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Ultrasound in sports traumatology

Ultraschall in der Sporttraumatologie

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ABSTRACT

Background Ultrasound (US) has numerous applications in sports traumatology. The technical progress of mobile US devices has led to increasing use of ultrasound as a primary diagnostic tool. New applications such as elastography and 3 D vascularization are used for special indications.

Method The purpose of this review is to present the current status of ultrasound in the diagnosis of sports injuries and sport traumatology including established applications and new technical advances. US is presented both in its comparison to other imaging modalities and as a sole diagnostic tool.

Results and Conclusion US can be used for initial diagnosis to improve the clinical examination and for intensive short-term follow-up imaging. The main areas of application are currently the diagnosis of acute muscle and tendon injuries as well as overuse injuries. In particular, the exclusion of structural muscle injuries can be adequately ensured with US in the majority of anatomical regions. The recently published guideline on fracture ultrasound has strengthened the clinical evidence in this area, especially in comparison to conventional radiography and in the development of algorithms and standards. The increasing use of mobile ultrasound equipment with adequate image quality makes US a location-independent modality that can also be used at training sites or during road games.

Key points:
- Typically used for quick, focused initial diagnostic assessment and short-term follow-up after injury
- Mobile US devices allow increased use in training centers and training camps
- New US applications (SWE, 3 D) increase standardization in follow-up of tendon injuries
- Targeted use of US for musculoskeletal diagnostic assessment saves money and frees up capacity

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ZUSAMMENFASSUNG

Hintergrund Die Ultraschalldiagnostik umfasst zahlreiche Anwendungsmöglichkeiten in der Sporttraumatologie. Der technische Fortschritt mobiler Geräte führt zu einer zunehmenden Nutzung der Sonografie als fokussierte Erstdiagnostik. Neue Verfahren wie die Elastografie und 3D-Vaskularisation umfassen vorrangig die spezialisierte Sonografie in wenigen Fragestellungen.

Methode Die vorliegende Übersicht soll den aktuellen Stellenwert der Sonografie in der Sporttraumatologie, ihre etablierten Anwendungsgebiete und neuen technischen Fortschritte vorstellen. Dabei wird der Ultraschall sowohl in seiner Stellung zu anderen bildgebenden Verfahren als auch als alleiniges Diagnostikum bewertet.

Ergebnisse und Schlussfolgerung Ultraschall kann sowohl zur Initialdiagnostik als auch als Verlaufsbildgebung angewendet werden. Hauptanwendungsgebiete sind aktuell die Diagnostik von akuten Muskel- und Sehnenverletzungen sowie Überlastungsschäden. Insbesondere der Ausschluss struktureller Muskelverletzungen ist mit dem US an ausgewählten anatomischen Regionen suffizient zu gewährleisten. Durch die kürzlich neu publizierte Leitlinie zur Fraktursonografie wurde die klinische Evidenz in diesem Bereich gestärkt, vor al-

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lem im Vergleich zum konventionellen Röntgen sowie in der Entwicklung von Algorithmen und Standards. Der zunehmende Einsatz mobiler Ultraschallgeräte mit adäquater Bildqualität machen die Sonografie zu einer ortsunabhängigen Modalität, die auch in Trainingsstätten als bildgebende Erweiterung der klinischen Untersuchung genutzt werden kann.

Introduction

Ultrasound (US) has become an established part of the diagnosis of acute sports injuries due to its broad availability and cost-effectiveness and the systematic further development of mobile ultrasound devices. It is typically used as the primary or focused examination modality (point-of-care US, "POCUS"). In individual cases it can be used in addition to other modalities (primarily magnetic resonance imaging [MRI]). US is used not only in the daily clinical routine but also directly as mobile US in training centers and training camps. As shown by the current example of pediatric fracture care, US is becoming increasingly established in clinical guidelines further highlighting its value [1]. In sports medicine US is primarily used in the acute initial diagnostic assessment or in the intensive follow-up of muscle and tendon injuries (multiple examinations in short time intervals after injury, e. g. 2–3 times per week or during weight bearing), while newer specialized ultrasound applications like shear wave elastography and highly sensitive Doppler methods (microvascular imaging) are used primarily in high-performance sports. However, due to the limited number of available studies, there are only a few use recommendations [2]. The implementation of US in musculoskeletal imaging, if suitable for diagnosis, can contribute to better utilization of MRI capacities (elimination of Doppler examinations) and significant cost savings in the healthcare system. [3]

This article provides an overview of the usual areas of application, frequently asked questions regarding ultrasound in elite sports, and the value of mobile ultrasound devices in sports traumatology.

Diagnostic assessment of muscle injuries

Regardless of the modality, imaging methods in addition to clinical examination are an essential part of the diagnosis of muscle injuries. On the one hand, the suspected clinical diagnosis can be confirmed and on the other hand the exact extent of the injury can be evaluated [4]. Based on these parameters, an optimal treatment decision and determination of the prognosis regarding a return to competition (RTC) can be made [5].

Although MRI is considered the gold standard in the diagnosis of muscle injuries (regarding the extent of a structural defect or the evaluation of non-structural lesions), US provides fast and reliable initial diagnosis and optimized determination of the further procedure [6–8]. Since US is usually more readily available than MRI, it is particularly suitable for initial diagnosis as well as for repeated follow-up examinations (▶ **Fig. 1**) in popular and elite sports to ensure close monitoring of training or to identify complications early [8]. In particular, the anterior thigh and the musculature of the lower leg – compared to the ischiocrural group – can be diagnosed with good sound quality due to the low penetration depth.

Close monitoring ensures the ability to plan early surgical measures or infiltration, e. g., when healing of the tendon is limited by a persistent hematoma. Calcification of a hematoma (in terms of post-traumatic myositis ossificans) can be definitively verified as a possible complication on ultrasound based on the calcified structure and corresponding dorsal acoustic shadowing. This makes expanded X-ray examination unnecessary (▶ **Fig. 2**). Consequently, muscle imaging (particularly in popular sports) is primarily performed using US in many countries due to a lack of MRI capacity.

Muscle injuries are categorized as direct (= extrinsic) and indirect (= intrinsic) injuries according to the underlying pathomechanism [9]. Direct muscle trauma corresponding to muscle injury by an external force with resulting contusion or laceration, is mainly caused by impact trauma (e. g. knee against thigh) and is typically seen in Germany in contact sports like soccer, handball, and football/rugby. This direct trauma often results in an intramuscular hemorrhage without actual tearing of the fibers. The role of US is to locate and visualize the initial finding as the baseline for follow-up. A correct patient history and an in-depth discussion of the type of accident are absolutely necessary here. The injury grade is determined based purely on clinical signs (mild, moderate, severe) corresponding to the loss of function and the duration of the recovery phase [9]. Standardized examination with longitudinal and cross-sectional scans and acquisition of panorama images should be used to ensure comparable follow-up examinations over the long term (▶ **Fig. 3**). In the case of mild contusion injuries, a focal inhomogeneous zone without a large hematoma that typically regresses quickly can be seen. Severe contusions with a large hematoma can have a different appearance depending on when the examination is performed. Within the first 24 hours, hematomas can appear both hyperechogenic and hypoechogenic. In the following days, hematomas tend to appear as hypoechoic fluid until they become inhomogeneous after coagulation (▶ **Fig. 3**). In addition, US offers the opportunity to quickly puncture intramuscular hematomas under US guidance to reduce pain and the RTC time. In addition, puncture of the hematoma makes it possible to better evaluate whether the muscle fibers are injured.

Ruptures of muscle fibers are considered indirect muscle trauma. The underlying mechanism is a pathological (over-) extension of the muscle fibers (typically during eccentric contraction), which exceeds the viscoelastic boundaries of the tissue consequently resulting in an injury. US is primarily suitable for the detection of structural muscle injuries. It is inferior to MRI with respect to determining the extent of an injury and characterizing the injury, especially in the case of small and non-structural muscle injuries [10]. Since muscle injuries of the lower extremities

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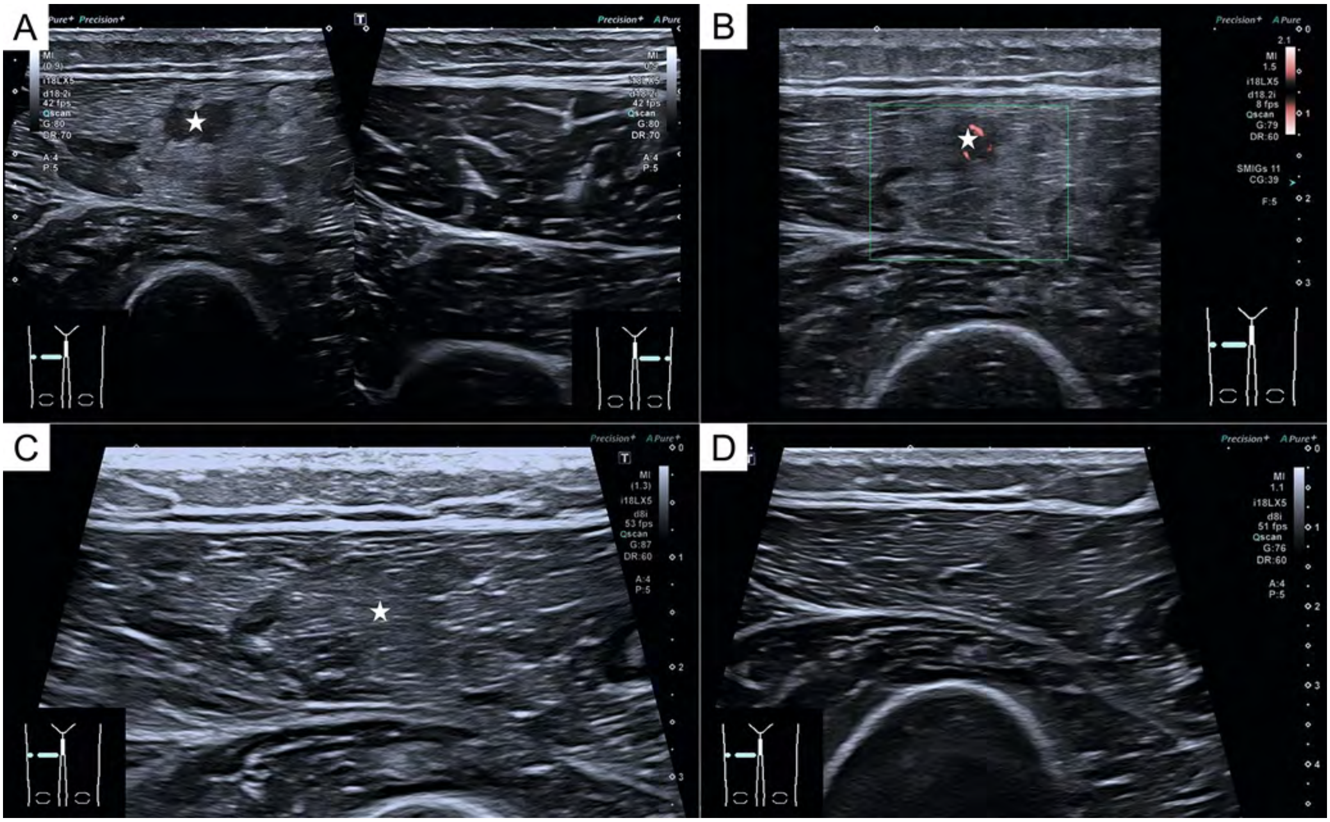

▶ **Fig. 1** Structural muscle injury (defect zone: 10 mm) in the rectus femoris muscle of a soccer player. In the initial diagnostic assessment (**A**), the hypoechoic zone of rupture (star) can be clearly defined and is surrounded by a clear hyperechoic zone of perilesional edema. A direct comparison to the healthy opposite side (right half of the image) can be performed here. Over the course of 7 days (**B**), the margins become increasingly blurry (star) and the hypoechoic zone of rupture becomes slightly smaller as a result of healing of the muscle while the surrounding edema remains clearly visible. After 17 days (**C**) only slight edema with inhomogeneous muscle fibers is still visible and the muscle still appears swollen. After 25 days, the structural defect and the zone of edema are no longer visible (**D**).

often occur at the myotendinous junction, the evaluation of tendon segments is relevant for the further prognosis. Optimal evaluation of the myotendinous junction is difficult on US but can be used in addition to MRI during interventions and short-term follow-up.

One limitation of non-contrast-enhanced US is the detection and evaluation of non-structural muscle injuries (corresponding to grades 1–2 of the classification according to the Munich Consensus Conference) [11]. Thus, Hotfiel et al. showed that conventional B-mode US showed discrepancies with respect to MRI in minor muscle injuries in a significant number of cases [12, 13]. However, in minor injuries, ultrasound functions as an effective gatekeeper: It can be used to rule out a structural muscle injury (differentiation between grade 2 and 3 lesions) [11]. In the case of discrepancies on US (clear symptoms with functional impairment but negative US result), MRI examination is helpful due to the higher sensitivity [14]. Even if imaging allows a basic estimation of the recovery time, the literature shows that imaging markers do not provide better prognostic evaluation compared to clinical parameters in the case of hamstring injuries. [15, 16]

Contrast-enhanced ultrasound (CEUS) which is now also used in the musculoskeletal region has shown in the first studies better detection than non-contrast-enhanced B-mode ultrasound for the diagnosis of non-structural muscle injuries. Perfusion in the areas of edema can be visualized based on the reduced and delayed contrast enhancement (▶ **Fig. 4**) [12, 13]. Therefore, in special cases, additional use of CEUS is helpful, particularly for precise short-term monitoring of injury-controlled training or targeted weight bearing.

Ligament tears and tendon injuries

The use of US for tendon injuries and ligament tears has been known and clinically established for decades [2]. The advantages result from the dynamic examination, the high spatial resolution, and the use of Doppler ultrasound (primarily in overuse injuries or tendinopathies). The method is established particularly in superficial locations like the Achilles tendon, patellar tendon, quadriceps tendon, and the ligaments of the knee joint (▶ **Fig. 5**). The differentiation between a partial tear and complete tear can usually be achieved here with high accuracy. The comparatively rarer (isolated or combined) injuries of the aponeuroses of the lower leg region, often in the region of the medial gastrocnemius and soleus muscle can be characterized optimally on ultrasound due to their superficial position. There are new classifications for evaluating

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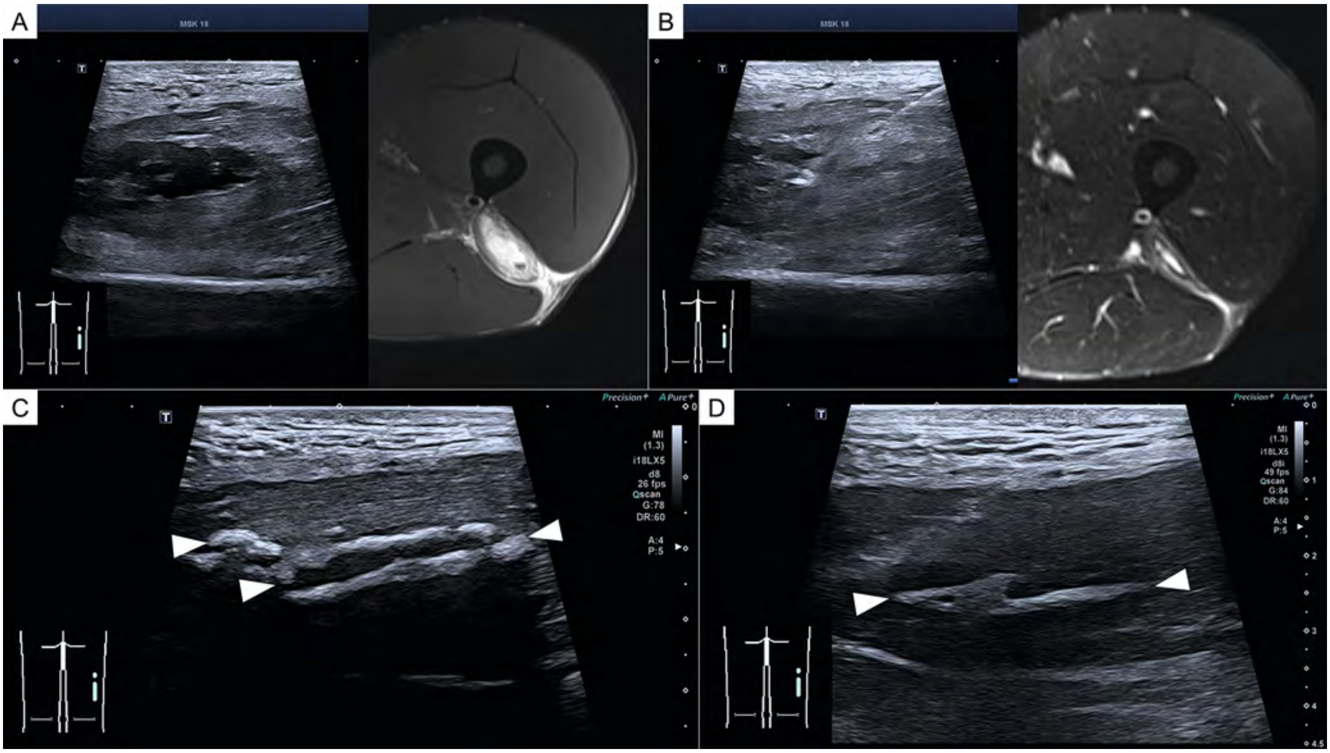
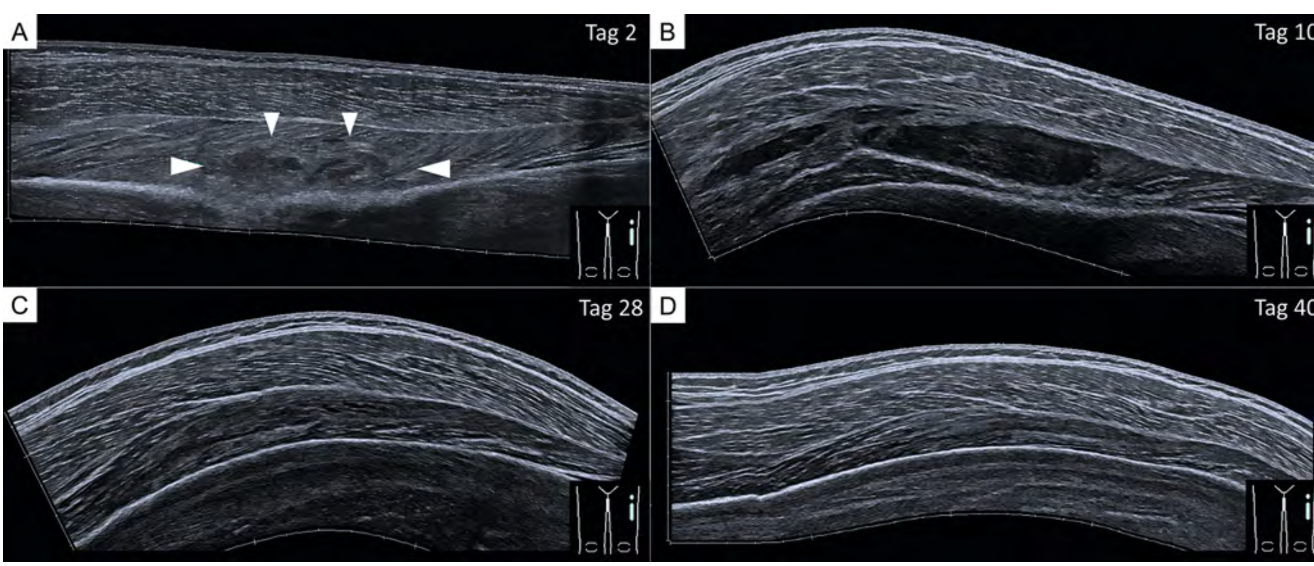


▶ **Fig. 2** Soccer player with tear in the left biceps femoris (caput breve). In the initial diagnostic assessment, the central hematoma and the ruptured fibers can be effectively visualized. For precise evaluation of the extent of the injury, a supplementary MRI examination is often performed in elite sports (**A**). After 3 days, extensive aspiration of the hematoma (**B**, left half of the image) is performed, thereby resulting in a significantly smaller size of the defect after 14 days (**B**, right half of the image). In the short-term follow-up, calcification of the hematoma with dorsal acoustic shadowing is visible 3 weeks after trauma (**C**, arrows). This increasingly disappears in the following 2 weeks due to targeted therapy and the acoustic shadowing is no longer present on US (**D**, arrows).



▶ **Fig. 3** Young soccer player with impact trauma (knee against thigh) and muscle contusion in the left vastus intermedius muscle. In the early phase, an inhomogeneous ("cloudy") defect zone with swelling in the muscle is visible (**A**), which becomes clearly demarcated and increases in size after 10 days (**B**). In the case of organized areas, aspiration was not performed (finding not compressible), and the defect zone is significantly smaller after 28 days and is only still visible as a small area of swelling (**C**). The area was imaged for the last time after about 6 weeks to check for complete healing (**D**).

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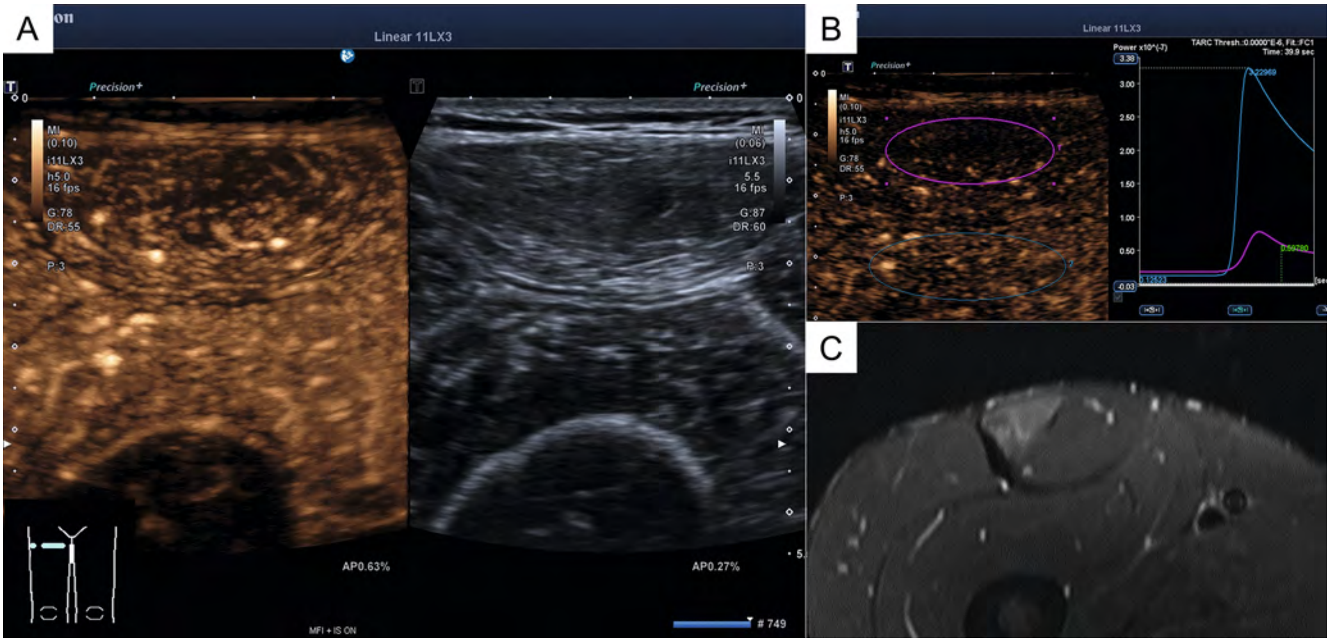
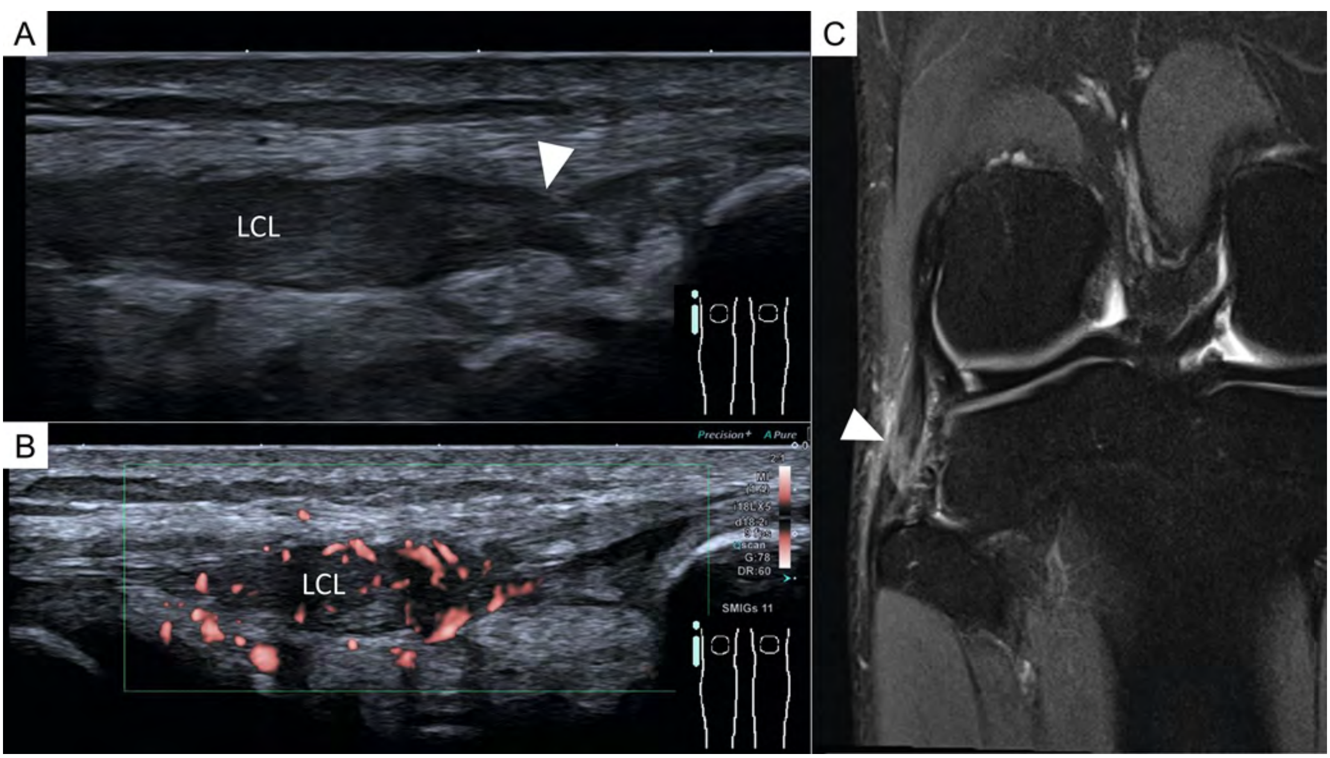


▶ **Fig. 4** Edematous swelling without a structural lesion in the rectus femoris muscle after multiple injuries in the past. CEUS shows a significant reduction in blood flow (**A**) and delayed and reduced contrast enhancement in the measurement via time-intensity curve (**B**). The violet ROI represents perfusion in the area with edema, and the blue ROI indicates normal perfusion in the reference muscle (vasus intermedius muscle). After 3 days, only partial edema in the muscle is still visible (**C**).



▶ **Fig. 5** Young soccer player injured during training with pain in the lateral knee joint. Initial US examination shows the partial tear of the lateral collateral ligament with significant swelling (grade II injury). Neither a complete tear nor a separating hematoma is visible. The clear hypervascularization on highly sensitive Doppler imaging (**B**) confirms the diagnosis of a new partial tear. A follow-up MRI examination after 14 days showed still increased signal intensity with continuous ligament tissue fibers (**C**). LCL: Lateral collateral ligament.

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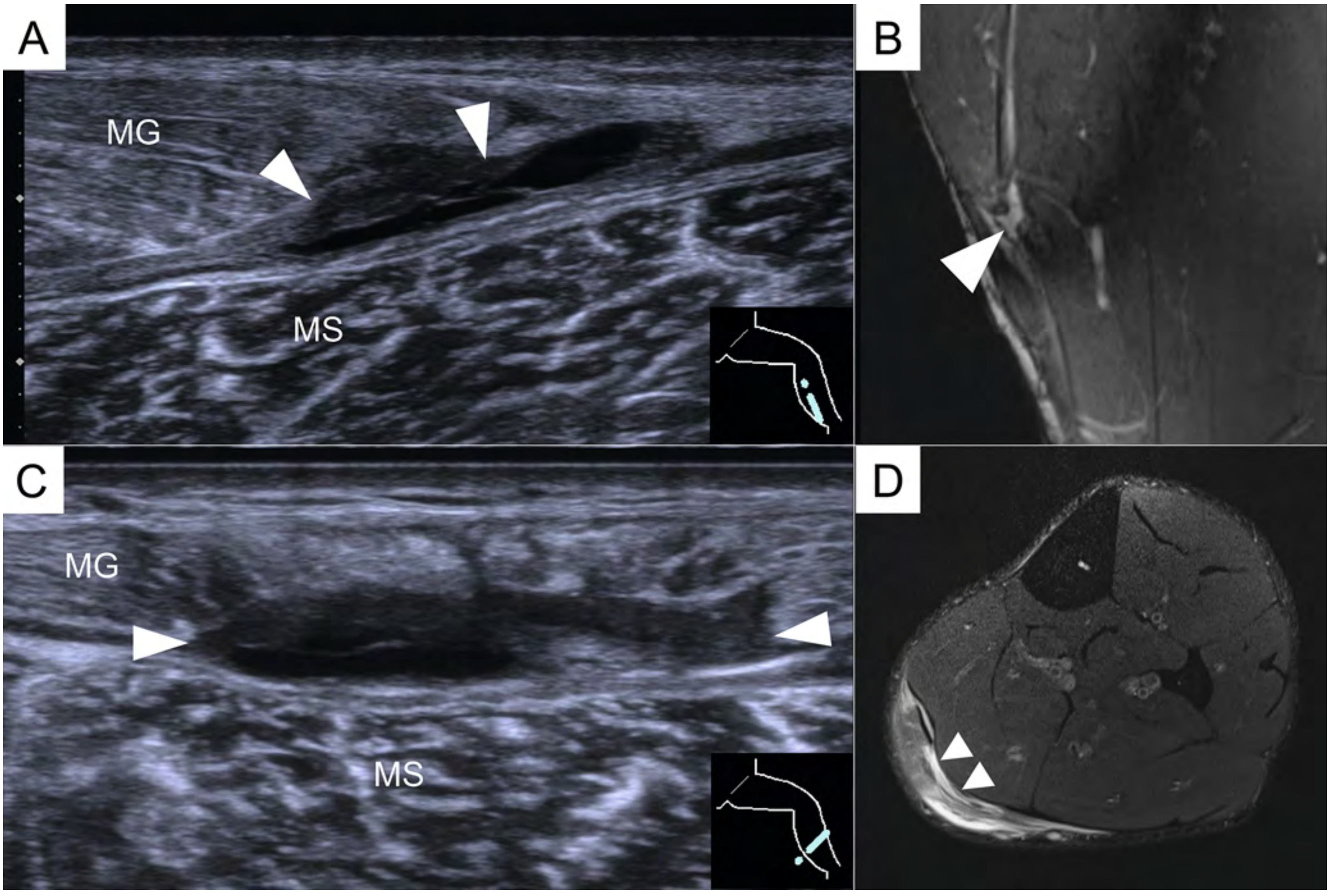

▶ **Fig. 6** Combined rupture of the aponeurosis of the medial gastrocnemius muscle affecting the muscle and the free aponeurosis with hemorrhage. US shows the exact location and extent of the rupture zone in the gastrocnemius muscle (MG) within the complex structure of this anatomical region (**A** longitudinal section, **C** cross-section). Corresponding comparison MRI images (**B** coronal, **D** axial). MS = soleus muscle.

the extent of injury of gastrocnemius aponeurosis and free gastrocnemius aponeurosis regarding the return-to-sport prognosis (▶ **Fig. 6**) [17].

US is now the method of choice for diagnosing tendinopathies, primarily jumper's knee and Achilles tendinitis. The use of multiparametric US (mpUS, [18]) with shear wave elastography (SWE) and new 3 D Doppler techniques for quantifying neovascularization elevate US to a new level and ensure continuous improvement of standardization and comparability (▶ **Fig. 7**). The quantification of 3 D vascularization reduces the subjectivity of examinations and improves diagnostic significance of follow-up examinations (▶ **Fig. 7B, E**). With respect to Achilles tendinitis, lower stiffness values in combination with neovascularization on Doppler ultrasound can be observed [19, 20]. With respect to jumper's knee, diagnostically significant studies on SWE are currently lacking, while B-mode characteristics like thickening, loss of structure, ossification together with neovascularization are established criteria and are sufficient for diagnosis. It can be clinically observed in a growing number of cases that the patellar ligament at the caudal patellar pole is increasingly stiff on elastography during follow-up after therapy, indicating fibrosis of the tissue in our opinion (▶ **Fig. 7C, F**).

Interventional ultrasound

Interventional ultrasound is to be used both for acute muscle injuries and chronic overuse injuries of the tendons. Intramuscular hematomas can usually be clearly defined after 2 to 3 days based on the organization process (hypoechoic to anechoic) [8]. This is the optimal point in time for US-guided aspiration [21]. In structural muscle defects (rupture of muscle fibers), the surrounding hematoma or the hematoma separating the tendon segments can be aspirated at this time and at the same time locally effective injection therapies (platelet rich plasma [PRP], autologous-conditioned plasma [ACP]) can be administered (▶ **Fig. 8**). This intervention can achieve faster healing of the muscle tissue with improved adaptation of the muscle fibers. In vitro studies show the regenerative potential of PRP in acute soft-tissue injuries but there are only a few randomized controlled studies showing a clear clinical benefit [22]. Thus, individual studies on PRP injection in muscle injuries show an imaging correlation for faster healing and reduction of the time until a return to training (“time to sports”) [23].

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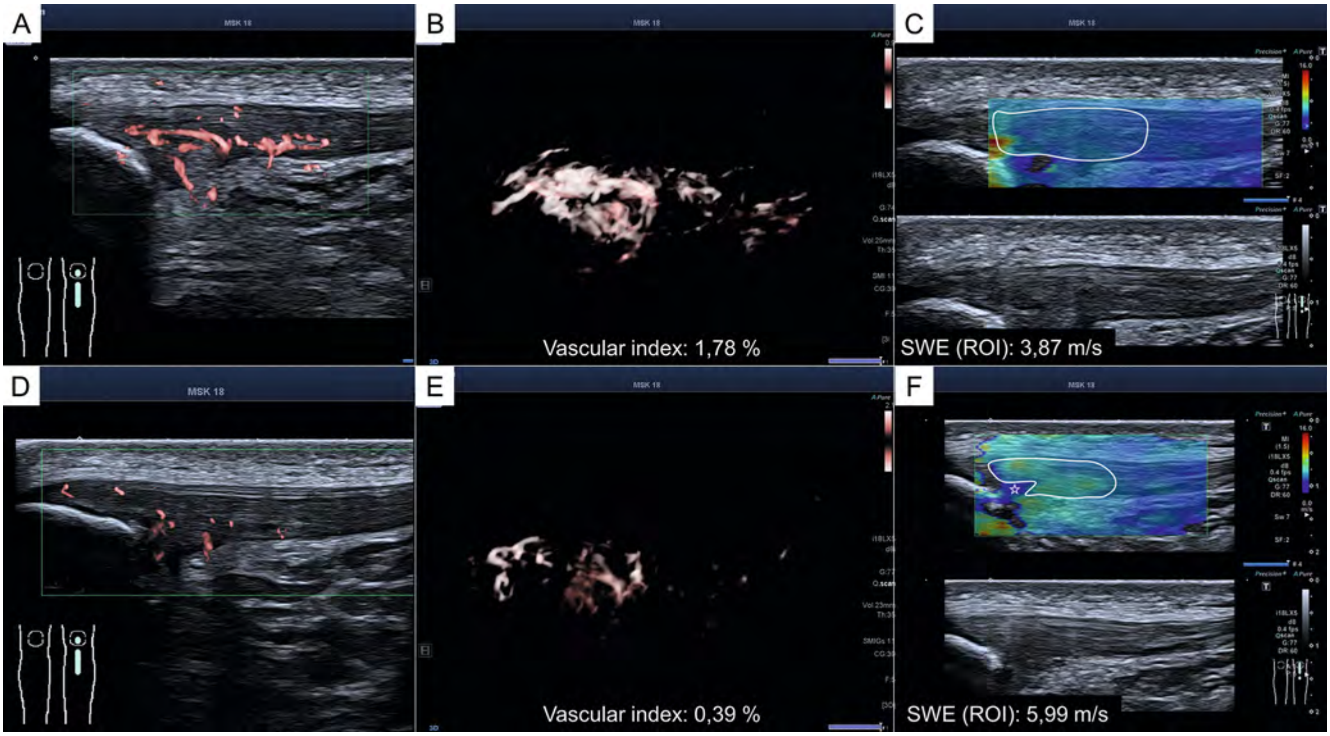

▶ **Fig. 7** Professional athlete (soccer) with jumper's knee. MpUS with baseline examination prior to the start of the season (**A–C**) and follow-up after the season (**D–F**) with over 40 mandatory games and three ACP treatments prior to the season. Neovascularization is significantly reduced over the course of the season in spite of the high physical strain during the season (**A**, **B** vs. **D**, **E**). This can be quantified by 3 D methods (ratio of color voxels to grayscale voxels). SWE shows increased stiffness of the patella tip after the season both on the color-coded map and in a metric analysis. The player became symptom-free over time.

Fracture ultrasound

US for fracture diagnosis is not capable of completely replacing projection radiography but should only be used as an additional method in defined indications and to avoid unnecessary imaging with ionizing radiation [24]. It is used for fracture diagnosis, for monitoring of fracture healing, and for imaging ligament instabilities and traumatic soft-tissue injuries – particularly in adolescence.

US imaging always visualizes the cortical bone surface and can be used to confirm or exclude a fracture (▶ **Fig. 9A, B**). A major advantage of US is the ability to additionally evaluate the soft-tissue sheath around the bone for detecting hematomas or joint effusion in the same examination. Additional X-ray examination is advantageous for precise evaluation of the fracture position/dislocation.

In adults, examination can be performed prior to X-ray in the case of suspected rib fracture(s). If a radiograph has already been acquired without detection of a fracture, the affected rib (patient scanned at the point of maximum pain) should be examined sonographically in the case of clinical suspicion of a fracture (▶ **Fig. 9D–F**). Particularly in the case of rib fractures, the intercostal muscle should always be additionally evaluated since the surrounding hematoma is helpful for fracture detection (▶ **Fig. 9E**). During follow-up, US can be additionally used in the case of a lack of callus detection on projection radiography since a callus can be visualized with greater morphological precision and earlier [25, 26]. Thus, follow-up examinations and the resulting radiation exposure can be increased in stages.

When documenting fractures, a standard protocol with corresponding documentation should always be used since it is absolutely necessary to be able to reproduce the exact location and sound plane in follow-up examinations (e. g., in the case of multiple examiners).

Mobile ultrasound

Technical innovations in equipment technology in the last decade have resulted in the availability of increasingly compact and cost-effective ultrasound equipment. These devices can be transmitted to a tablet or cell phone with a cable or via Wi-Fi (Bluetooth or WLAN). This makes ultrasound a location-independent modality that can be used clinically as well as preclinically. It is becoming increasingly established in different medical disciplines. Therefore, mobile devices can be used directly at the patient bedside as an expansion of the clinical examination and can be used preclinically in emergency medical care (e. g., for diagnosing pneumothorax after trauma or for FAST ultrasound). In sports traumatology, such systems have not yet become fully established or are only used on a supplementary basis. In a comparison of multiple mobile US devices (hand-held devices), none of the evaluated devices had all of the features desired by experts (image quality, ease-of-use, portability, total cost, availability of different probes)

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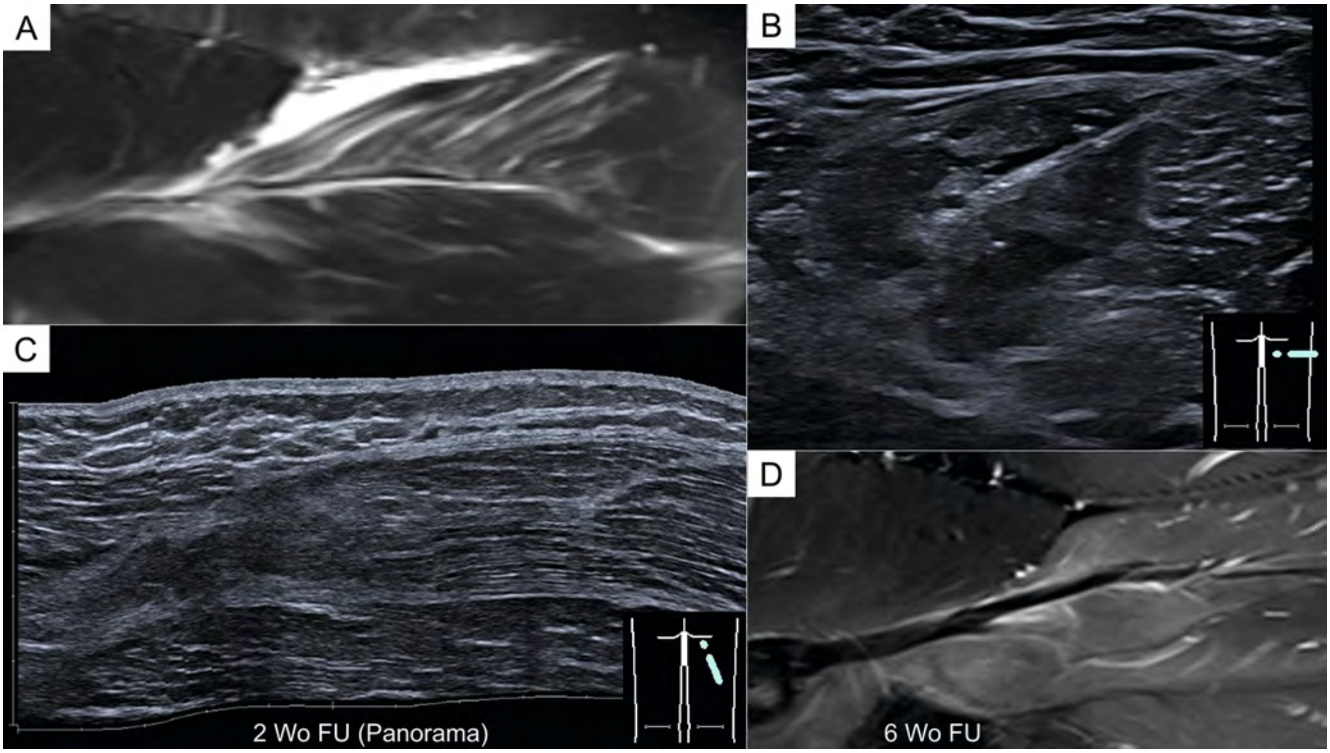

▶ **Fig. 8** Combination of modalities and US-guided intervention. Partial tear at the myotendinous junction of the biceps femoris (caput longum) of a soccer player (**A**). After aspiration of the hematoma, ACP was injected during the same intervention directly into the injured fibers (**B**). The short-term follow-up US examination after 2 weeks shows proper healing without hematoma. Precise evaluation of the tendon segment is difficult on US (**C**). The follow-up MRI examination after 6 weeks shows good healing of the tendon with the continued presence of surrounding edema (**D**).

[27]. However, due to their compactness, these devices offer advantages for individual areas (▶ **Table 1**).

The published literature on the use of mobile ultrasound devices in sports traumatology is currently still sparse. Individual studies were able to show that standard measurements of muscle thickness and the evaluation of muscle architecture with mobile ultrasound devices have good comparability with standard ultrasound [28]. From clinical experience, it can be reported that superficial structures, e. g., the quadriceps muscle or the muscles of the lower leg, can be evaluated with mobile devices with acceptable image quality. Difficulties arise at anatomical locations with significantly greater muscle volumes, e. g. when evaluating the ischiocrural group (hamstrings) or their proximal tendon insertions. Mobile ultrasound devices reach their limit here regarding image quality due to the penetration depth and view.

Use of mobile ultrasound devices on-field (e. g., on the sideline)

Due to their compact size, mobile ultrasound devices can be used directly on the field at sporting events/competitions [29]. As a rule, they are suitable for quick confirmation of findings from the clinical examination [5], but their diagnostic significance when used on the field during sporting events/competitions is limited. Even if they complete the clinical examination, they are not able to handle the complexity of the situation. In addition to the time pressure, the opinion of the athlete who may not be able to continue the game/competition even without a pathological finding (clinical or sonographic) must be taken into consideration in these situations. In addition, it is important to note that the visualization of an intramuscular hematoma as a correlate of a structural muscle defect or contusion trauma is relevant for the diagnosis of acute muscle injuries but cannot be sufficiently evaluated in the early phase (a few minutes after the injury). Thus, fast evaluation on the field at sporting events/competitions has the following risks: false-positive findings can be unsettling for both athletes and examiners; false-negative findings can result in further diagnostic workup and corresponding targeted therapy or training management not being sufficiently implemented [30]. For these reasons, the use of ultrasound on the field at sporting events/competitions has not yet become established and is also not recommended by us.

A much more established area of application is the use of mobile ultrasound after a competition in the locker room or at training centers. A comprehensive clinical examination including a focused ultrasound examination can be performed in a quiet environment. US is helpful not only for the detection of a muscle or tendon injury but also for the determination of the further course of action (compression bandage, MRI, injection therapy, physiotherapy, training management). Depending on the findings, an MRI examination can be planned or these resources can be saved. Thus, acute diagnosis can be improved and the athlete can receive treatment that is prompt, optimized, and cost-effec-

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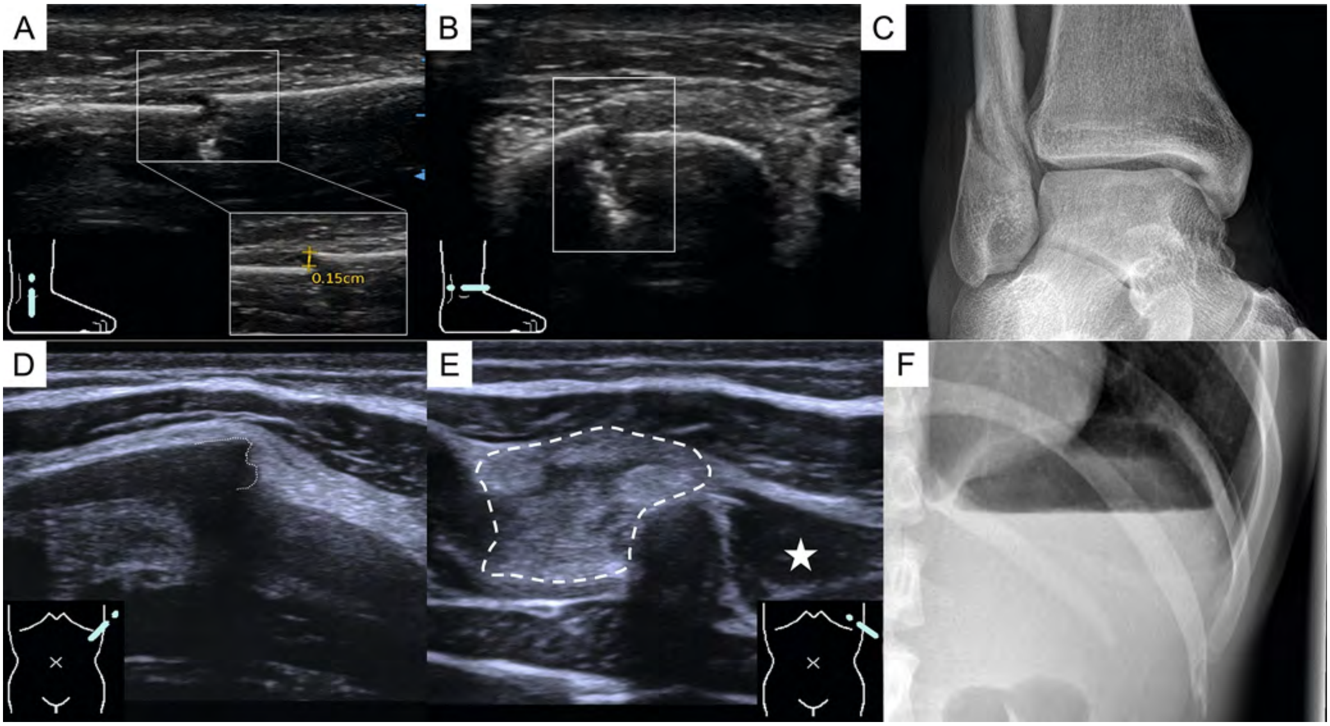

▶ **Fig. 9** Examples of point-of-care US (**A**–**C**) and supplementary US examination (**D**–**F**) in fracture diagnosis. **A**–**C** 28-year-old amateur athlete after a climbing accident (bouldering) with visible interruption of the cortical bone on ultrasound (**A** longitudinal section, **B** cross-section) resulting in diagnosis of a Weber B fracture. The supplementary preoperative X-ray examination (**C**) is used to evaluate the position of the fracture. **D**–**F** 29-year-old professional ballet dancer with initial suspicion of splenic rupture in left-sided upper abdominal pain. After the patient history is taken and splenic trauma is ruled out, the circumscribed point of pain in the region of the 11th rib indicated by the patient is examined. Dislocated rib fracture with a significant interruption of the bone (**D** longitudinal section) and surrounding diffuse hyperechoic hematoma (marked) compared to the normal intercostal musculature (star, **E** cross section) can be seen here. The initial X-ray examination was negative (**F**).

▶ **Table 1** Overview of the areas of application and general advantages and disadvantages of mobile ultrasound. Adapted based on Hees et al. [27].

Application area	Advantages	Disadvantages
▪ Tendon rupture	▪ Transportable	▪ Small display format
▪ Ligament injury	▪ Location-independent	▪ Limited battery life
▪ Muscle tear	▪ Cost-effective	▪ Moderate image quality
▪ US-guided intervention ▪ Fracture diagnosis ▪ Trauma (eFAST)	▪ Real-time diagnosis	▪ No quality assurance (anyone can use US)

tive as well as resource-efficient. If mobile ultrasound devices are compared to traditional stationary ultrasound devices with respect to diagnostic significance, the results in the literature are acceptable, but they are highly dependent on the examiner and the body region being examined. [31]

Mobile ultrasound devices have special importance in the framework of away games or at training camps since interdisciplinary cooperation with the athlete's established radiology partners and the necessary infrastructure are often not available on site. The areas of application include acute injury diagnosis, monitoring, training management in the case of pain from overuse, and US-guided infiltration. Remote devices are an interesting option here and represent a possible future use. They allow telemedicine consultation or a second opinion from a specialist either in real time or with a delay after transfer of the images (tele-ultrasound) [32].

Summary

US in sports traumatology includes many clinical areas of application – especially muscle and tendon ultrasound – and is primarily used for a focused initial diagnostic assessment and intensive follow-up. As a result of technical advancements, mobile US devices are increasingly being used in training centers and extraclinically,

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which includes both advantages and risks (keyword: structured training of examiners). In contrast, the use of US for diagnostic assessment at sporting events/competitions has not become established yet due to the complexity and the time pressure. However, US is used intensively at training centers and training camps. New US applications like SWE and 3 D vascularization are increasingly being used in tendon diagnosis, albeit currently primarily in the field of research. In the coming years, tele-ultrasound will become increasingly important since the focused acquisition of sonographic images in sports traumatology can be effectively interpreted by an additional specialist (standardized and focused examination structure).

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Ackermann O, Fischer C, Grosser K et al. AWMF 085-003 S2e Leitlinie, Fraktursonografie. Accessed June 30, 2023 at: https://register.awmf.org/de/leitlinien/detail/085-003

[2] Sconfienza LM, Albano D, Allen G et al. Clinical indications for musculoskeletal ultrasound updated in 2017 by European Society of Musculoskeletal Radiology (ESSR) consensus. Eur. Radiol 2018; 28: 5338–5351

[3] Parker L, Nazarian LN, Carrino JA et al. Musculoskeletal imaging: medicare use, costs, and potential for cost substitution. J. Am. Coll. Radiol 2008; 5: 182–188

[4] Heiss R, Janka R, Uder M et al. Bildgebung von Muskelverletzungen im Sport. Die Radiol 2023; 63: 249–258

[5] Guillodo Y, Bouttier R, Saraux A. Value of sonography combined with clinical assessment to evaluate muscle injury severity in athletes. J. Athl. Train 2011; 46: 500–504

[6] Connell DA, Schneider-Kolsky ME, Hoving JL et al. Longitudinal study comparing sonographic and MRI assessments of acute and healing hamstring injuries. Am J Roentgenol. Am. J. Roentgenol 2004; 183: 975–984

[7] Paoletta M, Moretti A, Liguori S et al. medicina Ultrasound Imaging in Sport-Related Muscle Injuries: Pitfalls and Opportunities. Medicina (Kaunas) 2021; 57 (10): 1040

[8] Maffulli N, Oliva F, Frizziero A et al. ISMuLT Guidelines for muscle injuries. Muscles. Ligaments Tendons J 2013; 3: 241

[9] Draghi F, Zacchino M, Canepari M et al. Muscle injuries: ultrasound evaluation in the acute phase. J. Ultrasound 2013; 16: 209

[10] Crema MD, Yamada AF, Guermazi A et al. Imaging techniques for muscle injury in sports medicine and clinical relevance. Curr. Rev. Musculoskelet. Med 2015; 8: 154

[11] Mueller-Wohlfahrt HW, Haensel L, Mithoefer K et al. Terminology and classification of muscle injuries in sport: The Munich consensus statement. Br. J. Sports Med 2013; 47: 342

[12] Hotfiel T, Carl HD, Swoboda B et al. Kontrastmittelsonografie (CEUS) in der bildgebenden Diagnostik von Muskelverletzungen – Perfusionsdarstellung in der früharteriellen Phase. Sportverletzung-Sportschaden 2016; 30: 54–57

[13] Hotfiel T, Heiss R, Swoboda B et al. Contrast-Enhanced Ultrasound as a New Investigative Tool in Diagnostic Imaging of Muscle Injuries-A Pilot Study Evaluating Conventional Ultrasound, CEUS, and Findings in MRI. Clin. J. Sport Med 2018; 28: 332–338

[14] Ossola C, Curti M, Calvi M et al. Role of ultrasound and magnetic resonance imaging in the prognosis and classification of muscle injuries in professional football players: correlation between imaging and return to sport time. Radiol. Medica 2021; 126: 1460–1467

[15] Wangensteen A, Almusa E, Boukarroum S et al. MRI does not add value over and above patient history and clinical examination in predicting time to return to sport after acute hamstring injuries: a prospective cohort of 180 male athletes. Br. J. Sports Med 2015; 49: 1579–1587

[16] De Vos RJ, Reurink G, Goudswaard GJ et al. Clinical findings just after return to play predict hamstring re-injury, but baseline MRI findings do not. Br. J. Sports Med 2014; 48: 1377–1384

[17] Pedret C, Balius R, Blasi M et al. Ultrasound classification of medial gastrocnemious injuries. Scand. J. Med. Sci. Sports 2020; 30: 2456–2465

[18] Sidhu PS. Multiparametric Ultrasound (MPUS) Imaging: Terminology Describing the Many Aspects of Ultrasonography. Ultraschall Der Medizin 2015; 36: 315–317

[19] Dirrichs T, Quack V, Gatz M et al. Shear Wave Elastography (SWE) for the Evaluation of Patients with Tendinopathies. Acad. Radiol 2016; 23: 1204–1213

[20] Dirrichs T, Quack V, Gatz M et al. Shear Wave Elastography (SWE) for Monitoring of Treatment of Tendinopathies: A Double-blinded, Longitudinal Clinical Study. Acad. Radiol 2018; 25: 265–272

[21] Orlandi D, Corazza A, Arcidiacono A et al. Ultrasound-guided procedures to treat sport-related muscleinjuries. Br. J. Radiol 2016; 89. doi:10.1259/bjr.20150484

[22] Setayesh K, Villarreal A, Gottschalk A et al. Treatment of Muscle Injuries with Platelet-Rich Plasma: a Review of the Literature. Curr. Rev. Musculoskelet. Med 2018; 11: 635

[23] Rossi LA, Molina Rómoli AR, Bertona Altieri BA et al. Does platelet-rich plasma decrease time to return to sports in acute muscle tear? A randomized controlled trial. Knee Surg. Sports Traumatol. Arthrosc 2017; 25: 3319–3325

[24] Tougas C, Brimmo O. Common and Consequential Fractures That Should Not Be Missed in Children. Pediatr. Ann 2022; 51: e357–e363

[25] Akinmade A, Ikem I, Ayoola O et al. Comparing ultrasonography with plain radiography in the diagnosis of paediatric long-bone fractures. Int. Orthop 2019; 43: 1143–1153

[26] Wawrzyk M, Sokal J, Andrzejewska E et al. The Role of Ultrasound Imaging of Callus Formation in the Treatment of Long Bone Fractures in Children. Polish J. Radiol 2015; 80: 473–478

[27] Le MPT, Voigt L, Nathanson R et al. Comparison of four handheld point-of-care ultrasound devices by expert users. Ultrasound J 2022; 14: 1–9

[28] Turton P, Hay R, Welters I. Assessment of peripheral muscle thickness and architecture in healthy volunteers using hand-held ultrasound devices; A comparison study with standard ultrasound. BMC Med. Imaging 2019; 19. doi:10.1186/s12880-019-0373-x

[29] James P, Barbour T, Stone I. The match day use of ultrasound during professional football finals matches. Br. J. Sports Med 2010; 44: 1149–1152

[30] Hees T, Bierke S, Häner M et al. Stellenwert portabler Ultraschallgeräte in der Sporttraumatologie. Sport. Orthop. Traumatol 2020; 36: 143–149

[31] Falkowski AL, Jacobson JA, Freehill MT et al. Hand-Held Portable Versus Conventional Cart-Based Ultrasound in Musculoskeletal Imaging. Orthop J Sports Med 2020; 8 (2). doi:10.1177/2325967119901017

[32] Constantinescu EC, Nicolau C, Săftoiu A. Recent Developments in Tele-Ultrasonography. Curr. Heal. Sci. J 2018; 44: 101–106

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