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Utility of computed tomography in children's ankle fractures from classification to surgical planning

Cristian Aletto[1*], Martina Marsiolo[2*], Michela Florio[2], Angelo Gabriele Aulisa[2,3], Renato Maria Toniolo[2], Francesco Falciglia[2] and Nicola Maffulli[4,5,6*]

Abstract

Background Ankle fractures are common in the pediatric population. Plain radiographs provide sufficient information for the diagnosis, but computed tomography (CT) can help to study the configuration of fracture and to plan fixation. Our study aims to study pediatric population with ankle fracture, understanding whether CT scans should be extended to all ankle fractures admitted to the Orthopaedic Department after a first radiographic evaluation, independent of the pattern of physeal plate fracture.

Materials and methods Data about patients with ankle fractures admitted to the Orthopaedic Department were retrieved. The diagnosis and classification of ankle fractures obtained from plain radiographs were compared with those obtained from CT scans. For each patient, data about conservative or surgical management were retrieved. After collecting all the mentioned data, a survey with 61 plain radiographs of children's ankle fractures was proposed to 16 orthopedic surgeons of the department divided into three groups according to their years of experience in Paediatric Orthopaedics and Trauma. The survey consisted of five questions for each radiograph regarding Salter–Harris (SH) classification, management, indication for CT, number, and direction of screws (if needed).

Results A total of 130 patients with ankle fractures satisfied the inclusion criteria and only 26 of them were classified according to the SH classification by orthopedic surgeons or radiologists after plain radiography. Almost all pediatric patients with ankle fractures admitted to the Orthopaedic Department, after evaluation of plain radiographs in the emergency department (ED), underwent CT with three-dimensional (3D) reconstruction to plan fixation or nonoperative management. CT may lead to reclassification of some fractures, showing that SHIV fractures may be more common than expected. A total of 6 orthopedic surgeons answered the survey on 61 ankle fracture plain radiographs. Independent of their experience, orthopedic surgeons tend to respond similarly to SH classification and fracture management, while they have contrasting opinions about performing CT scans. Analyzing their response to the number of screws, entry points, and directions and comparing them with postoperation radiographs, the results between responders were very discordant.

*Correspondence:
Cristian Aletto
cris.aletto28@gmail.com
Martina Marsiolo
martina.marsiolo@opbg.net
Nicola Maffulli
n.maffulli@qmul.ac.uk
Full list of author information is available at the end of the article

Conclusion In children's ankle fracture involving the physeal plate, the SH classification, fracture management planning, the identification of the entry point and the direction of the screw could be more accurate using CT compared with plain radiographs.

Levels of Evidence: Level IV, according to the Oxford 2011 Levels of Evidence.

Keywords ankle, pediatric, pediatric fractures

Introduction

The distal end of the tibia and fibula are frequent sites of children's fractures after twisting injuries or low-energy falls [1]. Ankle fractures represent approximately 5% of all pediatric fractures and 15–20% of all physeal injuries, placing them second among all growth plate fractures [2]. Boys are more frequently involved than girls, probably because of the delayed physeal closure in males [3]. The peak incidence of ankle fractures is between the ages of 8 and 15 years when the skeleton is still immature, and there is a high potential for secondary complications [4]. Alterations in bone growth following a fracture can lead to asymmetrical healing, causing shortening and deformation of the tibia [5]. At the same time, ridge formation and intraarticular fragments may lead to post-traumatic arthrosis when the articular surface is involved. In the ED, plain radiographs are used to confirm the diagnosis. The complex variety of fracture types requires detailed description of fracture morphology, correct classification, and accurate management choice [6]. Still, fractures are identified in only 12–21% of patients, resulting in unnecessary radiation, increased wait times, and increased healthcare expenditures [7]. In 1992, Stiell et al. [8] proposed the Ottawa ankle rules (OAR) to clinically ascertain whether imaging in adults (> 18 years old) with acute ankle and midfoot injuries is required. The OAR shows 100% sensitivity to identify clinically significant fractures in the adult population [9]. Further, OAR is not readily applicable to children because the physical evaluation in a child is more complex than in adults, and thus it can only be applied to children able to walk [10]. For these reasons, the OAR can be used for patients older than 5 years [7].

Ankle radiographs with anteroposterior (AP), lateral (LL), and mortise views are the most widely used imaging method to evaluate ankle fractures [11]. The Salter–Harris classification of the injuries involving the epiphyseal plate is widely accepted and frequently applied to ankle fractures [12]. Ankle injuries may affect the growth plate, metaphysis, epiphysis, or both. Intraarticular fractures of the distal tibia involve SHIII and IV [13]. Transitional fractures are the triplane and the juvenile Tillaux fractures and are encountered in adolescents over approximately 18 months during the asymmetric closure of the distal tibial physis [14].

Plain radiographs provide sufficient information to diagnose the fracture. Still, three-dimensional imaging modalities, such as computed tomography (CT), help study the configuration of the fracture, the number of fracture fragments, and their displacement, especially in intraarticular and transitional fractures [3]. The exact fracture pattern should be known to reduce and fix fractures accurately, though CT scans deliver much more radiation to the patient than conventional radiographs [4].

Several studies have investigated and shown the utility of CT in distal tibial physeal injuries, especially in intraarticular fracture, to evaluate the amount of displacement and articular congruity. Tillaux fractures are Salter–Harris type III fractures of the anterolateral distal tibia epiphysis; in a cadaveric study, the accuracy of plain radiographs and CT scans in Tillaux fractures were compared, and CT scans were more accurate than plain radiographs to identify displacements of < 2 mm or more [15]. Operative management with a lag screw is indicated when displacement is more than 2 mm [15]. Triplane fractures, instead appear as SHIII fracture on anteroposterior (AP) radiographs and as SHII fracture on lateral radiographs; hence, triplane fractures extend into three planes: frontal, horizontal, and sagittal [16].

For Tillaux and Triplane fractures, CT scans are considered mandatory, whereas some authors do not consider necessary cross-sectional imaging for other patterns of children's ankle fractures [3, 17].

In our setting, the request of CT scans, often supplemented by 3D reconstruction for ankle fracture, is performed almost automatically to complete the diagnosis after first-level imaging; independent of Salter–Harris classification, CT scans help surgeons classify ankle fractures better and plan optimal management.

This study consists of two parts. In the first, young patients with ankle fractures admitted to our Orthopaedic Department were retrospectively evaluated considering general features (sex and age), the day of injury, and days passed to perform CT scans and to be treated, as well as diagnosis based on plain radiographs and on CT according to Salter–Harris classification and definitive treatment.

The second part consists of a survey in which orthopedic surgeons, divided by their experience, analyzed selected plain radiographs of the patients without knowing their management (including whether they had undergone CT).

The aim is to evaluate whether CT scans should be routinely performed for all pediatric ankle fractures following plain radiography in the emergency department, regardless of the physeal plate fracture pattern.

Materials and methods

All data regarding patients with ankle fractures admitted to the Orthopaedic Department from January 2019 to April 2022 were retrieved. Patients were admitted to the Orthopaedic Department when they required closed or open reduction and internal fixation or closed reduction without internal fixation under general anesthesia. Inclusion criteria were ankle fracture involving the growth plate or epiphysis, patient's age less than 15 years for female patients and less than 18 years for male patients, no polytrauma, and no open fractures. The age above cutoff limits were selected considering that the average age for distal tibial physeal closure is 12–15 years for girls and 14–18 years for boys [18]. Each patient's plain radiographs and CT scans (including 3D reconstruction) were retrieved from the Bambino Gesù Paediatric Hospital database. Diagnosis and classification of ankle fracture were retrieved from the radiologist report and confirmed by an orthopedic surgeon in the ED. The Salter–Harris classification was used to classify the fracture [19].

When radiographs were not performed in our setting, the orthopedic surgeons recorded the diagnosis on the admission form to the orthopedic department. The diagnosis and classification of ankle fractures obtained from plain radiographs were compared with those obtained from CT scans. CT protocol is optimized to reduce patient radiation dose, including patient positioning, tube current and potential, detector configuration, reconstruction algorithm, scan range, and reconstructed slice thickness. The days between radiographic imaging and computed tomography and between the index injury and definitive treatment were also recorded. For each patient, data about conservative or surgical management were retrieved, and when patients underwent internal fixation, the number of cannulated screws used was recorded.

After collecting all the above data, a multiple-choice survey was administered to 16 department orthopedic surgeons, divided into three groups (young, intermediate, and senior) according to their years of experience in pediatric orthopedics and trauma. The survey consisted of five questions to answer after visualization of a plan radiographs of patients who underwent imaging in our setting (Table 1). There were 61 plan radiographs to analyze, and the surgeons were also asked to indicate whether CT was indicated and whether plain radiographs were sufficient to classify the type of fracture according to Salter–Harris classification, select the appropriate treatment for

Table 1 Survey proposed for this study

(1) Check the type of fracture according to Salter–Harris classification:
• SHI
• SHII
• SHIII (including juvenile Tilleaux)
• SHIV(including triplanar fracture)
• Other
(2) After viewing the relevant plain radiographs, how would you manage this fracture?
• Nonoperatively
• Operatively
(3) After viewing the radiographical image, would you prescribe CT scans?
• Yes
• No
(4) If you consider that internal fixation should be undertaken, how many screws would you use?
• 1
• 2
• 3
• More
(5) Check (or draw) the directions of the screws

distal tibial growth plate fractures, and choose the right entry point, number, and direction of screws if needed.

The sample size represented the age and sex of children and adolescents with ankle fractures. All radiographs were anonymized. Responders did not know whether the patients had undergone CT. All results from the survey were collected by one orthopedic resident (C.A.) and compared with 3D reconstruction on CT scans and plain radiographs after surgery.

The survey results were expressed as percent values, and overall accuracy was calculated. Results were also stratified according to SH classification. The interrater reliability of responders was assessed using multirater Fleiss' kappa. The k coefficient and accuracy were calculated to estimate the reliability of the fracture classification, need for CT, usefulness of CT, and treatment plan formulated by different observers. Fleiss' kappa has the following interpretations for agreement: 0–0.2, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; and 0.81–1.00, almost perfect agreement. The χ^2 test was performed to evaluate the association between the survey results and the orthopedic surgeons' experience grade. Statistical significance was set at $p < 0.05$.

Results

A total of 130 patients, including 77 (59%) male patients and 53 (41%) female patients, satisfied the inclusion criteria. The mean age was 13 years ± 1.95; the youngest patient was 5 years old and oldest were two 17-year-old male patients. Of these 130 patients, 68 (52%) underwent plain radiography at the Bambino Gesù Paediatric Hospital, and 62 (48%) patients were transferred from other hospitals where radiographs had already been taken. In Fig. 1 the data regarding the 130 patients studied are summarized.

In the ED, an ankle fracture was diagnosed or confirmed in all patients admitted to the orthopedic department. Still, only 26 (20%) of them were classified according to Salter–Harris classification by orthopedic surgeons or radiologists: on 26 radiographs, no physician identified an SHI (0%), while there were 10 (38%) SHII, 7 (27%) SHIII (including Juvenile Tilleaux), and 7 (27%) SHIV. Two (8%) radiographs were considered dubious, one a SHII or III, and one either II or IV.

After a mean of 1 day from injury, 124 (95%) patients underwent CT scanning on the injured ankle. Of the six patients on whom CT was not performed, four were SHII, one SHIII, and one SHIV.

Of 26 patients previously classified according to SH classification, 4 (15%) did not undergo CT. In 14 patients (64%), the diagnosis was confirmed with 3D CT (6 patients were classified as SHII, 4 as SHIII, and 2 as SHIV). In comparison, eight patients (36%) were classified differently after 3D reconstruction on CT (three patients with a diagnosis of SHIV were SHII, one patient classified as SHII was a SHIV, two patients classified as SHIV were SHIII, one patient classified as SHIII was a SHIV, and one patient classified as SHIII was an SHII).

Of 124 patients on whom CT was performed, 48 patients (40%) were classified as SH II, 29 patients (24%) were classified as SH III (including Tilleaux fracture), and 44 patients (36%) were classified as SHIV.

Patients were operated on after a mean of 2 days from injury, and patients in whom CT was not performed received definitive treatment after a mean of 1 day.

Conservative management with closed reduction under general anesthesia and casting was in 10 patients (8%), closed reduction and internal fixation with cannulated

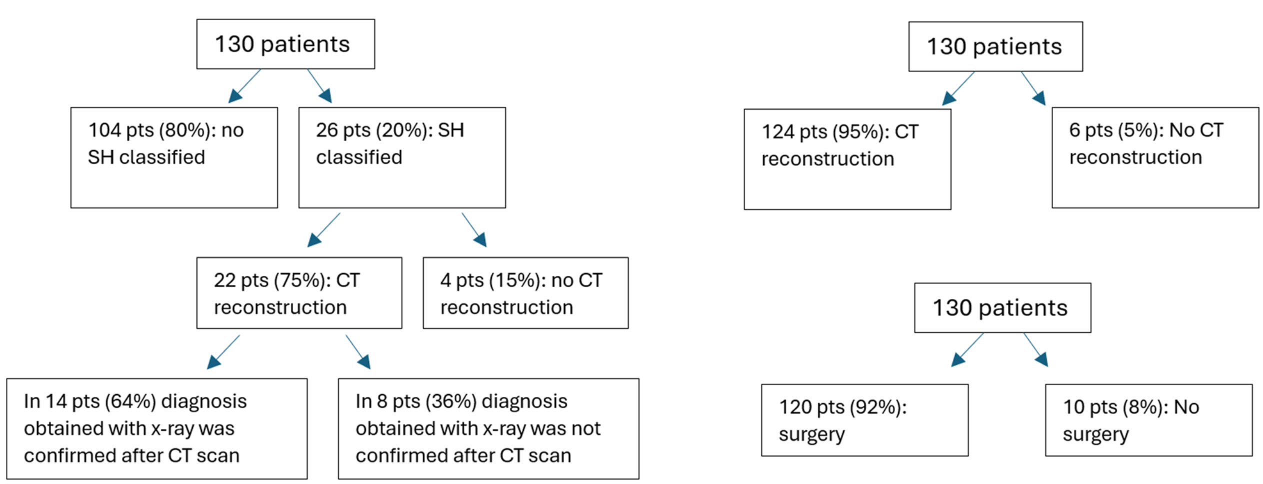

Fig. 1 Summary of data about the 130 patients

screws were performed in 111 patients (85%), closed reduction and pinning with Kirschner wires was performed in 6 patients (4%), 2 (2%) patients required closed reduction and use of both screws and Kirschner wires, and 1 patient (1%) required open reduction and internal fixation with plates and screws. Of 111 patients treated with closed reduction and internal fixation with cannulated screws, 66 patients (59%) required one screw, 39 patients (36%) required two screws, and 6 patients (5%) required three screws. The treatment of the 130 patients is summarized in Table 2.

The 6 patients in whom CT scanning was not performed are included in these 111 operated patients: the 4 patients with SHII injury and the single patient with SHIII injury were operated on using one screw, and the patient with SHIV injury was operated on with two screws. Eight of the ten patients who underwent casting under general anesthesia were SHII fractures (80%), one SHIII, and one SHIV injury.

A total of 16 orthopedic surgeons received the survey, but only 6 answered all questions: 2 young, 2 intermediate, and 2 senior. Per each question, results were reported as percentages, and 61 plan radiographs of patients with ankle fractures were analyzed: 29 (47%) were SHII, 10 (16%) were SHIII, and 21 (34%) were SHIV.

In total, 30 patients (49%) were treated with one screw, 14 patients (23%) with two screws, and 4 (7%) ankles were fixed with three screws; 12 patients (20%) were treated with cast or Kirschner wires and one patient with one screw and one Kirschner wire.

All 61 patients, with a mean age of 13 years, underwent CT scans and then were treated; the entry point, direction, and several cannulated screws were analyzed (Fig. 2).

Of the 29 SHII fractures, 21 patients (73%) underwent operative treatment; one screw was used in 13 patients, two screws in 4 patients, and 1 patient required three screws. Three patients were treated with Kirschner wires, and nine patients were treated conservatively with casting.

All ten SHIII fractures were treated surgically with one screw. In total, 20 (95%) of the 21 patients with SHIV were treated operatively, 7 received one screw, 10 were managed with two screws, and 3 cases were treated with three screws. One patient received a screw and a Kirschner wire.

Regarding the survey, for the first question ("Check the type of fracture based on Salter-Harris classification"), the answers formulated on the basis of plain radiographs were compared with the classification obtained with 3D reconstruction on CT. In 21 radiographs (34%), all responders (100%) gave the same diagnosis obtained with CT and 3D reconstruction. Four patients (6%) received a completely different diagnosis on plain radiographs and CT scans. Percent accuracy for all raters was 34%, and interrater reliability calculated with Fleiss' kappa was 0.42, a moderate level of agreement.

Stratifying the fractures according to Salter–Harris classification, SHII injury was confirmed in 10 of 29 patients (35%), SHIII in 5 of 10 patients (50%), and SHIV in 6 of 21 patients (29%).

For the second question, ("After viewing the relevant plain radiographs, how would you manage this fracture?"), orthopedic surgeons chose between operative or nonoperative management of fracture on the basis of only plain radiographs. Results were compared with the definitive management of each patient. All responders (100%) agreed with the final treatment in 28 patients (46%). Percent accuracy for all raters was 46%, and interrater reliability was calculated with a Fleiss' kappa of 0.30, which is a fair level of agreement.

Stratifying for SH type of fracture, the definitive treatment was agreed on by all responders in 8 patients with SHII injury (28%), in 6 patients with SHIII injury (60%), and in 14 patients with SHIV injury (67%).

Table 2 Operative and nonoperative treatment

Treatment	Patients	Patients
Closed reduction under general anesthesia and casting	10 (8%)	
Closed reduction and internal fixation with cannulated screws	111 (85%)	• 66 (59%): one screw • 39(36%): two screws • 6 (5%): three screws
Closed reduction and pinning with Kirschner wires	6 (4%)	
Closed reduction and internal fixation with screws and Kirschner wires	2 (2%)	
Open reduction and internal fixation with plates and screws	1(1%)	

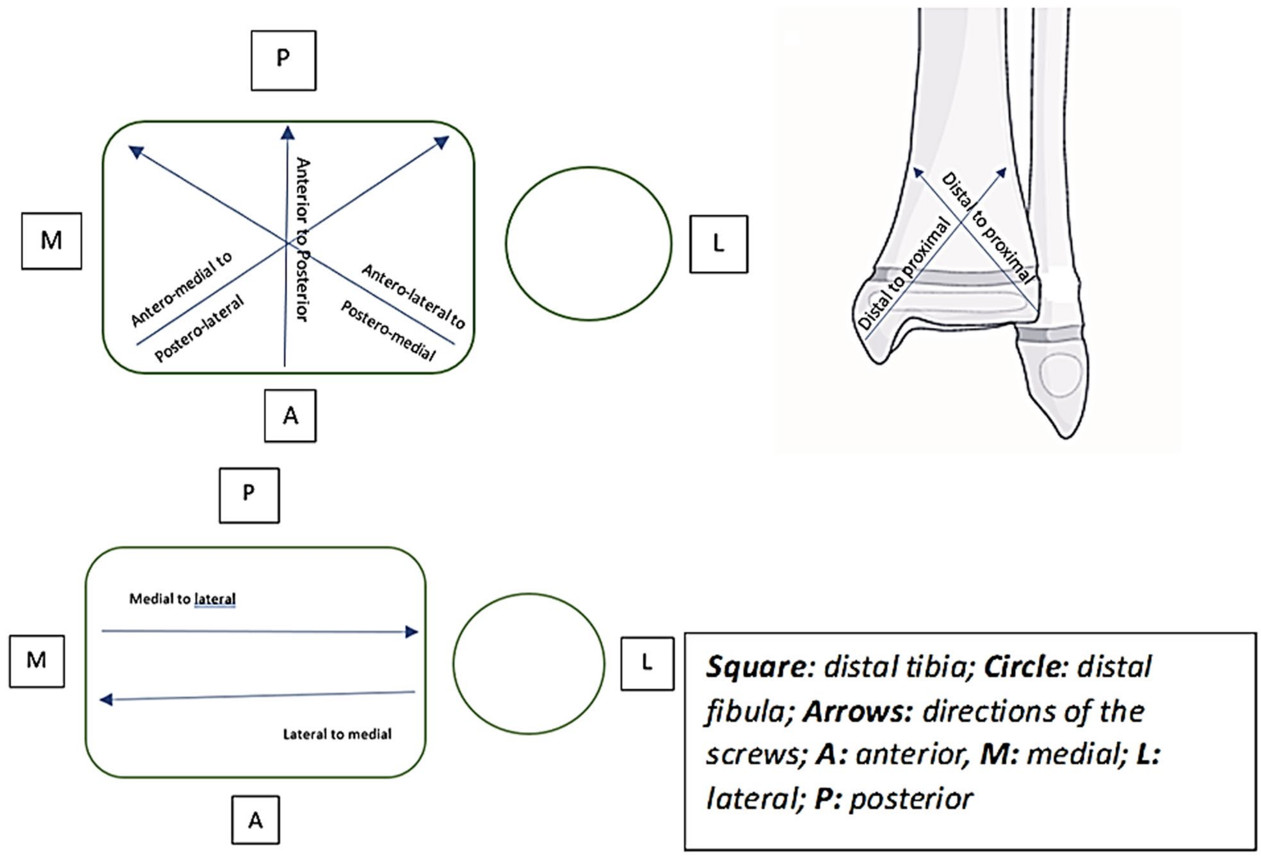

Fig. 2 Graphical representation of possible direction of the screws on transverse and frontal view

For the third question, ("After viewing the radiographical image, would you prescribe CT scans?"), the responders did not know that all patients analyzed with plain radiographs had also undergone CT scanning. Request of CT by all responders (100%) was confirmed in 11 patients (18%). Percent accuracy for all raters was 18%, interrater reliability, calculated with Fleiss' kappa, was < 0, which represents no agreement.

Stratifying for SH type of fracture, request of CT by all responders was confirmed in one patient with SHII (3%), in three patients with SHIII (30%), and in seven patients with SHIV (33%).

For the fourth question, ("If you consider that internal fixation should be undertaken, how many screws would you use?"), the number of screws suggested to be used to fix a given ankle fracture was compared with the number used observing postoperative radiographs, and 100% correspondence with postoperative radiographs was observed in eight patients (13%), while 0% correspondence was observed in seven patients (12%). Percent accuracy for all raters was 13%, and interrater reliability calculated with Fleiss' kappa was 0.20, representing a slight level of agreement.

Stratifying according to SH type of fracture, the number of screws inserted was confirmed in three patients with SHII injury (10%), in four patients with SHIII (40%), and in two patients with SHIV (9%).

In the final question, ("Check (or draw) the directions of the screws"), the surgeons were asked to describe or draw the possible direction of the screws. No one tried to pull the direction of the screw on anteroposterior and/or lateral plain radiographs, but all of them described the directions of the screws, and 100% correspondence with postoperative radiographs was observed in only five patients (8%). Percent accuracy for all raters was 8%, and interrater reliability calculated with Fleiss' kappa was < 0, which represents no agreement.

Stratifying results on the basis of SH classification, three patients with SHII (10%) and two patients with SHIII (20%) received the right direction of the screws according to all the orthopedic surgeons (100%). For SHIV injury, the right direction was never obtained by any orthopedic surgeon (100%).

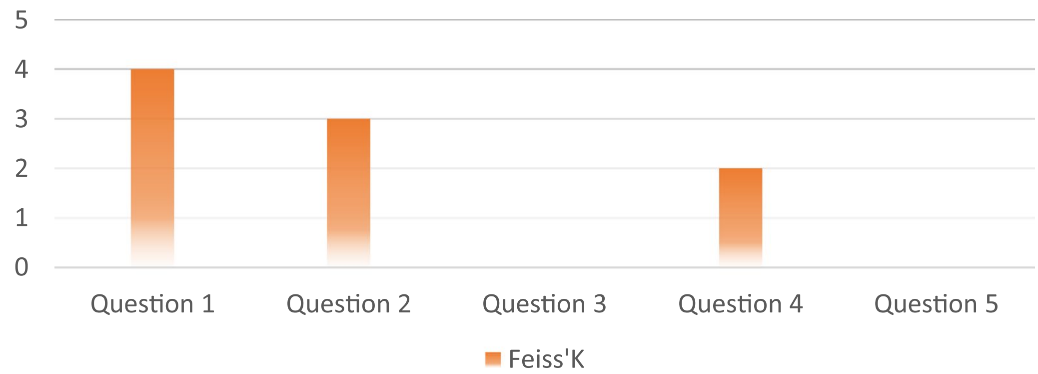

Fig. 3 Fleiss' kappa for questions proposed

Summarizing, Fleiss' kappa showed moderate (0.41) agreement between responders for the first question, fair agreement (0.3) for the second, slight agreement (0.2) for the fourth question, and no agreement (0) for the third and fifth questions (Fig. 3).

The χ^2 test did not identify a statistically significant association between answers and experience levels in pediatric orthopedic and trauma.

Discussion

Ankle fractures represent approximately 5% of all pediatric fractures [3] and 15% of all physeal injuries. The distal tibial physis contributes approximately 45% of the length of the tibia; one of the primary aims of treatment of pediatric ankle fracture is to protect the physis to avoid deformities or leg length discrepancy following growth progression [18]. This study analyzed children with ankle fractures admitted to the orthopedic department. Boys were more commonly affected and were of the age typical for tibial growth plate injury [4]. Most fractures occurred on the right, possibly related to the use of the dominant foot in athletic activities involved in these injuries [20, 21]. After admission to the ED, plain radiographs of the injured ankle were performed. Anteroposterior, lateral, and mortise views of the ankle were obtained and reviewed, with special care given to the appearance of the physis and its widening. Children's ankle fractures are typically classified, according to Salter–Harris, into five types: approximately 15% of all ankle fractures are SHI injuries, while SHII injuries account for 40% of distal tibial fractures. Approximately 25% of all ankle fractures are type III injuries, and a further 25% are SHIV [18]. Unexpectedly, in the present study, a few ankle fractures were classified according to Salter–Harris classification by orthopedic surgeons or radiologists after viewing plain radiographs. Neither specialist commented on SH type, preferring to await 3D CT reconstruction. The ankle fractures classified before CT followed the distribution of SH types in the pediatric population, but some ankle fractures were misclassified after only viewing plain radiographs. CT may demonstrate additional fracture lines, sometimes with the involvement of the joint, leading to the reclassification of some fractures from type II to type IV. SHII injuries are the most frequent (40%), while SHIV injuries are 25% of all children's ankle fractures [18]. In the present study, after 3D CT reconstruction, SHIV injuries are almost as frequent as SHII, suggesting that SHIV fractures may be more common than expected, and they are often not recognized without 3D reconstruction.

Plain radiographs are one of the most important elements in planning the management of ankle fractures, and orthopedic surgeons in the ED evaluate plain radiographs performed in our setting or another hospital. Admission to the orthopedic department occurs when patients require closed reduction and internal fixation or closed reduction without internal fixation under general anesthesia. In this retrospective study, almost all patients received CT scans, probably because it was considered necessary to delineate fracture fragments, manage borderline cases, and guide treatment. For this reason, CT scans were not performed after admission in a few patients; we could not ascertain why orthopedic surgeons preferred not to perform 3D reconstruction on these patients. The fracture pattern may have been clear enough, or they did not want to spend more time before definitive treatment. However, CT did not delay definitive management, and patients were treated within 48 h of admission. After admission to the orthopedic department, many patients underwent closed reduction and fixation.

Only 6 of 16 orthopedic surgeons answered all questions, probably because of the many images to comment on and the time required to respond. The reason to propose this survey is that some authors believe that SHI and SHII do not necessarily need CT, while in SHIII and SHIV fractures, 3D reconstruction CT is widely recommended [15, 22]. In our opinion, 3D reconstruction CT is valid for classifying the fracture better, recognizing undetected intraarticular fractures or displacement, and above all, planning treatment. In our study, observing the percent of accuracy, < 50% of the classification given with plain radiographs was then confirmed after CT, and there was a moderate general agreement between observers on the diagnosis. At the same time, responders disagreed on whether to perform CT. These findings were recently confirmed [23]; a change of diagnosis and a change in treatment decision was observed after 3D reconstruction compared with plain radiographs. CT permits visualization in multiple planes through complex joints and bony surfaces where the anatomy cannot be demonstrated with conventional techniques such as plain radiography. In addition, CT allows for the definition of the fracture line(s) in all three planes, the size and position of the displaced fragments, the location of the intraarticular fracture, and any associated articular incongruency [22]. This information helps decide nonoperative versus operative management, explaining the fair agreement of the responders of the present study to treat pediatric ankle fracture patients without CT surgically.

Furthermore, the role of CT is not only to assess the type of fracture and plan management, but above all, to understand how many screws should be used and where they have to be positioned. According to Arbeitsgemeinschaft für Osteosynthesefragen (AO) principles, lag screws should be inserted through the center of the fracture and perpendicular to its plane to exert the most compression and avoid secondary displacement [22]. In our study, responders showed a slight level of agreement on the number of screws to use and no agreement on their direction without CT reconstruction.

Decisions on managing children's ankle fractures involving the physeal plate and/or epiphysis are usually based on SH classification. Hence, our analyses also consider results that stratify the pattern of physeal fractures.

According to the European Federation of National Associations of Orthopaedics and Traumatology (EFORT), Salter–Harris I or II fractures with a varus or valgus deviation of 5° or more, ante-curvatum or recurvatum of 10° or more, or displacement at the physis level of > 3 mm and/or a joint gap > 2 mm require surgical treatment [24, 25]. In particular, regarding SHII, displacement at the physis and/or joint gap with intraarticular involvement can only be evaluated by CT. Consequently, orthopedic surgeons were very discordant on the use of CT and on the decision whether to operate on these fractures. Responders gave the correct number of screws and their direction in only 10% of patients with SHII injuries.

Plain radiographs of patients with SHIII fracture should be carefully examined for evidence of displacement [26]. The most common SHIII fractures are medial malleolus fractures and juvenile Tillaux fractures. Medial malleolus fractures usually require surgical fixation if there is ≥ 1 mm of displacement. Juvenile Tillaux fractures require surgical intervention when joint incongruency is > 2 mm [27]. The use of CT in these patients is well described [15]. In our study, SHIII injuries were quickly recognized and managed by half of the responders. Furthermore, the use or not of CT and the number and direction of the screws obtained a higher level of agreement compared with other type of fractures.

Salter–Harris type IV fractures can be treated conservatively in the absence of displacement, but the presence of step or joint displacement of > 2 mm necessitates surgery [1]. Triplane fractures require careful assessment, as conservative treatment is indicated if there is no displacement and the joint gap is < 2 mm [1]. If closed reduction is possible, stabilization is performed with percutaneous screws; to achieve adequate joint congruency, reduction of the anterolateral fragment has to be performed first, followed by reduction of the posteromedial component [22]. Eismann et al. [17] asked several qualified observers to classify 25 triplane fractures radiographs alone, and then follow CT on two separate occasions. After reviewing the CT, raters changed their opinion on fracture pattern, displacement, treatment from nonoperative to operative, and either the orientation or number of screws [17]. In our study, SHIV, once identified, was considered frequently worthy of 3D reconstruction and surgical treatment, but the direction of the screws hypothesized viewing plan radiographs never reached 100% agreement.

There is not enough evidence to support the use of routine CT scans to analyze and manage ankle fractures in children. Additionally, the study showed that the clinical experience of surgeons did not influence decision-making regarding the use of CT scans.

Nenopoulos et al. included all distal tibial intraarticular fractures (SHIII and IV) and observed that the number of patients in whom surgery was investigated on the basis of radiographs alone rose from 19 to 42 after CT imaging, concluding that despite its higher cost, CT gave indisputable benefits to the understanding and appropriate treatment of intraarticular ankle fractures [6]. On the contrary, some authors posited that CT scans would not significantly change the management of these fractures [28, 29]. The potential disadvantages of CT include radiation exposure to a growing skeleton, increased time, and cost. In our study, CT did not significantly increase the time of surgery. This is a crucial aspect because the consolidation process is advanced after 7–10 days, and a delayed reduction could complicate surgical intervention and damage the physis [1, 5, 25]. Regarding radiation exposure, the literature reported that the doses for a plain radiograph series of the foot and a CT of the foot are 0.001 and 0.07 millisieverts, respectively, both very small doses compared with CT of the head, chest, or abdomen, which deliver between 1 and 10 millisieverts [30].

The strength of this study is the large sample of patients analyzed with data regarding epidemiology and management. Further, there are some limitations: data about patients with ankle fractures managed conservatively after evaluation in the ED and not admitted to the orthopedic department were unavailable, and only patients admitted to the ED and the orthopedic department were analyzed. Complications and quality of life of patients undergoing CT scans before surgery were not evaluated, and patients were not followed in the long term, thus we cannot assess whether CT scanning improved treatment. Furthermore, we did not perform CT after surgical treatment, so we did not know whether lag screws were indeed inserted through the center of the fracture and perpendicular to its plane. Another limitation is that only 6 of 16 orthopedic surgeons answered the survey, decreasing statistical power. Future studies will be performed, reducing the number of radiographs in the survey to a few relevant ones, allowing them to respond easily and permitting more responders to answer, and in addition, the same survey could be conducted with the CT scan images of the same patients to assess changes during the responses.

Conclusions

In children's ankle fracture involving the physeal plate, SH classification, fracture management planning, and identification of entry point and direction of the screw could be more accurate using CT compared with plain radiographs. We recommend routinely using CT scan for intraarticular ankle fractures and for all dubious SHII types of injury in conjunction with plain radiographs for preoperative planning of fixation of distal tibial physeal fractures if its use does not delay final treatment.

Author contributions

Cristian Aletto, Renato Maria Toniolo, and Nicola Maffulli participated in the conception, design and coordination, acquisition of data, analysis and interpretation of data, drafted the manuscript, and performed the statistical analysis. Marsiolo Martina, Francesco Falciglia, Angelo Gabriele Aulisa, and Michela Florio helped to draft the manuscript and participated in the acquisition of data. All the authors have read and approved the final manuscript.

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Data availability

Considering the retrospective nature of the analysis, the current study did not require the approval of the local ethics committee according to current legislation, but a notification was sent. The study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Bambino Gesù Children Hospital, Rome.

Declarations

Ethics approval and consent to participate

The participants provided written informed consent to participate in this study.

Consent for publication

The participants provided written consent for the publication of data.

Competing interests

There is no conflict of interest for this paper.

Author details

[1]Department of Orthopaedic Surgery, Santobono - Pausilipon Children's Hospital, AORN, Naples, Italy. [2]Department of Orthopaedic Surgery, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy. [3]Department of Human Sciences, Society and Health, University of Cassino and Southern Lazio, 03043 Cassino, FR, Italy. [4]Centre for Sports and Exercise Medicine, Queen Mary University of London, Barts and the London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, England. [5]Faculty of Medicine, School of Pharmacy and Bioengineering, Keele University, Guy Hilton Research Centre, Thornburrow Drive, Hartshill, Stoke-on-Trent ST4 7QB, England. [6]Department of Trauma and Orthopaedic Surgery, Faculty of Medicine and Psychology, University La Sapienza, Rome, Italy.

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