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PDF issue: 2026-11-23

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(Citation)
Annals of Joint,9:41

(Issue Date)
2024-10

(Resource Type)
journal article

(Version)
Version of Record

(Rights)
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(URL)
https://hdl.handle.net/20.500.14094/0100492441

Review Article

Diagnostic strategies for chronic lateral ankle instability: a narrative review

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Background and Objective: Diagnosing chronic lateral ankle instability (CLAI) involves a comprehensive evaluation encompassing medical history, physical findings, and imaging examination. The optimal method of diagnosis of CLAI remains controversial. Therefore, the objective of this review was to summarize the current literatures regarding recent evolution and technical improvement of diagnostic methods for CLAI.

Methods: A literature regarding the diagnosis of CLAI was reviewed on PubMed, including articles written in English until May 2024.

Key Content and Findings: In the manual examination for the diagnosis of CLAI, the anterior drawer test is the standard evaluation for lateral ligament insufficiency. The anterolateral drawer test, meanwhile, which focuses more on lateral instability biomechanically, has also been performed. Ultrasonography is a point-of-care tool that is less invasive than stress radiography and can dynamically assess ligament integrity, making the diagnosis of CLAI more accurate and convenient. Magnetic resonance imaging (MRI) is a useful modality that allows extensive preoperative evaluation of ligamentous properties and associated osteochondral damage, and it is essential in the preoperative diagnosis of CLAI.

Conclusions: A combination of physical examination and imaging studies is especially important to more accurately diagnose CLAI. Future research should focus on standardizing testing and measurement methods to objectively define CLAI.

Keywords: Chronic lateral ankle instability (CLAI); diagnosis; ultrasonography; magnetic resonance imaging (MRI); stress radiography

Received: 25 July 2024; Accepted: 24 October 2024; Published online: 29 October 2024.

doi: 10.21037/aoj-24-31

View this article at: https://dx.doi.org/10.21037/aoj-24-31

Introduction

Background

Ankle sprains are one of the most common musculoskeletal injuries in the sports activity, and the anterior talofibular ligament (ATFL) is the most commonly damaged in the ankle sprain, followed by the calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL). However, if not properly diagnosed and treated initially, chronic lateral ankle instability (CLAI) may develop and require surgical treatment, regardless of the severity of the injury (1). CLAI is a chronic condition that presents with symptoms of pain, persistent swelling, ankle instability and giving-way, which may prevent participation in work and sports (2-4).

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Proper diagnosis of CLAI is crucial to guide appropriate management strategies and prevent long-term sequelae such as chronic pain and ankle osteoarthritis caused by CLAI (5,6). Despite its high prevalence and significant impact on quality of life, the optimal diagnostic strategies for CLAI remain a topic of ongoing research and debate. Diagnosis of CLAI involves a comprehensive evaluation encompassing medical history, physical findings, and imaging examination.

The first step in diagnosing CLAI is to obtain a medical history. The clinician should collect information regarding the patient's ankle injury history, including the mechanism of injury, number of previous sprains, and associated symptoms such as pain, swelling, and functional limitations. Understanding the circumstances of previous ankle sprains can help assess the severity of the instability and identify potential contributing factors such as sports participation, occupational activities, or previous ankle surgeries. A combination of physical findings and imaging examinations plays a pivotal role in evaluating the clinical signs of CLAI after obtaining the patient's medical history. The traditional physical examination test for the ankle instability is the anterior drawer test (ADT), which evaluates anterior talus displacement against an anteriorly orientated force, and control of ankle plantarflexion to tense the lateral ligament (7,8). However, due to the poor reliability of the physical diagnosis of ankle instability, stress radiography has been shown to be useful. Furthermore, it is a complicated procedure, and results depend on the position of the patient's foot, the magnitude of the force applied to the foot, and the ability of the patient to withstand the force (9).

With the recent development of ultrasonography technology, ultrasonography has become a greatly useful modality for the diagnosis of ankle-foot region. Ultrasonography can dynamically assess instability by providing real-time visualization of ligament structure and its response to stress. Since ultrasonography offers the advantages of being non-invasive, cost-effective, and radiation-free, with the ability to perform dynamic assessments compared to stress radiography, many studies have reported that dynamic assessment with ultrasonography is useful in the diagnosis of CLAI (9-20). On the other hand, diagnosis of CLAI using ultrasonography with stress requires sophisticated skills in image delineation and stress application.

Magnetic resonance imaging (MRI) and stress radiography are commonly performed in combination with physical examination (21-25). MRI has been shown to have high specificity and high sensitivity for ATFL tears especially in the acute phase (26), and has been used to evaluate soft tissue conditions such as torn ATFL or thickening in the diagnosis of CLAI (27), but is not optimal for assessing the ankle instability because of a static character.

Thus, clinicians use a variety of diagnostic modalities, alone or in combination. The effectiveness of different diagnostic modalities and their implications for treatment decision-making are areas of ongoing debate.

Objective

The objective of this review is to provide a comprehensive overview of diagnostic strategies for CLAI. We present this article in accordance with the Narrative Review reporting checklist (available at https://aoj.amegroups.com/article/view/10.21037/aoj-24-31/rc).

Methods

A PubMed database search was conducted to gather studies on diagnosis for CLAI using the terms "Chronic lateral ankle instability" and "Diagnosis". Inclusion criteria were (I) original articles and review articles about diagnosis and treatment of CLAI, (II) written in English. Exclusion criteria were (I) articles not written in English, (II) case reports or studies reporting less than 10 cases. The selection of articles was based on author-determined credibility, relevancy to the topic, and current trends in the diagnostic methods of CLAI. A summary of the search strategy including the search terms is provided in *Table 1*. A total of 872 articles were found in the initial search. Furthermore, additional articles were searched by referencing the bibliographies of previously acquired articles. The related articles from the initial search and additional searches are reviewed, 72 articles were ultimately included to this review article.

Discussion

Anatomy

At first, a well-developed knowledge of anatomy is fundamental to understanding the proper diagnosis and treatment of CLAI. The lateral ankle ligament complex plays a crucial role in maintaining the stability of the ankle joint, it comprises three primary ligaments: ATFL, CFL, and PTFL (28). The ATFL originates from the anterior margin of the lateral malleolus and inserts onto the talus bone near the sinus tarsi. The most common forms of ATFLs are bifurcated with a superior and inferior band (50–70%), although unifurcated

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Table 1 Summary of the search strategy

Items	Specification
Date of search	May 28, 2024
Databases searched	PubMed
Search terms used	"Chronic lateral ankle instability"; "Diagnosis"
Timeframe	From origin until May 28, 2024
Inclusion and exclusion criteria	Inclusion criteria: (I) original articles and review articles about diagnosis and treatment of chronic lateral ankle instability, (II) written in English
	Exclusion criteria: (I) articles not written in English, (II) case reports or studies reporting less than 10 cases
Selection process	Selection was conducted by a single author (K.K.)

(23–38%) and trifurcated (6–18%) anatomical variations are also present (29,30). It primarily resists anterior displacement of the talus in relation to the tibia and fibula, especially when the ankle is in plantarflexion (28-32). The CFL, which runs from the tip of the fibula to the lateral aspect of the calcaneus, resists inversion of the calcaneus with respect to the talus and plays a significant role in stabilizing the ankle during dorsiflexion (28-30,32,33). The PTFL, although less commonly injured, provides additional support by stabilizing the talus within the ankle mortise, particularly during dorsiflexion and external rotation (29,30). Understanding the detailed anatomy and biomechanics of these ligaments is essential for clinicians when diagnosing and treating CLAI.

Manual examination

In the physical examination, tenderness can be valuable information in acute ankle injuries, but it is not uncommon for patients with CLAI who do not have tenderness on examination. Furthermore, evaluation of ankle instability is complicated because the tension on the lateral ligaments varies with the relative angles of dorsiflexion and plantarflexion (34). Therefore, manual test should be performed in an appropriate method based on an understanding of the anatomical and functional characteristics of each ligament.

In clinical practice, ADT and talar tilting test (TTT) are commonly used classical manual test to evaluate ankle instability. It is usually assumed that the ATFL mainly resists anterior translation of the talus, ADT is performed with application of an anterior load with one hand stabilizing the distal tibia and the other hand pulling the foot anteriorly (*Figure 1A*) (7,35). Since its inception, ADT has undergone various modifications to improve its accuracy and reliability. Early study highlighted clinical utility of ADT to evaluate lateral ligamentous integrity of the ankle more critically than TTT (35). Subsequent research has aimed at standardizing the test procedure and improving inter-examiner reliability. For instance, studies have investigated the optimal positioning of the foot and the degree of force application to ensure consistent and reproducible results. Several reports mentioned the importance of ankle position when performing these tests, as the ATFL is maximally tensed at ankle plantar flexion and the CFL is maximally tensed at ankle dorsiflexion (7,8,34). Ozeki *et al.* quantified ankle position relative to maximal ligament tension, finding that the ATFL was tensioned in plantar flexion over 16.2°, CFL and PTFL were tensioned in dorsiflexion over 18° (8). They also measured the tensile forces of the ATFL, CFL, and PTFL, in various foot positions using the cadaver foot, and reported that ATFL has an important role in supination with plantarflexion, CFL has an important role in pronation with plantarflexion, and PTFL is an important stabilizer in dorsiflexion (36). On the other hand, Kovaleski *et al.* reported that the greatest amount of anterior translation and isolation of the ATFL occurred with the knee flexed to 90° and the ankle in 10° of plantar flexion (37). These understanding of the anatomical and biomechanical characteristics of the lateral ankle ligaments could lead to more accurate ADT. Regarding the magnitude of instability by ADT evaluation, the grading scale published by Nyska *et al.* in 1992 has been commonly used [grade 0: 0.2±0.8 mm (no movement), grade 1: 2.0±0.8 mm (slight movement), grade 2: 2.3±1.1 mm (significant movement)] (38). In 2013, Croy *et al.* reported the interesting application of this grading (39). They set the standard for laxity by ADT at 2.3 and 3.7 mm and evaluated its diagnostic accuracy against

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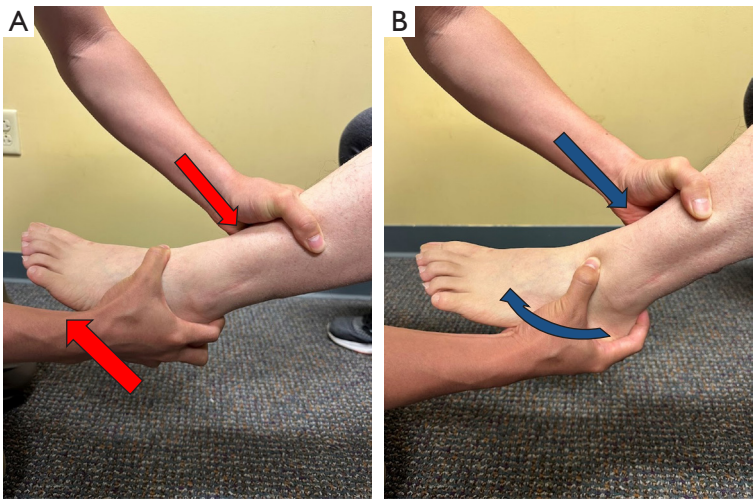


Figure 1 The representative images of the ADT and ALDT. (A) ADT is performed with application of an anterior load (red arrows) with one hand stabilizing the distal tibia and the other hand pulling the foot anteriorly. (B) ALDT is performed with the hindfoot held with the thumb overlying the lateral joint line and the ankle a little plantarflexed with the other hand stabilizing the distal tibia. While applying an anterior load, the foot is allowed to internally rotate and the palpating thumb assesses any progressive step-off between the anterior fibula and the lateral talus. ADT, anterior drawer test; ALDT, anterolateral drawer test.

subjective grading. As a result, they concluded that ADT has limited ability to detect excessive laxity of the anterior talar joint.

Because the ADT comprehensively evaluates the laxity of the tibio-talar and subtalar joints, and an intact deltoid ligament might also constrain the anterior translation (40) , the anterolateral drawer test (ALDT) was developed and its usefulness has been reported subsequently (41-43). ALDT technique, which can also assess anterolateral rotational instability, was reported to be highly accurate and reliable in the cadaveric study by Phisitkul *et al.* (41). Their ALDT technique consisted of holding the hindfoot on the lateral ankle joint with the thumb, and then plantar flexing the ankle joint 10° to 15° while stabilizing the tibia with the other hand. While translating the foot anteriorly, the foot is allowed to internally rotate and the palpating thumb assesses any progressive step-off between the anterior fibula and the lateral talus (*Figure 1B*) (41). In a cadaver study, Vaseenon *et al.* found that ADLT showed equivalent high sensitivity (100%) and specificity (66.7%) compared to ADT (respectively, 100%, 66.7%) when using >4 mm threshold, and ALDT was less dependent on examiner experience than ADT (42). Furthermore, Miller *et al.* demonstrated ALDT induced about twice greater anteroposterior displacement of the lateral talus than ADT in cadaver ankle instability models (43). These studies suggest that biomechanical superiority in ALDT over ADT for the clinical detection of lateral ankle instability.

TTT is also a physical examination method commonly used in clinical practice to assess CFL integrity. The CFL is primarily responsible for resisting the inversion stress during dorsiflexion in the neutral position, and the CFL also acts as a stabilizer of the subtalar joint with ATFL during planter flexion (33,44). In a cadaveric study by Pellegrini *et al.* investigating the contribution of the ligaments to the subtalar joint, it was demonstrated that sectioning the CFL produced increased inversion and external rotation, which was most evident in the dorsiflexion position (45). The TTT evaluates CFL integrity by combining the talocrural and subtalar joints, which has the potential to overestimate ankle joint laxity. Nonetheless, there is currently no manual test that evaluates each of these joints individually. Although TTT is considered the most appropriate means of assessing CFL competence, clinicians should be aware that these biomechanical backgrounds are one of the limitations of the accuracy of TTT in diagnosing CLAI.

In recent years, attempts have been made to quantify ankle instability in order to objectify manual examination, which is a subjective evaluation. Teramoto *et al.* quantitatively evaluated anterior drawer laxity using a capacitance-type sensor fixed alongside the ATFL of a specially made brace (46). They used this method in cadaver and reported that the

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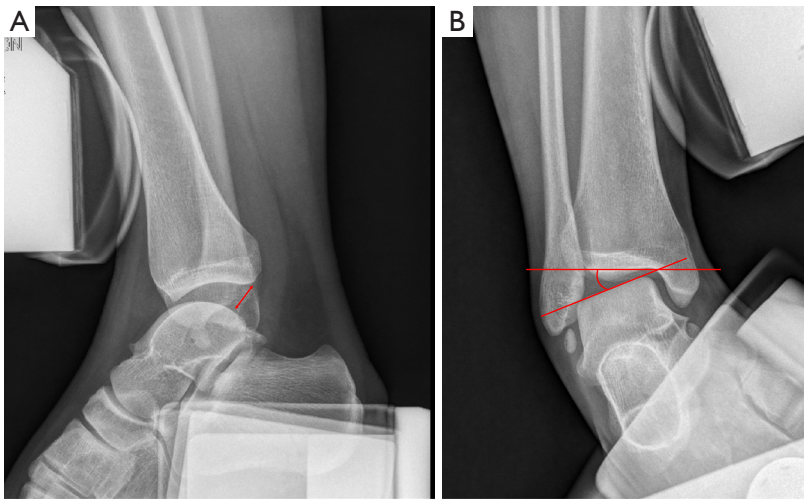


Figure 2 Stress radiography of the ankle. (A) Anterior drawer stress examination: the anterior talar translation is measured as the distance between the posterior edge of the distal tibial articular surface and the closest point on the articular surface of the talar dome. (B) Talar tilt examination: the tibial-talar tilt angle is measured as the angle between a line representing the articular surface of the distal tibial edge and another line representing the articular surface of the talar dome.

intrainvestigator intraclass correlation coefficients (ICCs) ranged from 0.862 to 0.939 and the interinvestigator ICC was 0.815. Also in the clinical setting, quantitative evaluation by this capacitance-type sensor-based method and the stress radiography showed a high correlation coefficient of 0.843. Kataoka *et al.* also quantify the ADT using electromagnetic sensor (EMS) (47). They found a strong positive correlation between the measurements using EMS and fluoroscope (correlation coefficient =0.91), and their intra and inter-examiner reliability was 0.99 and 0.89. Although these quantitative modalities have the potential to improve measurement accuracy and sensitivity for detecting abnormal anterior laxity of the ankle joint without the use of radiation, they have not yet been widely applied clinically. These devices are much more complicated than other measurement methods because they require additional procedures to set the coordinate system for ankle joint movement before the examination and to analyze the acquired data after the examination, and there is still room for improvement before they can be widely applied in clinical practice.

Imaging studies

Stress radiography

When a patient presents with an ankle joint complaint, almost all clinicians will take plain radiographs of the ankle joint, which could detect fracture, osteoarthritis, bony avulsion, accessory bone. Furthermore, evaluation by stress radiography, which combines ADT and TTT, has long been widely accepted and allows visual evaluation of ankle joint laxity as an angle (22,48). Generally, the anterior talar translation is measured as the distance between the posterior edge of the distal tibial articular surface and the closest point on the articular surface of the talar dome, and the tibial-talar tilt angle is measured as the angle between a line representing the articular surface of the distal tibial edge and another line representing the articular surface of the talar dome (*Figure 2*). Although the capability to compare angles with the contralateral ankle is also an advantage of stress radiography, past studies have reported wide variation in threshold values for stress radiography of the ankle joint, which makes interpretation of the results difficult (23-25,48,49). Little agreement exists regarding the range of normal values obtained using stress radiography, as thresholds to support the diagnosis of instability, an anterior translation of 10 mm or at least a 5 mm side-to-side difference on the ADT and an absolute TT of at least 10° or side-to-side difference of at least 5° have also been reported to correlate with ankle instability (50). Dowling *et al.* found a normal value of 2.00±1.71 mm for the ADT and 3.39°±2.70° for the talar tilt test, supporting that the threshold for diagnosing an instability of the lateral ankle joint is much lower than previously reported (23). Guerra-Pinto *et al.* conducted a systematic review including 3,235

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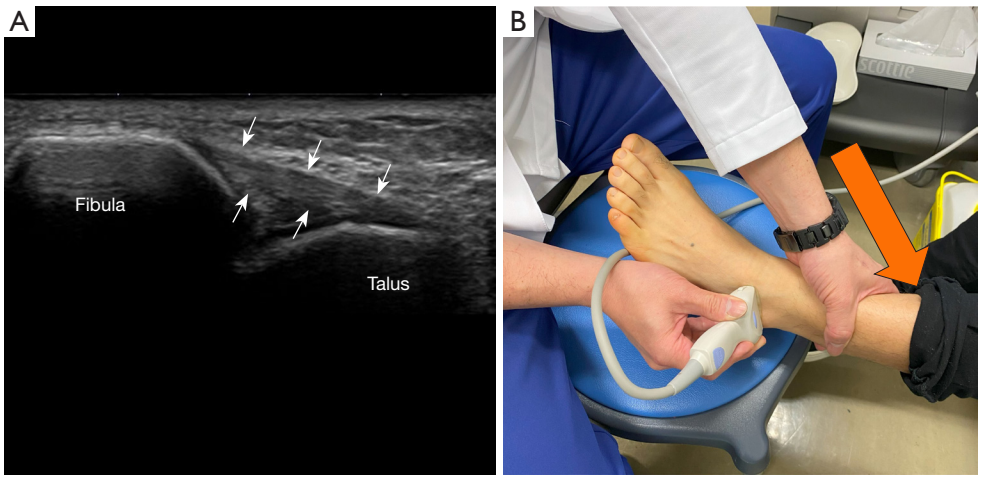


Figure 3 The representative images of ultrasonography of the ATFL and ultrasonographic technique with anterior drawer test. (A) Long-axis ultrasonographic image of the ATFL under the condition of anterior drawer stress. (white arrows: ATFL). (B) The transducer was placed sequentially over the ATFL under the condition of anterior drawer stress by reverse anterior drawer test. Orange arrows: direction of force. ATFL, anterior talofibular ligament.

ankle joints and 68 studies of chronic ankle instability to specifically define normal and abnormal values of ADT and TT to detect lateral ankle instability (51). It was reported that the common pathological thresholds for the ADT were an absolute of ≥10 or ≥3 mm side-to-side difference, while the most common pathological thresholds for the TTT were an absolute of ≥10° or ≥6° side-to-side difference. However, they found high heterogeneity in the side-to-side differences of ADT and TTT, and in the total amount of translation and tilt angle of the injured ankles. In a recent study, Choi *et al.* reported that despite excellent interobserver reliability of radiographic measurements with an ICC of 0.926, ankle stress radiographic consistency was less acceptable with an ICC of 0.763 for tibiotalar tilt angle and ICC 0.456 for anterior talar translation (24). Further disadvantages of stress radiography include radiation exposure for both the patient and the physician, time-consuming and complicated procedures and preparations, and difficulty in imaging under accurate stress due to the patient's pain and the amount of stress load.

Ultrasonography

Ultrasonography is a rapidly growing field in recent years due to its point-of-care, radiation-free, real-time, dynamic evaluation characteristics and significant advances in image-resolving technology to depict more detailed structures. The dynamic characteristics has great value in the diagnosis of CLAI, which requires the evaluation of ankle joint instability and ligamentous integrity. The foundation for the ultrasonographic diagnosis of CLAI is the clear delineation of the ATFL. To visualize the fibers of ATFL clearly, the transducer should be placed sequentially over the ATFL; the proximal edge of the transducer is adjusted on the distal edge of the lateral malleolus of the ankle, and the distal end of the transducer is then turned carefully parallel to the sole of the foot. ATFL fibers are often found to be slack or absent in cases of CLAI (*Figure 3A*). Hua *et al.* reported a 95.2% accuracy and 97.7% sensitivity of the ultrasonography for detecting chronic ATFL injury, with the ankle joint fixed in the maximum adduction and plantar flexion positions, not dynamic evaluation (11). Lee *et al.* demonstrated that the length of the ATFL under anterior stress and the ATFL length ratio (ATFL stress/ATFL resting) could be useful in the diagnosis of chronic ankle instability (12). This method took advantage of the dynamic characteristics of ultrasonography, and the report by Cho *et al.* using this method subsequently followed (9). According to their report, in patients operated on for CLAI, all patients had a slack ATFL on ultrasonography, with the affected ATFL elongated 2.8±0.3 cm under stress compared to only 2.1±0.2 cm on the healthy side, and the ATFL ratio (stress/resting) was 1.3±0.1. Interestingly, the length of the ATFL did not differ significantly between the injured and uninjured sides at rest, and this result supports the usefulness of dynamic ultrasonographic assessment in the diagnosis of CLAI (9). On the other hand, Liu *et al.* focused

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Figure 4 The representative magnetic resonance images of the ankle. (A) The anterior talofibular ligament (white arrow) and the calcaneofibular ligament (black arrow) on the axial and coronal planes of the ankle. (B) The osteochondral lesion of the talus (gray arrow) on the coronal and sagittal planes of the ankle.

on ligament thickness, comparing healthy and unstable ankle joints by ultrasonographic imaging and found that the ATFL of a previously sprained ankle joint was thicker than that of an uninjured ankle joint (13). Abdeen *et al.* also supported that the ATFL is longer and thicker in the injured group compared to healthy subjects (10). However, the reliability of ATFL delineation and length measurement appears to be highly dependent on the experience and skill of the examiner in ultrasonographic assessment (52), and no consistent consensus on these parameters in the diagnosis of CLAI has yet been reached. Anterior stress application technique in ultrasonographic assessment may vary among clinicians, and we have used the reverse anterolateral drawer test (RALDT) method, which the patient's heel is placed on a stool and the lower leg is pushed in to apply an anterior drawer stress (*Figure 3B*) (53). This method is relatively easy to apply forward withdrawal stress with one hand and would be suitable for ultrasonographic examination which require the transducer to be held in the other hand.

MRI

MRI can be used to precisely visualize the structural integrity of the ankle joint, including the lateral ankle ligaments, surrounding tendons, and concomitant secondary lesions such as cartilage damage and bone marrow signal changes caused by CLAI. In general, the undamaged ankle ligament has low T1 and T2 signal intensities and is consistent in thickness (*Figure 4A*). Jung *et al.* classified the MRI findings of ATFL and CFL in CLAI of 132 surgically treated ankles and evaluated the correlation between these findings and stress radiography (54). They showed several morphologies of ligaments; such as the amount of thickness: thickened or

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attenuated or non-visualized, the presence of discontinuity, wavy or irregular contour, and increased signal intensity on T2-weighted images. The feet of CLAI patients who underwent surgery mostly often had the wavy pattern ligaments, and ligament thickening correlated with the degree of instability (54). In a report by Jolman *et al.*, 190 ankles were retrospectively reviewed from medical record and the diagnostic accuracy of MRI was evaluated using 115 feet diagnosed with CLAI and 75 feet with other diagnoses (55). MRI has a high sensitivity (82.6%) but low specificity (53.3%) in their evaluation of clinical ankle instability.

Although MRI is valuable as a screening tool for ankle pathologic complications, it should not be considered diagnostic for lateral ankle instability due to its static characteristics. It has been reported that 23–50% of patients with CLAI have an osteochondral lesion of the talus (OLT) (*Figure 4B*) (56,57). Lee *et al.* reported that compared to OLT without CLAI, OLT with CLAI is associated with an increased proportion of larger lesions (>150 mm^2), additional chondral lesions at the tips of the medial malleolus and tibial plafonds, and patients with both OLT and CLAI are likely to have decreased performance in sports and recreational activities (58). Since drilling and other procedures for OLT are often performed simultaneously with lateral ligament repair or reconstruction (59), the presence or absence of these osteochondral lesions associated with CLAI should be carefully assessed preoperatively. In addition, diagnostic methods for CLAI using stress MRI have been evaluated in recent years and their usefulness has been reported (60,61), but they have not yet reached the stage of widespread practical application. Furthermore, a recent study by Yin *et al.* reported high accuracy in CLAI diagnosis as well as detection of ligamentous injuries by combining MRI with deep learning by artificial intelligence (62), MRI is also expected to be further developed in the diagnosis of CLAI. Although there is room for improvement in MRI evaluation of ankle instability, it is a unique method that allows for extensive preoperative assessment of ligamentous properties and concomitant osteochondral damage, MRI is a very useful modality that is difficult to exclude for the preoperative diagnosis of CLAI.

The previously reported major papers on each examination in CLAI diagnosis are summarized in *Table 2*, with sensitivity, specificity, thresholds, and key points.

Subtalar instability

Subtalar instability is a condition closely related to CLAI, and although the mechanism of injury and clinical symptoms of CLAI and subtalar instability largely overlap, the method of evaluation remains a topic of debate (63,64). Chronic tears of the CFL, the cervical ligament (CL), and the interosseous talocalcaneal ligament (ITCL) are among the causes of subtalar instability, the evaluation of subtalar instability is especially important in determining how to treat CFL when deciding on a surgical procedure (65,66). Although it is believed that there is no manual examination that can reliably diagnose subtalar joint instability or truly distinguish between instability of the subtalar joint and instability of the ankle joint (67), Thermann *et al.* demonstrated that there was an increased medial shift of the calcaneus (>5 mm) or a larger opening of the subtalar angle (>5°) with the rotation stress test assisted by radiography in cases of subtalar instability (68). Lee *et al.* reported that stress radiographic assessment of the anterior-supination drawer test showed increased talar rotation in the case of combined ATFL and CFL injuries, and further increased talar rotation when CL injuries were also associated (69). Some literature states that radiographic subtalar instability on ankle and Broden varus stress views (ipsilateral subtalar tilt >10° or contralateral subtalar tilt difference >5°) is one of the criteria (70,71). Ultrasonography has also been attempted to evaluate subtalar joint instability (72), but an accurate diagnostic modality in this area has not yet been established, and future development is expected.

We acknowledge several limitations inherent to this review article. Since this is not a systematic review, it does not cover all previous papers related to the diagnosis of CLAI. The characteristics of the narrative approach has led to a selection bias in the cited literature. However, the authors cite many important publications from classical methods to the latest research based on our experience and expertise, and this review could be informative for young surgeons. Further studies with higher evidence levels are required to establish the golden methods to diagnose of CLAI. Breakthrough diagnostic modalities utilizing the advanced technologies are also expected to be developed.

Conclusions

For diagnosing CLAI, the ADT is the standard evaluation, and the anterolateral drawer test has also become widely practiced. Ultrasonography, being less invasive and capable of dynamic ligament assessment, enhances the accuracy and convenience of diagnosing CLAI. MRI is invaluable for preoperative assessment of ligament conditions and related osteochondral injuries, making it essential for diagnosing

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Table 2 Summary of the previously reported major papers on each examination in CLAI diagnosis

Author (year)	Diagnostic method	Patients	Sensitivity	Specificity	Threshold	Key point
Croy, 2013 (39)	ADT with ultrasonography	66 patients with a history of lateral ankle sprain	74%	38%	2.3 mm or greater (grade 2 or above)	The ADT provides limited ability to detect excessive anterior talocrural joint laxity
			83%	40%	3.7 mm or greater (grade 2 or above)	
			26%	67%	2.3 mm or greater (grade 3 or above)	
			33%	73%	3.7 mm or greater (grade 3 or above)	
Phisitkul, 2009 (41)	ADT	10 fresh cadavers	75%	50%	3 mm or more	ALDT showed high accuracy
	ALDT		100%	100%		
Vaseenon, 2012 (42)	ADT	9 fresh cadavers	100%	66.7%	4 mm or more	ALDT was less dependent on examiner experience than ADT
	ALDT		100%	66.7%		
Li, 2020 (53)	ADT	38 injured ankles and 34 normal ankles	5.3%[j], 39.5%[s]	100%[j], 100%[s]	–	RALDT is more sensitive and accurate in diagnosing chronic ATFL injuries than ADT and ALDT
	ALDT		44.7%[j], 50%[s]	100%[j], 97.1%[s]	–	
	RALDT		86.8%[j], 91.2%[s]	92.1%[j], 88.2%[s]	–	
Hoffman, 2011 (50)	Stress radiographs (1.7 N-m)	20 lower extremity cadaver	–	–	Intact ADT: 3.7 mm; cut ADT: 8.6 mm; intact TTT: 6.1°; cut TTT: 18.6°	Radiographic stress testing assessment of ankle instability appears to be much less accurate than previously believed
Dowling, 2014 (23)	Stress radiographs (not described)	46 participants (76 normal ankles)	–	–	ADT: 2.0 mm; TTT: 3.39°	A much lower threshold for the diagnosis of lateral ankle injury than previously reported
Lee, 2014 (12)	Stress radiographs (150 N)	73 CLAI patients	–	–	ADT: 5.1 mm (grade 1); 5.7 mm (grade 2); 6.0 mm (grade 3)	The value of ATFL length (ATFL stress) and ATFL ratio of stress ultrasonography could be used for diagnosis of CLAI; ATFL ratio = ATFL stress/ATFL resting
	Ultrasonography		–	–	ATFL stress, ATFL ratio: 1.9 mm, 1.1 (grade 1); 2.0 mm, 1.3 (grade 2); 2.4 mm 1.4 (grade 3)	
Choi, 2021 (24)	Stress radiographs (15 dN)	45 CLAI patients	–	–	ADT: 6.9 mm; TTT: 10.8°	The consistency of the ankle stress radiographs was not as acceptable
Seebauer, 2013 (60)	Stress radiographs (150 N); stress MRI (500 kPa)	50 volunteers	–	–	ADT: uninjured ankles 1.7/2.5 mm (M/W), CLAI ankles 3.6/3.2 mm (M/W); TTT: uninjured ankles 2.8°/4.5° (M/W), CLAI ankles 8.9°/4.8° (M/W)	Stress examination under MRI control has advantages in the assessment of mechanical ankle instability (men/women)
Rosen, 2015 (49)	Stress radiographs (15 dN)	39 CLAI, 17 ankle sprain copers, and 32 healthy controls	49% (non-CLAI *vs.* CLAI)	82% (non-CLAI *vs.* CLAI)	TTT: 16.6° (healthy controls), 17.7° (copers), 22.5° (CLAI)	Both clinical and arthrometer laxity testing appear to have poor overall diagnostic value for evaluating CLAI as stand-alone measures

Table 2 (*continued*)

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Table 2 (*continued*)

Author (year)	Diagnostic method	Patients	Sensitivity	Specificity	Threshold	Key point
Hua, 2012 (11)	Ultrasonography	83 patients with chronic ATFL injury and subsequent ankle arthroscopy	97.7%	92.3%	–	US is a reliable and accurate method to evaluate chronic ATFL injury
Cho, 2016 (9)	Stress radiographs (150 N)	28 patients who underwent ankle arthroscopy and subsequent modified Broström repair	–	–	Anterior translation: 7.4 mm; difference in anterior translation: 1.7 mm; TTT: 9.2°; difference in TTT: 5.7°	Stress ultrasonography may be useful in addition to the manual anterior drawer test and stress radiography
	Ultrasonography		–	–	ATFL length (stress): 2.8 mm; difference in ATFL length (stress): 0.5 mm; ATFL ratio: 1.3	
Cheng, 2014 (19)	Ultrasonography	120 CLAI patients	98.9%	96.2%	–	Ultrasonography is useful for evaluation of CLAI
Elkaïm, 2018 (20)	CT arthrography	286 patients with arthroscopically treated CLAI	85.7–89.8%	66.7–83.3%	–	Arthroscopic assessment provided more accurate information on the lesions and quality of the ATFL compared to the imaging studies
	Ultrasonography		61.2–69.8%	85.7–0.90%	–	
	MRI		78.8–84.8%	45.5–63.6%	–	
Jung, 2017 (54)	Stress radiographs (150 N)	132 CLAI underwent ligament reconstructions	71%	52%	TTT: 10°	ATFL and CFL wavy appearance were the most frequent MRI pattern, and their thickness was related to the degree of instability
	MRI		AUC: 68.3% (ATFL thickness)	AUC: 63.9% (CFL thickness)	ATFL thickness, CFL thickness	
Jolman, 2017 (55)	Stress radiographs (not described)	115 CLAI underwent operative reconstructions	66.1%	97.3%	TTT: 3° side-to-side difference, or an absolute of 9°; ADT: 4 mm side-to-side difference, or an absolute of 10 mm	MRI has high sensitivity but low specificity in the evaluation of CLAI
	MRI		82.6%	53.3%	–	
Wenning, 2021 (61)	Ultrasonography	50 athletes	92%	60%	>5.4 mm increase in ATFL length	3D stress MRI and ultrasonography can be used to quantitively assess mechanical ankle instability
	Stress MRI (150 N)		71%	80%	>43% loss of articulating surface in the fibulotalar joint	
Yin, 2024 (62)	MRI with deep learning	2,267 patients	AUC: 87%; accuracy: 80.5%		–	Deep learning model using MRI was able to detect lateral and medial collateral ligament injuries and demonstrate high performance in diagnosing CLAI

j: junior doctor; s: senior doctor; ADT, anterior drawer test; ALDT, anterolateral drawer test; RALDT, reverse anterolateral drawer test; ATFL, anterior talofibular ligament; TTT, talar tilting test; CLAI, chronic lateral ankle instability; CAI, chronic ankle instability; US, ultrasonography; CT, computed tomography; MRI, magnetic resonance imaging; AUC, area under the curve; CFL, calcaneofibular ligament; ATFL, anterior talofibular ligament.

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CLAI. Combining physical examinations with imaging studies improves diagnostic accuracy. Future research should aim to standardize testing and measurement methods to provide an objective definition of CLAI.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://aoj.amegroups.com/article/view/10.21037/aoj-24-31/rc

Peer Review File: Available at https://aoj.amegroups.com/article/view/10.21037/aoj-24-31/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://aoj.amegroups.com/article/view/10.21037/aoj-24-31/coif). Y.H. serves as an unpaid editorial board member of *Annals of Joint* from December 2022 to November 2024. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Informed consent was obtained from all individual participants.

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doi: 10.21037/aoj-24-31
Cite this article as: Kamada K, Hoshino Y, Yamamoto T, Kamachi M, Kanzaki N, Kuroda R. Diagnostic strategies for chronic lateral ankle instability: a narrative review. Ann Joint 2024;9:41.

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