

Cuboplasty: A novel approach to management of traumatic cuboid fracture with impeding peroneal tendon imposition

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This study describes a minimally invasive operative technique commonly described for vertebral compression fractures. This was applied to a rare presentation of cuboid injury with peroneal tendon entrapment. A chart review was performed of a 35-year-old male following an all-terrain vehicle accident. The patient was subject to a dorsiflexion/inversion crush injury to the left foot. Initial radiographs from an outside facility were inconclusive for osseous abnormality. Upon presentation to the clinic, radiographs were concerning for compression fracture of the cuboid. An MRI revealed a comminuted fracture of the cuboid with entrapment of the peroneus longus tendon. The patient underwent peroneus longus tendoscopy in conjunction with percutaneous balloon kyphoplasty for reduction of the fracture and the interposed peroneal tendon. The cuboid fracture was then stabilized using injectable calcium sulfate bone cement. The patient experienced a timely return to function with significant pain improvement quantified by AOFAS scores obtained in the postoperative period. This study demonstrates the utilization of an innovative, minimally invasive operative technique in the foot and ankle. Through use of various imaging modalities and a novel procedure, the patient returned to previous levels of function. This unique practice offers advancement of current treatment methods.

Keywords: cuboplasty, inflatable bone tamp, cuboid Fracture, peroneal entrapment, tenogram, tendoscopy

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A trend toward the development of minimally invasive surgical techniques has gained momentum in recent years as benefits include equivalent outcomes with expedited recovery times and decreased risk of wound complications. Since its inception in 1945,

minimally invasive surgical techniques have continued to grow in popularity, with rapidly expanding applications in a multitude of surgical specialties. One minimally invasive procedure that has become more prevalent of late is the kyphoplasty, initially

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described as the use of a percutaneously placed inflatable bone tamp (IBT) for intraosseous vertebral fracture reduction under fluoroscopic guidance. Since being developed for use in 1998, the technique's application has expanded to orthopedic surgery for use in the extremities to now include tibial plateau and plafond, talar dome, distal radius and calcaneal fractures [1,2]. Through introduction of an arthroscopic cannula, the IBT or balloon is used to reduce peri- and intra-articular fractures. Fracture segments are then stabilized using an injectable bone graft substitute or bone cement, which has been shown to have equivalent outcomes as traditional fracture reduction and internal fixation [1-4]. The placement of fast-setting calcium phosphate cement into fresh orthopedic fracture sites has been proven to provide decreased subjective pain levels and allow earlier mobilization [2]. Additionally, other authors have demonstrated that calcium phosphate cements are superior to traditional bone graft, or no bone graft, with respect to preventing fracture subsidence [1-3]. Heim, et al., first described the successful treatment of an isolated cuboid compression fracture utilizing this technique [5].

A novel surgical approach was utilized in this case report to manage a comminuted cuboid compression fracture with peroneus longus tendon entrapment due to concerns regarding wound healing and the patient's need for expedited recovery. Peroneal longus tendoscopy was utilized to view the interposed tendon in conjunction with percutaneous IBT for intraosseous fracture reduction under fluoroscopic guidance, followed by fracture segment stabilization using injectable calcium sulfate bone cement. Adequate reduction of the cuboid fracture was confirmed along with near anatomic course of the peroneus longus tendon via intraoperative tenogram.

Case Report

A 35 year-old male presented to the Ambulatory Care Clinic after initially being treated in a community hospital Emergency Department for a left foot injury stemming from an all-terrain vehicle (ATV) accident. The patient reported he was riding at approximately 15-mph when he struck a tree root and the vehicle began to roll over. While attempting to stabilize the

vehicle, the patient's left foot was pinned beneath the ATV as it overturned, resulting in a dorsiflexion-inversion injury. The patient was unrestrained, there was no loss of consciousness at the scene and no other concomitant injury. The patient reported hearing a "pop" at the time of injury, followed by immediate pain and swelling to the left mid- and hindfoot. Initial radiographs on the day of injury were reported as negative for acute fracture or osseous abnormality. The patient was subsequently discharged and was made non-weight bearing in a compressive wrap with instructions on rest, nonsteroidal anti-inflammatory medication and outpatient follow-up in the podiatric clinic.

Upon presentation to the office, new radiographs revealed a subtle radiolucency within the body of the cuboid with associated diastasis of the calcaneal-cuboid joint, concerning fracture-subluxation (Figure 1). On clinical examination, the skin was intact and the patient was neurovascularly intact to the left foot. There was localized edema of the lateral mid- and hindfoot with tenderness upon palpation of cuboid, calcaneal-cuboid joint (CCJ), and along the course of peroneal tendons. An MRI was obtained, which confirmed a comminuted fracture of the cuboid with entrapment of the peroneus longus tendon between the fragments, a chronic partial tear of the ATFL and stenosing tenosynovitis of both peroneal tendons posterior to the distal aspect of the fibula (Figure 2).

The patient had a past medical history significant for hyperlipidemia, asthma, hypertension and was employed as a roofer by trade, being the sole provider for his family.

He was also noted to be a current pack per day smoker with a 7.5 pack-year history. Due to his medical history, current smoking status, and need for limited downtime, it was determined that the patient would benefit from a minimally invasive approach to limit the risk associated with wound complications and to provide an expedited return to function. The patient was scheduled for surgical intervention consisting of cuboid kyphoplasty and peroneus longus tendoscopy.



Figure 1 Initial anterior-posterior radiograph revealing subtle radiolucency in cuboid, and calcaneo-cuboid joint diastasis.

On the day of surgery, the patient received a preoperative popliteal and saphenous nerve block by the anesthesia team. The patient was placed supine on a radiolucent flat-top operating room table. A 2.7mm arthroscope was used for peroneal tendoscopy (Smith and Nephew Inc., Andover, MA). The tendon sheath was accessed via a small incision just distal to the lateral malleolus.

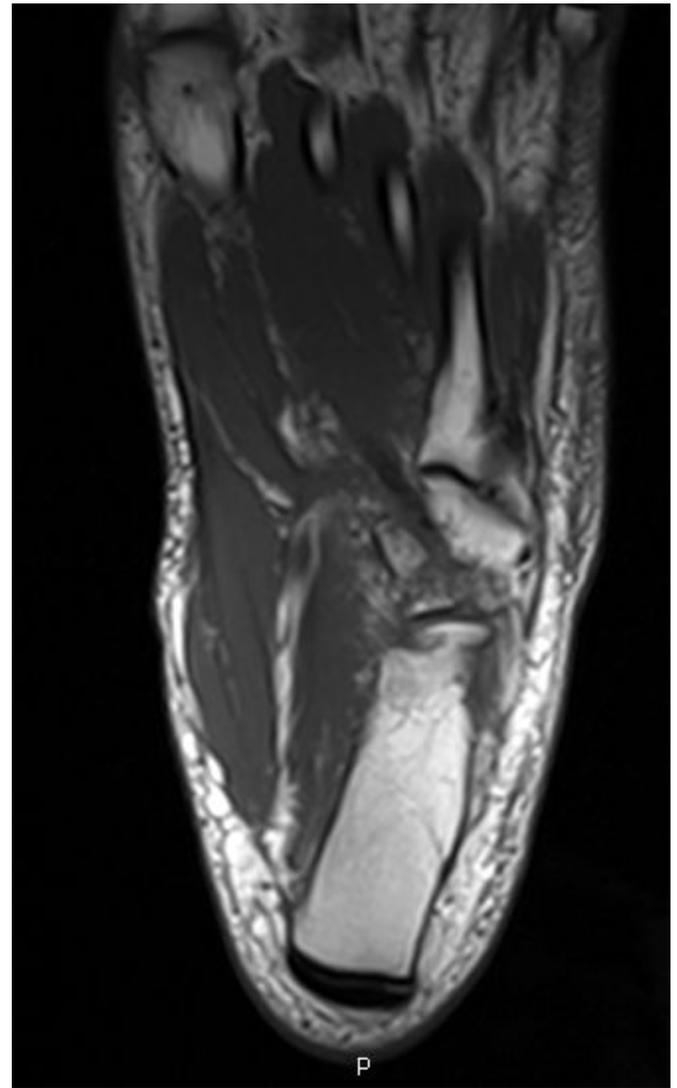


Figure 2 Axial MRI film revealing diffuse cuboid comminution and interposed peroneus longus tendon.

Tendoscopy revealed mild fraying along the course the peroneus longus tendon without rupture. Iodine contrast medium (Visipaque, General Electric Healthcare Inc, Princeton, NJ) was then injected distally into the tendon sheath to track the course of the entrapped peroneus longus tendon through the fractured cuboid fragments. Attention was then drawn to the lateral aspect of the midfoot where, under the guidance of C-arm fluoroscopy, a small incision was made at the dorsal/lateral aspect of the cuboid. The trocar/cannula was then placed under fluoroscopy through a stab incision overlying the central fracture fragment.



Figure 3 Initial medial-oblique radiograph revealing subtle radiolucency in cuboid and CCJ diastasis.



Figure 4 Initial lateral radiograph revealing subtle radiolucency in cuboid and CCJ diastasis.



Figure 5 Procedure clinical image; From left to right: Cannula, IBT, hemostat holding reduction of PL tendon prior to IBT inflation.



Figure 6 Intraoperative fluoroscopy demonstrating bone tamp inflation and reduction of fracture fragments.



Figure 7 Intraoperative fluoroscopy of bone cement placement.



Figure 8 Intraoperative tenogram revealing course of reduced peroneus longus tendon within peroneal groove.

A 1.5cm long tunnel was then drilled through the cannula with a 3.5mm drill. Two additional trocars were placed through portals utilizing a similar technique on the medial and proximal margins of the cuboid to ensure no extravasation of the bone graft substitute and also to guide the IBT during inflation. A fourth and final trocar was placed centrally over the dorsal aspect of the cuboid (Figure 3). The kyphoplasty balloon (Kyphon, Medtronic Inc, Memphis, TN) was inserted through the pre-drilled tunnel and inflated to 200 psi (Figure 4). Fracture reduction was confirmed under live fluoroscopy. This step was repeated in a second location, lateral and slightly inferior to the first position.

Following reduction, the balloon was deflated and five milliliters of flowable calcium phosphate bone graft substitute (NoriaN, Depuy-Synthes Inc, West Chester PA) were injected through the cannula into the void left in the cuboid as fracture fixation (Figure 5).

Final fluoroscopy confirmed adequate reduction of the fracture with no extravasation of the flowable bone graft substitute into the calcaneal-cuboid or lateral tarsometatarsal joint. Finally, attention was directed to the plantar aspect of the cuboid, where tenogram was repeated, which revealed the peroneus longus tendon coursing plantarly to the cuboid, representing restoration of normal anatomy. All instrumentation was removed from the surgical sites, the incisions were copiously irrigated with normal sterile saline and sutured closed with No. 3-0 nylon in portal stitch fashion. The patient was placed into a CAM boot and was instructed to remain non-weight bearing to the left foot with crutch assist for 10 to 14 days.

Once evaluated postoperatively in the office, the patient was then transitioned to weightbearing as tolerated in a CAM walker with crutch assist at two weeks postoperatively once sutures were removed. At four weeks, the patient was referred to physical therapy with focus on increasing strength and function of the affected peroneus longus muscle. Radiographs revealed interval placement of injectable calcium phosphate bone cement within the cuboid with adequate anatomical reduction of fracture. (Figures 7 and 8). The patient was able to gradually progress weight bearing as directed by physical therapy and return to full duty at six weeks postoperatively.

Final postoperative radiographs were taken at a 16-week follow up visit, which revealed the maintained position of the bone cement along with adequate alignment of the calcaneocuboid joint and anatomic cortical restoration of the cuboid (Figure 9 and 10). At both six and 12-month postoperative visits, there was notable improvement seen in both the American Orthopedic Foot and Ankle Society (AOFAS) midfoot and lower extremity functional

scores in comparison to preoperative values (Figure 11 and 12).

Figure 10 Lateral radiograph obtained 4-weeks postoperatively anatomic restoration of cuboid and calcaneocuboid joint.



Figure 9 A: Anterior-posterior radiograph obtained 4-weeks postoperative with adequate restoration of CCJ. B: Medial-oblique radiograph obtained 4-weeks postoperative with anatomic restoration of cuboid and calcaneocuboid Joint.



Figure 11 A: Anterior-posterior radiograph obtained 16-weeks postoperatively with improved cortical alignment to cuboid along with preservation of the calcaneocuboid joint. B: Medial-oblique radiograph obtained 16-weeks postoperatively with improved cortical alignment to cuboid along with preservation of the calcaneocuboid joint.



Figure 12 Lateral radiograph obtained 16-weeks postoperatively with maintained position of the bone cement spacer along with calcaneocuboid Joint alignment.

The patient was noted to have minimal pain after his six month follow-up visit and was able to fully return to pre-injury levels of activity and function. Most recently, the patient was noted to be completely pain free upon final one-year postoperative visit.

Discussion

In a typical skeletally mature foot, the cuboid bone articulates with the calcaneus, lateral cuneiform, fourth and fifth metatarsal, making it an integral contributor to the stability of the lateral column.

The restoration of the lateral column is the goal in reduction of cuboid fractures and is essential to maintain the motion and function of the foot [6]. Various fracture patterns of cuboid injury exist, ranging from avulsion, transverse and oblique body fractures, to more extensive comminuted-crush injuries commonly described as a nutcracker fracture [7]. Surgical techniques to reduce such fractures include percutaneous pinning using Kirschner wires or screws, spanning external fixator, or open reduction and internal fixation from least to most invasive. Due to the high energy associated with this injury, there is a high incidence of soft tissue insult, thus the least invasive technique is most often preferred. Percutaneous pinning and cannulated screws, however, are only possible in the presence of stable, non-comminuted fracture fragments to allow for adequate purchase to hold fixation, while external fixation is often complicated with superficial or pin-site infections. Open reduction-internal fixation with or without the addition of bone graft may be a viable option if the soft tissues are amenable but only lend itself as a viable option in non-comminuted, fairly simple fracture patterns.

Techniques used for high-energy crush injuries with a high-degree of comminution, such as spinal compression fractures and tibial plateau fractures, can be translated to the small bones of the foot. The outcomes of kyphoplasty in the spine have been shown to be quite effective with success rates as high

as 95% in significant pain relief following the procedure [1]. For intra-articular fractures of the extremities, use of an IBT followed by an injectable calcium sulfate bone cement was shown to be effective in maintaining articular reductions in a good or adequate manner at 12-weeks postoperatively [2]. Complications in kyphoplasty patients have also remained relatively low with only up to 10% of patients experiencing extrusion of bone cement [8]. By utilizing the IBT for the presenting cuboid fracture in this instance allowed for minimally invasive means for adequate reduction for the fracture fragments.

The current case report describes percutaneous balloon reduction of the cuboid and entrapped Peroneal tendons, followed by internal fixation of the fracture segments by backfilling of the defect with an injectable calcium sulfate bone cement. In a meta-analysis, authors found the infection rates were significantly lower in fractures managed with calcium phosphate bone cement than in controls who were managed with no bone graft substitute [3]. Other authors have demonstrated that the use of calcium phosphate cements is superior to traditional bone graft or no bone graft in regard to preventing fracture subsidence and allow for less pain and earlier mobilization due to its fast setting nature and lack of need for union [3,4,9]. The compressive strength of calcium sulfate bone cement has been reported as 55 megapascals, equivalent to the strength of intact cancellous bone, essentially eliminating the need and potential complications associated with the use of allograft [3,9,10].

Peroneus longus tenogram used in conjunction with cuboid fracture management has not been previously described in literature. The utility of Peroneal tenography has been demonstrated in identifying the prevalence of Peroneal tendon impingement in patients with lateral pain following calcaneal fractures [11]. Additionally, several authors have shown the efficacy of tenography in diagnosing various tendon and ligament abnormalities in the ankle to successfully dictate appropriate therapy [12].

In this case report AOFAS Midfoot and Lower Extremity functional outcome scores were collected

preoperatively, and were repeated at six and 12 months postoperatively.

	Preoperative Score	6 months Postoperative Score	12 months Postoperative Score
AOFAS Midfoot	53	82	100
LEFS	26/80= 32.5%	44/80= 55%	80/80=100%

Table 1 AOFAS and LEFS Functional Outcome Scores, taken preoperatively and at six and twelve months

AOFAS scores revealed significant increases at both the six and 12-month marks postoperatively, with scores of 82 and 100 respectively, when compared to the preoperative score of 53. The LEFS scale revealed similar results with significant increases at six and 12-month followup (55%, 100%) when considered in comparison to the preoperative value (Table 1).

Sequential radiographs taken immediately postoperatively, and again at four and 16 weeks postoperatively revealed maintenance of the internal fixation via the injectable calcium phosphate bone cement. Adequate anatomic restoration of both the calcaneocuboid joint and the cortical alignment of the plantar and lateral surfaces of the cuboid including the peroneal sulcus were also noted. On final, 16-week radiographs, there was no notable migration of the bone cement spacer, which remained confined within the cortices of the cuboid bone. Fracture fragments were noted to be stable as well, and appear to have achieved union when compared to preoperative films.

Overall, this application of percutaneous balloon reduction with use of calcium phosphate bone cement and use of tenography for management of a comminuted cuboid fracture is a viable and reproducible alternative to previously described techniques for these types of injuries. Expected risk and complication rates in our application of “Cuboplasty” should be less than or equal to those previously described for spinal kyphoplasty due to lack of proximity to vital neurovascular structures. Using an injectable calcium sulfate bone cement as opposed to bone grafting, the time to healing is

expected to decrease as compared to the traditional approach due to lack of need for biologic graft incorporation. Overall, injectable calcium sulfate bone cement proves to be an acceptable method of fixation for fracture comminution or impacted articular surfaces in various crush injuries, and in conjunction with a percutaneous reduction, this technique will allow patients to return to activity in a timely manner. Peroneus longus tenography was vital to confirm the reduction of the tendon along its natural anatomic course through the peroneal groove, which was unable to be visualized via standard intraoperative fluoroscopy. This technique allows for a percutaneous reduction of a severely comminuted cuboid fracture with restoration of the lateral column and reduction of the entrapped peroneus longus tendon while preserving the soft tissue envelope. To our knowledge, this is the second instance of this type of surgical technique described in the foot and ankle literature. We believe future studies are warranted to determine the efficacy and the long-term results of this procedure.

Conclusion

This case report demonstrates the successful utilization of an innovative, minimally invasive operative technique in the foot and ankle, previously described only once before [5]. Through use of various imaging modalities in conjunction with a novel surgical procedure, this technique allowed a patient with a complex pathology, complicated by firm medical and social restrictions, to return to previous levels of function in a pain-free and timely

manner. This unique practice offers advancement of current treatment methods.

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