

## Advantages of preoperative planning using computed tomography scan for treatment of malleolar ankle fractures

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### Abstract

Malleolar ankle fractures have been classified using plain radiographs, and there is no consensus regarding the role of computed tomography (CT) scans in preoperative planning. We analyzed critical aspects, such as limits of standard radiographs, types of injury, classification methods and cost/benefit evaluations. CT scans allow a 3D analysis of the fracture to be obtained and consequently assess the indication for surgical procedure, surgical access and the type of fixation devices required. This exam is useful for detecting lesions that may go unnoticed on radiographs and will help surgeons to clarify the pathoanatomy of ankle fractures. According to Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification, CT scan is recommended in medial malleolar fractures with vertical rim, type 44B fractures with posterior malleolar involvement and all type 44C fractures (according to AO/OTA). Also Tillaux-Chaput fractures (43-B1 according to AO/OTA), malleolar fractures in the presence of distal tibial fractures (43 according to AO/OTA) and distal tibia fractures in adolescents should be studied with CT scans.

**Key Words:** Computed tomography scan; Malleolar fractures; Planning; Trauma; Imaging

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**Core Tip:** Computed tomography scan is recommended in medial malleolar fractures with vertical rim, type 44B fractures [according to Arbeitsgemeinschaft für

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Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification] with posterior malleolar involvement. All type 44C fractures (according to AO/OTA), Tillaux-Chaput fractures (43-B1 according to AO/OTA), malleolar fractures in the presence of distal tibial fractures (43 according to AO/OTA) and distal tibia fractures in adolescents should be studied with computed tomography scans.

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## INTRODUCTION

Ankle fractures represent 10.2% of all fractures<sup>[1]</sup> and are the most common fractures of the lower extremity after proximal femur fractures<sup>[2]</sup>. The incidence number is approximately 1000 out of 1000000 people per year<sup>[3]</sup> with higher rates reported in the European literature<sup>[3,4]</sup>. Single malleolar fractures are the most frequent followed by bimalleolar fractures (25% of ankle fractures) and trimalleolar fractures (5%-10%)<sup>[5]</sup>.

Isolated posterior malleolar fractures are rare<sup>[6]</sup> because they are usually associated with other bone or ligament injuries<sup>[7]</sup>. Ankle syndesmosis injury occurs in 10%-13% of cases, and 20% of cases require surgical treatment<sup>[8,9]</sup>. Malleolar fractures, in some cases, are associated with tibial pilon injuries<sup>[10-13]</sup>.

The Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) fracture and dislocation classification is one of the most used classifications. Malleolar segments are categorized as 44 and are based on the direction of the fracture lines and of the fracture degree of comminution (A-C)<sup>[14]</sup>. This classification is based on standard plain radiographs, although often this diagnostic assessment can underestimate the nature, extent and severity of the injury because of the complex three-dimensional anatomy of the joint<sup>[15]</sup>.

Compute tomography (CT) scan is used in some cases in order to obtain a 3D analysis of the fracture and to consequently assess the indication for the surgical procedure, surgical access and type of fixation devices required. The anatomical reduction of fractures demonstrated higher functionality and improved long-term outcomes<sup>[16]</sup>.

However, approximately one-third of patients aged 10-21 years with bimalleolar and trimalleolar fractures presented clinical signs of post-traumatic arthritis, and more than 97% showed pathological radiological findings<sup>[17-19]</sup>. Possible causes are due to minor inconsistencies, axial malalignment and syndesmosis instability. This study aims to identify the cases in which a CT scan is recommended in order to avoid or reduce the risk of long-term complications.

## CRITICAL ASPECTS

### Plain radiographs

Radiological assessment, usually performed in the emergency room, presents noncanonical projections because of patient pain or the presence of immobilization devices<sup>[2,16]</sup>. Furthermore, it is subject to the variable accuracy of the action and the scarce penetration of the radiations. Therefore, it is difficult to determine if the diagnostic assessment is adequate to perform a surgical fixation procedure with satisfying results. CT scan study does not replace an adequate plain radiograph study. Instead, it can provide precious information regarding the assessment of the fracture lines pattern and the number of fragments.

### High-energy injuries

CT is fundamental to determine if surgical treatment is required due to the increase of the energy of the injury, which consequently increases the possibility of associated dislocations as well as complex injuries secondary to rotation flexion. Kumar *et al*<sup>[16]</sup>

reported that in ankle fracture cases the increase of malleolar involvement and the increase of the severity of the injury led to a different type of treatment strategy (that is surgical procedure) after CT scan study was performed. Hence, the presence of occult fractures and complex fracture lines is more likely in such injuries. The severity of the fracture is predictive of the increased risk of intra-articular abnormality<sup>[20,21]</sup>, and in such cases preoperative CT scan assessment could identify additional lesions and mobile bodies requiring surgical treatment. The global change of the management plan rate was 23.2%, which was comparable with another retrospective study<sup>[2]</sup>.

### **Classification methods**

The most used classifications in the literature are AO/OTA, Weber or Lauge-Hansen classifications and are all based on standard plain radiographs. Clinical studies report that such classifications are not correlated with the fracture mechanism<sup>[22,23]</sup> and are not predictive of the sequence of bone and ligament injuries like CT, magnetic resonance imaging and surgical exploration are<sup>[24,25]</sup>.

### **Cost/benefit analysis**

Currently, CT scan studies represent the standard of care for all lower extremity joint fractures, especially acetabular fractures<sup>[26]</sup>, femoral head fractures<sup>[27]</sup>, distal femur fractures<sup>[28]</sup>, tibial plateau fractures<sup>[29]</sup>, tibial pilon fractures<sup>[30]</sup>, talar fractures<sup>[31]</sup>, calcaneal fractures<sup>[32]</sup>, metatarsal fractures<sup>[33]</sup> and tarsometatarsal fractures<sup>[34]</sup>. Therefore, the CT scan study is by definition higher and larger than radiological analysis, although it is not assumed that it is required in all types of malleolar fractures<sup>[2]</sup>.

CT requires higher costs, timing and exposure to radiation. Medical facilities are unfortunately more sensitive to cost and timing containment due to the constant increase of the demand for services; for this reason, it is essential to determine when a CT scan assessment is required. Radiation exposure is a sensitive aspect, particularly in pediatric patients. It was reported that the actual dose of an ankle CT scan study (0.07 mSv) was low and equivalent to a plain radiograph with anterior-posterior planes of the chest<sup>[35]</sup>. This value is ten times lower than the required dose of a CT scan study of the chest, abdomen and pelvis. It could be further reduced by limiting the exposed body segment or using a cone-beam CT scan and other protocols without the risk of losing essential information<sup>[36-38]</sup>.

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## **ADVANTAGES OF CT ANALYSIS**

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The advantages of using CT in the preoperative planning of malleolar fractures are: more accurate planning to determine the conservative/surgical approach and the type of fixation device required (and this is the major advantage because of the long-term results in spite of the surgical treatment<sup>[17-19]</sup>); the identification of unknown lesions in order to obtain a more accurate prognosis, including the detection of tibial pilon fractures; and more diffuse use of CT in the preoperative planning could clarify some unresolved biomechanical aspects regarding the relationship between the mechanism of injury and the pattern of fracture.

The most used classification, among the studies regarding the use of CT in the preoperative planning is the Danis Weber-AO classification, limited only to the three main categories: infrasynsdesmotic (44-A according to AO/OTA classification), transsynsdesmotic (44-B according to AO/OTA classification) and suprasynsdesmotic (44-C according to AO/OTA classification). However, there is no absolute consensus among the authors<sup>[2,16,39]</sup>. This classification is attractive for clinicians because it is simple. The disadvantage of this system is that it does not incorporate a staging system to allow the degree of injuries falling only under one heading in terms of severity<sup>[40]</sup>.

In our opinion this system is extremely simple and does not allow the differentiation of significant varieties within each group. Therefore, we reassessed the published system in order to determine a more detailed algorithm specifically referring to the Danis Weber subclassifications.

In our revision of the literature, the Lauge-Hansen classification was useful and significant in the evaluation of the importance of CT in the preoperative planning<sup>[7,41]</sup>. The classification is based on the rise of the mechanic forces, and there is a direct correlation between the increase of the energy of the injury and the usefulness of the preoperative CT study<sup>[2]</sup>.

**Infrasyndesmotic fractures (44-A according to AO/OTA classification)**

Isolated lateral malleolar fractures [type 44-A1; Lauge-Hansen supination adduction (SA) stage I] and isolated medial malleolar fractures (type 44-A2.1/2; Lauge-Hansen SA stage II) are largely caused by injuries with no associated lesions. The use of CT is not recommended in this type of case. In a retrospective study<sup>[2]</sup> of 100 patients, no significant changes were noted regarding the treatment option (only 1 patient out of 24 cases of infrasyndesmotic fractures) following a CT scan study compared to the plain radiograph analysis<sup>[2]</sup>.

The vertical medial malleolar fracture (Lauge-Hansen SA stage II) represents a particular condition because a medial tibial pilon injury can occur in the case of persistent energy of injury in adduction<sup>[11,42]</sup>. This type of lesion was described in 61% of SA stage II in the retrospective study conducted on 120 patients by Alluri *et al*<sup>[43]</sup>. In such cases, CT is recommended because the ideal treatment should provide the specific approach with elevation and bone grafting to significantly improve the prognosis<sup>[44]</sup>. In our opinion, the angulation of the line of fracture increases or decreases the suspected rate of tibial pilon injuries.

The above described subjects regarding the study of medial malleolus can be applied to bimalleolar fractures type 44-A2.3 (Lauge-Hansen stage II). In fracture type 44-A3 with a medial malleolus involvement associated with part of the posterior malleolus, a CT scan study is always recommended.

The importance of the preoperative CT scan study in the case of posterior malleolus fractures is documented by numerous publications in the literature. In fact, classifications based on CT scan studies have been proposed<sup>[13,45,46]</sup>. CT images allow the identification of impacted fracture fragments not visualized with conventional plain radiographs and with possible changes to the preoperative planning.

Black *et al*<sup>[2]</sup> and Magid *et al*<sup>[47]</sup> demonstrated that the use of CT scan study varies between 24.0% and 38.7% of the treatment planning compared to simple plain radiographs in cases of trimalleolar fracture<sup>[2,47]</sup>. Donohoe *et al*<sup>[48]</sup> and Palmanovich *et al*<sup>[49]</sup> reported that CT scan images increased the diagnostic accuracy and the intraobserver and interobserver agreement compared to conventional radiographs<sup>[48,49]</sup>. Furthermore, Evers *et al*<sup>[50]</sup> showed that in 25.1% of cases (430/1710), the planning was revised after CT scan study was performed with an increase of surgical indications and fixation device technique<sup>[50]</sup>.

**Transsyndesmotic fractures (44-B according to AO/OTA classification)**

In transsyndesmotic fractures of isolated fibular fractures (type 44-B1 and B2) or bimalleolar fractures, the preoperative CT scan study does not significantly change the surgical treatment option<sup>[11,51]</sup>. This could be related to the fact that the standard radiographs are sufficient to adequately detect this type of fracture.

This assumption cannot be applied to transsyndesmotic fracture of posterior malleolar fracture (type 44-B3). In this case the study of posterior malleolus, as in fractures type 44-A3, cannot be based only on plain radiographs (Figures 1-3).

**Suprasyndesmotic fractures (44-C according to AO/OTA classification)**

In suprasyndesmotic fractures, despite the degree of fracture (C1, C2, C3 Lauge-Hansen PER stage 1-4), CT is always recommended. This study allows the evaluation of the syndesmosis and the possible involvement of the Tillaux-Chaput fragment<sup>[52,53]</sup>. Plain radiographs are not sufficient for syndesmosis evaluation because of the extreme variability among the individuals<sup>[54,55]</sup>, whereas axial CT scan images allow a correct diagnosis as well as a determination of the best direction of the transsyndesmotic screw placement.

**Tillaux-Chaput fractures (43-B1 according to AO/OTA classification) and malleolar fractures in the presence of distal tibial fractures (43 according to AO/OTA classification)**

Conventional plain radiographs did not detect the Tillaux-Chaput fragment, which is more frequently present in fractures type B and C according to AO/OTA classification, in the studies conducted by Black *et al*<sup>[2]</sup> and Kumar *et al*<sup>[16]</sup>. This suggests an absolute advantage of the use of CT in fractures involving the anterior tibial tubercle<sup>[44]</sup> or in suspected cases considering the above-mentioned posterior malleolus fractures. The fixation of the anterolateral fragments re-establishes the anterior incisure and provides the stability of the anterior syndesmosis<sup>[56]</sup> (Figures 4 and 5).

The presence of occult fractures of the medial malleolus in fractures of the distal shaft of the tibia are described by some authors<sup>[57-60]</sup>. In the study by Jung *et al*<sup>[57]</sup>, 89% of



Figure 1 Transsyndesmotic fracture (44-B3). A: Anteroposterior; B: Lateral view.



Figure 2 Computed tomography scans of the coronal plane and sagittal plane allow detection for the best screws direction. A: Coronal plane; B: Sagittal plane.

patients with distal tibia spiral fracture (type 43 according to AO/OTA) associated with malleolar fracture underwent surgical fixation. The importance of the preoperative identification derives from the risk of intraoperative decomposition during a surgical procedure of nailing with a consequent increase of surgical difficulties and duration of surgical treatment.

CT is additionally recommended in distal fracture of the leg because the line of fracture (even closed fracture) involves the epiphyseal/malleolar regions.

#### **Malleolar ankle fractures in adolescents**

The preoperative CT scan study represents the gold standard in malleolar ankle fractures in adolescents. Plain radiographs tend to underestimate this type of fracture. It is noted that consolidating fractures of the distal tibia present some features because the ossification of the growing cartilage is medial-lateral and posterolateral. This implies extraordinarily complex patterns of fractures (*i.e.* triplane fractures) and only with axial, sagittal and coronal planes is it possible to obtain adequate treatment



**Figure 3 Postoperative X-rays in the anteroposterior and lateral view.** Fractures treated with plate and screw fixation. A: Anteroposterior view; B: Lateral view.



**Figure 4 Suprasyndesmotom fracture (44-C2).** A: Anteroposterior; B: Lateral view.

planning<sup>[11,61]</sup> (Figures 6-8).

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## CONCLUSION

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The aim of malleolar fracture treatment is the anatomical reduction of the articular surfaces and of the syndesmosis. The use of CT in the preoperative planning could improve the clinical outcomes and reduce the risk of intraoperative difficulty and surgical duration in vertical medial malleolar fractures, in fractures type 44B with posterior malleolus involvement and in fractures type 44C. A CT scan study is mandatory in cases of Tillaux-Chaput fracture, malleolar fractures associated with the distal third of the leg and in adolescent patients. Additional large-scale clinical studies with cost/benefit analysis are required to confirm this hypothesis.

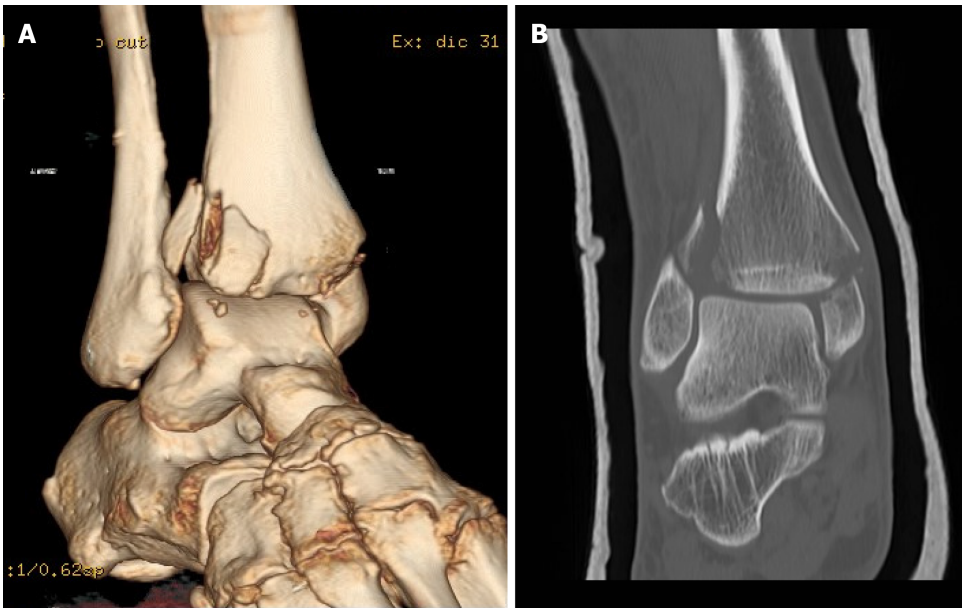


Figure 5 Computed tomography scans shows the involvement of the Tillaux-Chaput fragment. A and B: Tillaux-Chaput fragment.



Figure 6 Ankle fracture in adolescent. A: Anteroposterior view; B: Lateral view.

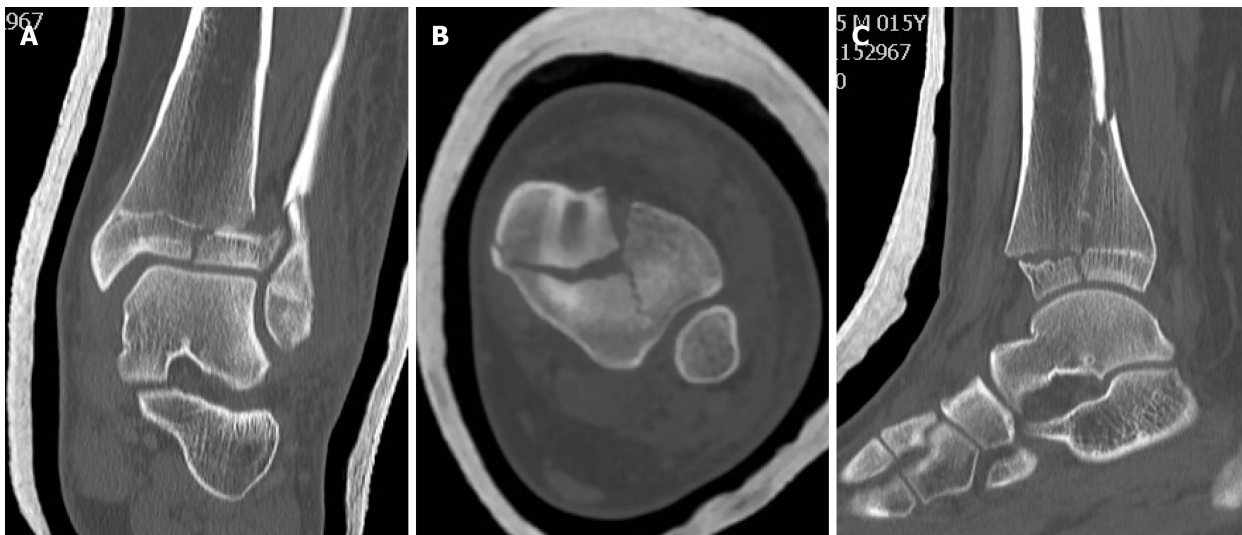


Figure 7 Computed tomography scan shows a triplane fracture. A: Coronal plane; B: Axial plane; C: Sagittal plane.



Figure 8 Postoperative X-rays in the anteroposterior view. Fractures treated with screws.

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