REVIEW ARTICLE

Imaging of snapping phenomena

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ABSTRACT. Snapping phenomena result from the sudden impingement between anatomical and/or heterotopical structures with subsequent abrupt movement and noise. Snaps are variously perceived by patients, from mild discomfort to significant pain requiring surgical management. Identifying the precise cause of snaps may be challenging when no abnormality is encountered on routinely performed static examinations. In this regard, dynamic imaging techniques have been developed over time, with various degrees of success. This review encompasses the main features of each imaging technique and proposes an overview of the main snapping phenomena in the musculoskeletal system.

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The main dynamic dysfunctions of the musculoskeletal system may be broadly divided into friction syndromes and snapping syndromes. Snapping syndromes result from the sudden impingement of a structure against a neighbouring one, with a subsequent jerky movement that is sometimes associated with an audible pop. Despite the existence of debate regarding the type of sound that is reported or the exact position of the phenomenon in relation to the joint, “clunking”, “locking”, “catching” or “triggering” syndromes may be considered as synonyms, and appear to be used somewhat interchangeably in the literature. On the other hand, friction syndromes result from a smoother impingement, causing insidious pain, and snaps are usually not a prominent feature. Some of the most common friction syndromes are intersection syndrome of the wrist and iliotibial tract syndrome seen in the knee. These two conditions are usually suspected, with high confidence, on MRI scans that show abnormal signal intensity in typical areas where friction occurs [1, 2].

Snapping phenomena have been reported in various regions of the body, usually in the close vicinity of joints that allow sufficient range of motion for an anatomical or heterotopic structure to interact with its close environment [3]. In some cases snaps may involve bony structures and result in so-called “joint instability” [4, 5]. In other cases, they involve a wide range of soft tissue structures that may be ligamentous, tendinous or fibrocartilaginous. Overall, snaps may therefore occur in intra-articular or extra-articular locations. It is interesting to note that non-symptomatic snaps are frequent in the general population [6–8], in most cases being regarded with only simple curiosity or causing mild discomfort. Less frequently, snaps may be associated

with significant pain or other debilitating symptoms, thus completing the definition of a true symptomatic “snapping syndrome”. Finally, one study has shown that silent snaps can also occur, being merely provoked and emphasised with dynamic ultrasound in volunteers to whom such snaps had previously never come to their attention [6].

Repeated snaps in the field of joint instability may result from torn ligaments, a situation that is not uncommon in the knee and wrist [4]. Evidence of a complete tear is therefore an indirect sign of instability. Nevertheless, as shown in the field of midcarpal instability, the sensitivity of such signs is questioned by the fact that the extrinsic ligaments generally responsible for the snaps may remain normal or only be mildly torn in certain cases [4]. As mentioned previously, recurrent snaps may lead to suffering of the involved structure and surrounding soft tissues [9, 10], albeit with much lower prevalence than in friction syndromes. The lack of specificity of indirect signs highlights the need for modalities that allow, if not real-time capabilities, then at least sufficient time frame resolution in order to image snapping phenomena that occur as fast as 0.17–0.25 s, as documented in the wrist [5]. Over time, almost all modalities have been used, with contrasting results. Despite some limitations, to date ultrasound is regarded as the most efficient tool in this regard when the snaps can be investigated with a probe.

Modalities available: the rise of dynamic ultrasound

Plain X-ray

Plain X-ray are the modality of choice for assessment of bony structures. Static radiography is generally a poor option for imaging snapping phenomena unless the

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given bony structure remains dislocated in the resting position. This rare situation has been reported in cases of snapping elbow due to congenital radial head dislocation [11]. When performed during joint movement, the use of real-time radiography has invariably been referred to as "dynamic or videofluoroscopy", "cineradiography" and "kinematography" [4]. Similar to ultrasound, this modality allows the patient to freely move the joint in question in order to elicit the snapping. In the field of carpal instability of the wrist, this technique has been used to emphasise abnormal motion between the carpal bones, with unknown accuracy [4, 12]. Although soft tissue contrast resolution is lacking in plain radiograph examinations, some authors have also suggested enhancing joint spaces, synovial sheaths or bursae with injections of iodine-containing contrast media in order to assess the dynamic behaviour of neighbouring structures such as tendons [10, 13, 14] or articular fringes [15]. This technique seems to be rather invasive and irradiating compared with other diagnostic tools that are available nowadays.

CT scan

CT scan offers better contrast resolution for soft tissues than plain radiographs. This technique is efficient for assessing tendons and their positions relative to underlying bones. For the ankle, CT scan is reported to depict tendon dislocation and explain clinical retro-malleolar snapping phenomena [16, 17]. In recent years, volume-rendering post-processing has been developed and, thanks to dedicated windowing thresholds, provides some interesting three-dimensional (3D) views of the areas studied. This tool has also proven to be useful for simplifying image interpretation [18]. However, visualisation of tendon displacement offers poor sensitivity in the detection of tendon instability, as tendons often remain in position when a joint is imaged in its resting position [9, 19, 20]. CT scan has long been hindered by a lack of time frame resolution. Nevertheless, in the last few years, an increase in the number of arrays, with up to 320 detector rows, has allowed quick and almost instantaneous acquisition of large volumes of interest with the capability to cover a whole joint such as the ankle or the wrist. Repeated visualisation of a reconstructed 3D view over a short space of time has led the way to what is known today as four-dimensional (4D) multidetector CT (MDCT) imaging. Using this technique while a patient is asked to reproduce snaps appears to be an interesting option. Nevertheless, despite recent improvements offering a time frame of the order of 0.8–1 s per 3D frame [4], this may not be sufficient to catch an event as sudden as a snap can be. Increasing time frame resolution would obviously involve higher radiation doses and raise the question of the acceptability of 4D MDCT in the investigation of snapping phenomena [4].

Ultrasound

Early on, ultrasound appeared as an interesting tool in the investigation of snapping phenomena. This modality provides real-time dynamic capabilities, easy clinical

correlation between a snap and the jerky movement of an underlying structure, and good contrast resolution for soft tissues. Initially used to image tendons, this modality has also been put forward to assess the kinematic behaviour of bony structures by analysing one of their cortical surfaces in snapping wrist syndrome [4]. Improvements in the spatial resolution of ultrasound relative to MRI [21], cheaper cost and fewer artefacts when orthopaedic hardware is present are other advantages in favour of ultrasound. In the last few years, dynamic ultrasound has won increasing support because of its capability to pinpoint a structure in the genesis of a snapping phenomenon with high confidence [6–8, 10, 16, 19, 22–33]. More than simply depicting snapping phenomena, it has also been proposed to improve surgical procedure planning in the case of multiple causes of a snap in a given location [6]. Additionally, this technique has recently improved the understanding of anterior snaps of the hip [24], which may possibly impact therapeutic procedures in the future. Dynamic examination of a limb requires firm application of the probe against the joint under investigation, the joint ideally being retained with the other attending sonographer's hand to prevent excessive displacement of the probe. This technique sometimes requires a certain amount of experience on the part of the sonographer, making dynamic ultrasound a relatively operator-dependent technique. Other possible limitations also exist. The first lies in the possible inability of the patient to reproduce a snap that intermittently occurs in daily life on demand in the course of the examination. Particularly in the case of the lower limbs, snaps may be hard to reproduce in a patient lying down on the examination couch. This situation can be avoided by asking the patient to stand in order to perform the exact movement that usually leads to the snap, while the probe is held against the joint being examined. Another obvious limitation of the technique may result from the depth of a snapping structure that is difficult to reach with the probe, a situation that is not uncommon in the hip or elbow [34]. The sum of these difficulties may explain why ultrasound has taken time to emerge in the field of instability. In a recent meta-analysis of 59 patients with posterior tibialis tendon instability, a condition easily detected by a probe, only 6 patients had benefited from this modality, while modalities involving static examination were favoured [16]. Owing to improvements in system capabilities and popularisation of the technique, barriers have recently been crossed and an increasing number of publications have praised the virtues of dynamic ultrasound [6–8, 10, 16, 19, 22–33].

MRI

MRI has long been recognised in the assessment of snapping phenomena. When present, displacement of a structure from its normal position is trusted as a reliable clue to the diagnosis of instability. The sensitivity of such a direct sign for the diagnosis of true clinical instability may be debated as the resting position of the limb required in routine MRI does not reproduce the usual conditions leading to instability in daily life. In a study of nine chronic injuries of the superior peroneal retinaculum at the ankle, only two in five patients with dislocated tendons had clinical peroneal instability, while three

patients with no clinical instability showed an abnormal position of the tendons [9]. This leads to the question of the reliability of static MRI and emphasises the need for dynamic capabilities. Improvements to MRI performance have been suggested by applying active or passive strain to the joint during the examination, a technique termed “dynamic MRI” [28, 35–39]. Despite lacking time frame resolution, this modality is able to prove the abnormal displacement of a structure that is suspected to be responsible for the snaps with better sensitivity than with static MRI. Indirect signs of instability, including bone oedema, bursitis, retinacular disruption, tendinopathy or peritendinopathy, are reported in snapping phenomena, but lack sufficient specificity when the incriminated structure is not dislocated. Overall, the lack of sufficient time frame resolution with real-time demonstration of snapping phenomena remains the main limitation of MRI.

Overview of the main snapping phenomena

Snapping hip

Hip snapping encompasses a wide variety of conditions that may occur in intra- or extra-articular locations. Intra-articular snaps result from labral lesions, cartilaginous flaps, free foreign bodies or, as reported more recently, intra-articular plicae [40]. Apart from the last, these conditions should be efficiently diagnosed as they are often associated with a risk of onset of osteoarthritis in later life. Suspicion of intra-articular snaps should therefore lead to further investigation of the labrocartilaginous environment with arthro-CT or arthro-MRI [41, 42]. To the best of our knowledge, and probably owing to the depth of occurrence of intra-articular snaps, no dynamic ultrasound investigation has been reported in the literature. On the other hand, extra-articular snapping hip is usually a benign condition in which long-term disability is highly unusual, emphasising the need to distinguish it from articular snaps. Fortunately, another distinguishing feature of extra-articular snapping compared with intra-articular snapping is the superficial location of the structure involved, allowing easy access to dynamic examination and, in particular, ultrasound. Snaps may occur in the anterior, lateral or, less frequently, posterior hip.

Anterior snapping hip

Snapping iliopsoas tendon is the most common cause of anterior snapping hip, sometimes reported as “internal” snapping hip. In sporting activities such as dance, a wide range of movement associated with abduction, flexion and external rotation of the hip are reported to favour snapping [22, 34]. Our understanding of the way the psoas tendon impinges on the superior pubic ramus has changed over time. A pathophysiological theory of an impingement between the psoas tendon and the iliopectineal eminence has been widely accepted since the syndrome was first described by Nunziata and Blumenfeld in 1951 [43], based on clinical [22, 43–45] and dynamic radiofluoroscopies demonstrations [10, 13, 14, 46]. More recently, a dynamic study of 18 hips with symptomatic snapping iliopsoas, added to mediolateral

movement of the psoas tendon, has yielded evidence of an associated rotational movement leading to projection of the tendon against the pubic ramus with subsequent snapping, while in all cases the iliopectineal eminence was not involved in the phenomenon [24]. As reported previously [6, 22, 24, 26, 34, 47], the dynamic course of the tendon was studied with the probe horizontally positioned along the groin during a return of the hip to extension from full flexion, abduction and external rotation, a position reported as the “frogleg position”. In rare cases, impingement of the iliopsoas tendon with a superiorly developed arthrosynovial cyst [24] or between the two bundles of a bifid tendon [24, 48] has also been reported. On MRI, indirect signs such as tendinopathy of the iliopsoas or iliopsoas bursitis are found with low prevalence [10]. In a recent article, based on an innovative study of the iliopsoas anatomy [49], dynamic ultrasound identified the main bundles of the iliopsoas muscle responsible for the snapping more precisely. In the frogleg position, the medial fibres of the iliacus muscle are caught between the superior pubic ramus and the psoas tendon. During the return to full extension, the former is suddenly freed while the psoas tendon abruptly snaps against the bone [6]. Interestingly, the same study has shown that true snapping of the iliopsoas tendon can be provoked in up to 40% of non-symptomatic patients, thus emphasising the risk of overestimating iliopsoas tendon involvement in snapping phenomena of the hip. In this regard, the exact correlation between the location and occurrence of the snap and the one provoked with dynamic ultrasound is necessary to avoid intra-articular snaps being overlooked. In a study of 46 patients with clinical snapping hip, dynamic ultrasound implicated the iliopsoas tendon in 59% and the iliotibial tract in 4% of cases, while no obvious cause could be found for the remaining cases, suggesting the possibility that intra-articular snaps may be present in the population studied with significant prevalence [34].

Lateral and posterior snapping hip

Snapping iliotibial tract is the main cause of lateral snapping hip. During a return of the hip to full extension, the iliotibial tract and anterior fibres of the gluteus maximus suddenly rub against the greater trochanter with a typical snap. This condition has been associated with various causes, including a thick junction between the tract and the gluteus maximus muscle, disparity of lower limb length and coxa vara [50] or impingement with orthopaedic hardware [51]. Dynamic ultrasound is proposed during hip flexion and extension with the probe in the axial plane of a patient lying in the lateral decubitus position (Figure 1) [23]. Posterior snapping hip is a rare condition. Snapping of the long head of the biceps femoris against the ischial tuberosity has been reported as the “snapping bottom” in the orthopaedic literature [52]. More recently, impingement between the lesser trochanter and the ischial tuberosity, termed “ischiofemoral impingement syndrome”, has been suggested to explain buttock pain that may rarely be associated with intermittent snaps. On MRI, this friction may be emphasised by the presence of a short distance between the two processes with associated

Figure 1. 28-year-old female with annoying snaps of the right lateral hip when working (as a waitress). (a) The patient lies on the left side in order to expose the area of the right trochanter. Dynamic sonography is performed by firmly applying the probe in the axial plane while the patient is asked to flex and extend the hip, thus reproducing the snaps. (b) Axial sonographic view of the greater trochanter area. While the hip returns from a flexed position, the muscletendinous junction between the gluteus maximus and the iliotibial tract (arrowhead) is shown to glide posteriorly (direction of the arrow) along the greater trochanter (asterisks). (c) Axial sonographic view of the greater trochanter area. When the hip almost reaches full extension, the muscletendinous junction between the gluteus maximus and the iliotibial tract suddenly rubs posteriorly along the greater trochanter in a jerky movement, while the patient recognises the typical snap she suffers from in daily life.

hyperintensity on T_2 weighted images in the quadratus femoris muscle [53, 54]. Depth of occurrence is probably the reason why none of the posterior snapping phenomena has been described with dynamic ultrasound.

Snapping knee

Besides pain, the occurrence of annoying snaps during joint movement is a relatively common symptom that should be systematically investigated during medical examination. Recurrence of snaps with true disability affecting sporting activities or daily life may require the cause to be surgically addressed. Owing to the wide variety of causes that may be encountered in each area of the knee, the anatomical or heterotopic structure responsible for the snaps should be accurately identified in the pre-operative planning phase. Differentiating intra- from extra-articular causes of knee snapping is especially important in order to avoid unnecessary arthroscopy

[55]. Intra-articular causes result from foreign bodies, tumours [56], capsulosynovial plicae [57] and meniscal tears (Figure 2) [58] that may or may not be associated with discoid deformity [59]. Extra-articular causes of snapping knee mainly involve tendons such as the biceps femoris [60–67], popliteus [68–70] and pes anserinus tendons [25, 55, 71]. Snaps in the field of knee replacement include impingement of the popliteus tendon [72], fabella [29] or a fibrous nodule, a condition reported as “patellar clunk syndrome” [73, 74]. It should be noted that gross instability associated with cruciate ligament tears is more responsible for knees giving away, while snaps are usually not a prominent feature. Similarly, snaps are unusual in the main friction syndrome of the knee, occurring between the patellar tendon and the lateral trochlea [75] and between the lateral epicondyle and the iliotibial tract [76]. MRI can confirm the presence of a foreign body or a discoid meniscus with or without a tear, or show indirect signs of suffering in the vicinity of the involved structure

Figure 2. 43-year-old male with lateral knee pain and recurrent snaps when flexing the knee. (a) Proton density coronal MRI image with fat saturation of the right knee, showing a vertical tear of the body of the lateral meniscus (arrow). (b) Coronal view of a dynamic sonography performed along the lateral femorotibial joint. In early flexion of the knee, the external wall of the lateral meniscus (arrowheads) remains within the articular space. A vertical tear of the meniscal body is visible (arrow). (c) Coronal view of a dynamic sonography performed along the lateral femorotibial joint. During further flexion of the knee, the external wall of the lateral meniscus (arrowheads) suddenly pops out of the articular space. F, femur; T, tibia.

Figure 3. 27-year-old male with intrasheath-type snapping peroneal tendons. (a) Axial view on T_2 weighted image with fat saturation sequence of the right ankle, showing mild tenosynovitis of the peroneal tendons (arrow). (b) Axial view of a dynamic ultrasound examination performed along the lateral retromalleolar groove, showing peroneus brevis tendon against the bone and covered by the peroneus longus tendon. (c) Axial view of a dynamic ultrasound examination performed along the lateral retromalleolar groove. During forceful eversion of the ankle, sudden clockwise rotational movement (arrows on Figure 1b) of both tendons lead the peroneus longus tendon to snap against the malleolar bone. b, peroneus brevis; l, peroneus longus.

without sufficient specificity to confirm its involvement in the snapping phenomenon [57, 77, 78]. Dynamic MRI has been used to show an abnormal shift of the anterior horn of the medial meniscus associated with meniscal snaps [38]. Dynamic ultrasound, initially reported in a limited number of studies involving the pes anserinus [55, 57] or the fabella [29], may be able to image almost all the above-mentioned causes of knee snapping when they remain superficial. Compared with other techniques such as MRI or CT scan, ultrasound is particularly efficient in the case of a total knee replacement because it is not hindered by artefacts [29, 79].

Snapping ankle

Snapping phenomena in the ankle typically occur in the retromalleolar grooves. These osteofibrous tunnels house the peroneal tendons on the lateral side and the tibialis posterior tendon on the medial side of the foot. The tunnel floor contains the bony malleolar grooves while the tunnel roof is represented by the peroneal and flexor retinacula. From a biomechanical perspective, the grooves sustain high strains as they act as reflection pulleys during eversion or inversion of the foot and ankle. In some instances, retinacular injury may lead to chronic deficiency with subsequent instability of the tendons, as reported for both the peroneal and tibialis posterior tendons [8, 16]. Abnormal tendon displacement may be seen with all modalities that provide sufficient contrast in soft tissues [80], including ultrasound [8], CT scanning [17] and MRI [9]. Detection of subluxation or dislocation of the tendons is reported to have a high positive predictive value [16, 81] and may be observed in up to 75% of cases with MRI in posterior tibialis tendon instability [16]. However, this sensitivity may be questioned when dealing with peroneal tendon instability. In a study by Rosenberg [9], only two out of five patients with clinical snaps showed peroneal dislocation on static MRI. Similarly, all patients included in a study with

ultrasound had no subluxation of the peroneal tendons at rest [8], once again emphasising the need for dynamic investigation of snapping phenomena. Although a partial solution to this problem has been found in dynamic MRI [35], dynamic ultrasound has emerged as a modality of choice when peroneal instability is suspected, being the only modality with the sufficient time frame resolution required to monitor tendon displacement [8]. It now appears early on in the proposed diagnosis and treatment algorithms for lateral ankle injury management [81]. Placing the probe in the axial plane along the retromalleolar groove during passive and active dorsiflexion with eversion of the foot allows visualisation of the two main types of peroneal instability (Figure 3). In a study of 12 patients, subluxation of the peroneal tendons over the lateral malleolus was most common ($n=10$), while retrofibular intrasheath subluxation was seen less frequently ($n=2$). In the latter condition, the peroneus longus and peroneus brevis tendons move abnormally relative to each other such that the two tendons temporarily reversed their normal anteroposterior relationship [8, 19, 20]. Peroneal splits are proven to be frequently associated with peroneal instability [8, 82]. Finally, it has been noted that mild dynamic subluxation of the ankle tendons may be found both in patients with no clinical findings of instability [9, 16] and non-symptomatic patients [8]. Impingement of ankle tendons with bone spurs, osteophytes, fracture fragments or orthopaedic hardware are other reported conditions that can be diagnosed with dynamic ultrasound [83].

Snapping shoulder

Chronic instability of the shoulder is frequently associated with transient locking or clunking sensations in the joint. Unlike most other joints, few extra-articular causes of snapping (*i.e.* occurring outside the glenohumeral joint) are reported in the literature. The main cause, named

Figure 4. 36-year-old male with a medial elbow snapping and associated ulnar neuropathy. (a) Axial view of a dynamic ultrasound examination performed along the ulnar tunnel. During early flexion of the elbow, the ulnar nerve (asterisk) moves forward but remains between the posterior aspect of the medial epicondyle and the triceps muscle. (b) Axial view of a dynamic sonography performed along the ulnar tunnel. During flexion of the elbow above 45°, the tendon suddenly dislocates anteriorly above the tip of the medial epicondyle while the triceps muscles glides forward. ME, medial epicondyle; Tr, triceps muscle.

“snapping or grating scapula”, occurs in the scapulothoracic space, and results from impingement between the medial border of the scapula and the adjoining ribs. A CT scan, performed in a position of maximum discomfort, usually during abduction of the arm has been proposed in the literature [84, 85]. Although measurement of the scapulothoracic space thickness has proven to give poor accuracy, this examination is necessary in the search for a mass effect that may cause the grating phenomenon. This situation accounts for about half of all patients [86] and includes exostoses, sarcomas, elastofibroma dorsi, scapulothoracic bursitis and congenital osseous abnormalities such as an omovertebral bone, curling of the vertebral border or hypertrophy of the superomedial tip of the scapula, named “Luschka tubercle” [84–88]. In this regard, 3D reconstruction offers a clear overview of the bony architecture [84]. Other reported extra-articular causes of snaps are few, and mainly occur between tendons and the bony processes of the shoulder. Impingement between the coracoid process and subcoracoid bursitis [33] or an aberrant arm of the pectoralis minor [32] have both been demonstrated with dynamic ultrasound. Similarly, snapping of the long head of the biceps brachii above the lesser tuberosity is visible with dynamic sonography performed in external rotation [89]. In another case, snaps occurred because of impingement of a tendinous flap, arising from a longitudinal tear of supraspinatus, against a subacromial spur on shoulder abduction [90].

Snapping elbow

Extra-articular snapping elbow

The most frequent causes of snapping elbow result from the anterior dislocation of the ulnar nerve and/or the distal end of the medial triceps above the medial epicondyle during full flexion of the joint [91]. The two conditions often occur in association when the triceps shifts the ulnar nerve anteriorly, producing two distinct

clinical snaps during flexion [92]. In a review of 17 cases, Watts and Bain [93] reported 14 patients exhibiting concurrent symptoms of ulnar neuropathy with a snapping triceps. More than half of the patients were athletes or manual workers, while five patients reported a history of supracondylar humerus fracture with varus deformity of the elbow [93]. Anatomical causes of medial elbow snapping are sometimes reported, and include a shallow ulnar groove and prominent medial head of the triceps tendon that may be due to an accessory band [92], also reported as the fourth muscular head of the triceps brachii [80]. Dynamic MRI and dynamic ultrasound are routinely used to emphasise an abnormal shift of the tendon or nerve during joint movement (Figure 4) [28, 33]. It should be noted that a certain degree of subluxation of the nerve is also seen in non-symptomatic patients with a high prevalence, amounting to 16% of the population clinically and up to 46% with ultrasound [7]. In clinical practice, the presence of real pain, discomfort or ulnar neuropathy in association with snaps is therefore necessary before considering the diagnosis of true “snapping triceps/ulnar nerve syndrome”. Other extra-articular snapping syndromes are rare, and include snapping of the triceps muscle above the lateral epicondyle [94] and snapping of the brachialis muscle above the medial edge of the humeral trochlea. The latter condition may contribute to irritation of the median nerve [95], and has been demonstrated with dynamic ultrasound in one study, while plain radiographs, CT scans and MRI were irrelevant [96].

Intra-articular snapping elbow

Apart from foreign bodies, intra-articular causes of snapping elbow include various capsular structures that may impinge on articular surfaces during joint movement, including the synovial fringe, lateral meniscus and annular ligament. The synovial fringe consists of the fold of the capsuloseynovial layer at the junction between the radial collateral ligament and the annular ligament [36,

97, 98]. In some cases of snapping elbow, the histological presence of fibrocartilaginous tissue has led to this structure being considered as a true meniscus [14, 88]. Snapping of the annular ligament is a very similar condition and results from interposition of the proximal edge of the ligament within the joint space [99]. This condition may occur in elbows revealing no abnormality or in association with congenital radioulnar synostosis [100]. From a histological perspective, this ligament is shown to merge with the synovial fringe [97]. Owing to the vicinity between the two structures, we believe that the terms may often be used interchangeably in the diagnosis of snapping elbow, or at least share exactly the same pathophysiology. With dynamic MRI [36], but also fluoroscopy after arthrography [14, 87], this capsulossynovial element has been shown to extrude out of the radiocapitellar joint with 90–120° flexion of the elbow and slip into the joint during extension, findings that could be confirmed surgically [14, 32, 87, 91]. Indirect signs of suffering such as chondral defects, annular intensity on T_2 weighted sequences or joint effusion have been reported [88, 89], but remain highly infrequent [89, 90, 92], emphasising once again the role dynamic imaging may play in proving their involvement in snapping phenomena. To date, and despite the superficial nature of these capsular structures, the use of dynamic ultrasound has not been reported in the literature. Additionally, snaps related to congenital [11] or traumatic [101] radial head dislocation have been discussed in surgical writings without gaining much attention in the radiological literature.

Snapping wrist and hand

Intra-articular snapping wrist

Intra-articular snapping wrist may result from the disruption of intrinsic or extrinsic ligaments [4, 12].

Among the causes, tears of extrinsic ligaments such as the dorsal radiotriquetral ligament and the ulnar limb of the palmar arcuate ligament typically lead to recurrent snapping of the triquetrum during coronal translocation of the wrist [4]. This condition has been termed “midcarpal instability”. Ligament tear visualisation is believed to have poor sensitivity [4]. On conventional radiographs with lateral projection, flexion of the scaphoid and lunatum with an increase in the capitolunate angle may be seen in the static position [4]. Initially performed with radiofluoroscopy, dynamic imaging of midcarpal instability has more recently been proposed with ultrasound [5]. While the probe is positioned dorsally in the sagittal plane during ulnar or, more rarely, radial translocation of the wrist, a palmar sag of the proximal row with a typical triquetral catch-up clunk is easily emphasised, thus confirming the instability. Given that ligament tear visualisation is believed to have poor sensitivity, MRI is mainly performed to exclude differential diagnosis [4, 5]. Other reported causes of snapping wrist may be extra-articular, and are usually related to tendons and/or retinacula.

Extra-articular snapping wrist and hand

A distinction may be made between instabilities that occur in the transverse plane, favouring true snaps along osseous surfaces, and instabilities occurring in the longitudinal plane, which are more likely to favour friction syndromes between tendons and retinacula, with infrequent snaps.

Snapping syndromes occurring in the transverse plane

Snapping extensor carpi ulnaris (ECU) is the most frequent cause at the wrist joint and results from a subsheath tear, thus allowing the tendon to dislocate medially [28, 102]. This condition is associated with overpronation injuries that are especially prevalent in tennis players [28]. Patients complain of clicking

Figure 5. 53-year-old female with a snapping extensor carpi ulnaris (ECU). (a) Axial view of a dynamic ultrasound examination performed along the ulnar groove. At rest, the ECU tendon is in position on the radial aspect of the ulnar wall of the groove (asterisk). (b) Axial view of a dynamic sonography performed along the ulnar groove. During supination, the tendon dislocates volarly (arrow) over the ulnar wall of the groove (asterisk), thus producing a typical snap that is recognised by the patient.

sensations during pronosupination of the wrist. Static imaging is often limited in showing an abnormal displacement of the tendon. MRI may show only indirect signs of suffering of the ECU tendon and sheath without depicting dynamic instability [28]. Recently, Montalvan et al [28] showed the superior accuracy of dynamic ultrasound in confirming abnormal tendon displacement. During supination, the ECU tendon dislocates volarly over the ulnar wall of the distal ulnar groove while it is relocated with pronation (Figure 5) [27, 28]. The technique is operator dependent and may require the help of a second operator to force supination while the first maintains the probe against the wrist [28]. In the same study, dynamic MRI was proven to show the same abnormalities. Other typical snapping conditions occurring in the frontal plane involve the extensor tendons in the vicinity of the metacarpophalangeal joints. Besides inflammatory joint disease, "boxer's knuckle" is usually due to direct trauma to the third or fourth ray of the hand, with subsequent disruption of the extensor hood. This condition is easily investigated with dynamic ultrasound and dynamic MRI. When clenching the wrist, the extensor tendon is shown to become dislocated ulnarly [39]. Non-traumatic snaps of the extensor system have particularly been reported in the fifth finger. In these cases, the junctura tendinum, a fascial or tendinous band linking adjacent extensor tendons, was responsible for a snap against the metacarpophalangeal joint while the dorsal hood was intact [103]. To the best of our knowledge, no descriptive study with imaging is available.

Snapping syndromes occurring in the longitudinal plane

Such conditions mainly concern tendinoretinacular impingements. Trigger finger results from the impingement of flexor tendons and proximal finger pulleys [104]. Extensor tendon impingements mainly include de Quervain's tenosynovitis [105], which occurs in the first compartment of the extensors, but other extensor tendons may also be involved [106, 107]. Impingement between flexor tendons and associated retinacula may also occur and favour snapping of the wrist [3, 108, 109]. Unlike snaps related to carpal instabilities, this condition occurs with finger movement independently of wrist joint movement [31]. Although such symptoms with painful clicks or snapping sounds are sometimes prominent in trigger finger or trigger wrist, true snaps are only very rarely seen in intersection syndromes or de Quervain's disease, being reported with a rate as low as 1.3% of patients in a study by Alberton et al [105]. In both of these conditions, diagnosis is usually made clinically, and expectations in terms of imaging lie merely in confirming the presence of a mismatch between tendon sheath and body volume, during pre-operative planning or when post-operative recurrence is encountered. Abnormal findings include thickening of involved tendons, retinacula or pulleys, and effusion or cyst of the tendon sheaths [110–114]. Presence of constitutional abnormalities should particularly be investigated with imaging when impingement on a flexor or extensor retinaculum is noted, including aberrant or accessory bundles of the tendons [31, 106, 107]. Dynamic ultrasound is contributive to diagnosis but has rarely been proposed in the studies available [31]. In the field of trigger finger, Guerini [114] justifies not

resorting to dynamic sonography, based on the fact that the data observed on static images is often sufficient to confirm diagnosis. The author also states that the linear probes usually used appear too large for the small finger joints, and therefore do not enable a proper dynamic study of the area to be carried out [114]. This limitation may be overcome by using "hockey-stick" high-frequency probes.

Conclusion

Snapping phenomena may be regarded by patients with simple curiosity when no or very mild symptoms are experienced. In other instances, the presence of significant discomfort that hinders daily activities may require investigation when specific treatment has to be considered. Static imaging may show abnormal findings with limited accuracy. Dynamic imaging has superior capabilities for confirming the existence of a snap and correlating the abnormal behaviour of an incriminated structure with patient symptoms. Among these, dynamic ultrasound has recently been shown to offer all the required features when a superficial structure is involved, including real-time capabilities and good contrast resolution for soft tissues. Training is necessary as this technique is operator dependent. In order to make this technique more popular with prescribing physicians, easy access to video content is necessary through the supply of relevant media, including CD-ROMs and efficient office computer viewers, for the benefit of their patients.

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