A New Look at the Hawkins Classification for Talar Neck Fractures: Which Features of Injury and Treatment Are Predictive of Osteonecrosis?

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Background: Osteonecrosis and posttraumatic arthritis are common after talar neck fracture. We hypothesized that delay of definitive fixation would not increase the rate of osteonecrosis, but that the amount of initial fracture displacement, including subtalar and/or tibiotalar dislocations, would be predictive. We investigated the possibility of dividing the Hawkins type-II classification into subluxated (type-IIA) and dislocated (type-IIB) subtalar joint subtypes.

Methods: The cases of eighty patients with eighty-one talar neck and/or body fractures who had a mean age of 36.7 years were reviewed. The fractures included two Hawkins type-I, forty-four type-II (twenty-one type-IIA and twenty-three type-IIB), thirty-two type-III, and three type-IV fractures. Open fractures occurred in twenty-four patients (30%).

Results: One deep infection, two nonunions, and two malunions occurred. After a mean of thirty months of follow-up, sixteen of sixty-five fractures developed osteonecrosis, but 44% of them revascularized without collapse. Osteonecrosis never occurred in fractures without subtalar dislocation (Hawkins type I and IIA), but 25% of Hawkins type-IIB patterns developed osteonecrosis ($p = 0.03$), and 41% of Hawkins type-III fractures developed osteonecrosis ($p = 0.004$). Osteonecrosis occurred after 30% of open fractures versus 21% of closed fractures ($p = 0.55$). Forty-six fractures were treated with urgent open reduction and internal fixation (ORIF) at a mean of 10.1 hours, primarily for open fractures or irreducible dislocations. With the numbers studied, the timing of reduction was not related to the development of osteonecrosis. Thirty-five patients had delayed ORIF (mean, 10.6 days), including ten with Hawkins type-IIB and ten with Hawkins type-III fractures initially reduced by closed methods, and one (5%) of the twenty developed osteonecrosis. Thirty-five patients (54%) developed posttraumatic arthritis, including 83% of those with an associated talar body fracture ($p < 0.0001$) and 59% of those with Hawkins type-III injuries ($p < 0.01$).

Conclusions: Following talar neck fracture, osteonecrosis of the talar body is associated with the amount of the initial fracture displacement, and separating Hawkins type-II fractures into those without (type IIA) and those with (type-IIB) subtalar dislocation helps to predict the development of osteonecrosis as in this series. It never occurred when the subtalar joint was not dislocated. When it does develop, osteonecrosis often revascularizes without talar dome collapse. Delaying reduction and definitive internal fixation does not increase the risk of developing osteonecrosis.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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A commentary by Sheldon S. Lin, MD, and Nicholas J. Montemurro, is linked to the online version of this article at jbjs.org.

Fractures of the talus occur infrequently and remain a treatment challenge[1-11]. Over the past twenty years, substantial improvements have occurred with respect to surgical treatment of these fractures. A refined understanding of both local anatomy and the complexity of the osteology have enhanced surgical tactics, such that many surgeons routinely employ dual anteromedial and anterolateral exposures to improve the quality of reduction[12-14]. A variety of mini-fragment and small-fragment implants have proven effective in maintaining fracture alignment, and these may be readily placed through the aforementioned exposures without damage to the local blood supply[12,14].

Despite these advances, several authors have reported minimal improvements in the frequency of osteonecrosis of the talar body and posttraumatic arthritis compared with earlier studies[15-23]. Certainly, a high-energy trauma event causing a talar fracture can generate osseous, chondral, and vascular destruction[24-26]. However, surgeon control of treatment timing, the preservation of soft-tissue attachments, and the accuracy of fracture reduction may also impact the prognosis. The amount of initial fracture displacement and the duration that adjacent joints remain dislocated, versus the timing of reduction and fixation, have been considered potential risk factors for osteonecrosis[4,16,17]. While the timing of reduction of dislocations has been poorly defined in prior reports, the timing of definitive talar neck fixation has not been shown to impact the rate of osteonecrosis[19,23].

The purposes of this study were to accurately determine the timing of reduction events (versus internal fixation) and to reassess the effectiveness of the classification scheme routinely used for talar neck fractures. Originally proposed by Hawkins, this classification described three groups of injuries based on initial fracture displacement: type I indicated a nondisplaced fracture; type II, a displaced subtalar joint (subluxated or dislocated); and type III, a dislocated tibiotalar joint[5]. A fourth type, consisting of a dislocated talonavicular joint, was subsequently described by Canale and Kelly[1]. Osteonecrosis has been shown to be more common with greater initial fracture displacement, as measured by the Hawkins classification[1,5,16,22,23]. However, we believe that fractures with a complete subtalar dislocation (versus mild subluxation) are more likely to have an associated injury to the talar blood supply. We propose dividing the Hawkins type-II classification into two subtypes: IIA, those with a subluxated subtalar joint, and IIB, those with a dislocated subtalar joint. We hypothesized that type-IIB injuries would have a greater risk of developing osteonecrosis. We further hypothesized that deliberately delaying definitive open reduction and internal fixation (ORIF) of talar neck fractures, which have undergone closed reduction of associated dislocations, would result in infrequent soft-tissue complications and no increase in the rate of osteonecrosis compared with emergent definitive fixation.

Materials and Methods

We reviewed the records of eighty patients with eighty-one fractures of the talus treated at a level-I trauma center between 2001 and 2011. Forty male and forty female patients with a mean age of 36.7 years (range, seventeen to seventy-two years) were treated. There were fifty-two talar neck fractures (Orthopaedic Trauma Association [OTA] classification 81-B) and twenty-nine concurrent talar neck and body fractures (OTA classification 81-C)[27]. Fractures of the medial malleolus occurred in association with twelve of the talar neck fractures, and nineteen of the talar neck fractures had an associated lateral process fracture. The fractures were classified according to the system described by Hawkins[5]: two were Hawkins type I; forty-four, type II (twenty-one type IIA and twenty-three type IIB); thirty-two, type III; and three, type IV. Patients with other isolated talar body fractures, lateral or posterior process fractures, or osteochondral lesions were excluded from study.

The mechanisms of injury were a motor vehicle collision (forty-seven patients), a fall from a large height (twelve patients), a motorcycle crash (fourteen patients), a fall from low height (five patients), and a sports-related injury (two patients). There were twenty-four open fractures (30%). Twenty-three (28%) of the talar fractures were isolated injuries, while nineteen patients had ipsilateral foot or ankle trauma and twenty patients had contralateral foot or ankle trauma. Thirty patients (38%) regularly used tobacco, and ten patients (12.5%) reported alcohol abuse, ten (12.5%) used recreational drugs, three patients (3.8%) were receiving treatment for mental illness, and one patient (1.3%) each had diabetes mellitus and psoriatic arthritis.

All fractures were treated surgically by five orthopaedic traumatologists. On presentation, patients with open fractures received intravenous antibiotics. Urgent surgical debridement and irrigation was performed in the operating room for all open fractures. Closed reductions were attempted emergently for all dislocations. Patients with irreducible dislocations were taken urgently to the operating room for reduction. Timing of definitive fracture fixation was at the discretion of the treating surgeon. For closed fractures, attention was directed to the severity of associated soft-tissue swelling to determine surgical timing. Frequently, patients requiring an open reduction underwent definitive ORIF in the same surgical setting. Standard dual anteromedial and anterolateral surgical exposures were used for seventy-seven fractures (95%)[13,14]. Fixation consisted of small-fragment and mini-fragment stainless steel implants in seventy-nine fractures (98%). Postoperatively, non-weight-bearing was recommended for twelve weeks or until adequate fracture union was seen radiographically. Advancement of weight-bearing was not delayed when osteonecrosis was present nor were any braces or other supportive measures used.

Osteonecrosis was defined on ankle and foot radiographs as increased radiographic density of the talar dome, relative to the adjacent osseous structures. Collapse of necrotic bone was assessed on radiographs as articular depressions and other irregularities in the presence of increased radiographic density of the talar dome. In all cases, collapse occurred within eleven months of injury. Posttraumatic arthritis was defined as any loss of joint space or the presence of subchondral sclerosis or osteophytes, localized to the tibiotalar joint, the subtalar joint, and/or the talonavicular joint. For the patients with preexisting radiographic features of arthritis, a radiographic progression of one or more of the original findings resulted in a diagnosis of posttraumatic arthritis.

Statistical Analysis

Clinical outcome variables included the development of osteonecrosis and posttraumatic arthritis and the need for secondary reconstructive procedures. Bivariate analysis with a Fisher exact test was used to test the association between the possible predictive variables and clinical outcomes. These variables included open versus closed fractures, fracture pattern, and the presence of a talar body or a medial malleolar fracture. The Student t test or analysis of variance was used to analyze the effect of patient age and the timing of reduction and fixation. Significance was set at the $p < 0.05$ level.

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This project was not externally funded.

Results

Forty-six fractures (57%) were treated with urgent ORIF at a mean of 10.1 hours (range, five to twenty-four hours) after the injury. Twenty-two of these were open fractures (92% of all

TABLE I Rates of Osteonecrosis and Posttraumatic Arthritis Associated with Talar Fractures*

	Osteonecrosis (N = 16; 25%)	Osteonecrosis with Collapse (N = 9; 14%)	Subtalar Arthritis (N = 25; 38%)	Tibiotalar Arthritis (N = 19; 29%)
Open fracture (n = 23)	7 (30%)	2 (8.7%)	10 (44%)	7 (30%)
Closed fracture (n = 43)	9 (21%)	7 (16%)	15 (35%)	12 (27%)
Hawkins classification				
I (n = 1)	0	0	0	0
IIA (n = 19)	0	0	4 (21%)	1 (5.3%)
IIB (n = 16)	4 (25%)	3 (19%)	4 (25%)	2 (13%)
III (n = 27)	11 (41%)	5 (19%)	15 (56%)	16 (59%)
IV (n = 3)	1 (33%)	1 (33%)	2 (67%)	0
Talar body fracture (n = 23)	6 (26%)	5 (22%)	13 (57%)	14 (61%)

*Table includes data on two patients with less than twelve months of follow-up: one who had a closed type-IV fracture and developed subtalar arthritis and another who had osteonecrosis with collapse of the talar dome at five months postoperatively.

twenty-four open fractures), fifteen (19% of all fractures) were irreducible, and nine were at the discretion of the surgeon to achieve early definitive fixation, with four of these patients taken to the operating room urgently for orthopaedic surgeries other than the talus. The Hawkins classification of the fractures treated urgently included eight type-IIA (38% of all twenty-one type-IIA fractures), thirteen type-IIB (57% of all twenty-three type-IIB fractures), twenty-two type-III (69% of all thirty-two type-III fractures), and three type-IV (100% of all type-IV fractures). Thirty-five patients were treated with delayed ORIF at a mean of 10.6 days (range, three to nineteen days), including ten type-IIB and ten type-III fractures initially reduced with closed and/or percutaneous methods at a mean of 9.5 hours after the injury.

Three patients did not return for follow-up in the weeks following the surgery and were unable to be located. Of the remaining seventy-seven patients (seventy-eight fractures), one (1.3%) developed a deep infection. She had a history of alcohol abuse and psoriatic arthritis. Following surgical debridement and intravenous antibiotics, the infection had not recurred after thirty-six months. One patient with an associated open foot wound had delayed healing of the traumatic wound requiring dressing changes for three weeks. There were no cases of surgical wound dehiscence. Fourteen patients had less than eleven months of follow-up. One of the fourteen patients died from a cause unrelated to the talar injury. The remaining sixty-three patients (sixty-four fractures) were followed for a mean of 30.3 months (median, twenty-eight months [range, eleven to 120 months]). Two fractures (3.1%) developed a nonunion. One occurred after a type-IIB fracture and was successfully treated with revision ORIF with iliac crest bone-grafting. The other nonunion occurred in a patient with a type-IIA fracture with a history of nonadherence to recommended medical treatment by initiating weight-bearing one month after ORIF along with heavy tobacco usage. He did not return until twelve months after treatment, at which time a nonunion was diagnosed, and he did not return subsequently for revision surgery. Two patients (3.1%) developed malunion, both after open fractures with associated talar body fractures and Hawkins type-III talar neck injuries. One was treated with subtalar arthrodesis and the other underwent a tibiotalar arthrodesis.

Osteonecrosis of the talar body occurred in sixteen (25%) of sixty-five fractures. One of these patients had developed osteonecrosis with collapse of the talar dome five months after surgery and was subsequently lost to follow-up. Although this patient had incomplete follow-up, her findings were included with our reported complications. The mean time to the appearance of osteonecrosis on radiographs was 6.9 months (range, three to eight months). However, seven (44%) of the sixteen patients had complete revascularization of the talus (a return to normal radiographic density) without talar dome collapse.

Table I presents the data on the patients who developed osteonecrosis with or without talar dome collapse. Osteonecrosis never occurred in patients with Hawkins type-I or type-IIA fractures, even though 26% of type-IIA fractures were open. However, patients with subtalar dislocation (Hawkins type-IIB) developed osteonecrosis 25% of the time ($p = 0.03$), and those with tibiotalar dislocation (Hawkins type III) developed osteonecrosis 41% of the time ($p = 0.004$). Collapse of the talar dome occurred in 19% of all of the patients who had Hawkins type-IIB or Hawkins type-III fractures. This included three of four patients with osteonecrosis after a Hawkins type-IIB fracture who developed collapse, and five of eleven patients with osteonecrosis after a Hawkins type-III fracture who developed collapse. With the numbers studied, patient age, open fracture, or the presence of a talar body, lateral process, or medial malleolar fracture was not associated with the development of osteonecrosis or with collapse following the development of osteonecrosis. Osteonecrosis occurred after 33% of the talar fractures with an associated medial malleolar fracture and after 13% of those with an associated lateral process fracture ($p = 0.16$). Osteonecrosis occurred after 30% of open fractures versus 21% of closed fractures ($p = 0.55$). No association was found with medical comorbidities, tobacco use, or mental illness and the development of osteonecrosis.

TABLE II Mean Times from Injury to Reduction and to Definitive Fixation Related to the Presence or Absence of Osteonecrosis

	All Patients		Presence of Any Osteonecrosis		No Osteonecrosis	
	Mean Time to Reduction *(hr)*	Mean Time to Fixation *(hr)*	Mean Time to Reduction *(hr)*	Mean Time to Fixation *(hr)*	Mean Time to Reduction *(hr)*	Mean Time to Fixation *(hr)*
All fractures (n = 65)	9.5	123	10.8	39.8	9.2	150.2
Hawkins classification						
IIA*	NA	201.5	NA	NA	NA	194.4
IIB	8.6	82.1	10.2	12.1	8.1	105.4
III	10.7	98.1	11.2	55.4	10.4	127.4
IV	8.3	8.3	9.1	9.1	8.0	8.0

*NA = not applicable.

The times from injury to reduction and to definitive fixation were assessed (Table II). The timing of the reduction within six hours, eight hours, twelve hours, or eighteen hours after injury was not associated with a change in the rate of development of osteonecrosis. However, due to the small sample of patients and the low rate of osteonecrosis, the study is underpowered to detect differences among these timing groups. All patients underwent reduction within twenty-two hours of the injury, except one who presented two days after the injury. With the numbers studied, urgent definitive fixation also did not appear to reduce the rate of osteonecrosis. Patients who developed osteonecrosis underwent definitive ORIF significantly earlier than those who never developed osteonecrosis (1.7 days versus 4.8 days; $p < 0.001$). Forty-six (57%) of eighty-one fractures were treated definitively at a mean of 10.1 hours after the injury, while thirty-five fractures underwent delayed ORIF at a mean of 10.6 days. The latter group included ten Hawkins type-IIB and ten Hawkins type-III fractures initially reduced with closed or percutaneously assisted methods at a mean of 9.5 hours after the injury, and only one (5%) of these twenty patients developed osteonecrosis.

At the time of the most recent follow-up, thirty-five patients (54%) had radiographic evidence of posttraumatic arthritis in one or more joints (Table I). Arthritis was most frequent in the subtalar joint (38%) and the tibiotalar joint (29%), while three patients (4.6%) had talonavicular arthritis. Twenty-three percent developed subtalar arthritis after a Hawkins type-II injury. Arthritis was more common after Hawkins type-III injuries, with subtalar arthritis in 56% and tibiotalar arthritis in 59% ($p < 0.01$ for both versus type-II fractures). The presence of a talar body fracture was the greatest risk factor for the development of arthritis as nineteen (83%) of twenty-three patients with a talar body fracture had arthritis in one or more joints after talar body fracture ($p < 0.0001$).

Fifteen patients had eighteen fractures immediately adjacent to the talus. All of them, which included ten ankle fractures, four tibial plafond fractures, and four calcaneal fractures, were treated surgically. Posttraumatic arthritis occurred in the subtalar joint in six of these patients and in the tibiotalar joint in six. Seventy-five percent of patients with an adjacent fracture of the calcaneus or of the tibial plafond developed posttraumatic arthritis.

Eleven (17%) of sixty-five fractures underwent twelve secondary procedures for pain relief. These included four patients who underwent removal of implants. In addition, four patients had subtalar arthrodesis, one patient had a total ankle arthroplasty, one patient had a tibiotalar arthrodesis, and one had both a tibiotalar and a subtalar arthrodesis. No other secondary procedures were anticipated at the time of writing.

Discussion

Because previous work has shown high rates of osteonecrosis and posttraumatic arthritis following talar neck fractures[1,2,5,10,11,16,19-23], emphasis has been placed on expeditiously reducing and stabilizing these talar neck fractures to decrease the risk of developing osteonecrosis[4,16,17]. However, controversy exists regarding the impact of the timing of definitive fixation on the development of osteonecrosis[8,19,23]. Controversy also exists around the advisability of simultaneous anteromedial and anterolateral surgical approaches when performing ORIF[1,20]. Theoretically, the additional (surgical) insult to the blood supply via this tactic could increase the potential for the development of osteonecrosis, although, to our knowledge, this has never been demonstrated. The goal should be to achieve anatomic fracture union, while minimizing the development of complications such as infection, osteonecrosis, and posttraumatic arthritis. Optimizing surgical techniques should reduce the complications to those associated with features of the initial injury, such as damage to the cartilage, bone, blood supply, and other soft tissues[28].

The purposes of this study were to review the treatment of a series of talar neck fractures with attention to the details of the timing of reduction and to reassess the effectiveness of the classification scheme routinely used for these fractures. Our goal was to enhance the understanding of the prognosis on the basis of the initial features of the injury and the type and timing of treatment. Strengths of this study include a large sample of patients treated by experienced orthopaedic traumatologists with similar surgical technique. Weaknesses include the retrospective design and 21% of patients being lost to follow-up.

Additionally, we did not obtain functional data such as motion, strength, walking ability, employment status, or outcome scores. Despite these shortcomings, several issues of importance were addressed.

We modified the Hawkins classification system to assess patients with type-II talar neck fractures in more detail. Originally described as "the subtalar joint subluxated or dislocated, and the ankle joint normal," this group of fractures could be expected to have varying potential for disruption to the medial blood supply of the talus, depending on the degree of subtalar joint displacement or disruption[5]. By dividing the Hawkins type-II fractures into two subtypes, we demonstrated a greater risk for the development of osteonecrosis after subtalar dislocation, consistent with our hypothesis. None of our patients with type-I or type-IIA fractures developed osteonecrosis.

Osteonecrosis was associated with increased initial fracture displacement as defined by the presence of a dislocated subtalar joint. Our patients with combined subtalar and tibiotalar dislocations (type III) had an even higher risk of osteonecrosis, which is consistent with the prior literature[1,5,16,22,23]. Future study to assess vascularity in the hindfoot immediately following talar fractures with and without dislocation would be informative.

Also, we found that delay of definitive fixation of the talar neck does not appear to be associated with an increased risk of osteonecrosis. In fact, the mean time to fixation was significantly longer in the patients who did not develop osteonecrosis, perhaps because these injuries were less severe. For example, there were more open fractures in the group that underwent urgent definitive fixation. Our analysis did not account for this potential confounding effect. Prior work has suggested no association between the timing of definitive fixation and osteonecrosis[19,23], although none of those studies specifically included the timing of reduction. Our practice is to urgently reduce dislocations in the emergency department, or in the operating room when successful closed reduction in the emergency department is not possible. We believe that expeditious closed reduction will eliminate tension on the surrounding soft tissues and blood supply. The mean time to reduction in all patients with dislocations was nine hours. Because of the small number of patients, we were unable to determine an association between the timing of the reduction of dislocations and the development of osteonecrosis.

Delay of definitive fixation is associated with a low rate of soft-tissue complications. In this series, no wound complications or infections were noted with staged treatment. Only one of the patients with a Hawkins type-III fracture treated in two stages, with deliberately delayed ORIF, developed osteonecrosis. We advocate urgent reduction of dislocations, proceeding promptly with open reduction when closed reduction fails. Subsequently, definitive ORIF should be undertaken when the patient's systemic status and the surrounding soft-tissue injury safely permits. Our experience suggests that waiting several days to perform ORIF improves soft-tissue healing. Surgical treatment of these fractures may then be undertaken in a planned, controlled fashion during daytime hours, when meticulous focus can be placed on soft-tissue handling and accuracy of reduction.

Although osteonecrosis occurred after 25% of all fractures, this percentage compares favorably with the prior literature[1,5,9,11,19,23]. Over the past ten years, osteonecrosis rates in other studies have ranged from 14% to 49%[10,19,20,22,23]. Of note, minimal mention about revascularization of the talar dome without collapse has been made[19,23,29]. We identified radiographic changes consistent with revascularization of the talar dome without any collapse in 44% of our patients with osteonecrosis (14% of all fractures). With the numbers studied, we were unable to associate this phenomenon with any specific injury or treatment features.

Posttraumatic arthritis has been identified as the most common complication after talar neck fracture[17,19,20,22,23,30,31] and has been cited as the most frequent indication for secondary reconstructive procedures[20,22]. Our work is consistent with this, as over half of our patients developed arthritis in the ankle and/or subtalar joints. Twenty percent of them underwent secondary reconstructive procedures. It is possible that more of our patients will develop radiographic evidence of arthritis over time. Six patients had only eighteen months or less of follow-up, and six others had between eighteen and twenty-four months of follow-up. Certain injury features appeared to be associated with progression to posttraumatic arthritis. These include Hawkins type-III fractures or talar body fractures. Tibiotalar arthritis has been reported to occur in as many as 90% of patients, and subtalar arthritis in up to 100% of patients, in prior studies of talar body fractures[6,7,15,16,19,32-34]. Additionally, associated articular fractures of the calcaneus and tibial plafond carry a poor prognosis with respect to posttraumatic arthritis[35-38]. Three-quarters of our patients in each of these groups developed radiographic evidence of arthritis. Strict attention to detail in optimizing the quality of fracture reduction and in placing strategic fixation to maintain the reduction may minimize the development of arthritis.

In summary, we found that osteonecrosis of the talar body is associated with the amount of initial fracture displacement, and separating Hawkins type-II fractures into those without (type IIA) and those with (type IIB) subtalar dislocation can help to predict the development of osteonecrosis. We also noted that the talar dome frequently revascularized without collapse in patients with osteonecrosis, and posttraumatic arthritis is common after a talar neck fracture, particularly those with an associated talar body, tibial plafond, or calcaneal fracture. ■

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