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REVIEW

Role of ultrasound versus magnetic resonance imaging in evaluation of non-osseous disorders causing wrist pain

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Abstract

Background: Wrist pain is a challenge, and imaging plays an important role in the evaluation of wrist pain.

Purpose: Assessment of the role of ultrasonography (USG) versus magnetic resonance imaging (MRI) in the diagnosis and evaluation of wrist pain

Results: Out of 50 patients, 35 males (70%) and 15 females (30%) (age range 12–62 years; mean = 31.7 years) were included in the study. The sensitivity, specificity, and accuracy of MRI and USG for tendinopathy were 95%, 100%, and 97.5% and 95%, 100%, and 97.5% respectively. The sensitivity, specificity, and accuracy of MRI and USG for TFCC tear were 75%, 100%, and 87.5% and 0%, 50%, and 50% respectively. The sensitivity, specificity, and accuracy of MRI and USG for simple ganglion were 100%, 100%, and 100% and 75%, 100%, and 87.5% respectively. The sensitivity, specificity, and accuracy of MRI and USG for solid mass were 100%, 100%, and 100% and 100%, 100%, and 100% respectively. The sensitivity, specificity, and accuracy of MRI and USG for foreign body were 50%, 100%, and 75% and 100%, 100%, and 100% respectively. The sensitivity, specificity, and accuracy of MRI and USG for carpal tunnel syndrome (CTS) were 77.8%, 100%, and 88.9% and 88.9%, 100%, and 94.4% respectively. Overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of USG Vs MRI were 79.2%, 96.1%, 95.0%, 83.3%, and 88.0% and 89.8%, 98.0%, 97.8%, 90.9%, and 94.0% respectively.

Conclusion: USG is near equal to MRI in the assessment of tendon abnormalities and better than MRI in the diagnosis of CTS and foreign body, but MRI is better than USG in the assessment of TFCC and in the assessment of swelling (simple ganglion) and characterization of masses.

Keywords: Ultrasonography (USG), Magnetic resonance imaging (MRI), Wrist pain

Background

Wrist pain is traditionally classified as acute pain caused by a specific injury or as subacute/chronic pain that usually develop gradually with or without a prior traumatic event. In these cases, the differential diagnosis is wide and includes tendinopathy, tendonitis, tenosynovitis, arthritis, and ganglions [1]. History and physical examination lead to the correct diagnosis in most cases. When the diagnosis remains unclear, further imaging, such as plain radiography, bone scan, ultrasonography (USG), computed tomography (CT), or magnetic resonance imaging (MRI), may help identify the cause [2].

MRI can be utilized to enhance detection and evaluation of several wrist disorders, allowing for discrimination of soft tissue structures, including marrow, ligaments, tendons, cartilage, muscles, nerves, and blood vessels. Also, MRI can be of aid in the evaluation of carpal instability of the triangular fibrocartilage, disorders, fracture, avascular necrosis, tendinopathy, nerve entrapment syndromes, synovial abnormalities, and soft tissue masses [3].

USG is the best technique for imaging tendons. It allows dynamic tendon examination which gives it a distinct advantage over MRI [4] as well as USG is ideal for

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assessing peripheral nerves and allows superior imaging definition when compared with MRI or CT [5].

The wide availability and recent improvement in technology coupled with portability, low cost, and safety make USG the first choice imaging investigation for the evaluation of MSK diseases [6]. In the current study, we aimed to assess the role of USG versus MRI in the evaluation of wrist pain.

Patients and method

This prospective study was conducted during the period between January 2017 and July 2017 at the Radiodiagnosis Department, Al-Azhar University Hospital, New Damietta, Egypt. Fifty patients with age ranging from 12 to 62 years (mean = 31.7) complained of wrist pain or wrist ligament tears were involved in this study. There were 35 male (70%) and 15 female (30%) patients. Thirty-two patients (64%) had a previous history of trauma. The right wrist was imaged in 38 (76.0%) cases and the left wrist in 12 (24.0%) cases.

The study was approved by the scientific and ethical committee of Al-Azhar University Hospital. Informed written consent was obtained from all patients.

Patients who are claustrophobic or unable to undergo MRI examination owing to a pacemaker, critically positioned metallic foreign body, or incompatible vascular implants; patients who are intolerant to contrast administration due to the need to inject contrast in some MRI examinations (specially patients with impaired renal functions); and patients with a history of operative intervention were excluded from this study.

Patients were subjected to full clinical history and the following examinations:

- USG examination
- Dynamic ultrasound when needed
- Color Doppler and/or power Doppler study when needed
- MRI examination with or without IV contrast according to the indications

Technique

Ultrasonographic examination

USG examinations were performed using 4–10-MHz superficial linear array transducer of Voluson E6, GE Medical Systems, Germany. During examination of wrist joints, the patient was examined while sitting upright, with the hand placed on a cushion and fully pronated then supinated.

The standard USG examination of the wrist begins with evaluation of its dorsal aspect; then, we follow by the palmar aspect. According to the clinical presentation of the patient, USG images can be obtained in different positions of the wrist (flexion and extension, pronation and supination), with the patient seated in front of the examiner.

We begin with the examination of dorsal aspect by placing the transducer on a transverse plane over the dorsal aspect of the wrist to identify the extensor tendons. In general, one should first recognize a given tendon and then follow it on short-axis planes down to the distal insertion with careful examination of the following compartments:

We start the examination of the first compartment by positioning the patient's wrist halfway between pronation and supination; we place the probe over the lateral aspect of the radial styloid to examine the first compartment of the extensor tendons—abductor pollicis longus (ventral) and extensor pollicis brevis (dorsal).

With the palmar aspect of the wrist facing the examination table, shift the probe medially on transverse planes to visualize the second compartment—extensor carpi radialis longus and extensor carpi radialis brevis tendons.

We examine the third compartment by finding the Lister tubercle over the dorsal radius as a bony landmark to separate the second compartment (lateral) from the third compartment (medial). Once detected at the medial side of the Lister tubercle, the extensor pollicis longus tendon is identified and examined.

For the examination of the fourth and fifth compartments, we place the transducer on the transverse plane over the mid dorsal wrist to examine the fourth compartment (extensor digitorum communis and extensor indicis proprius) and fifth compartment (extensor digiti minimi tendon).

For the examination of the sixth compartment, namely the extensor carpi ulnaris tendon, we place the wrist in slight radial deviation. Axial and longitudinal plane images should be obtained over this tendon.

For the examination of the ventral aspect of the wrist, namely the proximal carpal tunnel, the patient keeps the dorsal wrist facing the examination table. We search for the bony landmarks of the proximal carpal tunnel—the scaphoid tubercle (radial sided) and the pisiform (ulnar sided)—placing the probe over the palmar crease on axial plane. The following contents are checked: flexor retinaculum and nine long flexor tendons.

For the examination of the distal carpal tunnel, we move the probe to a more distal transverse plane to identify the two bony landmarks of the distal carpal tunnel—the trapezium tubercle (radial sided) and the hamate hook (ulnar sided).

Magnetic resonance imaging

All patients were examined by conventional MRI. The MRI machine used was Philips Achieva MRI system (1.5 T). Using dedicated wrist coil, patients were scanned in the prone position with the arm above their head. The examination protocol included coronal, sagittal, and axial planes according to imaging sequences in Table 1.

In case of contrast injection, gadopentetate-dimeglumine (magnevist) was manually injected in cannula inserted in the contra-lateral arm just after the acquisition of the pre-contrast series at a dose of 0.2 ml/kg body weight. The average duration time of the examination was from 25 min up to 40 min in case of contrast injection.

Patients underwent ultrasonography followed by MRI conducted by two different radiologists, and both were blinded to the imaging findings of the other modality to reduce bias. Imaging findings on both modalities were then statistically correlated.

Statistical analysis

Statistical analysis between USG and MRI in different wrist injuries was compared in terms of sensitivity, specificity, PPV, NPV, accuracy, and *P* value using the chi-square test. All statistical calculations were done using the computer program SPSS (Statistical Package for the Social Science: SPSS Inc., Chicago, IL, USA) version 20.

Results

This study included 50 patients. It included 35 male patients and 15 female patients with age range from 12 to 62 years. All of the examined patients were complaining from wrist pain.

This study included 50 patients with different pathologies, tendinopathy (20 cases; 40%), TFCC tear (8 cases; 16%), simple ganglion (8 cases; 16%), solid masses (3 cases; 6%), foreign body (2 cases; 4%), and CTS (9 cases; 18%). This diagnosis confirmed by different gold standards: post-operative follow-up, histopathological studies, MRI arthrography, and nerve conduction velocity (Figs. 1, 2, and 3).

In the 50 patients, MRI detected a total of 19 (38%) tendinopathy (tenosynovitis in 9 cases, stenosing tenosynovitis (synovial thickening) in 4 cases, tendinosis in 1 case, and tendon tear in 5 cases), TFCC tear in 6 cases (12%), simple ganglion in 8 cases (16%), solid mass in 3 cases (6%), foreign body in one case (2%), and CTS in 7 cases (14%). MRI missed 6 cases (1 case of tendinosis diagnosed by USG, 2 cases of TFCC diagnosed by MR arthrography, 1 case of foreign body which was detected by USG, and 2 cases of CTS which were detected by nerve conduction velocity) (Table 2).

While USG detected a total of 19 (38%) tendinopathy (tenosynovitis in 9 cases, stenosing tenosynovitis (synovial thickening) in 4 cases, tendinosis in 1 case, and tendon tear in 5 cases), simple ganglion in 6 cases (12%), solid mass in 3 cases (6%), foreign body in 2 cases (4%), and CTS in 8 cases (16%), USG missed 12 cases (1 case of tendinosis diagnosed by MRI, 8 cases of TFCC diagnosed by MR arthrography, 2 cases cystic lesion detected by MRI, and 1 case of CTS detected by nerve conduction velocity) (Table 3).

The sensitivity, specificity, and accuracy of MRI and USG for tendinopathy were 95%, 100%, and 97.5% and 95%, 100%, and 97.5% respectively. The sensitivity, specificity, and accuracy of MRI and USG for TFCC tear were 75%, 100%, and 87.5% and 0%, 50%, and 50% respectively. The sensitivity, specificity, and accuracy of MRI and USG for simple ganglion were 100%, 100%, and 100% and 75%, 100%, and 87.5% respectively. The sensitivity, specificity, and accuracy of MRI and USG for solid mass were 100%, 100%, and 100% and 100%, 100%, and 100% respectively. The sensitivity, specificity, and accuracy of MRI and USG for foreign body were 50%, 100%, and 75% and 100%, 100%, and 100% respectively. The sensitivity, specificity, and accuracy of MRI and USG for carpal tunnel syndrome (CTS) were 77.8%, 100%, and 88.9% and 88.9%, 100%, and 94.4% respectively (Table 4).

Overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of USG Vs MRI were 79.2%, 96.1%, 95.0%, 83.3%, and 88.0% and 89.8%, 98.0%, 97.8%, 90.9%, and 94.0% respectively (Table 5).

Discussion

USG and MRI play an important role in the characterization of wrist pathologies. MRI helps in the assessment of various ligaments, tendons, and nerves. It can also aid in the visualization of bones and soft tissue lesions including marrow, cartilage, and blood vessels [7], while USG provides a reliable diagnosis regarding cystic or solid nature of lesions and can help in diagnosis based on their imaging patterns [8].

Table 1 MRI protocol parameters

MRI protocol sequences	TR (ms)	TE (ms)	FOV* (mm)	No. of slices	Slice thickness (mm)	Inter-slice gap (mm)
Axial T1	400–600	10–20	80–100	18–24	3	0.5
Axial T2	3000–4000	80–100	80–100	18–24	3	0.5
Coronal T1	400–600	10–20	80–100	18–24	3	0.5
Coronal T2	3000–4000	80–100	80–100	18–24	3	0.5
Coronal PD SPIR	3000–4000	80–100	80–100	18–24	3	0.5
Sagittal T2	3000–4000	80–100	80–100	18–24	3	0.5

*FOV** field of view

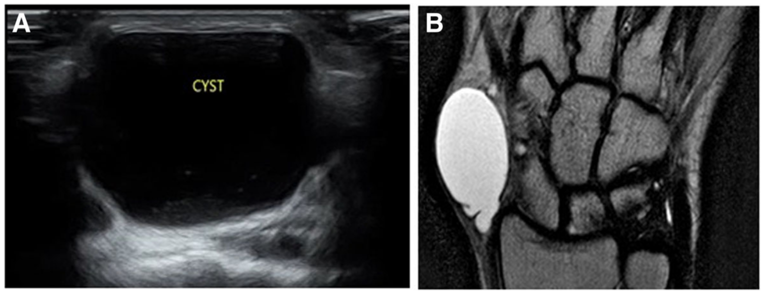

Fig. 1 Cystic lesion; simple ganglion. **a** USG of radial side of the wrist demonstrates well-defined hypoechoic lesion with clear content and posterior acoustic enhancement. **b** MRI (coronal T2 WI) of the wrist demonstrates well-defined hyperintense lesion with clear content

In our study, USG and MRI agreed in 95% of cases with tendinopathy. Both equally detected synovial thickening, fluid collection, and discontinuity of tendons. USG was better than MRI in the detection of calcification. Significant advantages of USG over MRI are the ability to home in on the area of symptoms and the ability of dynamic examination of the tendons and comparison of the finding in one side with the contra-lateral side.

Our study is in agreement with Robinson, in that USG is an efficient and accurate imaging method for the evaluation of common tendon abnormalities. And its accuracy is equivalent to that of MRI for imaging tendon abnormalities [9]. Also, Hoving et al. found USG (using a high-frequency probe, 10 MHz) equivalent to MRI in the detection of tendon sheath disease at the hand and wrist [10].

Also, Stevic and Dodic [11] concluded that USG is well suited for evaluating tendons. In most cases, its accuracy is at least equivalent to that of MRI for imaging tendon abnormalities. But the advantages of USG such as accessibility, low cost, dynamic capability, and needle guidance make it as a first-line imaging technique in tendon evaluation [11].

As regards to TFCC abnormalities, MRI in our study adequately detects its pathologies (75% sensitivity); it showed promising results with regard to the detection of TFCC tears as compared to USG where no cases were detected by it. Kaddah et al. [12] compared MRI and magnetic resonance arthrography in the evaluation of pathologies of the TFCC and other intrinsic ligaments of the wrist with regard to site and type of tear. Arthroscopy was used as the gold standard for final diagnosis. Their study showed high sensitivity and specificity of MR arthrography in ligamentous pathologies, proving its added advantage over MRI [12].

The poor sensitivity of MRI in the diagnosis of TFCC tears was attributed to the presence of the striated fascicles at the periphery of the TFCC, which were believed to be difficult to be evaluated by MR imaging [13].

In our study, USG missed all cases of TFCC that is diagnosed by MR arthrography. This point was in agreement with Singh et al.'s [14] study, where USG showed less sensitivity compared to MRI with regard to the detection of ligamentous pathologies [14]. So USG is not performed routinely in the practice due to the complex anatomy of wrist ligaments. Against our study, dynamic evaluation of wrist ligaments using USG was performed by Gitto et al. [15]; they described normal USG appearance of wrist ligaments using bony landmarks and dynamic maneuvers [15].

As regards to the evaluation of mass lesions, USG in our study detected 6 of 8 cases (75%) with simple ganglion and 3 of 3 (100%) cases with solid mass lesions. USG missed 2 cases of simple ganglion because they were too small in size with no posterior acoustic enhancement. USG is a good modality in the characterization of mass lesion as solid or cystic and assessment of lesion size, internal structure vascularity, and its relation to surrounding structures. MRI

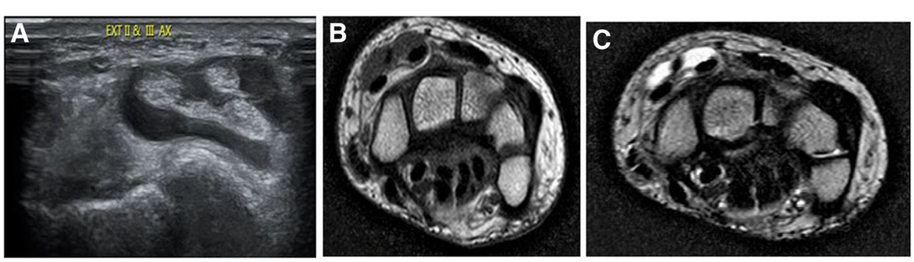

Fig. 2 Tenosynovitis. **a** USG of the dorsal aspect of the wrist demonstrates fluid collection around the second and third extensor compartments. **b**, **c** Axial T1I and axial T2WI MRI of the wrist demonstrates fluid collection around the second and third extensor compartments

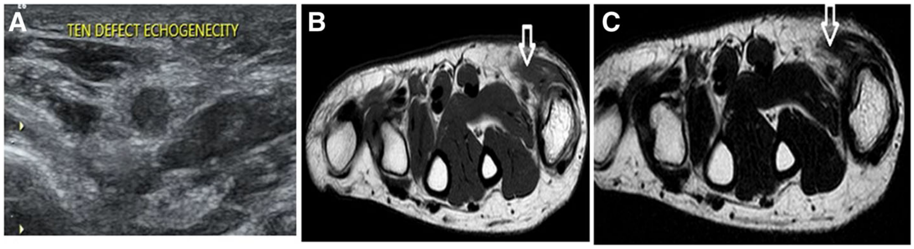

Fig. 3 Complete tendon tear. **a** USG of the dorsal aspect of the wrist demonstrates complete FPL tendon tear. **b**, **c** Axial T1I and axial T2WI MRI of the wrist demonstrates abnormal SI of FPL tendon

detected 8 of 8 (100 %) cases with simple ganglion and 3 of 3 (100 %) cases with solid mass lesions.

Our study's result is little different from Teefey et al.'s [16] results in which USG diagnosed 87% of ganglion cases and 73% of solid lesions. It may be due to larger patient sample in their study and USG is an operator-dependent technique [16].

MR imaging helps analyze the tumor matrix by identifying fatty and cystic tissue in a given lesion. MR imaging shows features of aggressiveness and signs of malignancy: poorly defined margins, invasion intovascular-nervous or osseous structures, peritumoral edema, heterogeneous signal in case of necrosis, and intense enhancement. MR imaging helps discriminate between benign and malignant lesions with a sensitivity of 93% and a specificity of 82% [17].

However, USG represents a reasonable technique to assess a mass of the wrist and hand as it helps identify the anatomical structure from which lesions originate. USG is essential to analyze the tumor matrix, by identifying if the lesion is cystic or solid. A cyst appears as a well-circumscribed walled lesion, anechoic with posterior acoustic enhancement. Finally, USG is also part of the treatment plan by guiding infiltration or biopsy procedures [18].

As regards to foreign body assessments, our study found that USG is better than MRI in the detection of foreign bodies and its depth, relations to surrounding structures and surrounding inflammatory reactions if present. USG detected 2 of 2 (100%) cases with foreign body while MRI detected 1 of the 2 (50%) cases. These results were in agreement with Turkcuer et al.'s study in that the overall sensitivity of USG in detecting radiolucent foreign body was 90% [19]. Tahmasebi et al. reported a higher accuracy and sensitivity (90.2% and 97.9% respectively) for USG in detecting radiolucent foreign bodies [17]. If high-resolution USG is available, we recommend it as the first imaging modality for evaluating the patients with clinically suspicious radiolucent foreign body because of its availability, high sensitivity, and absence of radiation. In patients with history of soft tissue foreign body and negative radiography, we recommend USG as the most important diagnostic tool before discharging patients. USG gives important information about the size, depth, and relationship of foreign bodies to other structures such as vessels and tendons and makes exploration easier for the surgeon. Furthermore, an important advantage of USG is the possibility of real-time guided removal of foreign body under sterile condition, and due to its safety and less complication rate, it may replace surgical exploration.

As regards to CTS, USG in our study detected 8 of 9 (88.9 %) cases with CTS using inlet to outlet ratio (IOR),

Table 2 Radiological abnormality in 50 patients with wrist pain by the MRI method

		Incidence	Percent
Valid	Tendinopathy	19	38.0
	TFCC tear	6	12.0
	Simple ganglion	8	16.0
	Solid mass	3	6.0
	Foreign body	1	2.0
	CTS	7	14.0
	Total	44	88.0
Missing		6	12.0
Total		50	100.0

TFCC triangular fibrocartilage complex, *CTS* carpal tunnel syndrome

Table 3 Radiological abnormality in 50 patients with wrist pain by the USG method

		Incidence	Percent
Valid	Tendinopathy	19	38.0
	TFCC tear	0	0.0
	Simple ganglion	6	12.0
	Solid mass	3	6.0
	Foreign body	2	4.0
	CTS	8	16.0
	Total	38	76.0
Missing		12	24.0
Total		50	100.0

TFCC triangular fibrocartilage complex, *CTS* carpal tunnel syndrome

Table 4 Radiological abnormality in 50 patients with wrist pain by USG method

	No	Methods	No	Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %
Tendinopathy	20	MRI	19	95	100	100	95.2	97.5
		USG	19	95	100	100	95.2	97.5
TFCC tear	8	MRI	6	75	100	100	80	87.5
		USG	0	0	100	100	50	50
Simple ganglion	8	MRI	8	100	100	100	100	100
		USG	6	75	100	100	80	87.5
Solid mass	3	MRI	3	100	100	100	100	100
		USG	3	100	100	100	100	100
Foreign body	2	MRI	1	50	100	100	66.7	75.0
		USG	2	100	100	100	100	100
CTS	9	MRI	7	77.8	100	100	81.8	88.9
		USG	8	88.9	100	100	90.0	94.4

PPV positive predictive value, *NPV* negative predictive value, *CTS* carpal tunnel syndrome

while MRI detected 7 of 9 (77.8%) of the cases. So, we believed that USG is better than MRI in the diagnosis of CTS. These findings were in agreement with Ulaşli et al.'s study in that the largest CSA of median nerve was more sensitive in USG diagnosis of CTS when the cutoff point was set at 10 mm (99% sensitivity) [20]. Also, Tengfei Fu et al., in their study, demonstrated that the IOR improves the diagnostic accuracy of ultrasound for the diagnosis of CTS. Optimal diagnostic cutoff value was 1.3, resulting in a specificity of 93% and a sensitivity of 91% [21].

In our study, we had found that the sensitivity, specificity, and accuracy of MRI assessment of wrist pain were 98.8%, 98.0%, and 94.0 % respectively versus the sensitivity, specificity, and accuracy of USG assessment of wrist pain 79.2%, 96.1%, and 88.0% respectively. In agreement with our results, Kaddah et al. [12] found the overall sensitivity, specificity, and accuracy of MRI in diagnosis of wrist pain were 84.21%, 100%, and 88.15% respectively [12]. Also, Singh et al.'s study showed high sensitivity of USG as well as MRI in wrist pathologies with the added advantage of MRI over USG in wrist abnormalities and ligamentous pathologies [14].

Table 5 Overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of USG Vs MRI in evaluation of all cases

	USG (%)	MRI (%)
Sensitivity	79.2	89.8
Specificity	96.1	98.0
PPV (%)	95.0	97.8
NPV (%)	83.33	90.9
Accuracy	88.0	94.0

PPV positive predictive value, *NPV* negative predictive value

USG is near equal to MRI in the assessment of tendon abnormalities and better than MRI in the diagnosis of CTS and foreign body, but MRI is better than USG in the assessment of swelling (cystic and solid) and characterization of masses.

Conclusion

Although ultrasound is operator dependent and the accuracy of its result depends on the experience of the operator, USG technology offers several inherent advantages; being noninvasive, fast, less expensive, and without radiation makes it well accepted by patients. It should be the first choice of investigation for the majority of the cystic, tendinous, vascular, and fibrotic pathologies of the wrist. However, less promising results were observed for ligamentous pathologies on USG in our study.

Abbreviations

CT: Computed tomography; CTS: Carpal tunnel syndrome; FOV: Field of view; MRI: Magnetic resonance imaging; TFCC: Triangular fibrocartilage complex; UGG: Ultrasonography; Vs: Versus

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Not applicable.

Authors' contributions

AM suggested the idea of the work, was responsible for blindly interpretate & reporting MRI cases, design the work, analyze and asses the data, and revised and edited the work. EM discussed the idea of the work, planning the work, was responsible for blindly examine and reporting musculoskeletal ultrasound cases, design the work, analyze & interpretate the data, and revised and edited the work. AA contributed to the acquisition of the data and saving the data and drafted the work. All authors have read and approved the manuscript.

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Availability of data and materials

All data and material included in our study are available. The data sets used and analyzed during the current study are available from the author named Ahmed Awad Mohammed on reasonable request.

Ethics approval and consent to participate
Informed consent obtained from study participants was written and assigned by participants or their first-degree relatives.

Consent for publication
All authors have agreed to the submission to the journal.

Competing interests
The authors declare that they have no competing interests.

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