

## STUDY ON THE ROLE OF ULTRASONOGRAPHY IN LIGAMENT INJURIES BY ANKLE SPRAIN

HASSAN BARZEGARI MD<sup>1</sup>, AZIM MOTAMEDFAR MD<sup>1</sup>, MEISAM MOEZzi MD<sup>1\*</sup>, SANA KOHANDEL MD<sup>1</sup> AND AHMADREZA RAFIEI MD<sup>2</sup>

<sup>1</sup>Department of Emergency Medicine, Golestan Hospital,  
Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

<sup>2</sup>Department of Neurosurgery, Shahrekord University of Medical Science, Shahrekord, Iran.

### ABSTRACT

Ankle sprain is among the debilitating problems which happen during everyday activities or sports such as volleyball, basketball, football, wrestling and martial arts, mountaineering etc and it will lead to inability to return to sport and even interfere with daily activities due to frequent sprains, pain, and uncertainty to ankle during walking in the case of improper and sufficient treatment. In the case of low intensity of ankle ligament strain and rupture, it can be held by wrist strap and treated by the same method, but in the cases where there is a high strain severity, it is preferred to make the ankle motionless by plaster for three weeks. The ligament strain severity diagnosis is done by physician and based on the examination and imaging methods. After three weeks of treatment, whether with wrist strap or plaster, the patient should do special exercise to increase the flexibility of joint and increase the shank muscles. If this exercise is not properly done, the ankle sprain may recur repeatedly. In the case of patient's repeated ankle pain, he should be examined for relevant injuries such as damage to cartilage or ligament instability in ankle ligaments. In the case of these injuries, the patient may have to undergo surgery. This study is conducted on the accuracy of ultrasonography in patients with foot and ankle trauma admitted to emergency department. Our findings of study indicate that the ultrasound is an effective method which can be used in emergency department for adults in order to diagnose the ankle tendon injuries. Sonographic imaging leads to high levels of satisfaction in patients. Furthermore, the ultrasound assessment can be safely used in pregnant women and children age groups. There is a need for further studies including the study on effects of ultrasound in emergency department over time and the time of diagnosing the patients with foot and ankle trauma.

**Keywords:** Ultrasonography, ligament injury, ankle, sprain, diagnosis and treatment.

### INTRODUCTION

Ankle sprain is an injury to ankle lateral ligament complex. This injury is graded based on the severity<sup>1</sup>. Grade I is a mild strain of ligaments without any damage to joint stability; Grade II is a partial tear of ligament with mild joint instability (such as rupture of the only anterior talofibular ligament); Grade III includes a complete rupture of ligaments along with joint instability. This grading is done for the most appropriate treatment of severe ankle sprain<sup>1</sup>. Ankle sprain is a common problem in acute medical care with estimated prevalence of 1 out of 10 thousand individuals per day<sup>2</sup>. The ankle lateral ligament injuries account for one quarter of all sports injuries<sup>2</sup>. The ankle sprain is common

especially in sports including running on uneven ground, repeated jumping or frequent changes in a direction such as basketball, volleyball, soccer and rugby<sup>3</sup>. The inversion and adduction injury to flexed foot towards plantar is the usual mechanism<sup>1</sup>. The use of appropriate modality for study is a way for diagnosing the extent of injury in ankle sprain. Ultrasonography is an accepted method with high sensitivity in diagnosing the damage to ligaments, tendons and in general the soft tissues<sup>4, 5</sup>. Several studies have been conducted on evaluation of ultrasound accuracy in damages to tendons and ankle ligaments and their results have often indicated that there is not any significant difference between the sensitivity of ultrasound and MRI in diagnosis of injuries to soft tissue, and thus

the ultrasound can be utilized as an appropriate modality to find the soft tissue injuries in ankle sprain<sup>6-10</sup>. Given the importance of issue and reduced costs of using the MRI in injured patients and also the need for further studies to clarify its details, this research investigates the ultrasound findings in acute ankle sprain in emergency department compared with MRI findings (as the gold standard of diagnosis). The ankle injuries are the most common injuries reported to emergencies and primary care centers. Patients with ankle sprain make up a large percentage of these injuries. The ankle ligaments create the mechanical stability, proprioceptive and movement information for joint. The recurrent ankle sprain can lead to functional instability and loss of ankle proprioceptive movement which can cause frequent injuries, chronic instability, bone deformities and premature degeneration of chronic pain. Acute ankle sprain can lead to loss of working ability or inability to participate in sports activities<sup>11, 12</sup>.

### ***Lateral ankle sprain***

This is the most common mechanism of ankle injuries which cause damage to lateral ankle ligament complex. This complex includes anterior, calcaneo fibular, and talofibular ligament. Due to the increased forces, the ligaments will be injured in a predictable sequence. The anterior ligament is the first or only ligament which is damaged in most of the ankle sprains. Stronger forces will lead to combined rupture of anterior and calcaneofibular ligaments and this can lead to significant instability of ankle joint. The injuries of calcaneofibular ligament are unusual. However, the stronger forces will damage all three ligaments. Such these injuries are uncommon, but extremely debilitating and more commonly associated with significant neural damage<sup>13</sup>.

### ***Midfoot ankle sprain***

Middle deltoid ligament is among the most powerful ankle ligaments and rarely gets hurt. Forced return (sprain) of ankle can cause damage to this structure, but due to the power of deltoid ligament, the ankle fracture is more common<sup>14</sup>. Syndesmosis (chronic ankle dorsiflexion) or ankle sprain may be lead to structural sprain and this includes anterior, posterior, tibiofibular and interosseous ligament. These structures are very critical for ankle. The injuries of Syndesmotic ligaments play roles in chronic instability of ankle and probably lead to repeated ankle sprains and heterotrophic ossification. The ankle sprain ankle

range is from 1 to 11 percent for all ankle sprains and it is higher for sports injuries<sup>15, 16</sup>.

### ***Treatment***

#### ***Immediate treatment***

All lateral ankle ligament sprains can be treated in a similar way. Primary management objectives include the reduction of swelling and inflammation and maintaining the range of motion. Initial treatment consists of RICE (rest, ice, compression and elevation) for the first two or three days.<sup>17</sup>:

- Rest is achieved by limiting the weight-bearing; the patients use canes until they are able to walk normally.
- Cold therapy is done by ice or cold water. The immersion is offered for 15 to 20 minutes every two or three hours for 48 initial hours or until swelling is reduced and whenever it occurs first.
- Compression by elastic bandage to minimize swelling should be applied early.
- Damaged ankle should be kept above the heart level to reduce swelling.
- Nonsteroidal anti-inflammatory drugs (NSAIDs) can be used in this regard and there are not any particular NSAID. Both topical and oral NSAIDs are more effective than placebo. There are not any studies for comparing the oral and topical NSAIDs and also comparison with analgesic NSAIDs, therefore, it is not obvious that the anti-inflammatory effect is important or not.

Exercises such as plantar flexion, dorsiflexion and foot circles should be started immediately after the acute swelling and pain subside in order to maintain the range of motion. The severity of rehabilitation is gradually increased. The splints or small braces of ankle can limit the extreme degree of motion and can handle the tolerance of primary pain while protecting against damage.

Treatment of chronic ankle sprain (Grade III) is controversial. A brief period of immobilization may be useful in some cases.

### ***Immobilization***

The patients with ankle sprain mild (grade 1) do not require immobilization. Treatment with elastic bandage is sufficient for a few days after the injury. Patients with moderate ankle sprain (Grade 2) may require sustained support after their injury. Treatment of chronic ankle sprain (Grade 3) is controversial. In one of the trials included in systematic review, over 80 patients with anterior ligament rupture Grade 3 are participated for immobilization in plaster or early mobility by

orthosis. The treated patients with primary mobility began the work and exercise earlier than the motionless patients and there was not any difference in stability of ankle during activity after a year of treatment (follow-up)<sup>18-21</sup>.

### **Rehabilitation**

According to results, it is difficult to determine the right rule and timing for immobilization or primary rehabilitation in patients with ankle sprain Grade 3. Suggestion of a short period (10 days) of immobilization in plaster seems reasonable for patients with chronic ankle sprain, especially if mobility is painful and the likelihood of compliance is difficult. Another method can use a comparable period of heavy weight intolerance and immobilization using a combination of Aircast™ splint and elastic bandage. The primary functional rehabilitation can start as soon as stopped immobilization<sup>22</sup>.

### **Splints and clamps**

The splints, clamps, elastic bandages or taping may be used during functional rehabilitation to reduce instability, protect ankle against more injury and limit swelling. The theory under which taping improves proprioception has remained uncertain<sup>23</sup>.

### **Surgery**

Sometimes the reconstructive surgery is considered for ruptured ankle ligaments in patients with ankle sprain. According to a meta-analysis on controlled trials of surgery for acute rupture of lateral ankle ligaments, the treated patients with surgery significantly have less possibility of giving-way than functional treatment. A prospective trial for treatment of lateral ankle ligament rupture studied 185 operated patients and 203 functionally-treated patients. After an average eight years of follow-up, the pain in operated patients was reported less than remained patients with functional treatment (16 vs. 25 percent) and frequent sprain (22 vs. 34 percent). There was not any difference between percentages of patients after worse radiographic evidence of joint degeneration. According to follow-up, the patients treated with surgery had a less chance of positive anterior drawer test (30 vs. 54 percent) although it had been diagnosed by physicians who knew how patients were treated. Based on these results, it is unknown whether patients with acute ankle sprain benefit from surgery. Given the costs and risks of surgery, it is unlikely that patients with mild to moderate ankle sprains will be healed by surgery. The surgery may be logical in some patients with chronic ankle sprain in professional

sports or other activities imposing high frequent pressures on ankle joint<sup>24-26</sup>.

### **Ultrasound and other recommended treatments**

According to a systematic review of six trials involving 606 patients, the ultrasound therapy is not an appropriate treatment for acute ankle sprain. Other treatments, which seem ineffective, include treatment by hyperbaric oxygen and low level laser<sup>27</sup>.

### **Review of research literature**

D'Erme et al (1996) have studied the ankle ligament injuries by MRI results and ultrasonography during a descriptive study in Italy. This study is classified into retrospective and prospective parts. In prospective study, the MRI test was conducted on 20 patients referred to in emergency department for acute ankle sprains, and then the splint was given to them for treatment after diagnosis. Patients with fractures were excluded. For follow-up, the MRI was performed on these patients 30 days of 6 months. 18 damaged ligaments remained in study and 5 ones were anterior talofibular ligaments (ATFL) and 13 ones were ATFL and calcaneofibular ligaments (CFL). In retrospective study, the sonographic findings in 78 patients with sprains (28 patients with acute sprains and 50 patients with chronic sprains) were compared with MRI findings (gold standard). In group of acute ankle sprain, there were 9 ATFL injuries, 5 ATFL and CFL injuries, 2 complete rupture of ligaments, 3 deltoid ligament injuries (DL), 2 ATFL and DL injuries and 2 damages to pairs of medial and lateral ligaments. Sonographic findings in 85% of ATFL, 67% of CFL, and 28% of DL were consistent with MRI findings. Ultrasonography also reported two false positive cases<sup>9</sup>. Gremeaux et al (2009) conducted a descriptive study in France to compare ultrasound findings in lateral ligament injury of ankle sprain and clinical examination findings. 34 patients were evaluated in this study. None of the patients had solely the clinical symptoms which suggest the severity of ligament injury in ultrasonography. This study indicate that the clinical symptoms and severity of anatomic injury do not match properly in ankle sprain and it seems better to spread the indications of using the ultrasonography in ankle sprain especially in vague circumstances<sup>28</sup>. Oae et al (2010) evaluated the anterior talofibular ligament injury with stress radiography, ultrasonography and MR imaging in Japan. 34 patients with ankle sprains were involved in study and the radiography, ultrasonography, MRI and arthroscopy (as the gold

standard) were performed on all patients. Arthroscopy diagnosed 30 out of 34 patients with ATFL injury. The accuracy of radiography, ultrasonography and MRI was reported equal to 67%, 91% and 97%, respectively. This study indicated that the ultrasonography and MRI imaging had satisfactory results<sup>29</sup>. Margetic et al (2012) studied and compared the MRI and ultrasonography findings in ligament and tendon injuries in ankle sprain in Croatia. 30 patients were included in this study and had no visible fractures on radiography images. The patients were examined by ultrasonography on the seventh day and by MRI on the seventeenth day. The joint effusion and ATFL injury were the most common cases while the tibialis anterior tendon injury had the minimum numbers. Both MRI and ultrasonography had equal sensitivity in terms of detecting the presence or absence of damage to tendons and ligaments of ankle, but MRI was more specific than ultrasonography in diagnosis of complete rupture of ligament<sup>5</sup>. Croy et al (2012) conducted a cross sectional study in America to examine the accuracy of ultrasonography in differences of lateral ankle laxity in 60 patients. They classified patients into three groups of control, chronic ankle instability (over a year), and non-chronic ankle instability (less than a year), and utilized the stress ultrasound to evaluate and compare groups. They found that the stress ultrasound was an appropriate modality for differences in length of anterior talofibular ligament in group of patients compared to control group<sup>6</sup>. Klein et al (2012) conducted a cross-sectional study in America to compare MRI and ultrasound to detect and localize the plantar plate tear in 51 patients with forefoot pain and one-sided possible tear of plantar plate in second metatarsophalangeal joint. The results of this study indicate that 46 patients had plantar plate tear; and the sensitivity, specificity and positive and negative predictive value were 73.9%, 100%, 100%, and 29.4% respectively in MRI and 91.5%, 25%, 91.5% and 25% respectively in ultrasonography. They have found that both modalities are appropriate for investigating the plantar plate and ultrasound is more sensitive and MRI is more specific<sup>8</sup>.

Ekinic et al (2013) studied the accuracy of ultrasound in foot and ankle trauma according to a descriptive study in Turkey. 131 Ottawa ankle rules-positive patients (positive based on Ottawa ankle rules) who were over 16 years of age and admitted to emergency department with complaint of foot and ankle injuries were included in this study. Ankle and foot ultrasonography were taken

from all patients, and then the ankle and foot radiography was done on each of them individually and data of two methods were compared. The radiographic evaluation found 20 fractures which were also detected by ultrasound; furthermore, the ultrasound could detect a hidden fracture. The ultrasound had sensitivity of 100%, specificity of 99.1%, positive predictive value of 95.2%, and negative predictive value of 100%. This study indicates that the ultrasound imaging is very useful in evaluating the foot and ankle injuries in emergency department in terms of diagnosing the fractures<sup>30</sup>.

### **Research methodology**

#### **Specific purposes of project**

1. Determining the sensitivity, specificity, positive and negative predictive values of ultrasound in soft tissue injuries in ankle sprain;
2. Determining the sensitivity, specificity, positive and negative predictive values of ultrasound in soft tissue injuries in ankle sprain on the basis of age distribution;
3. Determining the sensitivity, specificity, positive and negative predictive values of ultrasound in soft tissue injuries in ankle sprain on the basis of gender distribution;
4. Comparing the sonographic and MRI results in soft tissue injury in ankle sprain based on clinical symptoms

The analytical-comparative study was conducted and the population included patients over 16 years of age referred to emergency of Golestan Hospital in Ahvaz during 72 hours after ankle sprain<sup>31</sup>. The exclusion criteria included the unstable vital symptoms, underlying disease of ankle, loss of consciousness, lack of patient satisfaction, and fracture. Patients were initially examined by ultrasound by emergency medicine residents who were trained for soft tissue ultrasonography. For ultrasonography of soft tissue, the patients were put in supine position while the ankle was in passive position in maximum inversion and flexion of plantar. A transducer with high linear frequency with central frequencies from 5 and 17 MHz was used in this regard. The transducer flows on the external area to find ATFL. The transducer was first located along the longitudinal axis of ATFL to investigate the whole length of ligament, and then rotated 90 degrees to show the transverse axis of ATFL. The ultrasound criteria for pathological diagnosis of ATFL include the following cases:

**Ligament rupture**

Complete or partial tear of ligament fibers in fibular, talar part between these two regions

**Lax ligament**

Ligament remains curved in maximum inversion and flexion of plantar

**Thick ligament**

Ligament width is more than 2.4 mm or more than 20 percent of normal lateral ligament

**Absorbed ligament**

There is no ligament

**External ankle fracture and detachment**

Afterwards, the MRI was taken from the ankle of all patients included in study and interpreted by a unit radiologist who was unaware of patient's ultrasound result. The diagnostic data of

ultrasonography and MRI was compared and analyzed by SPSS software. According to the article by D'Erme et al<sup>8</sup>, the prevalence of ligament injuries is about 82% in people who have suffered from ankle sprains. On the other hand, according to the study by Gremeaux et al [9], the sensitivity of ultrasonography is 93 percent in ligament injuries. If the error coefficient is  $d=0.05$  and the probability of error type I is  $\alpha=0.5$ , the estimated sample size will be obtained equal to 121 according to the following formula, but the information of 135 patients is first collected due to the exclusion of some patients during the study. The quantitative variables such as mean and standard deviation and qualitative variables such as frequency and percentage are utilized to describe data. The Roc core is used to determine the sensitivity, specificity, positive and negative predictive values. All statistical analyzes are performed using SPSS version 18.

**Table 1**  
**Research variables**

Variable specifications	Independent	Dependent	Quantitative		Qualitative		Scale
			Continuous	Discrete	Nominal	Ranking	
Injured Ligament		*			*		Yes/No
Age	*			*			Year
Gender	*				*		Female/male
Ankle sprain		*			*		Yes/No
Diagnosis type	*				*		Sonography/MRI
Clinical symptoms		*			*		Patients' statements

**RESULTS**

During the study, a total of 135 patients are admitted with foot and ankle injuries occurred in walking or running or sports activities, or the result of car accidents. 3 patients are excluded from study due to lack of consent to participate in study and 11 ones are excluded due to fracture diagnosis. Finally, a total of 121 patients are included in study; from

this number one hundred and three patients (85.1 percent) had sprain and 18 (14.9 percent) with blunt trauma. The average age of all patients was  $37.2 \pm 13.2$  years. The average age of patients with blunt trauma was  $33.2 \pm 12.2$  years and the average age of patients with sprain was  $38 \pm 13.6$ . There was not any statistically significant correlation between the mean age of patients according to trauma form ( $P=0.26$ ).

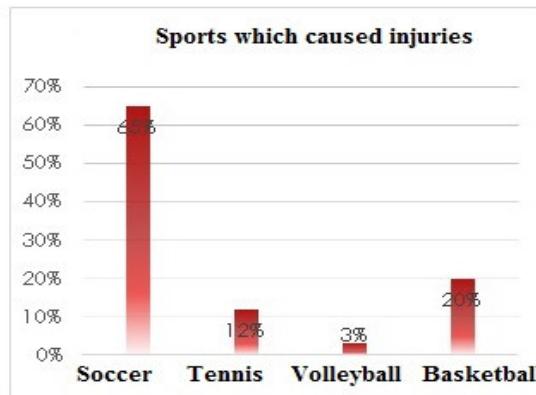
	Mean age
All patients	$37.2 \pm 13.2$
sprain	$38 \pm 13.6$
Blunt trauma	$33.2 \pm 12.2$

From all patients, 67 ones (35.3%) were women and 54 (44.7%) male. In terms of men and women ratios, there was not any statistical significant difference between them in terms of strain or blunt trauma ( $P=0.89$ ). 82 ones (67.7 percent) were injured by working (sprain or blunt trauma), 16 (13.2 percent) in running, and 8 (6.6%) during sports activities, and 15 (12.3%) by stroke of foot

or ankle due to the pedestrian accident or a motor vehicle accident. Sports which caused injuries were soccer (64 percent), basketball (18 percent), volleyball (9 percent), and tennis (9 percent). The tendon tear was diagnosed by ultrasonography in 20 patients (16.5 percent). 15 patients (75%) had sprains and 3 (25%) had tendon injury caused by blunt trauma. The mean age of patients with blunt

trauma was  $39 \pm 22.7$  (15-52 years). The average age of patients with buckling was  $38.5 \pm 16.5$  (21-63)

years.



There was not any statistical significant difference between gender and fracture ( $P=0.389$ ). The maximum rate of tendon injury was seen in ATFL. The tendon injury was diagnosed in 21 patients (17.3 percent) through MRI assessment. The ultrasonographic evaluation had the ability to potential to detect the injury in 20 individuals and all of them were diagnosed by MRI imaging. Furthermore, MRI diagnosed a tendon injury in a patient, while the ultrasonographic images were reported as normal. When MRI is considered as a standard criterion, the sensitivity of ultrasonography will be equal to 95.2%, the specificity 88.3%, positive predictive value 80%, and negative predictive value 99% in diagnosing the tendon injury.

## SUMMARY AND CONCLUSION

The foot and ankle injuries are very common at emergency department. The ankle joint is the most commonly joint which can be injured in human body<sup>32</sup>. About 5 percent of emergency department patients complain of an acute ankle injury<sup>33</sup>. The most common form of ankle injury is buckling or blunt trauma and usually occurs at push, sprain, or rarely fracture<sup>34</sup>. The body function may be affected in foot and ankle injuries. Thus, the early diagnosis or timely and specifically designed treatment will improve the prognosis<sup>35</sup>. Almost all patients referring to emergency department with a chief complaint of pain in foot or ankle will be examined for radiographic exams. Despite the widespread use of Ottawa Ankle Rules (OAR), the fracture is seen in less than 15% of these patients<sup>36-37</sup>. The rate of tendon injury is equal to 15.2% in this study. The ultrasound has been an imaging technique to study muscular tissue for many years<sup>38</sup>. The ultrasonography has been utilized to

evaluate the acute fracture, the tendon injury in foot, and ankle trauma since 10 to 15 years<sup>39-40</sup>. The time should be passed for a successful ultrasonographic examination in terms of experience and integrity of examination range. The focus on the symptomatic of body is preferred for rapid diagnosis. Jamadar et al have found that most of the pathologic examinations can be diagnosed at the end of body such as foot and ankle by focused assessment<sup>42</sup>. In addition to full examination, the diagnosis rate will be increased by ultrasonography. When the symptoms are spread or there is another anatomical point with more pain, the focused ultrasonography examination may lead to incorrect results. This study investigates the bone structure in foot and ankle by a comprehensive ultrasonography evaluation. Furthermore, a more detailed examination is carried out in organs with severe symptoms, and the sensitivity of ultrasonography is obtained equal to 100% and its specificity 90.1 percent. Despite the fact that there are a few studies on the effect of ultrasonography in diagnosing the foot and ankle fracture, Margetic et al<sup>5</sup> found that both MRI and ultrasonography had equal sensitivity in terms of diagnosing the presence or absence of damage to ankle tendons and ligaments, but MRI was more specific than ultrasonography in diagnosing the full tear of ligament. Klein et al<sup>8</sup> found that the sensitivity, specificity and positive and negative predictive values were 73.9, 100, 100 and 29.4 percent respectively in MRI, and 91.5, 25, 91.5 and 25 percent respectively in ultrasonography. They have found that both modalities are appropriate for investigating the plantar plate, and the ultrasonography is more sensitive and MRI is more specific. Oae et al<sup>12</sup> reported the accuracy of radiography, ultrasonography and MRI equal to 67, 91 and 97 percent, respectively. This study indicates that the

results of imaging by ultrasonography and MRI are satisfactory. Simanovsky et al<sup>41</sup> emphasized that the sensitivity and specificity of ultrasonography was very high (100 and 96 percent) for diagnosis of ankle fracture in pediatric patients. Gurgenidze et al have argued that the ultrasonography can be utilized as a standard criterion not only in injuries due to hit on foot or also in diagnosing the inflammatory diseases and conditions such as soft-tissue mass, and this decision of radiologic examination should be at the light of ultrasonographic findings. This study investigates the accuracy of ultrasonography in patients with

foot and ankle trauma admitted to emergency department. Our findings of study indicate that the ultrasonography is an effective method which can be used to detect adults' ankle tendon injuries at emergency departments. The sonographic imaging leads to high levels of satisfaction in patients. Furthermore, the sonographic examination can be safely used in pregnant women and children. There is a need for further studies including the assessed effects of using sonography at emergency department over time as well as diagnosis time in patients with ankle and foot trauma.

## REFERENCES

1. Struijs P, Kerkhoffs G. Ankle sprain. Clin Evid (Online). 2010; 2010: 1115. PMCID: PMC2907605
2. Katcherian D. Soft-tissue injuries of the ankle. In: Lutter, LD, Mizel MS, Pfeffer GB, eds. Orthopaedic update knowledge, 1994. Foot and Ankle. Rosemont, IL: The American Academy of Orthopaedic Surgeons, 1994: 241–255.
3. Purcell SB, Schuckman BE, Docherty CL, Schrader J, Poppy W. Difference in ankle range of motion before and after exercise in 2 tape conditions. Am J Sports Med 2009; 37(2): 383-9.
4. Moosmayer S, Smith HJ. Diagnostic ultrasound of the shoulder—a method for experts only? Results from an orthopedic surgeon with relative inexperience compared to operative findings. Acta orthopaedica. 2005 Jan 1;76(4):503-8..
5. Peetrons P, Creteur V, Bacq C. Sonography of ankle ligaments. Journal of Clinical Ultrasound. 2004 Nov 1;32(9):491-499..
6. Marjetić P, Pavić R. Comparative assessment of the acute ankle injury by ultrasound and magnetic resonance. Coll Antropol. 2012 Jun; 36(2):605-10.
7. Croy T, Saliba SA, Saliba E. Differences in lateral ankle laxity measured via stress ultrasonography in individuals with chronic ankle instability, ankle sprain copers, and healthy individuals. J Orthop Sports Phys Ther. 2012 Jul; 42(7):593-600.
8. Klein EE, Weil L Jr, Weil LS Sr et al. Magnetic resonance imaging versus musculoskeletal ultrasound for identification and localization of plantar plate tears. Foot Ankle Spec. 2012 Dec; 5(6):359-65.
9. D'Erme M. Lesions of the collateral ligaments of the ankle: diagnosis and follow-up with magnetic resonance and ultrasonography. Radiol Med. 1996 Jun; 91(6):705-9.
10. Breitenseher M J, Haller J, Kukla C, Gaebler C, Kaider A, Fleischmann D, Helbich T, Trattnig S. MRI of the Sinus Tarsi in Acute Ankle Sprain Injuries. Journal of Computer Assisted Tomography: 1997 Mar; 2(21):274-279.
11. Boruta PM, Bishop JO, Braly WG, Tullos HS. Acute lateral ankle ligament injuries: a literature review. Foot Ankle 1990; 11:107.
12. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. Br J Sports Med 2005; 39:e14; discussion e14.
13. Nitz AJ, Dobner JJ, Kersey D. Nerve injury and grades II and III ankle sprains. The American journal of sports medicine. 1985 Jun 1;13(3):177-82..
14. Williams GN, Jones MH, Amendola A. Syndesmotic ankle sprains in athletes. Am J Sports Med 2007; 35:1197.
15. Taylor DC, Englehardt DL, Bassett FH III. Syndesmosis sprains of the ankle: The influence of heterotopic ossification. Am J Sports Med 1992; 20:146.
16. Trojan TH, McKeag DB. Ankle sprains: expedient assessment and management. Physician and Sportsmedicine 1998; 26:10. Available from: [www.physportsmed.com/issues/1998/10Oct/mckeag.htm](http://www.physportsmed.com/issues/1998/10Oct/mckeag.htm) (Accessed on June 10, 2005).
17. Hocutt JE, Jaffe R, Rylander CR, Beebe JK. Cryotherapy in ankle sprains. The American journal of sports medicine. 1982 Sep 1;10(5):316-9..
18. Seah R, Mani-Babu S. Managing ankle sprains in primary care: what is best practice? A systematic review of the last 10 years of evidence. Br Med Bull 2011; 97:105.

19. Kerkhoffs GM, Rowe BH, Assendelft WJ, et al. Immobilisation and functional treatment for acute lateral ankle ligament injuries in adults. *Cochrane Database Syst Rev* 2002; CD003762.
20. Jones MH, Amendola AS. Acute treatment of inversion ankle sprains: immobilization versus functional treatment. *Clinical orthopaedics and related research*. 2007 Feb 1;455:169-72.
21. Lamb SE, Marsh JL, Hutton JL, Nakash R, Cooke MW, Collaborative Ankle Support Trial (CAST Group). Mechanical supports for acute, severe ankle sprain: a pragmatic, multicentre, randomised controlled trial. *The Lancet*. 2009 Feb 20;373(9663):575-81.
22. Wolfe MW. Management of ankle sprains. *American family physician*. 2001 Jan 1;63(1).
23. Refshauge KM, Raymond J, Kilbreath SL, Pengel L, Heijnen I. The effect of ankle taping on detection of inversion-eversion movements in participants with recurrent ankle sprain. *The American journal of sports medicine*. 2009 Feb 1;37(2):371-5.
24. Pijnenburg AC, Van Dijk CN, Bossuyt PM, Marti RK. Treatment of ruptures of the lateral ankle ligaments: a meta-analysis. *The Journal of Bone & Joint Surgery*. 2000 Jun 1;82(6):761-..
25. Kerkhoffs GM, Handoll HH, de Bie R, et al. Surgical versus conservative treatment for acute injuries of the lateral ligament complex of the ankle in adults. *Cochrane Database Syst Rev* 2007; CD000380.
26. Pijnenburg AC, Bogaard K, Krips R, Marti RK, Bossuyt PM, Van Dijk CN. Operative and functional treatment of rupture of the lateral ligament of the ankle. *Bone & Joint Journal*. 2003 May 1;85(4):525-30.
27. Van den Bekerom MP, van der Windt DA, Ter Riet G, et al. Therapeutic ultrasound for acute ankle sprains. *Cochrane Database Syst Rev* 2011; CD001250.
28. Gremeaux V, Coudreuse JM, Collado H et al. Comparative study of clinical and ultrasonographic evaluation of lateral collateral ligament sprains of the ankle. *J Sports Med Phys Fitness*. 2009 Sep; 49(3):285-91.
29. Oae K, Takao M, Uchio Y et al. Evaluation of anterior talofibular ligament injury with stress radiography, ultrasonography and MR imaging. *Skeletal Radiol*. 2010 Jan; 39(1):41-7.
30. Ekinci S, Polat O, Günalp M et al. The accuracy of ultrasound evaluation in foot and ankle trauma. *Am J Emerg Med*. 2013 Nov; 31(11):1551-5.
31. Green T, Refshauge K, Crosbie J, Adams R. A randomized controlled trial of a passive accessory joint mobilization on acute ankle inversion sprains. *Physical therapy*. 2001 Apr 1;81(4):984-94.
32. Beynnon BD, Renström PA, Alosa DM, Baumhauer JF, Vacek PM. Ankle ligament injury risk factors: a prospective study of college athletes. *Journal of Orthopaedic Research*. 2001 Mar 1;19(2):213-20..
33. Geiderman JM, Katz D. General principles of orthopedic injuries. In: Marx JA, Hockberger RS, Walls RM, Adams JG, Barsan WG, editors. *Rosen's emergency medicine: concepts and clinical practice*. Philadelphia: Elsevier; 2010. p. 467.
34. Trinh E, McMillan D, Gough JE, Brewer KL. Emergency department use of ultrasonography to detect lateral ankle fractures. *Annals of Emergency Medicine*. 2004 Oct 31;44(4):S61-2..
35. Bauer M, Bengnér U, Johnell O, Redlund-Johnell I. Supination-eversion fractures of the ankle joint: changes in incidence over 30 years. *Foot & Ankle International*. 1987 Aug 1;8(1):26-8.
36. Pijnenburg AC, Glas AS, de Roos MA, Bogaard K, Lijmer JG, Bossuyt PM, Butzelaar RM, Keeman JN. Radiography in acute ankle injuries: the Ottawa Ankle Rules versus local diagnostic decision rules. *Annals of emergency medicine*. 2002 Jun 30;39(6):599-604.
37. Brooks SC, Potter BT, Rainey JB. Inversion injuries of the ankle: clinical assessment and radiographic review. *Br Med J (Clin Res Ed)*. 1981 Feb 21;282(6264):607-8.
38. Michelle Jenkin MS AT, Kelly IV JD. Clinical usefulness of the Ottawa Ankle Rules for detecting fractures of the ankle and midfoot. *Journal of athletic training*. 2010 Sep 1;45(5):480.
39. Kane D, Grassi W, Sturrock R, Balint PV. Musculoskeletal ultrasound—a state of the art review in rheumatology. Part 2: clinical indications for musculoskeletal ultrasound in rheumatology. *Rheumatology*. 2004 Jul 1;43(7):829-38.
40. DaCruz DJ, Taylor RH, Savage B, Bodiwala GG. Ultrasound assessment of the suspected scaphoid fracture. *Archives of emergency medicine*. 1988 Jun 1;5(2):97-100.
41. Simanovsky N, Lamdan R, Hiller N, Simanovsky N. Sonographic detection of radiographically occult fractures in pediatric ankle and wrist injuries. *Journal of Pediatric Orthopaedics*. 2009 Mar 1;29(2):142-5.
42. DaCruz DJ, Taylor RH, Savage B, Bodiwala GG. Ultrasound assessment of the suspected scaphoid fracture. *Archives of emergency medicine*. 1988 Jun 1;5(2):97-100.