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Current Concepts of Minimally Invasive Treatment Options for Plantar Fasciitis: a Comprehensive Review

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Abstract

Purpose of Review Chronic foot pain constitutes a large portion of the chronic pain burden in the overall population. Plantar fasciitis is one of the most common and most easily identifiable causes of chronic foot pain. The syndrome has been estimated to cause 11 to 15% of foot pain visits, requiring professional care. Moreover, studies have suggested that 1 in 10 people will develop plantar fasciitis at some point in their life. Conservative management has been shown to be effective and considered first-line treatment. Minimally invasive treatment options are typically reserved for those who fail conservative management. With the advent of new techniques and improvements in current therapeutic options, there has been an expansion of available minimally invasive treatment options. The purpose of this review is to provide a comprehensive update on the current understanding of minimally invasive treatments of plantar fasciitis.

Recent Findings This review shows that conservative management continues to be the first-line therapy, whereas other treatment options were those who failed conservative management using modern techniques that have shown improving effectiveness, with successful restoration of patient functionality, recovery, and satisfaction. However, a multitude of these minimally invasive treatment options are evolving.

Conclusion While conservative management continues to be the mainstay of treatment for plantar fasciitis, multiple minimally invasive treatment options are emerging with potential effectiveness in reducing pain and improving the function.

Keywords Ankle and foot pain · Plantar fasciitis · Manual therapy · Joint mobilization · Soft tissue mobilization · Corticosteroid injections · PRP injections

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Introduction

US spending on personal health care and public health from 1996 to 2013 showed the third-largest increase for musculoskeletal disorders in back and neck pain [1•]. Dieleman et al. [1•] showed an estimated spending of and $95.9 billion in managing musculoskeletal disorders, excluding back and neck. In addition, the US Burden of Disease Collaborations and the state of US health care from 1990 to 2010 study showed musculoskeletal disorders ranking number 2 and low back pain ranking number one in causing disability [2•]. Among multiple musculoskeletal disorders, chronic foot pain constitutes a large proportion of the burden in the overall population. It has been estimated that plantar heel pain is one of the main sources of complaint in the general population, affecting approximately 2 million Americans each year and as much as 10% of the population over the course of a lifetime [3••, 4, 5]. Plantar heel pain may be secondary to multiple sources of pain, involving various diagnoses such as myofascial pain syndrome, plantar fasciitis, or neuritis, among multiple other causes. While estimates show, heel pain is seen in 11–15% of provider visits requiring professional care, plantar fasciitis accounts for 1–2 million physician visits each year. In fact, analysis of trends in foot and ankle studies published from 2000 to 2017, in 5 high-impact general medical journals, showed an increase in publication rate and support for non-operative management [6–9]. Plantar fasciitis is treated with multiple modalities of treatments including drug therapy, noninvasive therapies, minimally invasive therapies, and surgical interventions [6–12, 13••, 14••, 15–22, 23••, 24–36, 37••, 38••, 39, 40•, 41•, 42–53].

Epidemiology

Even though there are few high-quality epidemiologic studies available, studies conducted in the USA between 1995 and 2000 found that consultations for plantar heel pain equaled approximately one million patient visits to physicians per year [3••, 4, 5]. The prevalence over a lifetime has been shown to be 10% [3••, 4, 5] and in a review of 75,000 patients, it was estimated approximately 1% of them self-reported plantar fasciitis with pain, with higher rates of incidence among those 45–64 years of age and higher in the obese [4, 5, 11, 12]. The economic burden of plantar fasciitis treatment in the USA has been estimated to be $192–$376 million per year [15]. Even though it is considered a self-limiting disorder, it has multifactorial etiology occurring in both active and sedentary individuals.

Risk Factors

Plantar fasciitis has been associated with occupations requiring substantial time spent standing up, long-distance runners, individuals aged 40–60 years old, and those with a high body mass index (BMI) [10, 13••, 14••, 35, 39]. Plantar fasciitis is the most common cause of heel pain requiring provider services and has been estimated to be as high as 10% of all injuries associated with running [3••, 4, 5]. In a review by Nahin [11], those aged 45–64 years had a prevalence of plantar fasciitis of 1.33% and those who were obese had a prevalence of 1.48%, both of which were higher than the overall population prevalence. Likewise, poor body biomechanics, such as poor ankle flexion and trauma to soft tissue and connective tissue, have been identified as other potential risk factors for the development of plantar fasciitis. Table 1 shows risk factors for developing plantar fasciitis [13••].

Pathophysiology

The term plantar fasciitis indicates an acute inflammatory process of plantar fascia. However, current research is indicating that it is more of a chronic degenerative process or fasciosis [20]. The fascia is damaged as a result of repetitive load bearing, resulting in micro-trauma, and resulting in symptoms of plantar fasciitis. Consequently, an inflammatory action develops bringing microphages, lymphocytes, and plasma cells to the area of the injury [13••]. With continuation of the repetitive trauma, the inflammatory response results in increasing fibrosis, resulting in tissue degeneration or fasciosis and thickening of the plantar fascia, resulting in reduction of elasticity [21]. In fact, some have hypothesized that plantar fasciitis is not an inflammatory condition due to lack of classic signs of inflammation such as erythema, edema, leukocyte, or microphage infiltration, rather it is a degenerative condition.

Table 1 Common risk factors for the development of plantar fasciitis

Occupations that require prolonged standing
Military personnel
Long-distance runners
Obesity
Female gender
Flat feet
High arches
Barefoot walking
Poor footwear (flip-flops)
Decreased ankle flexion
Tightness of Achilles tendon
Sedentary lifestyle

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Plantar fascia is comprised of 3 bands of dense, fibrous connective tissue on the plantar aspect of the foot. The plantar fascia is an aponeurosis and not fascia, originates at the medial tuberosity of the calcaneus, and extends distally into five bands that run up each digit and insert into the base of the proximal phalanx of each toe, and each metatarsal head [20]. It provides support to the longitudinal arch of the foot and plays a role in the dynamic action of a foot during motion, and load bearing, acting for the foot to store potential energy, and release kinetic energy during movements [20].

Clinical Presentation

Common clinical presentation includes pain and discomfort, normally in the inferior heel region, and it can also be associated with radiation of pain along the entire foot as well [22]. The physical examination consists of pain with causation into the medial plantar aspect and point tenderness where the fascia enters into the medial calcaneus [13••]. Passive dorsiflexion of the toes and ankle or a Windlass test elicits pain in the medial plantar aspect [12]. The Windlass test achieves a direct stretch on the plantar aponeurosis and is thus effective in examining the dysfunction of the plantar fascia. The primary mechanism of the Windlass test is to lift the medial longitudinal arch during the toe-off. As the toes extend, the plantar fascia lengthens and increases the tension on the medial longitudinal arch. There is also a decreased range of motion in the ankle in addition to the pain. Ankle dorsiflexion of less than 10° has been identified as a risk factor for plantar fasciitis [35].

Clinical presentation and physical examination should focus on various differential diagnoses for plantar fasciitis as the cause of plantar heel pain including heel contusion, neuropathy, posterior tibial tendonitis, tarsal tunnel syndrome, calcaneal fracture or tumor, Sever's disease, arthritis, Achilles tendonitis, plantar fascia rupture, and retrocalcaneal bursitis [14••].

Diagnostic testing with imaging or laboratory assessment yields poor results. Imaging is required only in a case of history of trauma to the foot, an atypical presentation, or refractory symptoms to treatment measures [36]. However, ultrasound and rarely MRI may be used in the later stages for focused measurement and evaluation of the plantar fascia [13••]. If radiography is performed, weight-bearing radiographs are preferred in the evaluation of heel pain. While MRI is rarely performed, it is indicated to delineate pathology between soft tissue and the bones of the foot. Findings consistent with plantar fasciitis are thickness of the proximal plantar fascia and increase in signal intensity [17, 35]. However, MRI findings may also show signs of plantar fascia tear or rupture.

Ultrasound is an easy-to-perform method, which is available bedside in many clinics, is used to confirm the diagnosis of plantar fasciitis, and rules out other pathology. The ultrasound measures the thickness of the proximal plantar fascia and locates areas of hypoechogenicity with increased thickness to greater than 4 mm supporting the diagnosis of plantar fasciitis [17]. However, specificity in evaluating plantar fasciitis is highly dependent on the operator and their training.

The classic symptom of plantar fasciitis is pain with the first step out of the bed in the morning. Typically, the pain is worse in the morning and may improve throughout the day. The location of the pain is predominantly on the bottom of the foot in or near the heel. The descriptive characters of pain may involve throbbing, dull, or burning. Patients often report the pain is on all surfaces of the inferior heel, with occasional radiation or focal sites of pain along the longitudinal arch of the foot.

Treatment

While treatment of plantar fasciitis includes predominantly conservative management, multiple modalities include drug therapy, physical therapy, strength training, manual therapy, minimally invasive treatments including local anesthetic and corticosteroid injections, platelet-rich plasma (PRP) injections, botulinum toxin injections, acupuncture, dry needling, prolotherapy, pulsed radiofrequency, and surgical interventions which can be classified as minimally invasive and open-surgical interventions [3••, 9, 13••, 38••, 39–53]. In fact, 82% of the patients reported complete resolution of plantar fasciitis symptoms with conservative management [54]. Further, the National Institute for Health and Care Excellence (NICE), in their 2005 clinical knowledge summary on the management of plantar fasciitis, primarily recommended self-care advice including education on complete recovery with conservative management within 6 months, rest, shoes with arch support and cushioned heels, insoles to correct foot pronation, analgesia or an ice pack for symptom relief, weight loss, and self-physiotherapy in the form of plantar fascia and Achilles tendon stretching [16].

Drug Therapy

Based on the theory of inflammation, multiple trials of over-the-counter drugs as well as non-steroidal anti-inflammatory agents are utilized in managing heel pain and plantar fasciitis.

Some patients also receive opioids. Opioid therapy has been associated with significant overuse, abuse, and adverse consequences including death [23••, 24–31]. Consequently, opioids are not recommended in managing chronic heel pain. Overall, Nahin [11] found that 41% of patients with plantar fasciitis used prescription medications, even though only 6.31% of these individuals reported using medications specifically for plantar fasciitis. This indicates that patients with

plantar fasciitis may suffer from a multitude of other problems. However, the use of over-the-counter medications was much more common, with 70% of individuals with plantar fasciitis reporting their use, of which mostly comprised over-the-counter NSAIDS and acetaminophen [11]. However, oral steroids and non-steroidal anti-inflammatory drugs have been shown to provide short-term pain relief and decreased disability in conjunction with other treatment modalities [17].

Rest

Rest or activity modification has been shown to decrease the inflammation of the plantar fascia, which also decreases the pain. The pressure reduction on the fascia by decreasing the amount of time standing and choosing non-impact exercise such as cycling or swimming has shown to reduce the pressure on the fascia [13••]. Even though it is not total bedrest, 2 weeks of rest with easing of the pressure on the pathological area with reduced activity is recommended to help during the acute phase and prevent the chronic phase. However, there is no indication for the benefits of extended rest.

Stretching

To reduce the pain, increase the activity and resolution of plantar fasciitis, stretching of the plantar fascia, Achilles tendon, and calf have been recommended [47]. It has been shown that plantar fascia specific stretching can lead to a significant difference in pain reduction with plantar fasciitis, as compared with more generic stretching [47].

Taping

Taping is an intervention where patients do it themselves without even consulting the physician; however, it is an easy intervention a provider can perform. It improves the pain relief and function and also provides support to the foot and allows for proper mechanical positioning [48]. There are various types of commercial tapes available for this purpose at local pharmacies or other departmental stores.

Application of Ice

Application of ice is a common method utilized by placing a frozen water bottle or ice itself under the foot and roll the foot on the bottle or the ice for approximately 10–20 min, 2–4 times a day. This has been shown to provide some benefit in the early stages of the plantar fasciitis as in any other musculoskeletal condition.

Inserts and Footwear

Proper inserts and footwear can provide comfort and reduce pain in the patient with plantar fasciitis. In patients with plantar fasciitis, it is recommended to avoid flat, unsupportive shoes, such as flip-flops. Even though in the past barefoot running was recommended as a treatment for plantar fasciitis [49], subsequent evident shows that barefoot running causes increased ankle plantar flexion rather than dorsiflexion [49] and causes more harm due to possible addition of other injuries [50]. There is also evidence supporting well-supportive shoes and foot orthosis to decrease pain, even though there is no significant improvement in the improvement of the plantar fasciitis itself [4]. The orthotics elevate the heel and provide motion control to help the pain [35]. Further, there have been no significant differences between customized and less expensive options of prefabricated orthotics.

Night Splints

Night splints are based on the theory that they provide prolonged stretching while keeping the ankle in dorsiflexion. The disadvantages include that the splint is sometimes uncomfortable to wear while sleeping, specifically for the recommended period of 1–3 months. Further, even though multiple types of night splints, such as soft or hard posterior splints are available, they all have shown to have the same effectiveness.

Immobilization

Immobilization has been performed to rest the foot and take off the load of the weight from the foot. Significant pain from plantar fasciitis may be resolved or reduced from immobilization. The most common device is a short-leg walking boot such as a controlled ankle motion walker; however, immobilization is not recommended beyond 2 weeks.

Strength Training

A systematic review identified that there is a significant association between intrinsic foot muscle weakness and painful foot pathology such as plantar fasciitis [53]. Subsequently, another systematic review assessed the influence of strength training for plantar fasciitis and the intrinsic foot musculature [37••]. In this systematic review, the authors identified 7 manuscripts meeting the inclusion criteria with moderate to high quality, even though external validity was low. In the comparison of the inventions in this systematic review, they highlighted significant differences in strength training approaches to treating plantar fasciitis and improving intrinsic strength. They only found limited external validity that foot exercises, toe flexion against resistance, and minimalist running shoes may contribute to improved intrinsic foot

musculature function. However, they also found no plantar fascia thickness changes through high-load plantar fascia resistance training and there were indications that it may aid in the reduction of pain and improvement in function.

Physical Therapy

Manual therapy employed in the treatment of plantar heel pain includes joint mobilization or soft tissue mobilization with deep tissue massage or myofascial release [16, 37••, 40•, 41•].

In a survey of current practices in the UK for physiotherapy for plantar fasciitis, the most frequently used modalities were massage, myofascial release, specific soft tissue mobilizations, and myofascial trigger point therapy [40•]. Further, it also has been recommended by the American Physical Therapy Association (APTA) in 2014 with their updated clinical practice guidelines on the best treatment for patients with plantar fasciitis, a combination of manual therapy and rehabilitative exercises to help patients with this foot condition [54]. They believed that there was strong evidence on the benefits of physical therapy for plantar fasciitis, but very few patients were given this treatment. A critical review of all available studies with an emphasis on randomized control trials performed by Pollack et al. [41•] identified 6 relevant RCTs, 2 of them examining the effectiveness of joint mobilization on plantar heel pain and 4 on the effectiveness of soft tissue techniques [55–60]. Five of the 6 studies showed a positive short-term effect after manual therapy treatment, mostly soft tissue mobilization, with or without stretching exercise for patients with plantar heel pain, compared to other treatments. One study showed a lack of positive findings showing that addition of joint mobilization to the treatment of plantar heel pain was ineffective. Overall, the authors concluded that soft tissue mobilization is an effective modality for treating plantar heel pain, even though outcomes of joint mobilization are controversial.

Extracorporeal Shockwave Therapy

For several decades, extracorporeal shockwave therapy (ESWT) has been a noninvasive treatment option for recalcitrant plantar fasciitis. Like other minimally invasive options, it is reserved for those who have failed conservative management and is often considered before surgical intervention. The exact mechanism of action is poorly understood, but previous literature suggests the mechanism of action may be via destruction of unmyelinated nerve fibers and simultaneous stimulation of neovascularization and collagen synthesis in crosslink formation [61]. The therapy is performed via an electromagnetic system that uses a magnetic field in a surrounding fluid medium to produce shockwaves delivered in microsecond pressure pulses through a probe with a targeted focus on the area of pain origination [62]. This therapy has also been demonstrated to increase ankle proprioception in patients with plantar fasciitis, although no statistically significant improvement in dorsiflexion strength, plantar flexion strength, or ankle stiffness has been demonstrated [63, 64]. ECST is generally considered safe, despite unknown long-term complications. A systematic review [65], which specifically examined treatment complications, reported that 403 out of 1946 (20.7%) patients experienced side effects. Adverse effects in decreasing incidence were transient red skin after treatment, pain during treatment, dysesthesia, swelling, ecchymosis and/or petechiae, severe headache, bruising, throbbing sensation, and pain within 1 week of treatment [65].

Several studies have shown ECST to be an effective therapy option for pain relief due to recalcitrant plantar fasciitis, with success rates ranging from 65 to 91% [66, 67]. A meta-analysis of nine studies found significant rates of reduction in overall heel pain and visual analog scale (VAS) score by 60% from baseline at both the first step in the morning and during daily activities [68]. Another meta-analysis compared 13 studies with a total of 637 patients treated with ECST and 548 treated with other therapy. They found that those treated with ECST had lower pain scales, greater increases in Roles and Maudsley score, and shorter return to work time compared to other therapy in patients with chronic plantar fasciitis [69]. When compared to botulinum toxin type A, and corticosteroid injection therapy, ECST exhibits a longer duration of action, with therapeutic effects of steroid injections reducing within 6 months after treatment [70, 71]. Improvements in pain, ankle function, and quality of life have been demonstrated to be comparable between ECST and kinesiology taping [72]. Some studies have suggested that ECST may be a superior option to corticosteroid injections, as there is no associated risk for rupture of the plantar fascia [73]. There is some variance in delivering the shockwave therapy, as some providers will administer therapy to specific areas of pain, while others span the entire plantar fascia. In many patients, only one treatment session is needed to achieve satisfactory pain relief, as reported by 76% of 284 patients receiving therapy in a recent study [74]. Its short-term, and possible long-term, benefits were also highlighted in a study conducted by Rompe et al. [75] in which 3 sessions of 1000 impulses at low energy showed a statistically significant decrease in pain and ability to walk without pain at 6 months, and a decreased rate of subsequent surgery as compared to a group who received only 10 impulses at low energy. Others may benefit from weekly therapy sessions to reduce the healing time of chronic plantar fasciitis [74]. While the exact mechanism causing therapeutic benefit is unclear, a recent study used magnetic resonance imaging (MRI) to demonstrate a 2 mm increase in the thickness of the plantar fasciitis, decreased high-intensity signal areas, and reduced edema around the plantar fascia in patients who received 6 months of shockwave therapy for chronic plantar fasciitis [76]. Another MRI study found decreased

plantar fascia thickening echoing the same reduction in soft tissue edema 6 months after receiving 3 weekly treatments of ECST [77].

Wang et al. [52] studied the efficacy of different energy levels used in focused and radial ESWT in the treatment of plantar fasciitis in a meta-analysis of randomized placebo-controlled trials. They included 14 manuscripts in the meta-analysis and showed that the high-energy ESWT group had a better success rate than the control group only at 3-month follow-up, but no significant differences between groups were observed for the other follow-up visits (1 and 12 months). However, the medium-energy ESWT group had significantly better success rates than the control group for all the follow-up visits at 3, 6, and 12 months. Further, the medium-energy ESWT group had significant improvement in VAS scores compared with the control group for all follow-up visits. After removing the extreme values, low-energy ESWT group also had significant improvement in VAS scores compared with the control group for all follow-up visits. Thus, focused ESWT seems to be more effective than radial ESWT when compared with the control group. Thus, they concluded that medium-energy ESWT in the treatment of plantar fasciitis was more effective than the control group, and low- and high-energy ESWTs needed future studies to confirm their superiority over the placebo.

Local Anesthetics and Corticosteroid Injections

Local anesthetic and steroid injections are two of the treatments in multiple musculoskeletal conditions and spinal pain including heel pain [18, 19, 38••, 45, 46, 57, 58, 78–83]. Local anesthetics have been utilized for interventional techniques and trigger point injections, as well as intra-articular injections.

Local anesthetic and steroids have been used extensively since 1901 for local anesthetics, and for steroids since the 1940s [80, 84]. Both local anesthetic and steroids have been shown to have a significant anti-inflammatory effect and also prolonged pain relief in clinical as well as experimental settings. In fact, shortly after the discovery of steroids by Phillip Hench [84] in the 1940s as a potent anti-inflammatory use agent, they have been used extensively for numerous painful conditions including spinal conditions and intra-articular injections. Often steroid injections are combined in clinical practice with local anesthetic [85]. Local anesthetic initiates immediate effect and also reduces the discomfort. However, there is no evidence that steroid injections or disease-modifying agents have any direct effect on pain generation or transmission with the exception of inflammatory conditions such as rheumatoid arthritis. Multiple studies have been conducted evaluating the effectiveness of injection therapy for plantar fasciitis with local anesthetics, with steroids, hyaluronic acid, polydeoxyribonucleotide, and PRP [38••, 45, 46, 86–93]. Lai et al. [89] in a randomized controlled trial compared ESWT and corticosteroid injections for chronic plantar fasciitis, with inclusion of 97 patients. The thickness of the plantar fascia was evaluated respectively before the treatments and at the 4th and 12th week after the treatment by ultrasonography. Results showed an increase of plantar fascia thickness in the ESWT group compared to the corticosteroid injection group at the 4th week. In addition, VAS was lower in patients receiving ESWT than with corticosteroid injection. However, both treatments were effective. Improvement was seen with pain reduction and increase in functionality in both groups. Yucel et al. [88] compared silicone insoles with ultrasound-guided corticosteroid injection in the management of plantar fasciitis in a randomized clinical controlled trial in 42 patients. Their results showed significant improvement in VAS, heel tenderness index, foot and ankle outcome score, and ultrasonographic changes of plantar fascia in both groups after 1 month. However, the results with pain, function, and plantar fascia thickness were better in the injection group than in the insole group. A systematic review and meta-analysis of PRP versus corticosteroid injections for plantar fasciopathy [93] showed the results were superior at 3 months for PRP injections; however, at 6-month follow-up, there was no difference between the groups. Patients showed improvement in both groups. Lee et al. [91] also compared autologous blood injection and corticosteroid injection in an RCT in 64 patients with follow-up of up to 6 months. Reduction in pain and tenderness threshold was significant in both groups over time. At 6 weeks and 3 months, the corticosteroid group had significantly lower VAS than the autologous blood group, but the difference was not significant at 6 months. Overall, the results show significant improvement in patients with corticosteroid injections with local anesthetic and corticosteroid injections [92–96]. It has also been shown that approximately 10% of patients receiving repeated steroid injections may experience plantar facial rupture [96, 97].

Regenerative Therapy

Regenerative therapy has been becoming increasingly popular in managing musculoskeletal conditions [45, 46, 90, 91, 98–100]. However, the evidence for regenerative therapy has been limited to injections with PRP or amniotic fluid solution in managing plantar fasciitis. There have been RCTs, as well as systematic reviews assessing the effectiveness of PRP, in comparison with corticosteroid injections [93]. Singh et al. [93] performed a meta-analysis of PRP versus corticosteroid injections for plantar fasciopathy. They included 10 studies totaling 517 patients. Of these, 7 were randomized trials [92, 95, 101–107]. All the studies included patients who had failed conservative measures and excluded patients with systemic illness and other causes of foot pain. They utilized outcome measures of pain relief with VAS and functionality measured

by the American Orthopedic Foot and Ankle Society (AOFAS) scores. The results showed that at 3-month follow-up, PRP injections were associated with improved VAS scores and AOFAS scores. However, at 6-month follow-up, there was no difference in VAS score. However, in both groups, there was a significant difference from baseline even though there was no difference in pain and function score at 1, 6, or 12-month follow-up. In addition, sensitivity analysis of high-quality studies showed no difference between the PRP and steroid group at any of the follow-up points. They also showed no adverse events. Further, a cost-utility analysis was not performed. They concluded that PRP injections were associated with improved pain and function scores at 3-month follow-up when compared with corticosteroid injections.

Among the individual RCTs, Shetty et al. [45] evaluated a total of 90 patients in an RCT with 3 arms utilizing placebo, corticosteroids, and PRP, with 30 patients allocated to each group. All the patients were followed at regular intervals until 18 months post-injection using validated instruments. The results showed significant improvement in VAS in all groups, between baseline and 18-month follow-up, with corticosteroid injection showing significantly better improvement than PRP in the short-term, whereas longer term PRP was significantly better than corticosteroid injections. In reference to functionality also, the results were similar with significant improvement from baseline to 18-month follow-up and corticosteroids showing significantly better improvement in the short-term, with PRP showing better results in the long term than corticosteroids.

Uğurlar et al. [46] also assessed treatment of chronic plantar fasciitis with a 36-month follow-up period utilizing 4 different treatment modalities in 158 consecutive patients. The inclusion criteria included chronic plantar fasciitis with a symptomatic heel spur. At the end of the follow-up period, the mean VAS scores for all 4 groups were similar to the mean VAS scores before treatment. Further, at the end of the follow-up period, no significant improvement was noted in the revised foot function index score in any of the groups. Overall, the effect of PRP was seen within 3 to 12 months; however, at 36-month follow-up point, no differences were found among 4 treatment groups.

Radiofrequency Ablation Therapy

Radiofrequency neural ablation involves targeted interruption of nerve conduction pathways responsible for recalcitrant plantar fasciitis pain with the aim to provide analgesia. The mechanism of action involves introducing a targeted lesion that will stop nociceptive output from A-δ and C fibers while preserving A-β motor and sensory fiber signals [32, 33, 108–114]. The lesion is introduced via an electrode tip that uses > 250 Hz radio waves to produce an electromagnetic field that will heat the surrounding few millimeters of tissue above 47 °C. As with other minimally invasive treatments, these modalities are normally reserved for patients experiencing pain refractory to conservative measures such as physical therapy, medical management, and ESWT [109].

Multiple studies have examined the efficacy of RF ablation of several different nerves including the lateral plantar nerve, medial calcaneal nerve, and inferior calcaneal nerve for recalcitrant plantar fasciitis pain management [109–115]. Arslan et al. [109] found 88% of the 37 patients who received radiofrequency nerve ablation of the medial calcaneal nerve and lateral plantar nerve for chronic refractory plantar fasciitis reported the procedure either very successful or successful at reducing their chronic pain at 12 months postoperatively. Erken et al. [115] reported similar findings with RF ablation of the inferior calcaneal nerve, with an overall progressive improvement on 10-point VAS and AOFAS scale scores in patients postoperatively over a 2-year period. In addition, 85.7% of patients in this study reported very successful or successful treatment efficacy at 1- and 2-year follow-ups. Another study [116] suggested ultrasound-guided radiofrequency stimulation of the posterior tibial nerve as a novel therapy for patients with recalcitrant plantar fasciitis. At 12-week follow-up, patients receiving this therapy experienced significantly improved pain, AOFAS ankle-hindfoot scale score, and plantar fascia thickness compared to control [116].

In addition to the above studies, Osman et al. [42], in a prospective evaluation of 20 patients, compared thermal radiofrequency to pulsed radiofrequency of the medial calcanean nerve for management of chronic refractory plantar fasciitis. Pulsed radiofrequency was administered for 6 min, whereas thermal radiofrequency was administered for 90 s. They showed significant improvement in both groups on pain scales after 24 weeks. However, the pulsed radiofrequency heels had significantly better pain scale and satisfaction scores at the first and third week's assessment when compared to the conventional radiofrequency. The onset of analgesia was also rapid in the pulsed radiofrequency group compared to the thermal radiofrequency group.

Overall, the evidence for radiofrequency is limited with pulsed radiofrequency preferred over conventional radiofrequency.

Conclusion

Chronic foot pain is a highly prevalent source of disability. It accounts for a high count of outpatient visits and imposes a substantial economic burden on the US economy, both in direct health care costs and in lost productivity [117]. Within the heterogenous causes of foot pain, plantar fasciitis is one of the most common etiologies. While conservative management is considered first-line therapy, other treatment options for those who fail conservative management using modern

techniques have shown improving effectiveness, with successful restoration of patient functionality, recovery, and satisfaction. Many of these minimally invasive treatment options are still in their infancy, as more practitioners are beginning to implement them into practice. The potential benefit of decreasing recurrence rates, increasing functionality, decreasing time back to work or activities, and improving efficacy will drive continued study of the treatment options investigated in this review. Further high-quality randomized controlled trials are needed to elucidate proper protocol and standardization of treatment for plantar fasciitis.

Compliance with Ethical Standards

Conflict of Interest Morgan Hasegawa, BS, Ivan Urits, MD, Vwaire Orhurhu, MD, MPH, Mariam Salisu Orhurhu, MD, MPH, Joseph Brinkman, BS, Stephen Giacomazzi, BS, Lukas Foster, BS, Laxmaiah Manchikanti, MD, Rachel J. Kaye, BA, and Omar Viswanath, MD, declare no conflict of interest. Alan Kaye, MD, PhD, is a speaker for Merck.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1.• Dieleman JL, Baral R, Birger M, Bui AL, Bulchis A, Chapin A, et al. US spending on personal health care and public health, 1996-2013. JAMA. 2016;316:2627–46 **This manuscript provides an outstanding pattern of utilization of health care expenditures on personal health care and public health, showing musculoskeletal conditions and neck and back pain constitute a significant proportion of growing health care expenditures.**

2.• U.S. Burden of Disease Collaborators. The state of US health, 1990–2010: burden of diseases, injuries, and risk factors. JAMA. 2013;310:591–608 **This manuscript shows the state of US health from 1999 to 2010 with burden of diseases, injuries, and risk factors. The manuscript also shows low back pain as the number one problem, followed by musculoskeletal conditions as number two. There are multiple other chronic pain conditions including depression and anxiety in the first 10 conditions of disability.**

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