Outcomes of Tibiotalcalcaneal Arthrodesis with Retrograde Anterograde Femoral Nail

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Statement of Purpose

The primary aim of this study is to review the outcomes of one surgeon's experiences with tibiotalocalcaneal arthrodesis utilizing a retrograde/anterograde femoral nail. Our secondary aim is to compare our outcomes with those reported in the literature for hindfoot arthrodesis nails. We hypothesized that outcomes would be negatively impacted by the higher risk patients with poorly controlled diabetes, peripheral neuropathy, and Charcot arthropathy. We also hypothesized that our outcomes would be similar to those of traditional hindfoot nail fixation in comparable patient populations.

Introduction

Tibiotalocalcaneal arthrodesis (TTCA) is a technically demanding surgical procedure that aims to reduce pain and provide a stable, plantigrade foot for ambulation. It is generally reserved for complex and debilitating hindfoot pathologies which include primary osteoarthritis, post-traumatic arthritis, congenital deformity, neuromuscular disease, avascular necrosis (AVN) of the talus, failed total ankle arthroplasty, and Charcot neuroarthropathy (CN). Many different techniques and hardware constructs have been described. Screw fixation, use of plates, intramedullary nails, and external fixators have been utilized to achieve bony fusion. Screw fixation has been shown to yield a relatively low union rate[1] and external fixation is correlated with higher complication rates, especially risk of infection.[2,3] Good outcomes have been reported using a various plate constructs including anterior or lateral locking plates as well as posterior blade plates.[4-6] Similar outcomes have been demonstrated with intramedullary nail fixation.[7] High fusion rates with intramedullary nail fixation are reported, with an overall 86.7% fusion in one large systematic review.[8] Although outcomes of TTCA are relatively good, there are numerous risks involved with this surgery such as non-union, malunion, peri-prosthetic fracture, wound healing issues, infection, chronic edema and chronic pain.

Intramedullary nail fixation has become an increasingly popular method of TTCA, in part due to its load sharing characteristics and superior biomechanical properties of higher bending stiffness and increased rotational stability.[9-13] As this particular procedure and fixation method have become more popular in recent years, the variety of hindfoot fusion nails has also increased. Current hindfoot nails offer better screw placement in regards to distal fixation and straight or valgus bent nails. In addition, they offer internal compression through the nail construct or external compression through mallet or the jig at the ankle and/or subtalar joint. Finally, static or dynamic locking options are available. However, despite the increasing number of hindfoot specific nails, there are still some limitations associated with these which include a narrow range of size options in length and diameter, local availability, and the cost of the implant itself. Nail length in particular has been thought to play a role in peri-prosthetic fractures and cortical hypertrophy at the proximal extent of the nail.[13-15]

Methods

The institutional review board at our university-based center approved this study with an expedited review (PRO17100205). A retrospective chart review of a single surgeon's surgical database revealed 109 tibiotalocalcaneal arthrodesis procedures with a retrograde anterograde femoral nail. Figure 1 illustrates subject selection for this study. Data collection included demographic information, co-morbidities, indications for initial procedure, and risk factors for complications.

Outcome measures included nonunion or malunion requiring revision, tibia fractures, deep infection, proximal amputation, and mortality. The total number of procedures was recorded and the time interval from primary procedure to initial revision and final revision procedure was evaluated along with overall follow-up time. The continuous variables were summarized with their mean and standard deviation. Categorical variables were summarized with frequencies and percentages. Categorical variables were then tested for an association with outcomes using Fisher's exact test and continuous variables were tested with the Wilcoxon rank sum test.

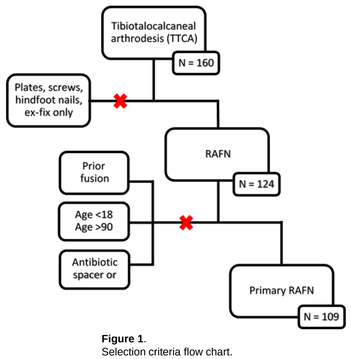

Figure 1.
Selection criteria flow chart.

Results

Variable	
Age	51.50 ± 15.23
Female	50(48%)
Left Side	44(40%)
BMI (kg/m²)	34.13 ± 10.74
Diabetes Mellitus	44(40%)
Insulin use	30(28%)
HbA1c (%) – Diabetic (n = 29)	7.75 ± 1.61
Tobacco use (active)	23(21%)
History of ulceration	28(26%)
Peripheral Neuropathy	67(61%)
Peripheral arterial disease	8(7%)
Autoimmune disorder	11(10%)
Revision	23(21%)
Time to Revision (m) (n=23)	9.38 ± 10.21
Follow-up time (m)	24.27 ± 18.59
Number of procedures Before After Total	 0.70 ± 1.08 0.81 ± 1.32 2.50 ± 1.73
External Fixator	32(29%)

Table 1. Demographics (n = 109)

Retrograde anterograde femoral nails were used for primary arthrodesis in 104 patients and 109 limbs. Fifty-four male and 50 female patients aged 51.50 ± 15.23 (range 21 - 82 years) were included in the study. The average follow-up time was 24.27 ± 18.59 months (range, 0.66 - 93.40 months). On average, patients underwent 2.50 ± 1.73 related procedures and 32/109 (29%) were placed into a circular ring external fixator prior to definitive fixation with intramedullary nailing. Twenty-three patients underwent revision procedures at an average of 9.38 ± 10.21 months. The average body mass index (BMI) at preoperative appointment was 34.13 ± 10.74 kg/m^2 (range, 20.3 – 68.1 kg/m^2). Peripheral neuropathy was the most common demographic variable among the study population, followed by diabetes mellitus, history of ulceration, and tobacco use. Less commonly reported were peripheral arterial disease and autoimmune disorders (Table 1). Over one-half of the 44 diabetic patients were insulin dependent (30/44, 68%). Glycemic control was reported with hemoglobin A1c (HbA1c) values within 3 months of the initial surgery. Data was available for 29/44 diabetic patients. The average HbA1c was 7.75% ± 1.61% in the diabetic population.

The most common indication for TTCA was Charcot arthropathy with 42 (39%) of all included procedures. Equinovarus deformities and arthridities were also common. Traumatic injuries or nonunion/malunion, failed total ankle replacements, and osteomyelitis were less common indications (Table 2). Primary outcome measures are reported in Table 3. Among the 104 patients, 4 (4%) had a below-knee amputation and 11 (10%) were deceased within the follow-up period. Deep infection was noted in 25 (23%) of limbs while recurrent or new post-operative ulceration was noted in 27 (25%) of the

Results

operative limbs. Other complications included nonunion/malunion requiring surgical intervention (n=20,18%), painful hardware (n=3,12%), and tibia fracture in 5 (5%) of limbs. Nearly all of the patients were ambulatory at final follow-up (n=104,96%) with many dependent on prosthesis/bracing (n=37,34%).

Four of the outcomes (ulceration, deep infection, nonunion/malunion, and below knee amputation) were evaluated for relationships with pre-operative variables and results were reported in Tables 5 – 8. Pre-operative variables which demonstrate a statistically significant relationship (p < 0.05) with an outcome are highlighted in red. Patients with diabetes mellitus, peripheral neuropathy, Charcot arthropathy, previous ulceration, and use of external fixator showed a positive correlation with post-operative ulceration (n = 27). Higher BMI and increasing number of procedures was similarly associated with post-operative ulceration while patients with osteoarthritis (OA) or post-traumatic arthritis (PTA) as their indications for surgery were negatively associated with ulceration. Although not statistically significant, higher HbA1c values trended toward outcomes with post-operative ulceration as well. Deep infections (n = 25) were positively correlated with diabetes mellitus, peripheral neuropathy, Charcot arthropathy, and revision procedures. Increasing HbA1c and increasing number of procedures were similarly associated with deep infections, while OA and PTA were again negatively correlated with the outcome. Those with a history of ulceration and with use of external fixator trended toward a significant correlation with deep infection. For nonunion/malunion (n = 20), peripheral neuropathy, Charcot arthropathy, revisions, and a greater number of procedures were positively correlated with the outcome. Patients with diabetes mellitus and peripheral neuropathy, as well as those with greater number of procedures, were positively correlated with an outcome of below-knee amputation (n = 4). Osteoyelitis and use of external fixator, although not statistically significant, trended toward this outcome too.

Indication	
AVN of Talus	15(14%)
Fracture	3(3%)
Failed total ankle	1(1%)
Nonunion/Malunion	5(5%)
Osteomyelitis	15(14%)
Equinovarus deformity	31(28%)
Osteoarthritis	18(17%)
Post-traumatic arthritis	19(17%)
Charcot Arthropathy	42(39%)

Outcome	
Nonunion/Malunion	20(18%)
Deep Infection	25(23%)
Tibial Fracture	5(5%)
Ulceration	27(25%)
Painful Hardware	13(12%)
Ambulatory Status	104(96%)
Prosthesis/Bracing	37(34%)
Below-knee Amputation	4(4%)
Deceased	11(10%)

Tables 2 & 3. Indications for and outcomes of procedures (n = 109)

Discussion

Tibiotalocalcaneal arthrodesis with intramedullary nail fixation is a successful method for treating complex hindfoot and ankle deformities with high overall fusion and/or limb salvage rates, but high overall complications rates. Our results are comparable to what is reported in the literature. The overall nonunion/malunion rate of 18% and revision rate of 21% is similar to the overall fusion rate of 86.7% and revision rate of 22% reported in a systematic review of 613 patients with 641 procedures (Jehan).

Our hypothesis that outcomes would be negatively impacted by the higher risk patients with poorly controlled diabetes, peripheral neuropathy, and Charcot neuroarthropathy was shown to be at least partially true. Our data suggests that CN, poorly controlled diabetes mellitus, peripheral neuropathy, ulceration, and increased body-mass-index were all negatively correlated with at least one of the outcomes reviewed. On the contrary, patients who underwent TTCA for primary osteoarthritis or post-traumatic arthritis seemed to have better outcomes in regards to post-operative ulceration and infection. Only diabetes mellitus, history of ulceration, and total number of procedures were statistically associated with major amputation, but this is likely secondary to the small number of patients involved. There were 11/104 (10%) patients deceased within the follow-up period as well. No cases were directly related to their TTCA (infection/sepsis, PE), which suggests an overall unhealthy patient population.
Although our data is presented in aggregate for all indications for TTCA, a large proportion 42/104 (39%) of our procedures were performed in CN patients. When comparing our outcomes to literature for this patient population, our results are comparable, with a limb salvage rate of 105/109 (96%). One study of 18 CN patients demonstrated a 71.4% union rate and a 92.8% limb salvage rate for treatment of rearfoot and ankle charcot with TTCA via IMN (caravaggi) and another review showed a limb salvage rate of 100 % in a series of 18 TTCAs (Dalla Paolla). Similarly, Chraim et al reported a CN limb salvage rate of 16/19 with 3 patients having below knee amputation for persistent infection.

In order to address some of the shortcomings of current hindfoot arthrodesis nails, we have utilized a retrograde/anterograde femoral nail (RAFN) which is commonly available for trauma applications and offers a wide range of size options (length 160 – 480 mm, diameter 9 – 15 mm). Thordarson identified an area of radiographic lucency about the proximal tip the IMN and theorized an area of local stress concentration, while Pinzur later described five patients who developed displaced stress fractures in the same area, which he later overcame with the use of a longer femoral nail. The RAFN has a 1500 mm femoral anteversion, which correlates to approximately 5˚ of valgus bend when inserted appropriately (Fig 6). In addition, the cost of the implant at our institution is 44% less expensive ($1415 vs. $2524) compared with the available hindfoot specific nail. Another advantage of the femoral nail is the option to add a spiral distal interlocking plate for superior purchase in soft or osteoporotic bone (Fig 2-4, 6). Of course, there are some disadvantages of utilizing this femoral nail, including lack of any internal compression component and no integrated talar screw fixation. To overcome this, we often augment with an additional 6.5 mm headed partially threaded cancellous screw from the plantar calcaneus crossing the subtalar and ankle joints and purchasing the distal anterior tibia (Fig 5). A cadaveric study suggests that screws provide less compression compared with intrinsically compressive IMN or plate fixation; however, this does not directly assess the utility of our screws augmenting a non-compressive IMN (Hamid). A technical disadvantage is free handing perfect circles for proximal interlocking fixation; however, this is often necessary with the longer hindfoot specific nails as well secondary to deflection with jig systems.

Figure 2. Pre- and post-operative radiographs with correction for midfoot Charcot

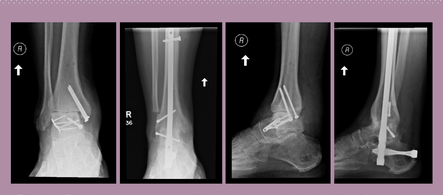

Figure 3. Pre- and post-operative radiographs with avascular necrosis of the talus

Figure 4. Pre- and post-operative radiographs with equinovarus deformity

Fig 5. Augmentation screw for compression.

Fig 6. Demonstrates 5˚ valgus bend.

	Ulcer (n = 27)	No Ulcer (n = 82)	p–value
Age	52.85 ± 12.57	51.05 ± 16.05	0.60
Female	11(41%)	39(51%)	0.38
BMI	39.11 ± 10.69	32.90 ± 9.80	0.01
Diabetes Mellitus	20(74%)	24(29%)	<0.0001
HbA1C (n = 29)	8.28 ± 1.72 (n=15)	7.17 ± 1.31 (n=14)	0.08
Smoker	3(11%)	20(24%)	0.14
History of Ulceration	11(41%)	17(21%)	0.04
Peripheral Neuropathy	21(78%)	46(56%)	0.04
AVN or Failed TAR	3(11%)	13(16%)	0.76
Fracture	0(0%)	3(4%)	0.57
Osteomyelitis	7(26%)	8(10%)	0.05
Equinovarus Deformity	5(19%)	26(32%)	0.19
OA or PTA	4(15%)	32(39%)	0.02
Charcot Arthropathy	18(67%)	24(29%)	0.001
Revision	8(30%)	15(18%)	0.21
Time to Revision (n = 23)	12.38 ± 15.61 (n=8)	7.53 ± 6.31 (n=15)	0.82
Total # Procedures	2.44 ± 1.76	1.20 ± 1.61	0.001
External Fixator	14(52%)	18(22%)	0.0003

Table 5. Outcome = Ulceration (n = 109)

	Infection (n = 25)	No Infection (n = 84)	p–value
Age	49.72 ± 14.55	52.02 ± 15.47	0.51
Female	10(43%)	40(49%)	0.62
BMI	37.54 ± 12.44	33.51 ± 9.51	0.09
Diabetes Mellitus	15(60%)	29(35%)	0.02
HbA1C (n = 29)	8.82 ± 1.57 (n=10)	7.19 ± 1.36 (n=19)	0.02
Smoker	6 (24%)	17(20%)	0.69
History of Ulceration	10(40%)	18(21%)	0.06
Peripheral Neuropathy	20(80%)	47(56%)	0.03
AVN or Failed TAR	4(16%)	12(14%)	0.76
Fracture	0(0%)	3(4%)	1.00
Osteomyelitis	6(24%)	9(11%)	0.11
Equinovarus Deformity	6(24%)	25(30%)	0.58
OA or PTA	2(8%)	34(40%)	0.002
Charcot Arthropathy	15(60%)	27(32%)	0.01
Revision	11(44%)	12(14%)	0.001
Time to Revision (n = 23)	10.25 ± 13.85 (n=12)	8.09 ± 4.99 (n=11)	0.29
Total # Procedures	3.32 ± 1.77	0.96 ± 1.30	<0.0001
External Fixator	11(44%)	21(25%)	0.07

Table 6. Outcome = Deep Infection (n = 109)

	Nonunion/ Malunion (n = 20)	No Nonunion/ Malunion (n = 89)	p–value
Age	49.40 ± 13.48	51.97 ± 15.62	0.50
Female	8(40%)	42(50%)	0.42
BMI	35.46 ± 10.17	34.21 ± 10.41	0.63
Diabetes Mellitus	11(55%)	33(37%)	0.14
HbA1C (n = 29)	8.30 ± 2.09 (n=9)	7.51 ± 1.33 (n=20)	0.29
Smoker	7(35%)	16(18%)	0.13
History of Ulceration	6(30%)	22(25%)	0.63
Peripheral Neuropathy	17(85%)	50(56%)	0.02
AVN or Failed TAR	1(5%)	15(17%)	0.30
Fracture	0(0%)	3(3%)	1.00
Osteomyelitis	5(25%)	10(11%)	0.15
Equinovarus Deformity	4(20%)	27(30%)	0.35
OA or PTA	5(25%)	31(35%)	0.40
Charcot Arthropathy	12(60%)	30(34%)	0.03
Revision	12(60%)	11(12%)	<0.0001
Time to Revision (n = 23)	7.33 ± 5.21 (n=12)	11.27 ± 14.14 (n=11)	0.73
Total # Procedures	3.10 ± 1.62	1.15 ± 1.55	<0.0001
External Fixator	8(40%)	24(27%)	0.25

Table 7. Outcome = Nonunion/malunion (n = 109)

	BKA (n = 4)	No BKA (n = 105)	p–value
Age	56.00 ± 12.03	51.32 ± 15.43	0.52
Female	3(75%)	46(46%)	0.34
BMI	37.73 ± 2.06	34.41 ± 10.50	0.18
Diabetes Mellitus	4(100%)	40(38%)	0.03
HbA1C (n = 29)	8.15 ± 0.64 (n=2)	7.72 ± 1.66 (n=27)	0.58
Smoker	0(0%)	22(21%)	0.58
History of Ulceration	3(75%)	25(24%)	0.05
Peripheral Neuropathy	4(100%)	62(60%)	0.16
AVN or Failed TAR	0(0%)	16(15%)	1.00
Fracture	0(0%)	3(3%)	1.00
Osteomyelitis	2(50%)	13(13%)	0.09
Equinovarus Deformity	1(25%)	29(28%)	1.00
OA or PTA	0(0%)	36(35%)	0.30
Charcot Arthropathy	3(75%)	39(38%)	0.30
Revision	2(50%)	21(20%)	0.20
Time to Revision (n = 23)	4.00 ± 4.24 (n=2)	9.71 ± 10.74 (n=21)	0.39
Total # Procedures	3.50 ± 2.08	1.44 ± 1.68	0.04
External Fixator	3(75%)	29(28%)	0.08

Table 8. Outcome = Below knee amputation (n = 109)

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