Costs and Radiographic Outcomes of Rotational Ankle Fractures Treated by Orthopaedic Surgeons with or Without Trauma Fellowship Training

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Introduction

Rotational ankle fractures are common injuries treated by orthopaedists with wide levels of training and sub subspecialty interests.[1, 2] Many ankle fractures are treated by surgeons without trauma-specific training. A variety of treatment methods and techniques can lead to good results with these injuries.[3, 4] While there have been numerous technologically advanced implants made available to surgeons to fix ankle fractures, there is minimal clinical evidence to justify using advanced implants with their associated increased costs compared to less expensive traditional implants. Interestingly, many orthopaedic surgeons use technologically advanced implants to fix ankle fractures despite a lack of supporting evidence. This may result from perceptions that newer implants are easier to use and lead to superior outcomes.

We have previously described a novel tool to readily identify material-based surgical costs by surgeon and procedure, and have shown significant cost variation for similar procedures among surgeons with similar training.[5] We have been unable to identify any studies examining the differences in care between orthopaedic surgeons with or without formal trauma fellowship

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training. The purpose of our study was to identify if there are practice differences between trauma trained orthopaedic surgeons (TTOS) and non-trauma trained orthopaedic surgeons (NTTOS) that specifically result in differences in ankle fracture surgical implant-related costs. In addition, we interrogated whether formal trauma training influenced the likelihood of technical success in rotational ankle fracture surgery. We hypothesized that formal trauma training would result in decreased surgical implant-related costs, but would not improve technical execution of surgery in patients sustaining ankle fractures.

Methods

Patient selection

Following approval of our Institutional Review Board, we identified surgically treated rotational ankle (malleolar and syndesmotic) fractures from July 2013 to June 2014 in our hospital system that includes one Level One trauma center and seventeen community-based hospitals. Eight of the seventeen hospitals were chosen for this study based on proximity, compatibility of the electronic medical records, and compatible radiology systems. Ankle fractures were identified using a CPT code search for codes 27792 (lateral malleolar with medial widening), 27814 (bimalleolar), 27822 (trimalleolar), 27823 (trimalleolar), and 27829 (syndesmosis). This identified fractures in the OTA44-A-C injury constellation. We excluded patients with open physes, open fractures, pilon fractures, isolated medial malleolus fractures, definitive treatment with external fixation, and treatment performed by surgeons who left our system during the study period. Patients treated definitively with external fixators were removed due to this type of treatment suggesting higher complexity of injury. In addition, cases that included multiple procedures in a single setting unrelated to the ankle fracture were excluded. The patient were separated in to two groups. The TTOS group included patients whose surgeon had participated in a one year orthopedic trauma fellowship. The remainder of patients were in the NTTOS group. The majority of the NTTOS group was composed of general orthopedic surgeons, with remainder being specialists in non-trauma areas of orthopedics. The majority of the group, ,57% of the NTTOS group, and 85% of the TTOS group, had been in practice less than 15 years.

Patients with poor quality follow-up radiographs or lack of definitive healing at final radiographic follow-up were excluded from the radiographic analysis evaluating maintenance of fixation but were included in the cost analysis and the evaluation of the initial fracture reduction. Minimum radiographic follow-up was six weeks to determine construct stability. While this is a fairly short follow up time frame, the vast majority of the constructs were stable at this time point. There was only one case with an intact construct at six weeks that went on to late displacement, which occurred at 10 weeks postoperative.

Radiographic analysis

The quality of the initial reduction and final follow-up reduction was blindly graded by three trauma fellowship-trained surgeons using previously defined criteria: acceptable or unacceptable reductions based on less than 2 mm of displacement of any fracture line near the joint or 2 mm of translation of the talus relative to its normal articulation with the tibial plafond.[6] Syndesmotic injuries were evaluated using the same criteria for the position of the talus as well as symmetry of the mortise medial clear space, congruency of the lateral talus and medial fibula, and position of the fibula on the lateral radiograph. The reduction of the syndesmosis could only be assessed in relative terms as neither postoperative CT scans nor comparison views of the contralateral ankle were available. The ability to accurately assess syndesmosis reduction with plain radiographs is limited as demonstrated in many studies.[7-11] Identical criteria were used to grade both the initial reduction and the final reduction. Fixation failure was defined as a change from acceptable reduction to unacceptable reduction (using identical criteria used for the intraoperative reduction described above) between the initial and final radiographs. Review of the radiographs was also performed to verify implant data such as use of locking plates, cannulated screws, and suture button fixation. Radiographic data of TTOS were compared to NTTOS using Fisher's Exact test.

Cost analysis

The utilization and costs of operating room implants and supplies was analyzed with a proprietary analysis tool that we have developed.[5] This tool identifies all disposable supplies used in the operating room such as surgical implants, drills, bone graft substitutes, drapes, and suture. All disposable, implantable, or chargeable items used in the operation are identified from inventory and charge records. These data are used to generate a cross tab on a standard data spreadsheet in which every column represents an operation, listing the patient by medical record number and the primary surgeon (Figure 1). Each row in the cross tab is assigned to a single item (product) listed with the manufacturer and the cost. The cost per item that is listed in the cross tab is the institutional cost; therefore, to avoid violating any confidentiality agreements that our health system has with vendors, costs were corrected to list price prior to data analysis. Each cell in the cross tab lists the quantity of an item used (row) for a given operation (column). The total cost of each operation is calculated by summing all the cost × quantity products for each column. The utilization of implants was confirmed by evaluation of post-operative radiographs. Plates were categorized as one of four groups, in descending order of cost: anatomic locking plates (highest cost), standard locking plate with locking screws, standard locking plate with non-locking screws, and non locking plate (lowest cost). "Standard locking plates" refers to straight "locking small fragment" type plates, usually 1/3 tubular or locking compression plates. Mean and median case costs were calculated for each surgeon group. Other variables included in the analysis were medical comorbidities, surgical time as defined by incision to closure, and planned or unplanned return to surgery. TTOS and NTTOS costs were analyzed via Mann-Whitney U test. Implant usage and comorbidity data were compared using Fisher's exact test.

Results

Patient Demographics

Our CPT code search yielded 295 fractures treated by the 9 institutions over the one-year period. Ninety-one met exclusion criteria (open fractures, multiple injuries treated under one anesthetic, patients treated by surgeons who left our system) leaving 204 fractures for cost analysis, 115 in the TTOS group and 89 in the NTTOS group. Table 1 shows patient demographic comparisons between the two groups of surgeons. Table 2 shows fracture patterns between the two groups. Trimalleolar fractures where the posterior lip was not fixed were placed in the bimalleolar group.

Cost Analysis

The median operative cost for the NTTOS group was $2406 (range $607 to $5274) versus $1004 (range $590 to $5684) for the TTOS group ($P<0.001$). Median values were felt to be more representative than mean values due to the non-normal distribution of case costs. Table 3 demonstrates a significantly increased use of locking plates (including distal fibula anatomic plates, locking 1/3 tubular plates, and locking medial plates), cannulated screws, and suture button fixation in the NTTOS group (Figure 2). A cost comparison of a typical lag screw with lateral plate and medial malleolus screws construct is shown in Table 4, demonstrating the difference between a non-locking construct with standard medial screws and a distal fibular locking construct with cannulated medial screws.

Radiographic Outcomes, Complications, and Return to Surgery

Three patients included in the cost analysis lacked immediate postoperative radiographs. Initial radiograph review revealed acceptable fracture reductions in 198 of 201 fractures (99%) with the 3 unacceptable reductions (no revision surgery performed) being in the NTTOS group (P=0.09). Eleven TTOS and 10 NTTOS patients were lost to follow-up prior to the 6-week postoperative radiograph or had equivocal healing at the 6-week postoperative radiograph. There were 5 cases in which fracture reduction changed from acceptable to unacceptable during the follow-up period, i.e., fixation failures. Thus, 98/101 (97%) patients in the TTOS group and 74/79 (94%) patients in the NTTOS group had acceptable reductions at final follow-up (P=0.30). Three fixation failures occurred with locking plate cases, and 2 occurred with non-locking plates (P=0.66). The mean surgical time for the TTOS group was 71 minutes (15-157) versus 69 minutes (19-161) for the NTTOS group (p=.88). A total of 25/115 patients in the TTOS group (22%) and 13/89 patients in the NTTOS group (15%) returned to surgery (p=.21). Reasons for return to surgery in the TTOS group were implant removal (20), irrigation and debridement of infection (3), , secondary syndesmotic reconstruction (1), removal of intraarticular bone fragment (1), and ankle arthroscopy (1).Reasons for return to surgery in the NTTOS group were implant removal (11), implant removal and arthroscopy (1), and below knee amputation (1)(BKA performed by the TTOS group on a patient initially in the NTTOS who had failure of fixation and wound complications).

Discussion

Value in healthcare is rapidly becoming an area of focus among healthcare researchers and administrators. [12] It is generally defined as the ratio of quality of care to the cost of care and can therefore be affected by changes in care quality and cost.[13] Historically, physicians have been held accountable for providing quality care with minimal focus on cost. However, the focus on the cost of care is rapidly changing throughout multiple facets of the modern healthcare environment. It is now common for surgeons to be exposed to cost control measures such as gain sharing, bundled payment models, inventory control incentives, or administration mandates.[13-21] Despite these trends, orthopaedic surgeons often have little understanding of the costs of the surgical procedures and associated implants.[22] In addition, surgeons have few tools that can provide them meaningful surgical cost data. The development of such a tool at our institution has led to investigation in this area. Surgeons typically have ready access to newly developed implants that are usually more expensive than traditional implants. However, evidence is remarkably lacking that technologically advanced implants for fracture care have improved outcomes. Surgeons may have a variety of reasons for using newer implants such as perceived patient benefit, ease of use, hospital inventory, and personal preference. In addition, these implants typically do not require proof of added patient benefit to be approved. They simply need to be proven to be safe for use. Therefore, appropriate use of these implants is left to surgeon discretion. Taken together, this means that maintaining or improving surgical value is largely the surgeon's responsibility.

The intraoperative material cost data in our study demonstrated that NTTOS group more than doubled the case cost of the TTOS group. This is despite a higher proportion of syndesmotic fixation and posterior lip fixation in the TTOS group. This was primarily driven by increased use of locking plates, cannulated screws, and suture button fixation in the NTTOS group. There is scant clinical evidence supporting the use of locking plates in most fractures including rotational ankle fractures. It is possible that the disparate use of these constructs between the two groups is related to surgeon preference, ease of use due to their pre-contouring, and perception that locking plates provide increased stability and thus improves outcomes. However, our data demonstrated that using advanced implants did not improve surgical reduction at the time of injury or at follow up and markedly drove up surgical costs. It is important to note the cost gradient of different locking plate constructs. Anatomically precontured locking cases were the highest cost (mean $3323), followed by standard locking plates with locking screws ($1770), standard locking plates with non locking screws ($1625), and non locking plates($1021).

The use of locking plates for fixation of distal fibula fractures has been discussed in the literature as a viable option in the setting of osteoporotic and/or comminuted bone. [23, 24] Several studies have compared the mechanical stability of non-locking plates and locking plates in either sawbones or cadaveric models that reveal no significant advantage with locking technology. [25-27] In one of the few comparative clinical evaluations, Tsukada et al. [28] published a blinded, randomized controlled trial of 52 patients with AO/OTA 44B lateral malleolar fractures treated with a lag screw and either a locking or non-locking neutralization plate. There were no differences noted in time to union, complication rates, time to resolution of tenderness at the fracture site, or final SF-36 scores. [28] In summary, there is no evidence that locking plates provide clinical benefit in the treatment of rotational ankle fractures. Other studies have failed to demonstrate a clinical benefit to locking plates in other anatomic locations. [29, 30]

The use of suture-button devices to treat syndesmotic injuries with non-rigid fixation has been popularized recently. Rigby and Cottom reported a series of syndesmotic injuries treated with a suture-button technique. Of the 64 suture-button constructs used in 37 patients, the mean post-operative AOFAS score was 97 (range 90-100) with only 4 devices (6.25%) requiring removal. [31] A recent prospective randomized, multicenter trial of syndesmotic injuries compared a suture-button device to a single 3.5mm screw. The suture-button group at 12 months had significantly higher Olerud-Molander scores ($p<0.046$) and trending higher AOFAS scores ($p<0.26$). The screw fixation group had 36% implant failure (compared to 0%, $p<0.05$) and 11% loss of reduction (compared to 0%, $p<0.06$).[32] In our study, the slightly increased rate of implant removal in the TTOS group could be related to the increased use of screw syndesmotic fixation by this group compared to the increased use of suture button fixation by the NTTOS group, or to a higher rate of syndesmotic fixation utilized in the TTOS group overall. Overall, the evidence for the role of suture-button fixation is still evolving, but may turn out to be both cost effective and have better outcomes.

For our study, initial reduction, healed reduction, fixation failures, surgical duration, and return to operating room were our surgical quality metrics. Our methods obviously did not quantify clinical outcomes. However, we felt that radiographic outcomes were a meaningful surrogate to detect differences in technical success based on the premise that radiographic outcomes correlate with clinical outcomes.[33-35] Radiographic outcomes showed no differences in the quality of care of rotational ankle fractures between the NTTOS and the TTOS groups. It is unlikely that longer term outcomes would reveal differences between the two groups, but such studies would be necessary to truly detect differences in surgical quality of rotational ankle fractures treated by TTOS and NTTOS.

There was a slightly increased rate of implant removal and irrigation and debridement for infection in the TTOS group. These costs were not accounted for in the overall cost of care in these patients and clearly would have affected final costs of treatment between the two groups. While medical comorbidities (except for smoking) were similar between the two groups (Table 1), there was a higher percentage of patients that were transferred for surgical care in the TTOS group. This suggests "non-routine" injury characteristics in transferred patients (irreducible dislocation, osteoporosis, and soft-tissue injury) may have had some jurisdiction over higher complication rates. Furthermore, it is possible that there were higher numbers of polytraumatized patients treated by the TTOS group. However, these injury and patient characteristics were not quantified and remain speculative. Certainly, complications or techniques that lead to a higher return to the operating room would negate any implant savings achieved at the time of the initial surgery.

While this study focuses on the operating room material costs these are only a small portion of the total treatment costs, which would include other hospital and operating room utilization costs, anesthesia provider and other professional fees, medications, durable medical equipment, and rehabilitation related costs. Although we included operative time in our results, this was for comparison of the procedure time between the two groups from a proficiency perspective. As the times were essentially equal, it was not practical to factor the cost for operative time into the procedural costs. It should be noted that there is no uniform evidence-based methodology for calculating operative time costs. Similarly, our data do not allow us to speculate on the time cost savings of any particular implant such as cannulated screws, although the similar operative times with very disparate implant utilization between the groups would suggest there are not significant differences in implant insertion times. Total costs related to the entire episode of care would provide a more comprehensive denominator to calculate quality differences between the two groups. However, the aim of this study is to focus on specific costs directly attributable to the treating surgeon. Considering the high number of ankle fractures treated by all surgeons, cost savings of $1500 to $2000 per case could rapidly translate into large costs savings to our healthcare system.[36]

Our study clearly shows that TTOS and NTTOS successfully treat ankle fractures based on radiographic outcomes. Our data also show that surgeons who are willing to participate in value improvement efforts, education regarding implant costs and indications for use can substantially reduce operative costs without affecting surgical quality. In conclusion, our study found intraoperative material costs were more than twice as high in NTTOS group compared to TTOS. Cost differences were largely a result of the use of advanced technologies such as locking plates, cannulated screws, and suture button fixation. Advanced technologies had no effect on radiographic outcomes. Subsequent investigation needs to expand to determine how surgical choices affect clinical outcomes.

Level of Evidence: Level III

Figure Legend

Figure 1. Example of a portion of the cost analysis cross tab.

Figure 2 A and B. Preoperative and postoperative mortise radiographs of a TTOS case demonstrating non locking plate fixation and non-cannulated screws for medial fixation.

Figure 2C and D Preoperative and postoperative mortise radiographs of a NTTOS case demonstrating locking plate fixation laterally, and locking hook plate fixation medially. This procedure cost $1360 more than the procedure in Figure 2B.

Table 1: Patient Demographics	TTOS (n=115)	NTTOS (n=89)	p-value
Mean Age (range)	46 (18-91)	46 (14-96)	0.77
Transfer from another facility, n (%)	23 (20%)	3 (3%)	0.0003
Comorbidity, n (%)			
Diabetes	21 (18%)	19 (22%)	0.60
Smoker	49 (39%)	18 (20%)	0.0016
Chronic or end stage renal disease	3 (3%)	6 (7%)	0.18
Lymphedema	1 (1%)	0 (0%)	1.0
Peripheral vascular disease	4 (3%)	2 (2%)	1.0

TTOS, trauma trained orthopaedic surgeons, NTTOS, non-trauma trained orthopaedic surgeons

Table 2: Fracture Patterns	TTOS (n=115)	NTTOS (n=89)
Lateral Malleolus	52	32
Bimalleolar	49	49
Trimallolar	6	0
Syndesmotic Fixation	60	30
Maisssouve Fracture	8	8

TTOS, trauma trained orthopaedic surgeons, NTTOS, non-trauma trained orthopaedic surgeons

Table 3: Implant Usage in NTTOS versus TTOS

	NTTOS (n=89)	TTOS (n=115)	p-value*
Anatomic Locking Plates	44	7	<0.0001
Straight LP (LS)	10	1	0.001
Straight LP (NLS)	26	1	<0.0001
Cannulated Screws	35	3	<0.0001
Suture Button Fixation	14	0	<0.0001

*Two-tailed Fisher's exact test, NTTOS, non-trauma trained orthopaedic surgeons, TTOS, trauma trained orthopaedic surgeons

Table 4: Cost comparison of a typical lag screw with lateral plate and medial malleolus screws

Item	**Price per Item**	**Total**	**Item**	**Price per Item**	**Total**
7 hole 1/3 tubular plate	$156	$156	5-hole distal fib locking plate	$993	$993
2.5 drill bit	$118	$118	2.5 drill bit	$118	$118
3.5 drill bit	$125	$125	3.5 drill bit	$125	$125
3.5 cortical screw (7)	$40	$280	3.5 cortical screw (5)	$40	$200
4.0 cancellous screws (2)	$34	$68	3.5 locking screws	$205	$205
			2.4 locking screw (5)	$186	$30
Case Total		**$747**	2.0 drill bit	$132	$132
			4.0 cannulated screw (2)	$320	$640
			2.7 cannulated drill	$728	$728
			1.25 k wire (2)	$14	$28
			Case Total		**$3894**

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