Received:
22 November 2018

Revised:
13 November 2019

Accepted:
14 November 2019

<https://doi.org/10.1259/bjr.20180989>

Cite this article as:

Allen GM, Wilson DJ, Bullock SA, Watson M. Extremity CT and ultrasound in the assessment of ankle injuries: occult fractures and ligament injuries. *Br J Radiol* 2020; **93**: 20180989.

FULL PAPER

Extremity CT and ultrasound in the assessment of ankle injuries: occult fractures and ligament injuries

^{1,2}GEORGINA M ALLEN, BM MRCP MRCGP MFSEM FRCR MScSEM, ^{1,3}DAVID J WILSON, MBBS BSc MFSEM FBIR FRCP FRCR, ¹STUART A. BULLOCK, MBChB, BSc (Hons), MA and ¹MARION WATSON, MSc DCR(R)

¹St Luke's Radiology Oxford Ltd, Oxford, UK

²University of Oxford, Oxford, UK

³Imperial College London, London, UK

Address correspondence to: DrGeorgina MAllen

E-mail: georgina.allen@gtc.ox.ac.uk

Objective: To assess the rates of fractures and ligament injuries in patients with an acute ankle injury and a normal radiographic examination, and to consider the most appropriate examination protocol.

Methods: Patients with an acute ankle injury who presented to the John Radcliffe Hospital Emergency Department with a normal radiographic examination were eligible for the study. They were invited to receive a cone beam CT and ultrasound examination at a local radiology department within 5 days of their ankle injury.

Results: Of the 100 patients recruited to the study, 19 patients were found to have major fractures and 42 patients had small avulsion fractures. Additionally, 42 patients had ankle effusions and there were a large number of soft tissue injuries. There were 83 acute injuries of the anterior talofibular ligament, 19 of the anterior tibiofibular ligaments, 26 of the calcaneofibular ligament, 39 of the deltoid ligament complex, 21 of the talonavicular ligament, 14 of the spring ligament and 3 of the calcaneocuboid ligament.

Conclusion: Conventional radiographic examination misses significant fractures of the foot and ankle and

the presence of an ankle effusion does not relate to the severity of injury. Ultrasound is a useful imaging technique that can supplement clinical practice, but it is unlikely to replace current protocols alone. Cone beam CT is an appropriate alternative to plain radiography, being more sensitive in detecting fractures and delivering a similar dose of radiation. However, neither CT or ultrasound examination can detect all avulsion fractures. Simple anterior process fractures of the calcaneus are associated with talonavicular ligament injuries and the medial ligaments are injured in almost 50% of cases when there is a lateral ligament injury.

Advances in knowledge: Fractures in the foot and ankle are detected more precisely with cone beam CT compared to radiographs. Cone beam CT delivers similar doses of to conventional radiographs which is around 10% of that resulting from conventional CT. Ultrasound examination is an effective assessment tool to detect ligamentous injuries. The absence of an ankle effusion does not exclude a major fracture.

INTRODUCTION

Injuries to the ankle are a very common reason for presentation at accident and emergency departments (EDs) and in the UK account for over 300,000 new cases each year.¹ The majority of these patients are diagnosed as acute soft tissue injury following assessment using the Ottawa foot and ankle principles and conventional radiographs.² They are managed using PRICE (Protection, Rest, Ice, Compression, Elevation) principles and return home to attend to their own recovery.³

Although the majority of these patients are managed conservatively, up to a third do not achieve optimal

recovery and may suffer from long-term disability and dysfunction.^{4–6} CT and ultrasound examination are recognized as techniques that can detect fractures and soft tissue injuries,^{7–9} yet are not often used in routine practice. To date, it does not appear that any previous publications have compared ultrasound examination and CT in patients with normal radiographs.

The hypothesis of this study was that occult fractures and complex ligament injuries may be significant factors contributing to delayed recovery following an ankle injury. The primary aim was to predict poor outcome after simple ankle injuries using several imaging methods and

Figure 1. The use of fusion imaging to correlate between an ankle CT and ultrasound. (1a) Picture of ultrasound machine in use for fusion imaging. (1b) Image of an anterior ankle with fusion of the CT and ultrasound.

to investigate whether injuries were missed using traditional screening tools and radiographic examination. The functional outcome of the patients from this study measured at 3 and 6 months, and the associations with ligament injury patterns has already been presented.¹⁰ Therefore, the objectives of this paper are to describe the study in total but to focus on examining the occult fracture incidence and associations, and to also consider the appropriateness of examination methods for acute ankle injuries.

METHOD

A prospective observational cohort study was undertaken by musculoskeletal radiologists, sports medicine physicians, a physiotherapist and the research team at St Luke's Radiology Oxford Ltd in collaboration with the ED at the John Radcliffe Hospital (Oxford University Hospitals NHS Foundation Trust). The study was approved and monitored by the UK Medical Research and Ethics Committee (12/SC/0596) and the study was funded by St Luke's Radiology Oxford Ltd

Patients arriving in the ED with an acute ankle sprain who were over 18 years of age, English speaking, not pregnant and had undergone a normal radiographic examination following the application of the Ottawa foot and ankle rules, were invited into the study. Once the treating ED clinician had deemed the radiographs normal and concluded their consultation, the patient was

provided with an information pack including contact details for the study coordinators. The radiographs were subsequently reviewed and reported by a radiology practitioner specialising in trauma imaging. Patients with fractures identified at this review were not included in the study.

Following discharge from the ED with conservative management advice, usually along the PRICE principles, patients who contacted St Luke's Radiology were invited to undergo an ultrasound and cone beam CT examination within 5 days of their presentation to the ED.

Recruitment took place between the 24 February 2013 and 4 November 2014 (21 months). After an initial consultation and the gaining of consent, the Euroqol five dimensions, five levels (EQ-5D-5L) quality of life score and a visual analogue scale pain score were completed as the outcome measures. Following this, a clinical assessment, an ultrasound examination and a cone beam CT examination were performed. The CT data were imported into the ultrasound apparatus and fusion imaging was performed. Patients with severe fractures (*vide infra*) were referred to the orthopaedic trauma unit at the John Radcliffe Hospital. All patients were invited to continue in the study and were followed up with repeat ultrasound examination, clinical review and outcome measure completion at 3 and 6 months. The ultrasound machine used was a GE Logiq E9 using a 5–15MHz linear array probe and a 5–15MHz hockey stick probe with fusion software and hardware. The examination was performed by one of two experienced musculoskeletal radiologists with 35 and 22 years' ultrasound experience. The CT was performed on a Verity (Planmed) extremity CT scanner with the patient in the sitting position, by one senior radiographer with 34 years' experience.

Cone beam CT has a radiation dose similar to a conventional radiographic examination. It has an 18 s volume acquisition and gives a 640 sliced isotropic volume with 0.2 mm pixels. The radiation dose is approximately 10% of a conventional CT examination.¹¹ Fusion technology installed on the ultrasound machine was also used to correlate between the CT and the ultrasound (Figure 1a, b).

Ultrasound examination included the joints, ligaments, tendons, bone surfaces, visible articular surfaces and bursae in the ankle, hind foot and mid foot recording findings in a template. The CT examination was then imported into the ultrasound machine and the two forms of image were fused. Probe position tracking was employed to allow simultaneous viewing of the ultrasound image with the multiplanar reconstruction of an isotropic volume CT data set in real time. This allowed the operator to review CT and ultrasound abnormalities with both imaging methods; the CT moved with changes of the ultrasound probe position.

FRACTURES IDENTIFIED BY CT EXAMINATION WERE GRADED AS MINOR OR SEVERE: -

Minor

Small avulsion fractures without loss of the parent bone stability, excluding Weber A avulsion fractures of the distal fibula.¹²

Table 1. Types of fractures

Type of fracture	Seen on ultrasound	Seen on CT
Avulsion	40 (4 not seen on CT)	43 (6 not seen on ultrasound)
Large fracture	7	19

Severe

Fractures across the width of a bone with the potential for instability. In particular, talar neck fractures, osteochondral fractures, medial or posterior malleolar fractures, Weber A, B or C fractures of the fibula,¹² fractures of the anterior process of the calcaneus, fractures of the body of navicular, calcaneus or cuboid fractures and fractures of the proximal fifth metatarsal.

RESULTS

100 patients (53 male and 47 female) were recruited with a mean age of 33 years (range 18–68). Within the cohort, 42 patients demonstrated ankle effusions. Severe fractures undetected by radiographs were seen in 7 patients using ultrasound and 19 patients using CT. All the ultrasound detected fractures were confirmed by CT, so there were no false positives using ultrasound. Minor avulsion fractures were seen, both using ultrasound and CT, 40 by ultrasound examination and 43 by CT examination. Four ultrasound detected minor avulsion fractures were not confirmed by CT and six CT detected minor fractures were not detected using ultrasound (Table 1).

Of the 19 severe fractures, 7 were of the anterior process of the calcaneus, 5 were Weber A fractures of the fibula, 4 were tibial (3 of which were posterior malleolar) (Figure 2a, b), 3 were cuboid, 2 were talar, 1 was of the sustentaculum tali and 4 had multiple fractures (Figure 3a, b). Three of the patients with multiple fractures included a fracture of the anterior process of the calcaneus (Figures 4a,b, c, and 5). There were two syndesmotom injuries.

Not all of the 42 ankle effusions, were associated with fractures. 10 of the patients with significant fractures had ankle effusions meaning that almost half of patients with severe fractures did not have ankle effusions. The largest effusions were seen in a patient with an anterior process fracture of the calcaneus and a patient with an anterior talofibular ligament tear with deltoid sprain, but

no fractures. Of the 19 patients with fractures only 1 had no ligamentous injury. The pattern of these injuries is shown in Table 2. When there was a simple, isolated fracture of the anterior process of the calcaneus there was always an injury to the talonavicular ligament.

Of the ligament injuries detected, 83 had new anterior talofibular ligament injuries. 19 had anterior tibiofibular ligament injuries, 26 had calcaneofibular ligament injuries, 39 had deltoid complex injuries, 21 had talonavicular ligament injuries, 14 had injury to the spring ligament and 3 had calcaneocuboid ligament injury.

DISCUSSION

This study has found that fractures, both severe and minor, and significant soft tissue injuries are not detected by the Ottawa foot and ankle rules and plain radiography. Many of the findings from this study correlate with other research projects looking at imaging techniques in ankle injuries.

The number of patients within this study with ankle effusions and significant fractures in the ankle and foot was 53%, which is similar to figures published in previous literature.¹³ It was also noted that 32 out of the 42 patients (76%) with ankle effusions had ligament injuries only with no identifiable fracture. It was not possible to identify any particular pattern of ligament injuries in those patients with significant fractures and ankle effusions. The one patient who had a significant fracture and no ligament injuries did not have an ankle effusion.

Cone beam CT examination used within this study has confirmed the generally established fact that CT is more sensitive than plain radiography in detecting fractures. When considering its role in the acute assessment of ankle injuries it has been shown in previous work that CT can add value in assessing the extent and displacement of fractures of the calcaneus and talus when compared to analysis by radiographs alone.⁷ One study following the criteria of the Ottawa foot and ankle rules for the indication for radiographic examination reviewed patients with negative radiographs who were considered to have signs highly suggestive of fracture. Using CT, they found 5 fractures of the lateral malleolus out of 21 patients (24%).¹⁴ They did not describe fractures of other bones which suggests that the “highly suspicious” features used as an indication for CT examination were weighted

Figure 2. A fracture of the posterior malleolus of the tibia seen on CT (2a) and ultrasound with a deltoid ligament rupture (2b) in the same patient (arrow).

Figure 3. Calcaneus (3a) (arrow) and navicular fractures (3b) (arrow) seen in the same patient on CT.

heavily in favour of lateral bone injury, thereby excluding other fractures. In addition to the research evidence, the cone beam CT that was used for this study has approximately the same radiation dose exposure as conventional radiographs. As such, the findings of this study and the evidence presented support the suggestion that cone beam CT could be an acceptable replacement for radiography in the examination of acute ankle injuries.

In this study, ultrasound examination was able to identify soft tissue injuries that are not detected by plain radiographs. Ultrasound was also able to detect fractures that were overlooked by plain radiographs and the Ottawa foot and ankle rules. This conclusion has been presented in several studies elsewhere albeit with varying detection rates. One group studied the detection rate of fractures by ultrasound compared to conventional radiographs and calculated a sensitivity for ultrasound of 87.3%, however, the authors did not discuss the severity of the fractures, *i.e.* avulsion or larger.¹⁵ They also claimed that one fracture seen using ultrasound but not seen on a radiograph was later confirmed by CT. Another study recorded an ultrasound detection rate for fractures of 100% when compared to radiographs alone.⁸ The usefulness of ultrasound has also been presented by

Wang et al who showed a detection rate of 9% of fractures by ultrasound in patients with negative radiographs.⁹

It has been suggested that if ultrasound is performed by experienced operators, then it may be used to triage patients for radiographic examination rather than using the Ottawa ankle rules as a sole discriminator. Hedelin et al presented that in an emergency room setting, it could have prevented 85 out of 122 radiographic examinations that would have been undertaken using Ottawa rules criteria only.¹⁶ If patients are selected by Ottawa rules criteria and then examined by ultrasound alone, there appears to be a good detection of malleolar fractures, 10 of 11 fractures being detected in a study by Canagasabay et al.¹⁷ This study used radiographs as the gold-standard and our study raises questions regarding the validity of this method.

It seems that ultrasound examination alone can be useful in assessing bone injury especially when a radiographic examination is not easily available.¹⁸ That the patient can point to the area of pain during examination is of some assistance. However, there are some limitations of the technique in the accurate diagnosis of fracture as described in this article. It seems unlikely that ultrasound examination alone will replace radiographic examinations to detect fractures, but with adequately trained professionals in place it has a role as a complementary examination.

Figure 4. A patient with an anterior process of the calcaneus fracture (4a) but also a cuboid fracture (4b) and a talar process fracture (4C) (arrowed).

Figure 5. The same patient as in four showing the cuboid fracture on ultrasound as well as CT (arrows).

Table 2. The other findings associated with the major fractures

Fracture	Effusion	ATalFL injury	ATibFL injury	CFL injury	Deltoid injury	TNL injury	Calcub injury	Spring injury	Syndesmosis injury
1 Anterior process of calcaneus	No	Yes	No	No	No	Yes	No	No	No
2 Anterior process of calcaneus and cuboid	No	No	No	No	No	No	No	No	No
3 Weber A	No	Yes	No	No	Yes	Yes	No	No	No
4 Weber A	No	Yes	Yes	No	No	No	No	No	No
5 Weber A and tibia avulsion	Yes	No	No	Yes	Yes	No	No	No	No
6 Posterior lateral tibia epiphysis complex injury	No	Yes	Yes	No	Yes	Yes	No	No	No
7 Talar dome and distal tibia	No	Yes	No	No	No	No	No	No	No
8 Anterior process of calcaneus	Yes	Yes	Yes	No	No	Yes	No	No	No
9 Fibula fracture and Distal tibia contra coup injury	Yes	Yes	No	Yes	No	No	No	No	No
10 Distal fibula avulsion and Anterior process of calcaneus	No	Yes	No	Yes	No	No	No	No	No
11 Weber A	No	Yes	No	No	Yes	No	No	No	No
12 Post-malleolar of tibia	No	Yes	Yes	No	Yes	No	No	Yes	No
13 Post-malleolar of tibia	Yes	Yes	Yes	No	Yes	No	No	No	Yes
14 Os naviculare avulsion	Yes	Yes	No	No	No	No	No	No	No
15 Sustentaculum tali, medial talus, navicular	Yes	Yes	No	Yes	Yes	No	No	No	No
16 Anterior process of calcaneus fragmented	Yes	Yes	Yes	No	No	No	No	No	Yes
17 Anterior process of calcaneus	Yes	Yes	No	No	Yes	Yes	No	No	No
18 Anterior process of calcaneus	Yes	Yes	No	No	No	Yes	Yes	No	No
19 Anterior process of calcaneus	Yes	No	No	No	Yes	Yes	No	Yes	No

ATalFL, Anterior Talofibular ligament; ATibFL, Anterior Tibiofibular ligament; CFL, Calcaneofibular ligament; Calcub, Calcaneocuboid ligament; TNL, Dorsal Talonavicular ligament.

None of the ultrasound studies discussed above used CT and ultrasound following negative radiographs in all patients. In this study, 7 out of the 19 significant fractures were detected using ultrasound (37%). There were many more fractures in our study when small avulsion injuries are included (47%), but these were not seen consistently on either CT or ultrasound and it may be that the two techniques are complementary in this respect.

The clinical significance of the fractures on functional outcomes as compared to patients with soft tissue injuries only has already been published. It appeared that there was no clinically significant difference in functional outcome based on the types of injury that patients underwent but it was presented that there are factors to consider early in the recovery after an injury to optimise a return to normal function.¹⁰

This study has shown a similar result to a paper comparing ankle ligament injuries detected by ultrasound as compared to MRI.¹⁹ Ultrasound has also been clearly shown to demonstrate soft tissue injuries of the ankle well, although, there is some attention to detail required to identify the ankle ligaments correctly.^{20,21} For example, none of the previous literature mentions injury to the talonavicular or calcaneocuboid ligament in association with ankle sprain. In this study, the musculoskeletal ultrasound was performed by very experienced practitioners and therefore the results may not be easily reproducible. The association of talonavicular ligament injury and fracture of the anterior process of the calcaneus noted in this study emphasises the significance of this injury. We propose that injury is the manifestation of a midfoot dislocation/relocation and an analysis of the talonavicular ligament and its' biomechanical function has been presented by De Dea et al.²²

Study limitations

At the outset of the study, it was believed that recruitment would not take long, as roughly 20 patients with ankle sprains attend the ED in Oxford each day. 400 invitations were given to patients with negative radiographs, but it took 21 months to recruit 100

patients and therefore the study pre-selected motivated individuals. It was noticed that most of the patients were either sporty males or females, or very active in their work. We did not correlate the CT with the original radiographs as it was thought this may introduce bias.

CONCLUSION

In conclusion, this study found 19 significant fractures within a cohort of 100 patients, using CT and ultrasound, that were overlooked by conventional screening tools and radiographs. It appears that an ankle effusion does not correlate with the severity of injury, so in clinical practice the lack of an effusion should not be used to rule out the possibility of a severe injury. When there is a lateral ligament injury, the medial ligaments are injured in almost 50% of cases and if there is a significant fracture present it should be assumed that there are also ligamentous injuries. It is also possible to conclude that simple anterior process fractures of the calcaneus are strongly associated with talonavicular ligament injuries. These are important considerations for clinicians when examining ankle injuries and planning ongoing treatment and rehabilitation to account for both fractures and soft tissue injuries.

Cone beam CT has been shown to be more sensitive at detecting fractures than ultrasound examination and the current practice of clinical examination and radiographs. With a similar radiation exposure compared to conventional radiography, it would appear that it is an equally safe and more accurate alternative imaging technique. Additionally, the findings of this study and the evidence presented would support the use of ultrasound, with appropriately qualified clinicians, to complement current practice for the detection of fractures and the diagnosis in acute ankle injuries.

ACKNOWLEDGMENT

Thanks is given to the study participants, the staff of the ED at the John Radcliffe Hospital in Oxford and Miss Sara Owen, Research Coordinator, for their help with this project.

REFERENCES

1. Bridgman SA, Clement D, Downing A, Walley G, Phair I, Maffulli N. Population based epidemiology of ankle sprains attending accident and emergency units in the West Midlands of England, and a survey of UK practice for severe ankle sprains. *Emerg Med J* 2003; **20**: 508–10. doi: <https://doi.org/10.1136/emj.20.6.508>
2. Stiell IG, Greenberg GH, McKnight RD, Nair RC, McDowell I, Worthington JR. A study to develop clinical decision rules for the use of radiography in acute ankle injuries. *Ann Emerg Med* 1992; **21**: 384–90. doi: [https://doi.org/10.1016/S0196-0644\(05\)82656-3](https://doi.org/10.1016/S0196-0644(05)82656-3)
3. Bleakley CM, O'Connor SR, Tully MA, Roche LG, Macauley DC, Bradbury I, et al. Effect of accelerated rehabilitation on function after ankle sprain: randomised controlled trial. *Br Med J* 1964; **2010**.
4. Kemler E, van de Port I, Backx F, van Dijk CN. A systematic review on the treatment of acute ankle sprain: brace versus other functional treatment types. *Sports Med* 2011; **41**: 185–97. doi: <https://doi.org/10.2165/11584370-000000000-00000>
5. Hossain M, Thomas R. Ankle instability: presentation and management. *Orthop Trauma* 2015; **29**: 145–51. doi: <https://doi.org/10.1016/j.mporth.2014.12.001>
6. Houston MN, Hoch JM, Hoch MC. Patient-Reported outcome measures in individuals with chronic ankle instability: a systematic review. *J Athl Train* 2015; **50**: 1019–33. doi: <https://doi.org/10.4085/1062-6050-50.9.01>
7. Hindman BW, Ross SD, Sowerby MR. Fractures of the talus and calcaneus: evaluation by computed tomography. *J Comput Tomogr* 1986; **10**: 191–6. doi: [https://doi.org/10.1016/0149-936X\(86\)90075-5](https://doi.org/10.1016/0149-936X(86)90075-5)
8. Ekinci S, Polat O, Günel M, Demirkan A, Koca A. The accuracy of ultrasound evaluation in foot and ankle trauma. *Am J Emerg Med* 2013; **31**: 1551–5. doi: <https://doi.org/10.1016/j.ajem.2013.06.008>

9. WangCL, ShiehJY, WangTG, HsiehFJ. Sonographic detection of occult fractures in the foot and ankle. *J Clin Ultrasound*1999; **27**: 421–5. doi: [https://doi.org/10.1002/\(SICI\)1097-0096\(199910\)27:8<421::AID-JCU2>3.0.CO;2-E](https://doi.org/10.1002/(SICI)1097-0096(199910)27:8<421::AID-JCU2>3.0.CO;2-E)
10. BullockSA, AllenGM, WatsonMS, WilsonDJ. Predicting poor outcome from simple ankle injuries: a prospective cohort study. *Br J Radiol*2018; **91**: 20170213. doi: <https://doi.org/10.1259/bjr.20170213>
11. LiG. Patient radiation dose and protection from cone-beam computed tomography. *Imaging Sci Dent*2013; **43**: 63–9. doi: <https://doi.org/10.5624/isd.2013.43.2.63>
12. HughesJL, WeberH, WilleneggerH, KurerEH. Evaluation of ankle fractures: non-operative and operative treatment. *Clin Orthop Relat Res*1979;: 111–9.
13. ClarkTW, JanzenDL, LoganPM, HoK, ConnellDG. Improving the detection of radiographically occult ankle fractures: positive predictive value of an ankle joint effusion. *Clin Radiol*1996; **51**: 632–6. doi: [https://doi.org/10.1016/S0009-9260\(96\)80057-2](https://doi.org/10.1016/S0009-9260(96)80057-2)
14. WangX, ChangS-min, YuG-rong, RaoZ-tao. Clinical value of the Ottawa ankle rules for diagnosis of fractures in acute ankle injuries. *PLoS One*2013; **8**: e63228. doi: <https://doi.org/10.1371/journal.pone.0063228>
15. AtillaOD, YesilarasM, KilicTY, TurFC, ReisogluA, SeverM, et al. The accuracy of bedside ultrasonography as a diagnostic tool for fractures in the ankle and foot. *Acad Emerg Med*2014; **21**: 1058–61. doi: <https://doi.org/10.1111/acem.12467>
16. HedelinH, GoksörLars-Åke, KarlssonJ, StjernströmS. Ultrasound-Assisted triage of ankle trauma can decrease the need for radiographic imaging. *Am J Emerg Med*2013; **31**: 1686–9. doi: <https://doi.org/10.1016/j.ajem.2013.09.005>
17. CanagasabeyMD, CallaghanMJ, CarleyS. The sonographic Ottawa foot and ankle rules study (the SOFAR study. *Emerg Med J*2011; **28**: 838–40. doi: <https://doi.org/10.1136/emj.2009.088286>
18. HoffmanDE, AdamsE, BianchiS. Ultrasonography of fractures in sports medicine. *Br J Sports Med*2015; **49**: 152–60. doi: <https://doi.org/10.1136/bjsports-2014-094217>
19. MargeticP, SalajM, LubinaIZ. The value of ultrasound in acute ankle injury: comparison with Mr. *Eur J Trauma Emerg Surg*2009; **35**: 141–6. doi: <https://doi.org/10.1007/s00068-008-7174-1>
20. PeetronsP, CreteurV, BacqC. Sonography of ankle ligaments. *J Clin Ultrasound*2004; **32**: 491–9. doi: <https://doi.org/10.1002/jcu.20068>
21. De MaeseneerM, MarcelisS, JagerT, ShahabpourM, Van RoyP, WeaverJ, et al. Sonography of the normal ankle: a target approach using skeletal reference points. *AJR Am J Roentgenol*2009; **192**: 487–95. doi: <https://doi.org/10.2214/AJR.08.1316>
22. De DeaM, L LoizouC, AllenGM, WilsonDJ, AthanasouN, UchiyaraY, et al. Talonavicular ligament: prevalence of injury in ankle sprains, histological analysis and hypothesis of its biomechanical function. *Br J Radiol*2017; **90**: 20160816. doi: <https://doi.org/10.1259/bjr.20160816>