The value of musculoskeletal ultrasound in geriatric care and rehabilitation

Büşra Can[a], Murat Kara[b], Özgür Kara[a], Zekeriya Ülger[a], Walter Frontera[c,d] and Levent Özçakar[b]

The WHO reports that one of the major chronic conditions affecting the elderly worldwide is musculoskeletal disorders that are associated with long-term pain and disability. Considering the healthcare needs of the elderly (i.e. comprehensive, accessible, efficient) and the advantages of ultrasound (US) use (patient-friendly, convenient, cost-effective, and does not require exposure to radiation or magnetic fields), there seems to be a 'gap' in the actual clinical practice. In this paper, we aimed to highlight the potential value of US imaging in the management of the elderly with a wide spectrum of musculoskeletal conditions (degenerative/rheumatic joint diseases, falls/trauma, nursing care, peripheral nerve problems, sarcopenia, and interventions). In this respect, electronic databases (ISI Web of Science, PubMed, Elsevier Science Direct) and reference lists of relevant articles/reviews were screened by two blinded investigators for each topic. The main medical subject heading terms selected to capture the most relevant papers on the topics in accordance with the literature were knee/hip/hand osteoarthritis, prevalence, rotator cuff injury, lateral epicondylitis, tendinopathy, rheumatoid arthritis, Sjogren's syndrome, polymyalgia rheumatica, crystal arthropathies, gout, pseudogout, carpal tunnel syndrome, fall, fractures, hematoma, pressure ulcer, ultrasonography, interventional, sarcopenia, body composition, rehabilitation, frail elderly, and aged. The search was limited to peer-reviewed full-text English journals starting from the earliest papers to May 2017. A study population (or part of the study population) of adults older than 65 years (if possible) was included. We especially underscore the use of US by clinicians as an extension of their physical examination or as a practical guide for an immediate intervention. ***International Journal of Rehabilitation Research*** **00:000–000 Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.**

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Introduction

During the last and current centuries, the proportion of the world's population older than 65 years of age has increased significantly as life expectancy has increased. The WHO reports that one of the major chronic conditions affecting older individuals worldwide is musculoskeletal disorders (World Health Organization, 2002), which are associated with disability and long-term pain. Approximately 23% of individuals older than 75 years have limitations while performing daily life activities because of musculoskeletal injury and/or disease and associated comorbidities (United States Bone and Joint Initiative, 2014)

Healthcare services for older adults must be comprehensive, accessible, and efficient. Musculoskeletal ultrasound (US), a widely available imaging modality, can contribute significantly toward this goal. With the aid of US, it is possible to assess, investigate, and treat musculoskeletal pathologies in the same visit, without having to refer patients from one clinic to another. However, in routine clinical practice, physicians taking care of older patients do not use US effectively (Leona *et al.*, 2012).

The role of US imaging has been established in the practice of musculoskeletal medicine because of its numerous advantages (Özçakar *et al.*, 2013). It is patient-friendly, convenient, cost-effective, and does not involve exposure to radiation or magnetic fields (Özçakar *et al.*, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g). With no contraindications, US imaging can provide additional advantages for imaging older adults with prosthetic devices, cardiac pacemakers, or for those who are immobilized. Furthermore, with the capability of comparative and dynamic imaging, the probe of the US is considered the 'stethoscope', 'extended hand', or 'the 6th finger' of physicians (Akkaya *et al.*, 2013). Indisputably, this is true not only for diagnostic but also for therapeutic procedures performed under real-time guidance (De Muynck *et al.*, 2012).

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Methods

Literature search and selection

To provide a snapshot of the potential value of US imaging in the management of older adults with a wide spectrum of musculoskeletal conditions (degenerative and rheumatic joint diseases, falls/trauma, nursing care, peripheral nerve problems, sarcopenia, and interventions), a narrative review was performed. Electronic databases (ISI Web of Science, PubMed, Elsevier Science Direct) and reference lists of relevant articles/reviews were screened for each topic. Two independent investigators (B.C. and M.K.) performed the screening/evaluation of the articles. The medical subject headings (MeSH) terms were selected to capture the most relevant papers on the topics in accordance with the literature, that is they were the most commonly used ones in the papers. The main keywords were chosen and combined in the literature search (Table 1): [‘Knee osteoarthritis’ OR ‘hip osteoarthritis’ OR ‘coxarthrosis’ OR ‘hand’ OR ‘osteoarthritis’] AND [‘prevalence’ OR ‘epidemiology’] AND [‘rotator cuff injury’ OR ‘shoulder impingement syndrome’ OR ‘lateral epicondylitis’ OR ‘tennis elbow’ OR ‘tendinopathy’ OR ‘Achilles’ OR ‘patellar ligament’] AND [‘rheumatoid arthritis’ OR ‘Sjogren’s syndrome’, OR ‘polymyalgia rheumatica’ OR ‘crystal arthropathies’ OR ‘gout’ OR ‘pseudogout’ OR ‘chondrocalcinosis’ OR ‘calcium pyrophosphate deposition disease’] AND [‘carpal tunnel syndrome’ OR ‘entrapment neuropathy’] AND [‘accidental fall’ OR ‘fractures’ OR ‘hematoma’ OR ‘pressure ulcers’ OR ‘decubitus ulcers’] AND [‘ultrasonography’] AND [‘interventional’] AND [‘sarcopenia’ OR ‘body composition’] AND [‘Rehabilitation’] AND [‘frail elderly’ OR ‘aged’]. The search was limited to peer-reviewed full-text English journals starting from the earliest papers to May 2017. Study populations (or part of the study population) of adults older than 65 years of age (if possible) were included. Disagreements were resolved by group consensus.

Table 1 **The search strategy**

Topics	MeSH terms	
Osteoarthritis	Osteoarthritis	
	Hip osteoarthritis	
	Coxarthrosis	
	Knee osteoarthritis	
	Hand osteoarthritis	
Periarticular diseases	Rotator cuff injury	
	Shoulder impingement syndrome	
	Lateral epicondylitis	
	Tennis elbow	
	Tendinopathy	
	Patellar ligament	
Rheumatic diseases	Rheumatoid arthritis	Ultrasonography
	Sjogren’s syndrome	Rehabilitation
	Polymyalgia rheumatica	Prevalence
	Crystal arthropathies	Epidemiology
	Gout	Frail elderly
	Pseudogout	Aged
	CPPD	
	Chondrocalcinosis	
Peripheral nerve problems	Carpal tunnel syndrome	
	Entrapment neuropathy	
Accidental fall	Accidental fall	
Trauma	Fracture	
Nursing care	Hematoma	
	Pressure ulcer	
	Decubitus ulcer	
Guidance/intervention	Interventional	
Sarcopenia	Sarcopenia	
Body composition	Body composition	

CPPD, calcium pyrophosphate deposition disease; MeSH, medical subject heading.

Results

The literature on degenerative joint and periarticular conditions, rheumatic diseases, peripheral nerve problems, falls, traumatic injuries, and bedside imaging in nursing care, therapeutic procedures, sarcopenia, and body composition) was searched using the related keywords (Table 1). The most commonly encountered musculoskeletal conditions in older adults are shown in Table 2.

Discussion

Degenerative joint and periarticular conditions

Joint diseases account for half of all chronic conditions in individuals aged older than 65 years (Woolf, 2000). An estimated 10% of men and 18% of women aged older than 60 years have symptomatic osteoarthritis (OA), the most frequent arthropathy in older adults. The most commonly affected joints are the knee, hip and hand (Murray and Lopez, 1996; Zhang *et al.*, 2002; Dillon *et al.*, 2006; Quintana *et al.*, 2008) (Table 2). Direct radiography, the main imaging modality used for OA, is not as sensitive as US and may not correlate with the clinical symptoms. US can identify synovial inflammation – a predictor of disease progression – as well as effusion, erosion, and osteophytes. US imaging proved more sensitive than radiography in detecting OA of the knee, hip, and hand joints (Figs 1 and 2) (Abraham *et al.*, 2014). Some authors have used US to analyze inflammatory and structural damages in knee and hip OA (Iagnocco *et al.*, 2012; Riecke *et al.*, 2014). In addition, it has been shown that large joint effusions identified sonographically were correlated with rapidly destructive OA (Birn *et al.*, 2014).

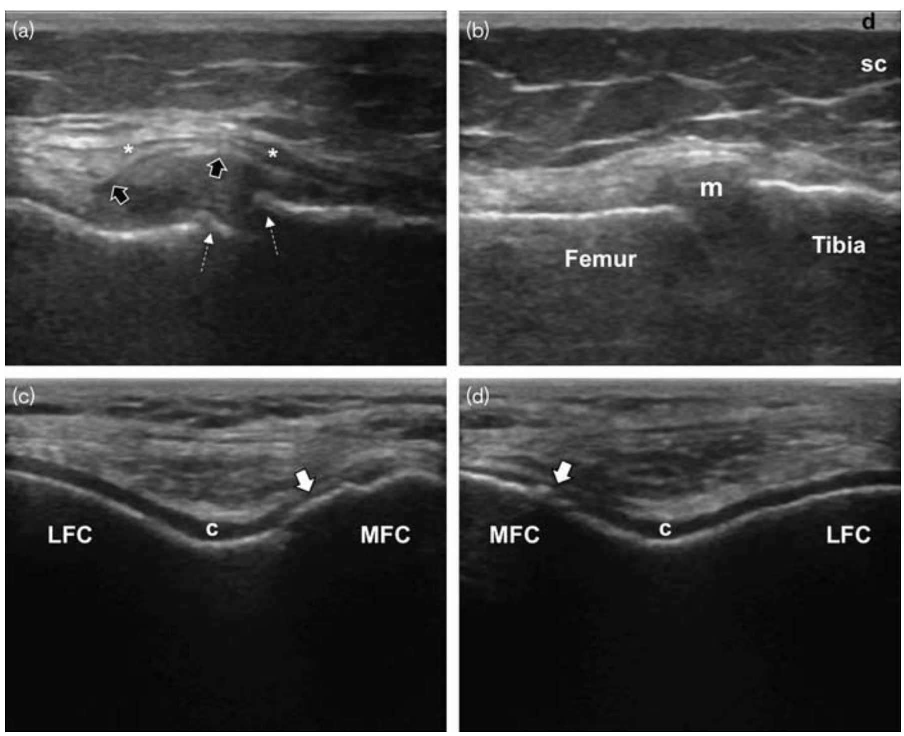
As aging has a negative effect on the mechanical properties of tendons possibly because of decreased blood supply, local hypoxia, free radical production, impaired metabolism/nutrition, and collagen degeneration, older individuals are prone to tendon/ligament damage, including shoulder rotator cuff and biceps tendon pathologies, lateral epicondylitis, Achilles/patellar tendinitis, de Quervain’s tenosynovitis, flexor tenosynovitis (trigger finger), and plantar fasciitis (Figs 3 and 4) (Abate *et al.*, 2009; Hodgson *et al.*, 2012). In addition, bursitis can also be observed in overuse or inflammatory/infectious conditions. The most commonly affected bursae in adults (also in older adults) are subdeltoid, olecranon,

Table 2 The most common musculoskeletal conditions in older adults

Diseases	Prevalence (%)	Sex (F/M)	Age (years)	References
Osteoarthritis				
Knee	12.1	1.4	≥ 60	Dillon *et al.* (2006)
Hip	7.4	1.2	≥ 60	Quintana *et al.* (2008)
Hand	21.6	2.0	> 70	Zhang *et al.* (2002)
Tendinopathies				
Rotator cuff disease	38.2	–	≥ 60	Teunis *et al.* (2014)
Lateral epicondylitis	2.0	> 1	≥ 60	Tajika *et al.* (2014)
Rheumatic diseases				
Rheumatoid arthritis	2.0	~ 1	≥ 60	Rasch *et al.* (2003)
Primary Sjogren's syndrome	1.4 (or 3.4)[a]	–	71–74	Haugen *et al.* (2008)
Polymyalgia rheumatica	0.7 (to 4.1)[b]	1.7	≥ 50	Doran *et al.* (2002)
Crystal arthropathies				
Gout	3.1	0.4	≥ 65	Adams *et al.* (1996)
Pseudogout (chondrocalcinosis)	8.1	~ 1	≥ 63	Felson *et al.* (1989)
Peripheral nerve problems				
Carpal tunnel syndrome	1.2	1.7	≥ 65	Tanaka *et al.* (1994)
Body composition analysis				
Sarcopenia	24.3	< 1	≥ 60	Spira *et al.* (2016)

F; female, M; male.
[a]Prevalence varies depending on the classification criteria.
[b]Prevalence increases with age and reaches up to 4.1% in ≥ 90 years.

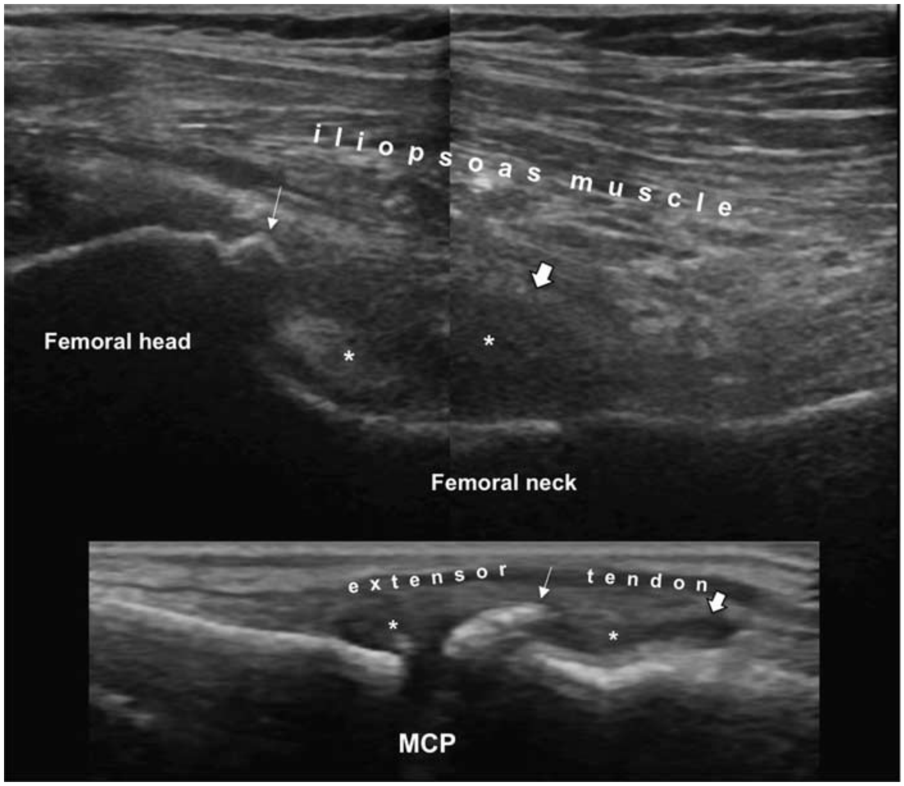
Fig. 1



Ultrasound imaging for knee osteoarthritis. Longitudinal imaging for the medial knee compartment shows decreased joint space with osteophytes (thin arrows) and bulging meniscus (black arrows) that indents the medial collateral ligament (stars) (a). Normal side (b). Bilateral suprapatellar axial imaging (c, d) in maximum knee flexion shows the distal femoral cartilage (c) as a thin anechoic band over the medial and lateral femoral condyles (MFC, LFC). Note that the cartilage layer is decreased on the medial compartments, where the bony surfaces are also irregular (white arrows). d, dermis; m, meniscus; sc, subcutaneous fat.

trochanteric, pes anserine, and prepatellar (Holland and Gonzalez, 1998; Gorevic 2004). US is currently considered to be the gold standard for assessing these disorders. The incidence and prevalence of rotator cuff tears increase with age (Teunis *et al.*, 2014) (Table 2). Therefore, shoulder pain in older adults requires prompt and appropriate investigation. A systematic meta-analysis (Ottenheijm *et al.*, 2010) showed that US has high

Fig. 2



Ultrasound imaging for hip and hand osteoarthritis. Anterior longitudinal image for the hip (above) and dorsal longitudinal image for the metacarpophalangeal (MCP) (below) joints show fluid and synovial thickenings (stars) indenting the joint capsules (thick arrows). The osteophytes can also be observed (thin arrows).

accuracy in diagnosing subacromial disorders including partial/full-thickness rotator cuff tears, subdeltoid bursitis, tendinopathy, and calcifying tendonitis (Fig. 3). A review comparing diagnostic tests for detecting rotator cuff tears found the sensitivity and specificity of MRI and US to be similar (Lenza *et al.*, 2013).

Lateral epicondylitis is a common source of musculoskeletal pain because of overuse of the forearm extensor muscles. Its prevalence is 1.3% in the general population and 7% in manual workers (Latham and Smith, 2014). A study on 422 participants (Tajika *et al.*, 2014) showed that the prevalence of lateral epicondylitis was 2.0% in adults aged older than 60 years (Table 2). The commonly encountered US findings include hypoechoic swelling of the common extensor tendon (insertion), bony irregularities at the attachment site, and/or calcifications within the tendon (Fig. 4). A recent systematic meta-analysis showed that US has an overall diagnostic sensitivity of 82% and a specificity of 66% for lateral epicondylitis (Latham and Smith, 2014).

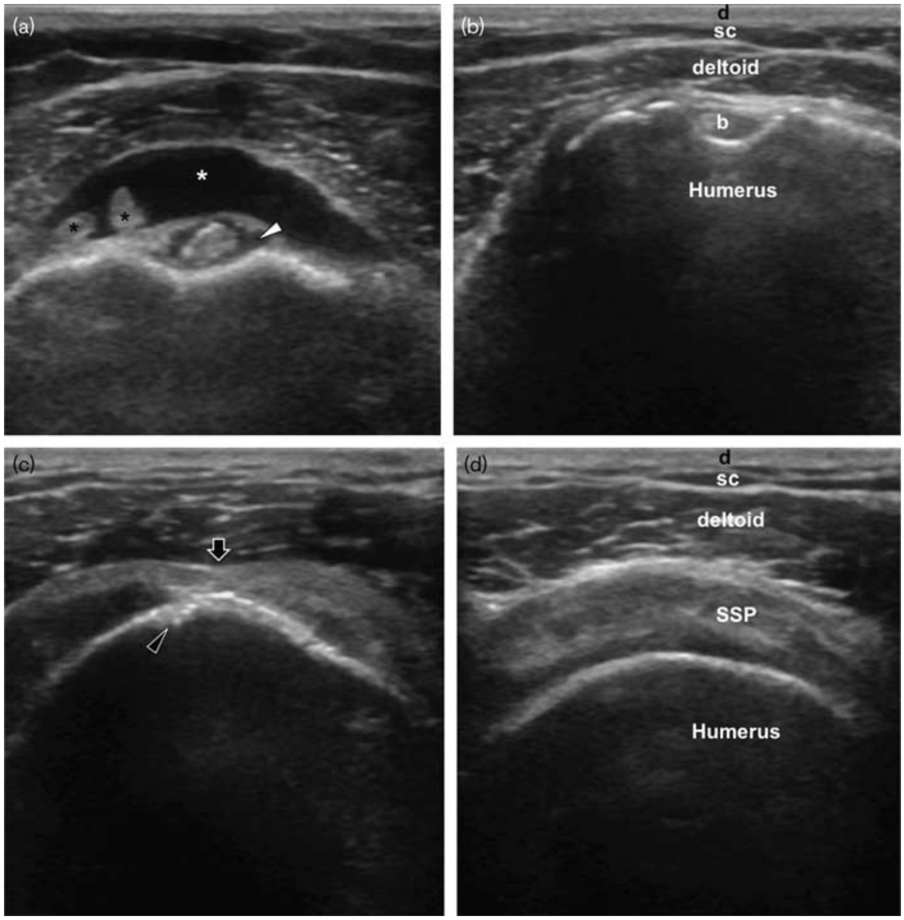
The incidence of Achilles tendon problems among the aging but physically active population is increasing (Fig. 4). However, it is overlooked in one-fourth of the cases (Mazzone and McCue, 2002). Partial tears are more common and more difficult to diagnose; therefore, a timely diagnosis using US can help preserve the functionality of the patient. US can be used to differentiate Achilles tendon pathologies with 92% accuracy and patellar tendinopathy with 83% accuracy (Hartgerink *et al.*, 2001). However, in a study comparing MRI and US for the diagnosis of patellar tendinopathy, whereas both modalities showed good sensitivity (both with 82%), US had better specificity (87 vs. 57%) (Warden *et al.*, 2007).

Rheumatic diseases in the older adults

Rheumatic conditions restrict mobility and reduce quality of life in older adults. Unfortunately, the prevalence of rheumatic disease is ~50% in individuals older than 65 years (Helmick *et al.*, 2008). In the USA, 13% of adults aged older than 75 years were hospitalized for rheumatic conditions (United States Bone and Joint Initiative, 2014).

The prevalence of rheumatoid arthritis in patients aged older than 60 years is 2% (Rasch *et al.*, 2003) (Table 2). A study shows that information obtained on the presence and activity of synovitis by US makes this imaging technique superior to clinical examination (Karim *et al.*,

Fig. 3



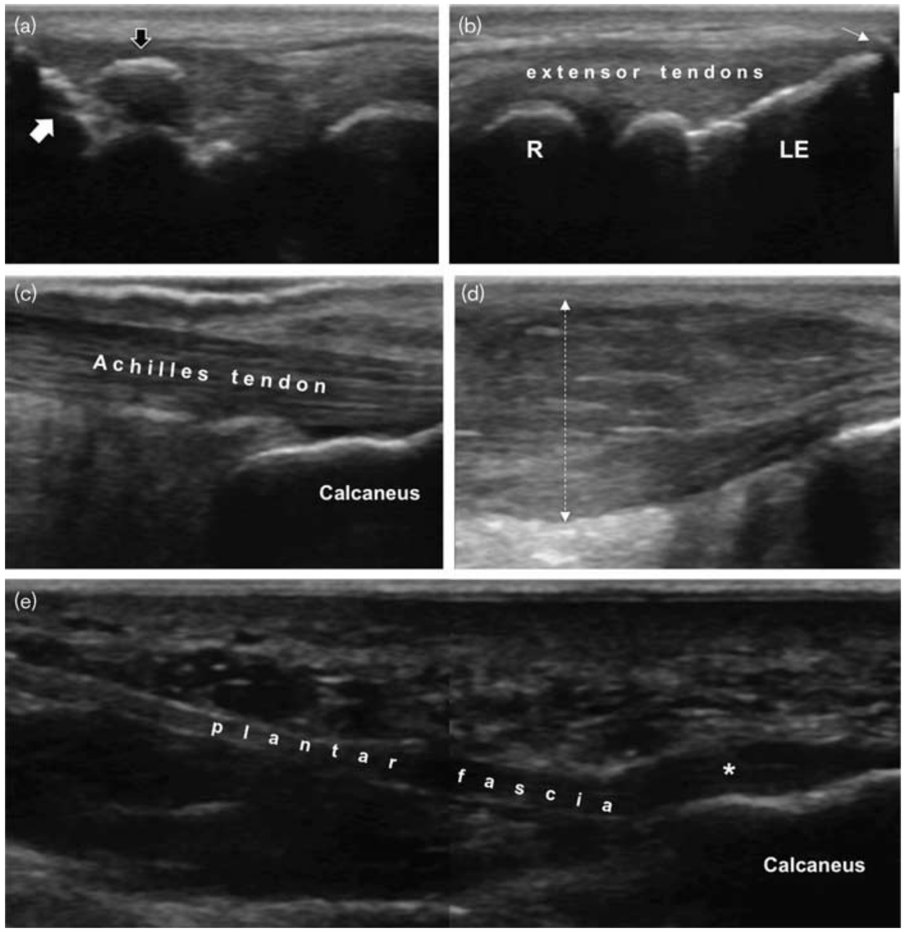
Ultrasound imaging for shoulder/rotator cuff problems. Anterior axial view shows a large amount of fluid (white asterisk) and some synovial hypertrophy (black asterisks) within the subdeltoid bursa (a). Note the small amount of fluid (arrowhead) around the biceps tendon as well. Normal side (b). Axial imaging over the rotator cuff shows focal thinning/partial-thickness rupture (arrow) of the supraspinatus tendon over the small cortical irregularity (arrowhead) (c). Normal side (d). b, biceps tendon; d, dermis; sc, subcutaneous fat; SSP, supraspinatus tendon.

2004). Confirming the presence of synovitis with US improved the accuracy of the 2010 American College of Rheumatology and European League Against Rheumatism criteria for rheumatoid arthritis, and helped better classify patients who require treatment (Nakagomi *et al.*, 2013). US is also superior to conventional radiography in showing bone erosions and synovitis (Wakefield *et al.*, 2000). With its ability to differentiate active and inactive synovitis, power Doppler US can be used as a reliable modality for the detection of inflammation (Fig. 5) compared with MRI (Szkudlarek *et al.*, 2001) and histopathologic examination of synovial biopsy samples (Walther *et al.*, 2001).

Primary Sjogren's syndrome (pSS) is another chronic autoimmune disease of unknown etiology predominantly affecting the exocrine gland functions. The clinical presentation is that of dry eyes/mouth, fatigue, myalgia, and cognitive dysfunction. It can be difficult to differentiate pSS from the side effects of medication. Its prevalence varies between 1.4 and 3.4% in older adults depending on the classification criteria (Haugen *et al.*, 2008) (Table 2). Being a noninvasive, widely available, inexpensive, and nonirradiating imaging modality, US imaging of the major salivary glands merits special attention for the assessment of disease involvement. A recent meta-analysis showed that US has an overall diagnostic sensitivity of 69% and specificity of 92% in pSS (Delli *et al.*, 2015).

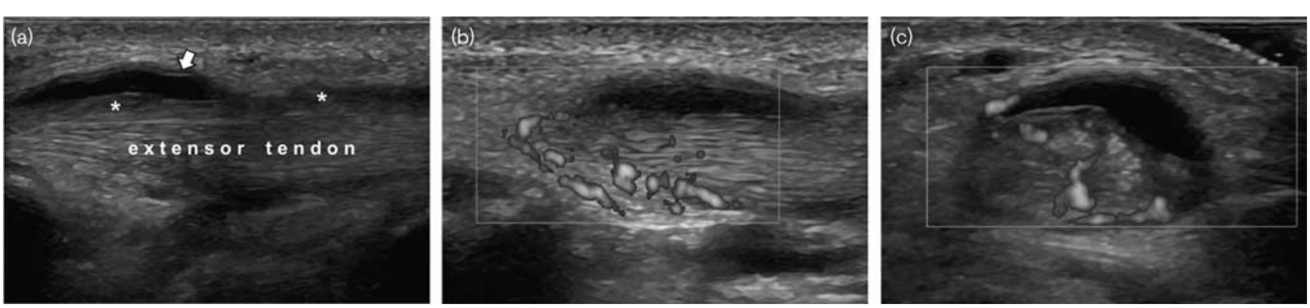
Polymyalgia rheumatica (PMR) is one of the most common inflammatory rheumatic disorders in older adults (Table 2). It should be considered in patients aged older than 50 years (prevalent in 0.7% of the patients) with chronic pain and stiffness (especially in the morning) of the neck, shoulder and pelvic girdles (Doran *et al.*, 2002). Shoulder joints are more frequently involved than the hips. Other musculoskeletal findings are found in about 50% of PMR patients including carpal tunnel syndrome (CTS), swelling of the hands/feet with pitting edema,

Fig. 4



Ultrasound imaging for overuse injuries. Longitudinal images over the lateral epicondyle (LE) show cortical irregularities (white thick arrow) and calcification (black thick arrow) on the symptomatic side (a) and a small bony spur (thin arrow) on the asymptomatic side (b) of the patient. Longitudinal images over the posterior heel show normal (c) and significantly swollen (d) Achilles tendons. Split-screen longitudinal image on the plantar surface shows the typical swelling (asterisk) of the fascia (fasciitis) at its insertion on the calcaneus (e). R, radius.

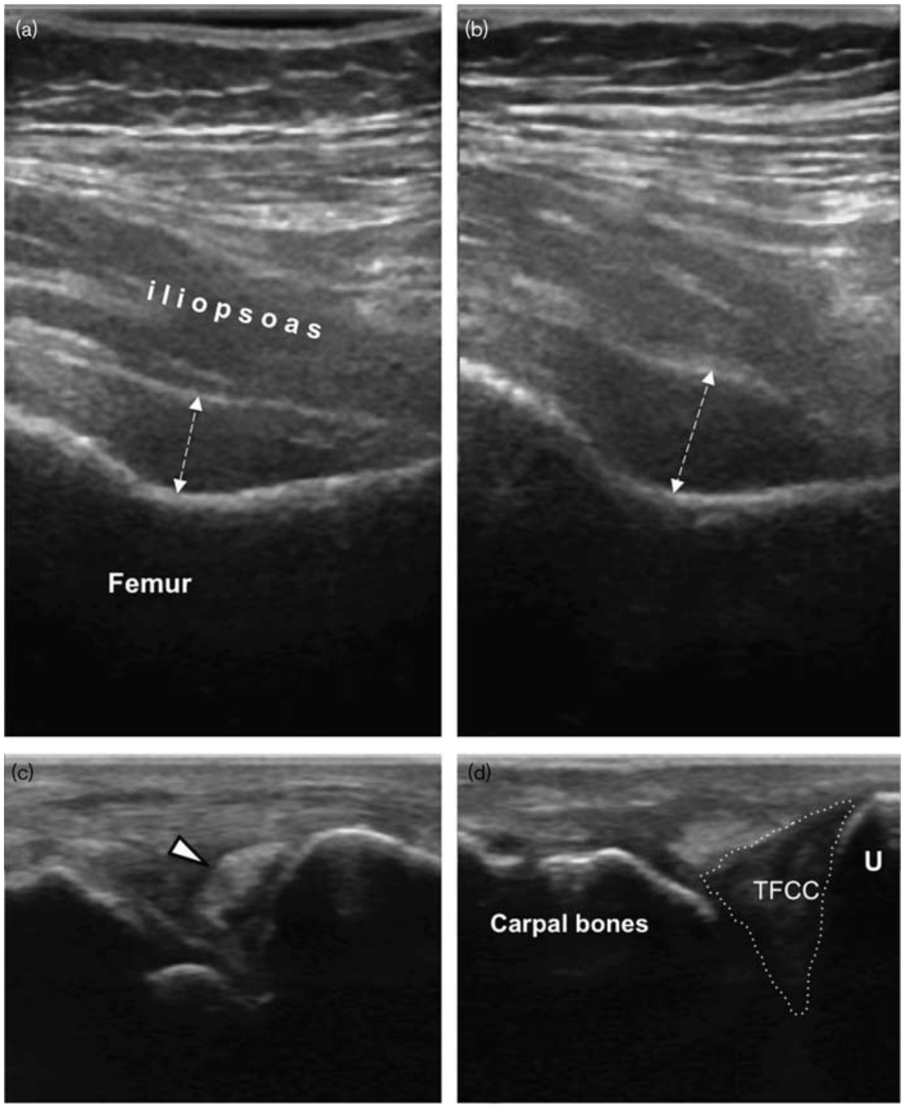
Fig. 5



Ultrasound imaging for tenosynovitis. Longitudinal image shows fluid (arrow) and synovial hypertrophy (stars) around the extensor tendon of the first digit (a). Longitudinal (b) and axial (c) imaging with Doppler ultrasound shows increased blood flow (inflammation) within and around the tendon.

and nonerosive peripheral arthritis (mainly involving the wrists, knees, and metacarpophalangeal joints) (Ceccato *et al*., 2006). US demonstration of subdeltoid bursitis, biceps tenosynovitis, or glenohumeral synovitis in at least one shoulder, and synovitis or trochanteric bursitis in at least one hip (Fig. 6) was shown to add value to the

Fig. 6



Ultrasound imaging for rheumatic conditions. Comparative hip imaging (longitudinal view) in a patient with polymyalgia rheumatica (a and b) shows fluid (arrows) indenting the joint capsule on both sides. Comparative wrist imaging (longitudinal view) in a patient with pseudogout shows hyperechoic calcium deposition (arrowhead) in the triangular fibrocartilage complex (TFCC) (c). Normal side (d). U, ulna.

diagnosis of PMR. These US findings have therefore been included in the 2012 American College of Rheumatology/European League Against Rheumatism diagnostic criteria for PMR (Dasgupta *et al.*, 2012).

Another rheumatic disease, gout, is the most prevalent inflammatory arthritis in developed countries, especially in older men (Adams *et al.*, 1996) (Table 2). In addition to US-guided joint aspiration for synovial fluid analysis, US enables visualization of the monosodium urate crystal deposition and is of diagnostic value in gouty arthritis and asymptomatic hyperuricemia (Howard *et al.*, 2011). US can further show findings such as synovitis, effusion, bony erosions, and soft tissue (cartilage, tendon, ligament, etc.) involvements. US features specific to gout are double contour sign (hyperechoic deposition over the cartilage), tophus (inhomogeneous hypo/hyperechoic material surrounded by a small anechoic rim), and erosions adjacent to tophaceous material (Døhn *et al.*, 2013). US also appears to correlate well with serum uric acid levels and efficacy of urate-lowering therapy (Ottaviani *et al.*, 2015). Moreover, power Doppler US is useful for follow-up of patients with synovitis (active or inactive) under colchicine treatment (Filippucci *et al.*, 2003).

Pseudogout (calcium pyrophosphate dihydrate deposition disease) occurs almost exclusively in articular tissues, commonly in hyaline and fibrocartilage. It is the most common cause of chondrocalcinosis (Gorevic, 2004). Pseudogout is primarily a disease of the elderly (Table 2) and mainly increases with age and OA. Crystal-induced inflammation involving the knee, wrist, or shoulder in a patient older than 65 years is likely to be acute pseudogout (Fig. 6). Other risk factors are joint trauma, metabolic disease, and familial predisposition. The usefulness of US in detecting chondrocalcinosis in the knee, wrist, and shoulder joints has been investigated. Typical US findings include hyperechoic bands within the hyaline cartilage and hyperechoic sparkling spots in the fibrocartilage compartments. Sensitivity (87%) and specificity (96%) are excellent for the detection of chondrocalcinosis at the knee, possibly better (more sensitive) than those of conventional radiographies (Filippou *et al.*, 2007).

Peripheral nerve problems

The most common entrapment neuropathy, CTS, is prevalent in 1.2% of patients older than 65 years (Tanaka *et al.*, 1994) (Table 2). In addition to invasive nerve conduction tests, the sonographic cross-sectional area of the median nerve can be used to diagnose CTS (Kara *et al.*, 2012). Other US findings include fascicular echo structure changes, nerve swelling proximal to the site of entrapment, and increased vascularity (Fig. 7). Similarly, the ulnar nerve can be observed with high resolution in patients with ulnar neuropathy (Scheidl *et al.*, 2013). In a comparison study using a validated clinical diagnostic tool (CTS-6) as the reference standard, US confirmed the diagnosis of CTS with similar sensitivity (both with 89%) but better specificity (90 vs. 80%) than the electrodiagnostic testing (Fowler *et al.*, 2014). Compared with MRI for the detection of mononeuropathies and brachial plexopathies, US imaging is found to be more sensitive (93 vs. 67%) with equivalent specificity (both with 86%) (Zaidman *et al.*, 2013). In short, US has the ability to morphologically confirm the peripheral nerve pathologies, identify the underlying etiology (e.g. ganglion, aberrant muscle), and guide operative procedures.

Falls, traumatic injuries, and bedside imaging in nursing care

For individuals older than 65 years, falls are the primary cause of injury (Yamada and Thomas, 2011). Among individuals older than 85 years, three out of four injuries are the result of a fall and 45% of hospitalizations are because of fractures (United States Bone and Joint Initiative, 2014). US imaging is feasible for evaluating these traumatic injuries, especially those because of falls. A practical tool to visualize muscle and tendon injuries, bedside US can also identify extremity/rib fractures or possible hematomas (Fig. 8) in older patients on anticoagulation (Chan, 2009; Joshi *et al.*, 2013). Portability of US is no doubt an advantage in trauma patients. Similarly, portable US may potentially be used for nursing home residents and nonambulatory patients. US even enables the prevention of pressure ulcers, a significant cause of morbidity in older patients with restricted mobility. Unclear layered structure, hypoechoic lesion, discontinuous fascia, and heterogeneous hypoechoic area are US findings of deep tissue injury that may help predict ulcer progression (Aoi *et al.*, 2009).

Therapeutic procedures

It is possible to perform therapeutic procedures such as glucocorticoid injections, aspiration of joint effusions, and nerve blocks using US. With real-time guidance, obscure and deep anatomic structures can be targeted without damaging nearby nerves or arteries (Fig. 9). There are a number of studies emphasizing the importance of US for accurate injections as opposed to blind injections (Balint *et al.*, 2002; Cunnington *et al.*, 2010). In a study of 184 patients (mean age: 58 years) with inflammatory arthritis, US-guided corticosteroid injections were found to be significantly more accurate than blind injections (83 vs. 66%) (Cunnington *et al.*, 2010).

Ultrasound-guided interventional procedures improve outcomes for pain management, one of the most important components of palliative care. Sacroiliac joint pain may comprise between 15 and 30% of mechanical low back pain, with higher prevalence rates in young athletes and the elderly (Cohen *et al.*, 2013). It has been suggested that US could be useful not only for detecting posterior sacroiliac ligament pathology but also for guidance during injections (Cohen *et al.* 2013). In another study, US-guided femoral nerve blocks performed in the emergency department led to sustained pain reduction in older adults with hip fractures (Beaudoin *et al.*, 2010).

Sarcopenia and body composition

Among other uses, US can quantify tissue thickness, which makes body composition analysis possible both for clinical purposes and for research. Crude indicators of body composition such as calf/thigh circumference fail to identify the actual quantity of tissue compartments, whereas US imaging can clearly delineate the dermis, subcutaneous fat, and muscle layers (Fig. 8b). It is capable of performing fast regional estimates of body composition, and was used in several studies to successfully measure muscle thickness as an index of lean soft tissue in the older adults (Tillquist *et al.*, 2014; Worsley *et al.*, 2014; Masaki *et al.*, 2015). High intrarater and interrater reliabilities for US measurements of quadriceps muscle thickness have been reported (Tillquist *et al.*, 2014). In addition, vastus medialis muscle measurement with US was validated against MRI (Worsley *et al.*, 2014). Masaki *et al.* (2015) suggested that rapid risk assessment of the individual using US may even help prevent the progression of kyphosis as erector spinae muscle thickness was found to be a significant determinant of the thoracic kyphosis angle.

Fig. 7

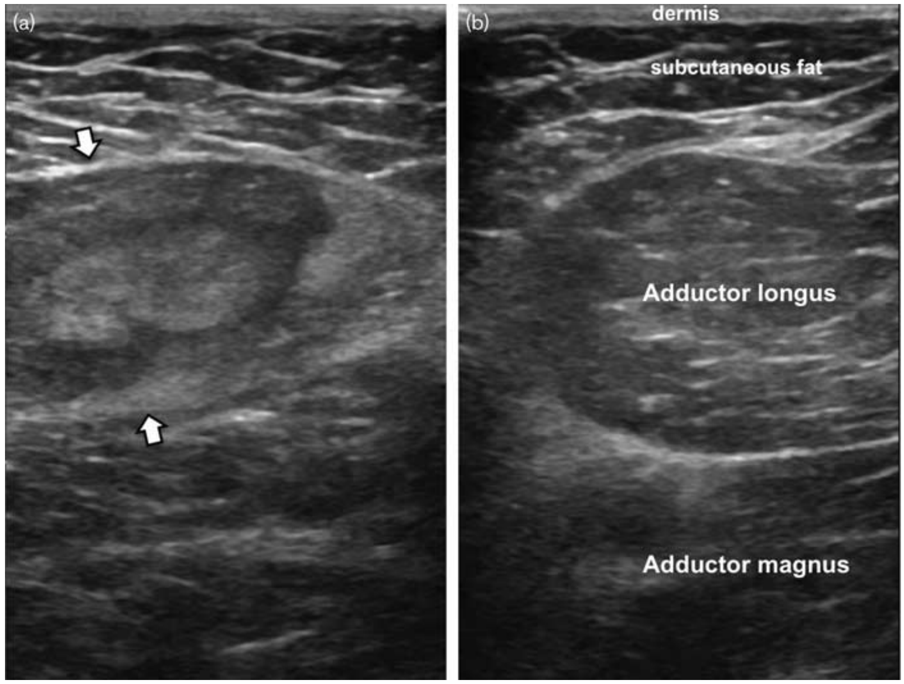
Ultrasound imaging for carpal tunnel syndrome. Longitudinal images (above) show the swollen median nerves (M) proximal to the site of entrapment (arrow). Note that the distal portions (m) have normal thickness. Axial images (below) show how the cross-sectional area of the median nerves (asterisk) can be measured.

Probably one of the most promising areas of US use is the assessment of sarcopenia. Defined as low muscle mass and strength, it occurs in about one in four community-dwelling older individuals (Spira *et al.*, 2016) (Table 2). The association of sarcopenia with disability and mortality in older adults emphasizes the significance of early diagnosis.

Available methods for the evaluation of sarcopenia include anthropometry, bioelectrical impedance analysis, dual-energy X-ray absorptiometry, computed tomography, and MRI. Computed tomography and MRI only reflect/predict muscle mass and have cost limitations. Anthropometric measurements fail to identify sarcopenic obesity. Bioelectrical impedance analysis may also overestimate fat-free mass in individuals who are obese. Muscle strength tests cannot be used in cognitively impaired or unconscious patients and dual-energy X-ray absorptiometry measurements are influenced by tissue thickness and hydration (Spira *et al.*, 2016). US, however, provides an opportunity to assess/predict muscle mass rapidly and accurately. As it can clearly delineate the dermis and the subcutaneous fat, US can also help calculation of the actual quantity of various tissue compartments.

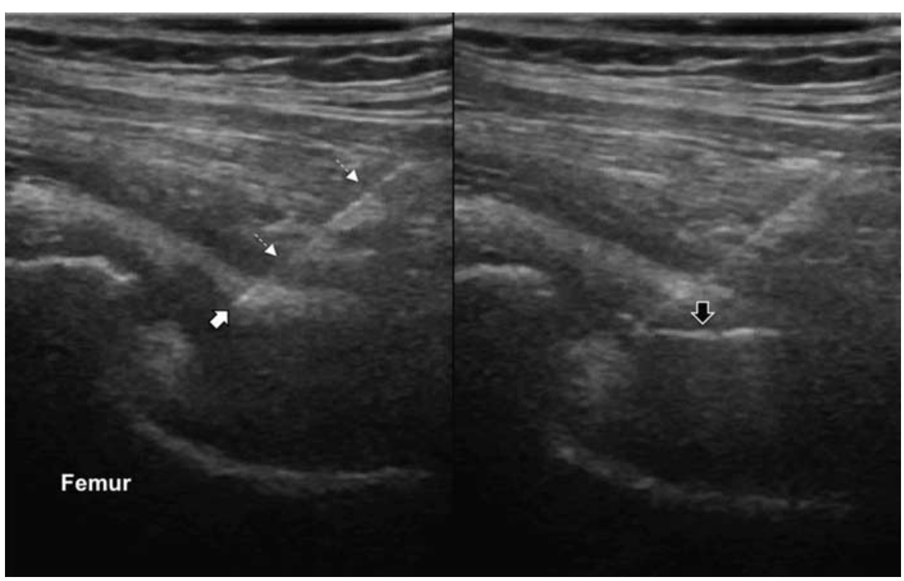
Ultrasound detects the cross-sectional area, architecture (pennation angle and fascicle length), and composition (echogenicity) of the muscle, which are related to muscle strength (Kuyumcu *et al.*, 2016). Pennation angle provides information on muscle strength as the larger the pennation angle, the more contractile muscle fibers can be packed within a definite volume and thus increases the muscle's ability to produce force (Strasser *et al.*, 2013). A 12% decrease in the pennation angle of gastrocnemius muscle has been reported in older adults (Morse *et al.*, 2005). Studies show that intramuscular fibrous and adipose tissues in a skeletal muscle (or echogenicity) can be used to determine the quality of the muscle. In this respect, an inverse association between echogenicity and muscle strength was observed in older men (Watanabe *et al.*, 2013). Sonographic estimate of muscle thicknesses may be a useful measurement for early detection of sarcopenia (Loenneke *et al.*, 2014). It has been suggested that US muscle thickness measurement (especially of the vastus medialis) can be used to accurately monitor the extent of sarcopenia (Strasser *et al.*, 2013). In a more

Fig. 8



Axial imaging of the medial thigh shows a healing hematoma (arrows) in the adductor longus muscle (a). Normal side (b).

Fig. 9



Ultrasound imaging for guiding interventions. Longitudinal hip image of the same case in Fig. 2 shows the needle (thin arrows) penetrating the joint capsule (thick arrow) on the left image. The injected material (black arrow) is seen as being distributed within the joint on the right image.

recent study, rectus femoris muscle assessments (thickness and density) with US were found to be associated with muscle strength and walking capacity in older individuals (Berger *et al.*, 2015).

Another study suggested that US muscle architecture of gastrocnemius and soleus muscles in older adults may account for interindividual differences in mobility (Stenroth *et al.*, 2015). Thigh composition assessed using

US might also be an indicator of musculoskeletal health in older individuals at risk of frailty and may help monitor the effects of nutrition and exercise (Agyapong-Badu *et al.*, 2014). Furthermore, US measurements of quadriceps muscle were found to be an independent risk factor for hospital readmission or death, which indicates that US might have broad and important clinical implications in the future (Greening *et al.*, 2015). Studies also show an association between masseter muscle thickness measured by US, chewing ability, and physical fitness in older adults (Ohara *et al.*, 2013; Gaszynska *et al.*, 2014).

Conclusion

There is highly suggestive evidence that the utilization of musculoskeletal US in older adults makes prompt diagnosis and treatment possible for a wide spectrum of conditions and disorders. With so many potential benefits, US should become part of geriatric care, both for clinical practice and for training/research. Finally, there are two important issues that might be considered restrictions/barriers in terms of the use of US in daily practice. First, access to an US machine may not be easy for each/every clinician. Second, as this technique is user dependent, extensive training is paramount. Fortunately, in recent years, many attempts have also been made toward its international and standardized education/use (Özçakar *et al.*, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g).

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Conflicts of interest

There are no conflicts of interest.

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