Introduction: Intractable pain following calcaneal fracture fixation is a rare, but debilitating complication for a patient. The aim of this study was to assess if a double axonal crush with deep peroneal nerve (DPN) implantation is effective in alleviating residual intractable pain following surgical repair of Sanders III and IV calcaneal fractures.

Methods: Eleven patients underwent DPN resection, double axonal crush, and bone implantation for entrapment of the distal portion of the DPN confirmed via EMG with a mean follow-up period of 26 months. The Visual Analog Scale and Quality of Life were used as scoring systems.

Results: Results show a statistically significant (p < 0.01) improvement in VAS with mean 6.6 point improvement with no stump neuroma noted at the annual follow-up.

Discussion: DPN resection, double axonal crush, and implantation into the tibia offers promising results, and further studies may be warranted to confirm as a valid treatment option.

Keywords: Double axonal crush; Deep Peroneal Nerve; Intractable pain; Calcaneal fracture; Sanders III and IV
The present study assesses our double axonal crush technique with distal deep peroneal nerve (DPN) neuro-osteodesis is effective in alleviating residual intractable pain after treatment for Sanders III and IV calcaneal fracture. The Sanders classification system describes calcaneal fractures based on the number of fracture fragments seen on CT in the coronal plane. Sanders I consists of a non-displaced fracture of the posterior facet. Sanders II consists of 2 displaced articular fragments involving the posterior facet. A Sanders III consists of three articular fragments involving the posterior facet with displacement. Finally, a Sander IV has greater than 3 articular fragments. Each level of the classification can be subdivided into A, B, C depending on the laterality of the fracture lines [13].

Methods
Assessment tools used in this case series where the visual analog scale (pain), numerical rating scale (pain), Quality of Life Questionnaire, and Sander’s calcaneal fracture classification system. Eleven patients (10 male, 1 female) with a history intra-articular calcaneus fractures (Sanders III and IV) with evolving subtalar pain to the level of incapacitation despite previous treatment for pain symptoms, seen between May 2011 and June 2015, were included in this study. Each patient received various treatments such as external fixation STJ distraction, physical therapy, STJ injections, offloading walking boots, and orthotics. These treatment modalities did not resolve patient pain long term. AP and lateral x rays revealed narrowing of the subtalar joint, associated with pain on STJ ROM (Figure A). A diagnostic block of the deep peroneal nerve noted a temporary relief in pain. Clinically, the only findings on EMG or NCV was decreased nerve conduction velocity to the extensor digitorum brevis muscle. It was determined by the authors through multiple discussions with the patients that resection, double axonal crush, and implantation into the tibia of the distal Deep Peroneal Nerve could drastically decrease patient’s pain with decreased incidence of neuroma formation.

All patients were cleared for surgical intervention by their primary care physicians. In the operating room, patients were placed supine and in bumped slight lateral decubitus position with a hip bump placed under the ipsilateral hip. The affected leg was scrubbed prepped and draped in the usual aseptic manner. Due to the deep peroneal nerve location on the floor of the anterior compartment of the leg, it was determined that a lateral approach would provide less trauma, better exposure, and easier dissection.

The anterior and posterior borders of the fibula were palpated as noted in (Figure B). A linear mid lateral compartment incision was made to be obtained to avoid all vital neurovascular structures. The superficial peroneal nerve was identified and retracted out of the field of dissection. Peroneus Brevis and Peroneus Longus were then displaced posteriorly to expose the fibula. At this time the anterior lateral compartment septum was visualized and incised exposing Peroneus Tertius. Peroneus Tertius was then reflected anteriorly exposing the interosseous membrane between the anterior and deep posterior compartments. The neurovascular bundle of the anterior compartment was identified at the floor of the anterior compartment and dissected in order to identify the Deep Peroneal Nerve (Figure C). The Deep Peroneal Nerve was dissected out in the distal one third of the lower extremity. An external neurolysis was performed on the deep peroneal nerve. The nerve was cut distally and a double axonal crush was performed on the proximal end of the nerve cut (Figure D). The tip of the proximal end of the nerve cut was cauterized with bipolar Bovie. The tibia was then exposed and a drill hole was made into the tibia (Figure E). The proximal end of the deep peroneal nerve was then buried into the drill hole of the tibia (Figure F). The nerve was secured to the tibia using a periosteal epineural stitch with 11.0 suture. The knee was then run through ROM to ensure know displacement of the nerve. Fascia was repaired and skin was closed.

Figure A: Lateral view x ray showing narrowing of the subtalar joint.
The post-operative course for all patients was non-weightbearing and no dressing change to the surgical limb for 12–14 days. Pain control as achieved with a multimodal oral medication regimen of Tylenol 1000 mg TID, tramadol 50 mg TID, and Lyrica 100 mg TID. At first dressing change sutures and/or staples were removed and the patient was advanced to weightbearing as tolerated in an offloading boot. Patient’s then advanced to regular shoe gear as tolerated.

The results of resection, double axonal crush, and implantation of the DPN and subsequent bone implantation were reviewed.
Results

Patients were followed for an average of 26 months (14–41) with VAS pain decreasing, on average, by 6.6 points as shown in Table 1. The results, summarized in Table 1, were found to be statistically significant with a p value <0.0001. The results of the pre and postoperative Quality of Life Questionnaires also demonstrated subjective decrease in pain and increase in quality of life after undergoing the procedure. The VAS pain improvement range was 4–8 points, alleviating a significant amount of pain in all patients. Post-operative clinical evaluation along with EMG and NCV yielded no stump neuroma formation.

Discussion

We describe here a series of patients with intractable lower-limb pain of long duration after Sanders Type III and IV Calcaneal fracture with symptomatic subtalar joint narrowing relieved by a surgical procedure to the deep peroneal nerve. Preoperative NCV revealed decreased nerve conduction velocities to the EDB. Dissection, revealed that the deep peroneal nerve was trapped in scar tissue that tethered the nerve to adjacent structures causing neuropathic pain. This coupled with biomechanical pain caused from secondary arthritis to the subtalar joint after injury giving the patients two modalities of causation for overall pain.

The patients experienced significant relief of their neuropathic pain symptoms (i.e. burning, allodynia, hyperalgesia) after the operations. This suggests that the neuropathic pain syndrome was dependent on neural activity originating distal to the resections [14]. This is consistent with the observation that neuropathic pain can be temporarily eliminated by local anesthesia of a nerve, which was demonstrated in our patient population preoperatively. Such a result challenges the concept that central neuroplastic changes always become permanent and independent of a peripheral afferent drive [15].

The fact that neuropathic pain did not return after the operation seems to be due to the lack of stump neuroma formation secondary to performing a double axonal crush on the deep peroneal nerve proximal to resection site and burying the nerve into bone.

Conclusions

The option of peripheral nerve surgery should be more recognized for long standing intractable leg pain that has failed conservative management. A surgeon skilled in nerve reconstruction and familiar with the techniques described in this case is essential for efficacy. Crushing the nerve proximal to the neuroma excision also seems to be essential for a positive outcome [7, 11]. It is also necessary to search for nervous adhesions. Involvement of a nerve(s) with a significant motor component may be a
contraindication. In these cases, the deep peroneal nerve was resected distal to motor branches to leg musculature, and proximal to branches to intrinsic muscles of the foot. These extensor digitorum brevis was deemed to be worth sacrificing because it is a supplementary muscle and is expendable [16]. That, coupled with decreased nerve conduction velocities to EDB clinically led the surgeon to proceed with the nerve transection. The risk that this type of surgery may fail or even exacerbate pain is unknown, and the true outcomes of this procedure can only be known from careful, quantitative follow-up of many other cases.

Ethics and Consent
We confirm that we have read the Journal’s position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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Author Contributions
• David Hoeft: Statistical analysis, wrote paper.
• Henry Spingola: wrote paper.
• Edguardo Rodriguez: performed procedure.

Guarantor
Edgardo Rodriguez is the guarantor.

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