantarflexion strength post-surgery. In order to obtain this corrective effect, gastrocnemius recession and tendo-achilles lengthening can be done. A systematic review was conducted that included 10 different studies consisting of 79 gastrocnemius recessions and 111 tendo-achilles lengthenings. All of these studies reported complications of flatfoot reconstruction, including those related to either

gastrocnemius recession or tendo-achilles lengthening. Complications included neuritis of the sural nerve, a decrease in plantar flexor power, stiffness, and Achilles tendon rupture. In total, there were 7 reported complications out of 79 (9% of patients) gastrocnemius recessions and 11 reported complications out of 111 (10% of patients) tendo-achilles lengthenings with adult acquired flatfoot deformity surgeries.[7]

Combined talocalcaneal coalition resection, graft interposition, and subtalararthroereisis

A study by Di Gennaro et al involved a combination surgical technique that included a talocalcaneal coalition resection, a graft interposition, and a subtalararthroereisis. This technique was used to correct painful rigid flatfoot in children. This study compared a nonoperative group with an operative group. The nonoperative group consisted of 34 children with 47 affected feet, whereas the operative group consisted of 21 children with 34 affected feet. Neither groups reported any complications. However, 6 patients were not satisfied with the nonoperative treatment, which consisted of manipulation in supination under anesthesia, a short-leg cast in inversion applied for 5 weeks, and custom shoe inserts to reduce overpronation and support the plantar arch. Although there were no complications noted in this study, it is important to note that complications of the subtalararthroereisis can involve loosening or breakage of the implant, pain and discomfort at the surgical incision, peroneal spasms, joint effusions, stress fractures, and infections.[8]

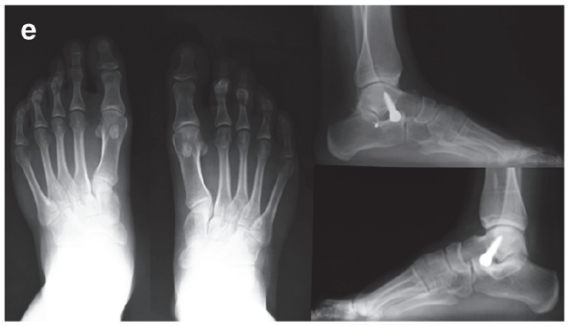

Figure 2: *Radiographic aspect showing the screw arthroeresis with correction of the flatfoot.*[8]

Calcaneo-cuboid-cuneiform osteotomy and the modified Kidner procedure

The calcaneo-cuboid-cuneiform osteotomy (triple C), a joint-sparing procedure, followed by the modified Kidner procedure were performed on 13 children and adolescents with 21 affected feet in a study by Kim et al. In addition to the severe flatfoot deformity present, these patients also had a symptomatic accessory navicular associated with the deformity. Postoperatively, all patients in this study rated their flatfoot reconstruction surgery outcomes as either good or excellent, and none of the patients had developed any recurrence of flatfoot deformity either clinically or radiographically. Although there were no wound complications or infections, one patient had varus alignment of the hindfoot, which is believed to be caused by overcorrection of the calcaneal osteotomy.[9]

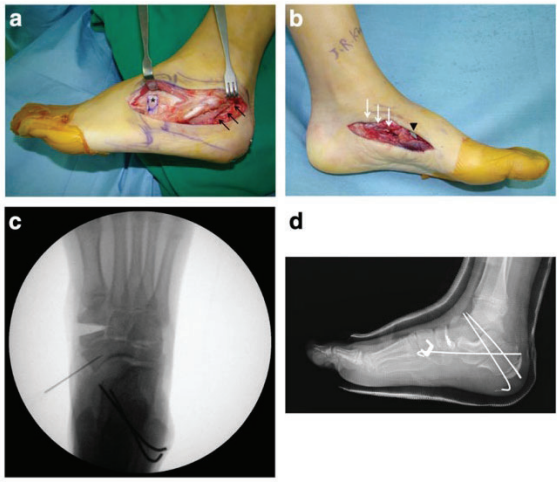

Figure 3: *Triple C combined with the modified Kidner procedure. (a) Lateral view of the foot showing calcaneal osteotomy (black arrows) and insertion of the opening wedge graft from the cuneiform into the cuboid (asterisk). (b) Medial view of the foot showing plantar flexion and pronation of the foot achieved with closing wedge osteotomy of the medial cuneiform (arrowhead), providing reconstruction of the longitudinal arch, and the TPT was advanced and attached to the navicular with the two no. 2 braided nonabsorbable sutures attached to the anchor (white arrows). (c) Positioning of the anchor was confirmed under intraoperative fluoroscopy. (d) Immediate postoperative radiography after combined triple C and modified Kidner procedure.*[9]

Discussion

In many of the studies, there were varying degrees of complications. All surgical techniques required at least 4-6 weeks of post-surgical care and each study, except for the studies by Cao et al and Di Gennaro et al, mentioned some sort of complication associated with a particular surgical technique. A lot of the complications noted were primarily discomfort and pain, but other complications included stiffness, decreased range of motion, inflammation, non-union, wound infections, abnormal gait, neuritis, tendon rupture, misalignment, and overcorrection. The two studies by Cao et al and by Di Gennaro et al, stated that there were no complications noted in relation to

the respective surgical techniques used in each of those studies. The patients' non-weightbearing activity post-surgery is likely the reason why these two studies reported no complications.

Another complication of flatfoot reconstruction not mentioned in the studies above is the undercorrected flatfoot. The undercorrected flatfoot is caused by either not being able to fully realize the extent of the flatfoot deformity, not fixing the underlying cause of the flatfoot deformity, or not addressing all necessary components that may have led to the deformity in the first place. Three different deformities can be a result of the undercorrection of pes planus, including, hindfoot valgus, midfoot abduction, and forefoot varus.[2] On the opposite end, the overcorrected flatfoot, though less common, has similar signs as the cavovarus foot, or pes cavus. Overcorrection is caused by a variety of problems, usually depending on the surgical technique performed during the first attempt at correcting pes planus. For example, overlengthening the lateral column or excessive medial or inferior translation during the medial displacement calcaneal osteotomy can result in the overcorrected flatfoot.[10] Overcorrection of the calcaneal osteotomy was seen in the study by Kim et al, where the triple C and modified Kidner procedure were performed causing varus alignment of the hindfoot.[9] For both, undercorrection and overcorrection, conservative treatments can be used at first to alleviate pain or other symptoms, but if conservative treatment fails, revision surgery is performed.[10]

Another important topic to note when discussing pes planus, is the Myerson Stage IV flatfoot. Although Stage IV flatfoot is rare, composing about 3% of all flatfoot cases, it is still a topic of debate in terms of treatment. At this stage, conservative treatment is rather nonexistent, and surgery is usually required, unless the patient is elderly or is considered a low-demand individual. Surgical operations range anywhere from joint-preserving surgery to tibiotalocalcaneal arthrodesis or pantalar arthrodesis to total ankle replacement.[11]

The primary limitation of this literature review was that studies tend to involve small sample sizes of less than 25 patients, with the exception of the study by Chang et al. Although a majority of the studies reviewed indicated some sort of complication, two studies indicated no complications at all. Pain and discomfort were seen in many studies, and most other complications occurred in only one or two patients per study. Studies that allowed for weightbearing soon after surgery indicated more complications compared to studies that required patients to avoid weightbearing activity. Physical therapy and exercise may also be major factors in minimizing postoperative complications after flatfoot reconstruction.

Conclusion

Pes planus treatments continue to expand and revolve around surgical intervention due to its greater success in correcting the deformity compared to conservative options. The results showed several surgical techniques along with the complications that could arise from the respective surgical operation. The studies that involved the medial displacement calcaneal osteotomy with posterior tibial tendon reconstruction and the combined talocalcaneal coalition resection, graft interposition, and subtalararthroereisis had the best outcomes as there were no complications associated with those procedures. Future research should be conducted with larger sample sizes and a wider array of surgical procedures in order to find the best procedure involving minimal surgical complications.

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Emotional Intelligence and its Effect on Podiatric Medical Students

Justin Luu, B.S., and Suaesi Tulifau, B.S.

ABSTRACT

Objective: Emotional intelligence (EI) is defined as the ability to monitor one's own and others' feelings and emotions, to discriminate among them, and to use this information to guide one's thinking and actions. In health care, a higher EI is associated with residents who are able to manage emotions of others and care for themselves and patients. The goal of this study is to determine whether or not EI scores will rebound in podiatric medical students by the time of graduation due to professional rewards earned from their work.

Methods: A longitudinal study was conducted at 3 separate times for podiatric medical students at Western University of Health Sciences from 2015-2019 (before matriculation, after completing 2nd year of Basic Sciences, and at the end of their 4th year after completing boards and placing in residencies). Data was collected at each time using the Emotional Quotient Inventory (EQ-i 2.0) test, a self-survey used to quantify participant's emotional intelligence traits. The author compared stats from the 3 different times and analyzed if there were any significant changes and determined possible reasons for these changes.

Results: Total EI scores decreased from the 1st administration of the EQ-i test compared to the 2nd administration. A rebound in EI scores were seen from the 2nd administration of the test to the 3rd administration similarly to the initial scores. There were notable differences in most EI traits throughout the study that may be attributed to a multitude of factors despite similar total EI scores.

Conclusion: Overall, most EI scores rebounded in the 3rd administration of the survey following a decline. Ideally, the scores would rebound back to the same level, if not higher, than upon matriculation. After the 3rd administration of the survey most of the EI scores rebounded except for happiness and assertiveness. There is speculation that this may be due to the fact that these students would begin residency relatively soon, enabling them to showcase their happiness and assertiveness traits with patients of their own. It would be beneficial to conduct a follow up study in order to examine if there were any significant changes for these same students in residency training.

Introduction

Emotional Intelligence (EI) is the ability to monitor one's own and others' feelings and emotions, to discriminate among them, and to use this information to guide one's thinking and actions.[11] In health care, a physician with high EI is said to be more compassionate and empathetic.[1] These residents are caring and able to manage the emotions of their patients and themselves, thus improving patient care. [1] Studies have stated that high EI correlates with increased patient compliance and positive clinical outcomes.[13, 15]

Methods

A longitudinal study was conducted at 3 separate times for podiatric medical students, Class of 2019, at Western University of Health Sciences from 2015-2019: upon matriculation (August, 2015), after completion of 2nd year (June 2017), and at the end of their 4th year (June 2019). There were 49, 29, and 26 participants respectively at these times. Data was collected using the Emotional Quotient Inventory (EQ-i 2.0) test, an online self-survey used to quantify participant's emotional intelligence traits.[8] Scores were recorded for 17 emotional intelligence traits overall.[8] These scores were analyzed for significant changes at each administration of the test and to determine possible reasons for these changes. The EQ-i 2.0 Test is offered by The Myers-Briggs Company, consisting of 133 brief statements that are rated on a 5-point scale from 0-5.[8] A score of 0 indicates not true and a score of 5 indicates true. Scores between 0-5 imply a level of partial agreement.[8] The test was created for participants 18 years and older.[8] Typically a participant would require 15-30 minutes to complete this test.[8] Some of these question examples are listed as following: "I become defensive when criticized", "I stay calm under pressure", "I handle setbacks effectively", "I am positive", "I maintain a sense of humor", "I recognize how my behavior affects others", "I utilize feedback and other criticism for growth", and "I manage my emotions well".[8] There are 6 available

score reports available, one of which was used for this study, the Higher Education Report.[8] The Higher Education Report provided a score report for students in order to foster both academic and life success. Following the completion of the test, a report is generated for each trait with the scores ranging from 70-130. The grading scale for these indicate: <85 is low, 90-100 is average, and >105 is high.[8] A table was then created in order to compare each EI trait score and the change over time along with its associated P-values.

Results

EQ-i test reports were generated for each administration of the test as seen in Table 1. The total scores decreased from the 1st test to the 2nd and increased from the 2nd to the 3rd with a minimal difference. However, the trait scores changes over time were not consistent with this minimal overall net change. From the 1st test to 2nd, all 17 EI trait scores were decreased. From the 2nd test to the 3rd, many of these EI trait scores increased, some more than others. The 3rd test scores had the most variance.Some trait scores rebounded up to equal to or greater than the 1st test scores, while other trait scores failed to rebound or at a lesser value than the 1st test scores. A large standard deviation was seen throughout the participants' trait scores.

EI Traits	1st Test	2nd Test	3rd Test	P-value
Assertiveness	98.91 ± 15.81	94.32 ± 19.49	95.64 ± 15.99	0.661
Empathy	104.27 ± 17.49	102.45 ± 17.01	102.86 ± 15.02	0.930
Emotional Self-Awareness	99.68 ± 19.61	97.09 ± 20.37	96.77 ± 18.27	0.863
Flexibility	104.14 ± 12.76	101.73 ± 16.01	106.64 ± 11.95	0.497
Happiness	102.64 ± 14.38	95.05 ± 17.27	97.86 ± 17.14	0.303
Impulse Control	103.68 ± 14.27	100.91 ± 17.69	106.68 ± 17.36	0.514
Independence	100.45 ± 15.99	98.14 ± 18.74	104.86 ± 16.38	0.420
Interpersonal Relationships	103.45 ± 12.12	100.86 ± 16.59	101.95 ± 13.99	0.835
Interpersonal	105.77 ± 15.35	103.23 ± 17.95	103.73 ± 15.16	0.859
Optimism	101.68 ± 15.82	97.5 ± 17.45	99.64 ± 15.37	0.696
Problem Solving	102.23 ± 14.13	100.36 ± 16.95	104.18 ± 16.06	0.725
Social Responsibility	107.91 ± 12.99	105.45 ± 16.68	104.86 ± 13.98	0.766
Reality Testing	104.23 ± 15.69	100.73 ± 21.25	104.95 ± 16.38	0.707
Self-Actualization	105.55 ± 12.83	101.86 ± 17.94	102.05 ± 15.47	0.678
Stress Management	102.82 ± 16.28	99.95 ± 19.25	104.23 ± 15.69	0.703
Self-Regard	102.32 ± 15.09	98.55 ± 19.54	100.64 ± 16.68	0.768
Stress Tolerance	101.27 ± 16.87	97.32 ± 17.9	101.91 ± 14.94	0.613
Total Score	103.5 ± 16.49	99.18 ± 19.79	103.23 ± 17.42	0.673

Table 1*: EQ-i test scores for EI traits in WesternU podiatric medical students, Class of 2019, from 2015-2019. The 1st test was completed by 49 participants upon matriculation in August, 2015. The 2nd test was completed after the 2nd year in June 2017. The 3rd test was completed at the end of their 4th year in June 2019.*
**Significance at the .05 probability level.*

Discussion

After the 3rd administration of the test, a significant decrease in both happiness and assertiveness was noted. The hypothesis was that there would be a drastic increase in happiness at this time due to the fact that it was near graduation, passing the APMLE Boards Part 2, and passing the Clinical Skills Patient Exam, but that was not the case.[17] A possible factor that may have caused a decrease in happiness is that students may not have placed into their desired residency.

Ghaharamani et. al conducted a study that looked at the relationship between emotional intelligence and happiness in medical students.[9] They conducted a cross sectional study of 300 medical students at Shiraz University of Medical Sciences from September 2014 to September 2017. They stated that happiness can be the effects of a successful marriage, relationship, and career, which would lead to a steady income, health, and longevity.[9] In their study they saw a gradual decrease and a fluctuation in happiness, similar to this study. Their reasoning for this decrease may be due to the increase in time in the clinic and hospital setting where it is said that the importance in Emotional Intelligence is put on display.[9] The reason for the decrease in happiness of the students in this study may be similar to the students of the Ghaharamani et. al study. These students may feel unprepared for residency. They may also suffer from having poor interpersonal and intrapersonal skills that are needed to communicate with patients in residency.[13, 15]

Assertiveness is defined as speaking up for one's interpersonal freedoms or as required by one's role responsibilities to engage others in finding viable, stable solutions.[5] Assertiveness is a learnable skill rather than a personality characteristic.[5] Most medical students believe that they are assertive upon matriculation, that a level of assertiveness was essential in being offered admission.[6] However, these same students realize that medical school is a difficult transition for everybody.[6] This appears to have factored into the large decline in the assertiveness EI trait from the 1st EQ-i test to the 2nd test. Following two years of intensive didactic training, medical student's commonly feel a sense of burnout and incompetence before beginning 3rd year rotations.[12] In the field of medicine, there is constant learning that may become overwhelming at times. Understanding this, it is noted that upon the 3rd administration of the EQ-i test, the assertiveness EI trait remains low, despite a slight increase from the 2nd test to the 3rd test. This increase is likely due to an increase in confidence and capabilities as a graduate student following two years of rotations and externships training.[3, 4] It is interesting to note that there is still an overall 3 point decrease in assertiveness when comparing the 1st test to the 3rd test. A student's confidence upon matriculation appears to be higher than when he or she starts residency training. After successfully completing medical school, student's understand how difficult it is to be assertive when facing these kinds of adversities.[13, 15]

In contrast, an overall increase is seen in both independence and flexibility. At the time of the 3rd administration of the survey students are in transition from rotations and externship towards residency.[17] During rotations, a student has various limitations in the clinic and surgical setting.[2, 17] Students may be looking forward to the ability to have less supervision and more independence in residency, which may be a probable reason for the increase in independence.[10] Supervision without progressive independence may stunt residents' acquisition of knowledge and skills and ultimately hamper their progression to competency in their fields.[10] Residents must be given that independence to learn on their own and while still under the watchful eye of an attending.[10]

There has been recent evidence that states that the one factor contributing to physician wellness is cognitive flexibility, defined as being able to hold multiple views or to reframe a thought, situation, or perspective.[10, 14, 16] Being able to adjust is essential in progressing through medical school curriculum.[7] Students develop the ability to adapt to the challenge of balancing both academics and their personal lives.[7] Throughout these challenges, students learn how to find success in their own way. The flexibility EI trait is notable in this study because of the overall increase seen from the 1st test to the 3rd test. There was an evident rebound observed from the 2nd test to the 3rd test, exceeding the initial 1st test score by over 2 points. This moderate initial decrease between the 1st and 2nd administrations of the test were likely due to students underestimating the challenges of didactic training and struggling to adjust to it. A large positive rebound followed between the 2nd and 3rd administration as hypothesized. A relatively high level

of flexibility would be needed to successfully complete didactic training, 3rd year rotations, 4th year externships, board examinations, residency interviews and applications.[4, 14, 17] This flexibility in medical schools is necessary in order to balance one's personal life and demanding curriculum on a daily basis.[14] After making the adjustments, most medical students have an improved sense of flexibility as they enter residency compared to upon matriculation into the program.

Limitations associated with this study involved sample size, data collection, and study design. As the curriculum intensified and schedules diversified, the number of participants in this study decreased after each test administration. The most participants were seen in the first administration of the test upon matriculation. At this time this test was administered before the didactic curriculum started, allowing ample time for encouragement and completion. The participants decrease over time may be attributed to a variety of factors that includes board exam, studying, rotations and residency preparation, and lack of interest or incentive.[13, 17] Because the EQ-i 2.0 test is a self-survey without incentives, this study was unable to follow every participant throughout the podiatric medical curriculum. In a self-survey, these EI trait scores may be overestimated and or underestimated by participants to improve one's score. Due to these limitations, high p-values were observed, suggesting an inconclusive study. This study also does not correlate EI with resident performance in the clinical setting, which would be beneficial in analyzing the effect on positive outcomes.

Conclusion

Measures of EI correlate with the skills that have been proven to increase clinical outcomes and both physician and patient satisfaction.[11, 13, 16] Overall, most EI scores rebounded in the 3rd administration of the survey following a decline. However the hypothesis that most of the scores would rebound back to the same level, if not higher, than upon matriculation was rejected and inconsistent. For a variety of reasons, this did not occur. It would be useful to conduct a follow up study in order to examine if there were any significant changes for the same students in residency training. Also repeating this study for future classes of podiatric medical students across all the other colleges of podiatric medicine would yield more accurate results for comparison and discussion.

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Variation in the Lateral Compartment of the Lower Extremity

Michael Amedeo, B.S., Mitchell Goldman, B.S., and Dr. Matthew Wedel, PhD

ABSTRACT

Objective: This study examines the prevalence of specific patterns of insertions in the peroneus brevis (PB) tendon, in addition to the prevalence of accessory peroneal muscles.

Methods: Cadavers included in this study were obtained from the Willed Body Program at Western University of Health Sciences. Dissection of 124 cadaveric feet was carefully carried out to expose the muscles of the lateral compartment so that tendon insertion and naturally occurring splits of the tendons could be documented.

Results: Dissections revealed a significantly higher degree of variation in the attachment site of the PB tendon than is reported in many medical texts, primarily with an additional tendon slip extending onto the aponeurosis of the fifth metatarsal. Furthermore, the population examined in this study displayed a significant prevalence of accessory peroneus muscles.

Conclusion: This study demonstrates that anatomic variation within the lateral compartment of the foot exists in a significant portion of the general population. Further studies are required to clarify the role genetics plays in the development of alternate tendon slips of the PB and other accessory peroneus muscles.

Introduction

The peroneus brevis is a muscle located in the lateral compartment of the leg deep to the larger peroneus longus muscle. The peroneus brevis originates in the distal fibula and continues distally behind the lateral malleolus to attach to the lateral bones of the foot, most consistently on the base of the fifth metatarsal. While most anatomy textbooks reference the fifth metatarsal base as the point of insertion for the muscle, there is substantial evidence to suggest that the tendon of peroneus brevis extends further distally beyond the fifth metatarsal base in many individuals.[1] Previous studies have demonstrated that these anatomic variations are quite common in the general population. For example, Demir et al. found a present peroneus digiti quinti in 32% of lower extremities analyzed.[1] Another study conducted by Yammine found a significant amount of variation in the muscle's insertion, to the point that these findings have become significant enough to warrant more research into the anatomic variation present in the muscle.[2] There has also been debate over the consistency with which additional muscles in the lateral compartment appear. Examples of common accessory muscles include peroneal muscles with tendons that insert on the fifth toe (peroneus digiti quinti), the dorsal surface of the fifth metatarsal (peroneus tertius), and the lateral calcaneus (peroneus quartus). This study aims to clarify the prevalence of these variations in the musculature of lateral compartment of the foot as well as variation within the PB tendon.[3]

Materials and Methods

The study was conducted using photos of cadavers from the anatomy laboratory at Western University of Health Sciences, obtained via the schools' Willed Body Program. The photos were taken from the Willed Body Program's donor groups in 2014 and 2019. There was a total of 62 cadavers reviewed for a total of 124 total feet. To begin, multiple photos were taken of each foot for review to determine the insertion point and slip extensions of the peroneus brevis tendon in that respective foot. To turn these observations into quantifiable data points, a list of possible insertion sites was created beforehand to be able to categorize the anatomic variation observed. Sarrafian's Anatomy of the Foot and Ankle was referenced for the insertion site categories, which included: styloid process, peroneus tertius tendon, extensor aponeurosis of the fifth toe, extensor aponeurosis fourth metatarsal shaft, fifth metatarsal shaft, dorsal fascia of fifth met head, peroneus digiti quinti tendon, and loop with peroneus tertius tendon.[3] Each foot reviewed was not limited to being put in one category; rather any given foot could be put in multiple categories depending on the number of extension slips present. After reviewing and categorizing the variation seen in the photos, data on the prevalence of each insertion site was obtained.

Results

After 124 cadaveric feet were examined in this study, it was found that:

· 123 had an insertion at the styloid process
· 32 had a present peroneus tertius tendon
· 54 had an insertion at the extensor aponeurosis of the fifth toe
· 3 had an insertion at the extensor aponeurosis of the fourth metatarsal shaft
· 4 had an insertion at the fifth metatarsal shaft
· 0 had an insertion at the fourth metatarsal shaft
· 17 had an insertion at the dorsal fascia of the fifth metatarsal head

· 22 had a present peroneus digiti quinti tendon
· 0 had a loop with peroneus tertius tendon
· 1 had an insertion at the calcaneus
· 1 had a present peroneus calcaneus tendon

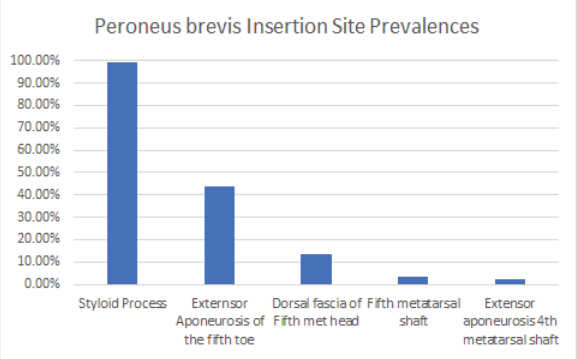

Figure 1: *The presence of each tendon insertion site that was visualized through dissection of the peroneus brevis muscle is shown above.*

The findings recorded in Figure 1 reveal that of the 124 feet examined, 123 (99.19%) had insertions on the styloid process. The one individual who lacked a PB insertion on the styloid process also possessed a peroneus calcaneus muscle. Additionally, 54 feet that possessed an additional PB insertion site on the extensor aponeurosis of the fifth toe were identified (43.55%). There were 17 feet (13.71%) that possessed an additional tendon slip that inserted in the dorsal fascia of the fifth metatarsal head, and 4 feet (3.23%) with PB insertions on the fifth metatarsal shaft. Finally, 3 feet (2.42%) possessed an additional tendon slip inserting onto the extensor aponeurosis of the fourth metatarsal shaft.

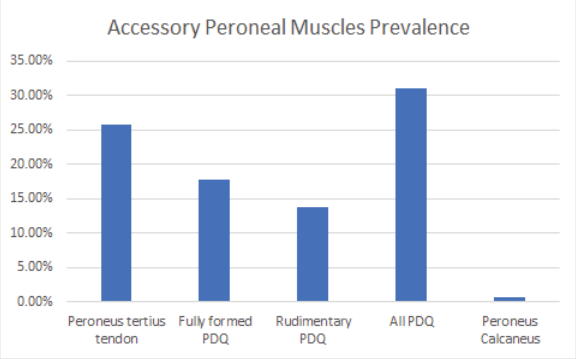

Figure 2: *The prevalence of accessory muscles in the 124 cadaveric feet included in this study is shown above.*

Figure 2 shows that 32 peroneus tertius muscles (25.81%), 22 fully formed peroneus digiti quinti muscles (17.74%), and 17 rudimentary peroneus digiti quinti muscles (13.71%) were identified. There was 1 peroneus calcaneus muscle identified (.81%).

Discussion

In consideration of the project's results, there are a number of findings that give credence to the existence of a large amount of variation in the peroneus brevis muscle. While the presence of an insertion at the styloid process was nearly unanimous (123/124), there was a large number of variants with an insertion at the extensor aponeurosis of the fifth toe (54/124) and a peroneus tertius tendon (32/124). Additionally, there was a large number of peroneus digiti quinti (PDQ) tendons recorded (39/124). The prevalence of PDQ tendons found in this study is comparable to other papers reviewed in the literature, as seen in Figure 3 below.

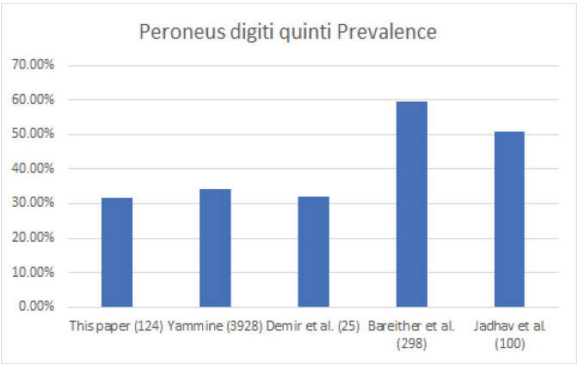

Figure 3: *The prevalence of the peroneus digiti quinti (PDQ) tendon in our study as compared to several other referenced papers is shown above.*

Findings from other papers include Demir et al. recording its presence in 32% of examined feet[1] and Yammine finding a PDQ in 34% of cases.[2] Bareither et al. recorded 59.7% of specimens as having a PDQ.[4] Finally, Jadhav et al. recorded 51% of cases having a PDQ present.[1] It is worth noting, however, that these results are quite arbitrary and depend heavily on how a given variation is defined to begin with. In the case of the PDQ tendon, there is no way to conclusively determine whether a given tendon qualifies as a true peroneus digiti quinti, as each case may contain a large amount of room for debate. For example, if the tendon does contain a slip extension distally towards the fifth toe but it does not attach to the distal phalanx as the PDQ is classically described, should this case be marked as having a present PDQ tendon? Cases like this demonstrate the subjective nature of this type of research and highlight the challenge investigators face when recording their results. In this study, an effort was made to be as inclusive as possible to any and all variants found, leading to classification of tendons that may or may not be considered PDQs as "rudimentary"

and more defined, classically presented PDQ tendons as "fully formed." Including both classifications in our tally of present PDQ tendons lead to the calculation of a 31% prevalence figure. It is important to note, however, that not all studies define their terms and quantify their data in the same way, and it is likely that the way this study recorded whether something was a variant or not is entirely different from the way other quoted studies did so.

One important takeaway that must be considered with this research question is whether or not any conclusions can be made between the presence of variation in the PB tendon and one's genotype. Unfortunately, this was a limitation of this study, as the Willed Body Program at WesternU gives little information about the donors' genetic background. Despite the fact that this project gives little insight into this question, its importance cannot be understated in several other studies on the topic. For example, Bareither et al. found the PDQ tendon to be present in 59% of cadaver feet examined.[4] This figure is significantly higher than most studies have reported. Notably, this study contained an almost exclusively European population of donors, which could account for the high prevalence figure. While the question of a connection between genome and variation in the PB tendon remains largely unanswered, it is a worthy consideration in future studies on this topic.

Conclusion

It is undeniable that the peroneus brevis has more anatomic variation present than almost any other muscle in the human body. In the cadavers studied, there was significant variation found to be present, particularly in the prevalence of peroneus digiti quinti and peroneus tertius tendons as well as insertions at the extensor aponeurosis. Much of the anatomic variability seen in this report was comparable to previously conducted studies, particularly in the case of the PDQ tendon. It would be beneficial for future research to explore the genetic component to this variation, so that a causal link between one's genotype and development of these variations can be better established.

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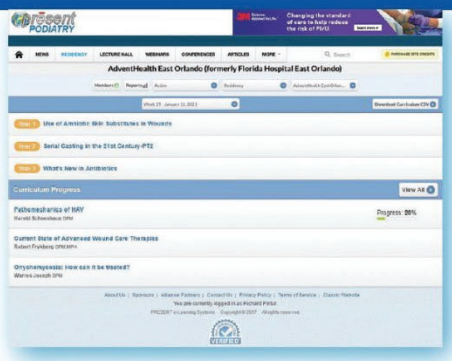

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