Nonunion of the Femur and Tibia: An Update

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KEYWORDS

• Nonunion • Tibial nonunion • Femoral nonunion • Dynamization • Exchange nailing • Bone grafting • Atypical femur fractures • Bisphosphonates

KEY POINTS

- Lower extremity nonunions, particularly of the tibia, have significant impact on both the patient and society.
- Radiographic union score for tibia fractures (RUST) is a method for more objectively describing fracture healing based on plain films.
- Fracture-specific and treatment-related risk factors have been associated with nonunion.
- Patient-related risk factors, both modifiable and nonmodifiable, have been associated with nonunion.
- Evaluating for the presence of infection is extremely important in the treatment of nonunion.

DEMOGRAPHICS AND ECONOMIC IMPACT

A retrospective review in the United States of 2006 managed care claims at 24 months after injury in 853 patients with tibial shaft fractures noted a 12% incidence of nonunion. This study also documented the increased costs of tibial nonunions for inpatient and outpatient services, as well as increased costs associated with narcotic usage (Table 1).[1,2]

According to one retrospective review of a prospective database collected by two level 1 trauma centers, patients with delayed union or nonunion also have significant lost productivity resulting in indirect costs. Records of 489 patients with 260 femur fractures and 282 tibia fractures were reviewed. Of the 423 patients who went on to known healing outcome, 138 (25%) experienced delayed union or nonunion. Seventy-two percent of patients with united fractures returned to work at 1 year, compared with 59% of patients with a delayed union or nonunion.[3]

DEFINITION

Fracture healing is assessed by a combination of clinical and radiographic criteria. Clinical markers of union include resolution of pain with weight bearing and radiographs that show progressive healing and cortical bridging of fracture lines.

The development of the radiographic union score for tibia fractures (RUST) is an attempt to objectively determine the extent of healing by scoring the degree of fracture healing from each of the 4 cortices, as viewed from anteroposterior and lateral radiographs. A recent modification of the initial scoring system differentiates bridging and nonbridging callus in an attempt to improve intraobserver agreement and the accuracy of predicting union (Table 2). Use of the scoring system results in a score ranging from 4 (no callus any of 4 cortices) to 16 (complete remodeling of all 4 cortices). A summary of the initial findings comparing the readings of academic orthopedic traumatologists defines that healing corresponds

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Orthop Clin N Am 47 (2016) 365–375
http://dx.doi.org/10.1016/j.ocl.2015.09.010

Table 1
Increased costs associated with nonunion of the tibia

	Tibial Nonunion	Tibial Union
Inpatient	$7263.96	$2868.56
Outpatient	$1300.95	$490.14
Narcotics	$1,0300.95	$605.44

Data from Antonova E, Le TK, Burge R, et al. Tibia shaft fractures: costly burden of nonunions. BMC Musculoskelet Disord 2013;14:42.

to bridging callus on at least 3 cortices. However, these findings remain to be correlated with clinical outcomes.[4,5]

The score for each individual cortex is summed yielding a score between 4 and 16.

In addition to the RUST, computed tomography is helpful for evaluating suspected nonunions.[6]

A nonunion is generally defined as radiographic evidence of nonprogression of healing for at least 3 months, or lack of healing by 9 months since injury. Although the clinical and radiographic criteria discussed above are routinely used by most surgeons, there is a lack of consensus as to the real-time functional definition of nonunion.[7] It can be agreed, however, that nonunion is the cessation of both endosteal and periosteal healing responses without bridging callus.[8]

CLASSIFICATION

The classification of nonunions has not changed, and both the biological and mechanical characteristics must be evaluated for each case. The most important biological factor is the presence or absence of sepsis. Mechanical characteristics are frequently described as

- Hypertrophic-exuberant callous but not united, indicating a lack of stability but good biology;
- Atrophic-absent or minimal callous, which indicates a poor biological healing response;
- Oligotrophic-incomplete callous formation, which completes the spectrum between hypertrophic and atrophic.

Table 2
Radiographic union score for tibia fractures, modified

Score	Radiographic Description
1	No evident callus
2	Callus present
3	Bridging callus
4	Remodeling – no fracture visible

Data from Litrenta J, Tornetta P III, Mehta S, et al. Determination of radiographic healing: an assessment of consistency using RUST and modified RUST in metadiaphyseal fractures. J Orthop Trauma 2015;29(11):516–20.

FRACTURE-SPECIFIC AND TREATMENT-RELATED RISK FACTORS

Opening of the fracture site,[9] severe open injuries,[10] and the presence or development of infection[10] have been associated with nonunion after intramedullary nailing of the long bones.

PATIENT-RELATED RISK FACTORS

Metabolic, Endocrine, and Other Systemic Factors

The importance of bone metabolism is increasingly recognized as a key component of fracture care. Brinker and colleagues[11] examined the results of endocrinology referrals for 37 patients with nonunion. Criteria for referral included an unexplained nonunion without obvious technical error or other cause (26 patients), a history of multiple low-energy fractures with at least 1 progressing to a nonunion (8 patients), or nonunion of a nondisplaced pubic rami or sacral alar fracture (3 patients). They found that 31 of 37 patients (84%) who met screening criteria had a new diagnosis of a metabolic or an endocrine abnormality. Twenty-four patients (65%) had more than 1 metabolic or endocrine abnormality. Eight patients (22%) healed with medical treatment alone. Among the new diagnoses, 87% had a vitamin D deficiency or abnormal calcium regulation, 24% had thyroid dysfunction, 22% had reproductive hormone dysregulation, 13% had pituitary dysfunction, and 11% had parathyroid dysfunction.[11]

25-Hydroxyvitamin D (25[OH]D) deficiency and insufficiency has been well documented in orthopedic trauma patients. Prevalence is high, as a majority (66%–86%) of patients have levels deemed insufficient (<30 ng/mL), whereas approximately half (40%–53%) are deficient (<20 ng/mL).[12–15] Dark-skinned individuals are disproportionately affected,[14,15] as are those between the ages of 18 and 60 years versus older or younger individuals.[12,14]

The ramifications of insufficiency or deficiency on fracture healing and risk of nonunion are still unknown. A recent review notes that fracture may result in higher interosseous vitamin D metabolites and lower serum vitamin D metabolites; however, this finding is not consistent among studies.[16] The prevalence of vitamin D deficiency in nonunion patients is also debated, as at least