The Value of Ultrasonography in Hand Surgery

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Abstract The quality of ultrasound imaging to examine anatomical structures in the wrist and hand has improved highly over the last years. The value of ultrasonography (US) performed by hand surgeons on treatment decisions was investigated in this study. One hundred and ninety-five patients with an unclear clinical hand problem were evaluated by high-definition ultrasonography from January 2005 until June 2007. In 21% of cases, the procedure and therapy were influenced by the ultrasonographic findings. In 26 patients examined by ultrasound, surgery was avoided, while 14 patients had unexpected ultrasound results that led to surgery. In 22 of the 84 performed operations, ultrasound had a direct impact on the surgical procedure itself. The agreement of the ultrasonographic diagnosis and the post-operative diagnosis ($n=80$) was better, though not statistically significant compared to the agreement between clinical diagnosis and diagnosis after operation ($n=84$). Ultrasound imaging performed by the hand surgeon improves quality in the evaluation of hand problems. Ultrasonography is a cost-effective high-

resolution investigation with the possibility of dynamic imaging.

Keywords Ultrasound · Hand surgery · Hand

Introduction

The quality of ultrasonographic assessment of anatomical structures in the hand has highly improved over the last time. The introduction of real-time B-mode imaging, digital processing, and high frequency transducers improved detailed visualization of superficial structures (2, 20). Recent papers on normal anatomy and of pathological changes of the hand and wrist give a comprehensive overview about the diagnostic possibilities (4–7). Several publications describe the use of ultrasonographic imaging of the hand in posttraumatic and sports-related injuries (13, 15, 19). Well described are tears of the collateral ligaments of the thumb with the typical Stener lesion (9, 14), tendon ruptures, annular pulley lesions in “climber’s finger” (17), and the detection of foreign bodies in the soft tissue (11). Sonographic evaluations in rheumatic diseases detect tenosynovitis, synovitis of the wrist and finger joints, and nerve compressions (23). The ultrasonographic measurement of the median nerve in carpal tunnel syndrome diagnostics is of interest to further investigations (1). Kijowski and De Smet (16) described comparable accuracy between MRI and ultrasound in specific cases of sport medicine injuries of the upper extremity. Because of these developments, ultrasound offers to the hand surgeon performing ultrasonographic examinations as additional information to the history and clinical examination. Is ultrasonography justified becoming a routine diagnostic tool? Does it improve the quality of treating hand

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problems? Does ultrasonography affect procedure and therapy?

By a retrospective study, we aimed at analyzing the agreement between clinical diagnosis, ultrasonographic assessment and operative findings to give an answer to the preceding questions.

Patients and Methods

The study included 195 patients, which were evaluated by ultrasonography in our hand surgical outpatient clinic between January 2005 and June 2007 (94 males, 101 females, median age 44, range 6–81 years). A history and physical examination were performed by seven different examiners. An uncertain diagnosis led to further evaluation by ultrasonography, which was performed by two hand surgeons trained in ultrasonography (Furrer M, Schweizer A). The equipment consisted of a commercial high-definition digital ultrasound instrument (Philips EnVisor HD) and two different linear scanning probes, a universal 12–3 MHz (contact area 1.0 cm×4.0 cm) and a small-part high-frequency 15–6 MHz (contact area 1.0 cm×3.3 cm) transducer. Real-time scanning was performed in longitudinal and transversal planes and, if necessary, in other planes to get more information. In case of unclear findings, the contra-lateral side was examined for comparison.

We used Cohen's κ statistic to measure the agreement between the clinical, ultrasound, and operative diagnoses. To determine whether there was better agreement between the clinical and operative diagnosis than between the ultrasonographic and operative diagnosis, we compute κ s comparing these diagnoses, including asymptotic confidence intervals (10).

As a matter of fact, we need to constrain ourselves to patients with clinical and postoperative diagnoses. Only patients who were operated have the diagnostic gold standard to compare with the US diagnosis. We compute κ s for the detailed diagnosis with all categories and for the six most-frequent clinical pathologies with a relative frequency of more than 5% (pooled diagnosis). In addition, the proportion of diagnoses that were influenced by performing an ultrasound assessment was estimated and complemented by a confidence interval for this proportion, where the confidence interval was computed according to Wilson's method.

In this exploratory analysis, no correction for multiple testing was performed. All tests and confidence intervals were computed using $\alpha=0.05$.

The procedure, therapy and operation as a result of ultrasonographic assessment are illustrated with three clinical cases.

Results

One hundred and ninety-five patients with an unclear clinical diagnosis were assessed by ultrasound imaging. The most frequent indications included suspected ganglion cysts, other soft tissue masses, tears of tendons and ligaments, posttraumatic adhesions, and trigger finger (pooled diagnosis, Tables 1 and 2).

In the 84 (43%) of the 195 patients that had surgery, the preoperative findings could be compared with the final diagnosis. One has to notice that despite normal ultrasonographic findings in four cases, an operation was carried out so that the number of comparisons between clinical—OP and US—OP diagnosis differs. Nevertheless, Cohen's κ statistic (Table 2) shows better agreement between US and OP diagnosis than between clinical and OP diagnosis generally and, furthermore, in patients with pooled diagnosis. Since confidence intervals are overlapping, agreements are not significantly different. According to Kirkwood and Sterne (3), $\kappa>0.75$ can be considered excellent agreement, those between 0.4 and 0.75 as far to good agreement.

In 40 (21%) of all cases, procedures and therapies were influenced by the ultrasonographic findings. The corresponding 95%-Wilson confidence interval is [0.15, 0.27].

Fourteen (35%) of these 40 patients were operated on and 26 patients (65%) had no operation as a result of the ultrasound imaging.

In 22 (26%) of the 84 performed operations, the ultrasonographic findings had consequences on surgical intervention. In seven cases, regional anesthesia was changed to local anesthesia, in five patients, regional anesthesia was applied instead of local anesthesia. The surgical approach was adapted (localization and extension) in six cases. Application of adequate technique was influenced four times.

In 19 patients (10%) the ultrasound evaluation did not show any pathological findings.

Clinical Examples

Patient 1

A 47-year-old patient presented with a recurrent swelling at the palmar aspect of his right wrist. Sensibility and motor function of the hand were normal. Seven months beforehand, a ganglion cyst had been removed from the same area. The patient was then referred for excision of a "recurrent" tumor. The ultrasonographic assessment demonstrated a hypoechoic solid soft tissue mass of size 1.8×1.2×1.8 cm adjacent to the median nerve (Fig. 1). This finding was suspicious for a neurogenic tumor. Thus, the operation was planned with optional technical features like microscope and intraoperative neurography. The tumor that was totally resected without any complications was diagnosed histologically as schwannoma.

Table 1 Synopsis: clinical diagnosis—ultrasound diagnosis—operative diagnosis of all patients ($n=195$).

	Clinical diagnosis		Ultrasound diagnosis		Operative diagnosis	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Ganglion cyst	42	21.5	26	13.3	10	5.1
Tendon adhaesion	25	12.8	24	12.3	11	5.6
Soft tissue mass	22	11.3	17	8.7	7	3.6
Tendon/muscle tear	19	9.7	13	6.7	7	3.6
Ligament tear/laxity	19	9.7	10	5.1	7	3.6
Trigger finger	17	8.7	11	5.1	7	3.6
Carpal tunnel syndrome	9	4.6	4	2.0	5	2.6
Pulley tear	8	4.1	5	2.6	1	0.5
Joint synovitis	6	3.1	7	3.6	3	1.5
Foreign body	6	3.1	3	1.5	4	2.0
Extensor tenosynovitis	5	2.6	6	3.1	7	3.6
Nerve lesion, compression	5	2.6	3	1.5	3	1.5
Flexor tenosynovitis	4	2.0	4	2.0	0	0
Tendon subluxation/luxation	4	2.0	3	1.5	1	0.5
Infectious tenosynovitis	1	0.5	0	0	0	0
Vessel injury	1	0.5	1	0.5	1	0.5
Soft tissue scar	1	0.5	6	3.1	0	0
Irritating osteosynth material	1	0.5	1	0.5	1	0.5
Calcification	0	0	3	1.5	1	0.5
Ultrasound without operation	0	0	40	20.5	—	—
No operation	—	—	—	—	111	56.9
Operation without pathology	—	—	—	—	2	1.0

We provide absolute (*n*) and relative (%) frequency. Values rendered in italics indicate pooled diagnosis

Patient 2

A 26-year-old physical therapist complained about a growing, painful soft tissue swelling with intermittent diffuse hypersensitivity over the medial side of her right upper arm. Clinically, we found a subcutaneous tight 1.5×1.5 cm tumor over the medial aspect of the neurovascular structures. There was no loss of motor function and sensibility in the median and ulnar nerve. Ultrasonographic evaluation could exclude involvement of important nerve structures (Fig. 2). Thus, resection of the tumor was performed in a local anesthesia with the final diagnosis of a lipoma.

Patient 3

After raising a heavy cap 6 weeks beforehand, a 53-year-old electrical engineer suffered from persistent pain in the middle finger of his non-dominant left hand. Clinical

examination showed a painful, limited grip with a bow stringing of the flexor tendon by the A2 pulley. Ultrasound confirmed an increased distance under flexion load between the basic phalanx (P) and the flexor tendon (T; PT-distance, normal value <1 mm) of 3.2 mm (Fig. 3). Thus, the complete tear of the A2 pulley (>3 mm) could be distinguished from an incomplete $PT > 2$ mm (8, 18) and the indication for surgery was clear. Three months after A2 pulley reconstruction, the clinical and ultrasonographic bow stringing was reduced ($PT = 1.4$ mm), pain disappeared and the strength of active finger flexion was symmetrical to the opposite middle finger.

Discussion

Ultrasound technology has been rapidly advancing over the past few years. The development of high-resolution trans-

Table 2 Agreement clinical (CI)—ultrasound (US) and operative (OP) diagnosis.

Comparison	Type of diagnosis	No. of categories	<i>n</i>	κ	95% Confidence interval
CI—OP	Detailed diagnosis	19	82	0.73	[0.63, 0.83]
US—OP	Detailed diagnosis	19	79	0.89	[0.82, 0.96]
CI—OP	Pooled diagnosis	6	48	0.85	[0.74, 0.96]
US—OP	Pooled diagnosis	6	47	0.95	[0.88, 1]

Pooled diagnosis, see Table 1

Figure 1 Transverse 15–6 MHz US image of a hypoechoic solid tumor mass palmar to the distal radius (*asterisk*) well defined by a thin capsule (*white arrowhead*) with its origin from the median nerve (*white arrow*). Adjacent to the tumor the ulnar artery (*open arrow*), the ulnar nerve (*open arrowhead*) and the flexor carpi radialis tendon (*fcr*).

ducers has increased the potential for of ultrasound to evaluate superficial anatomical structures of the musculo-skeletal system. This has allowed the hand surgeon to include ultrasonography in his routine diagnostic program as a useful extension of the physical examination. By performing the examination himself, he benefits from his anatomical and functional knowledge. In addition, he has the possibility to verify the ultrasonographic findings in comparison with the operative diagnosis in terms of a quality control. In our opinion, the efficient availability,

Figure 2 Transverse 12–3 MHz US image 8 cm proximal over the medial upper arm. Hyperechoic homogeneous well-marginated solid tumor mass (*asterisk*) surrounded by a thin capsule (*white arrowheads*). The ulnar nerve (*open arrowheads*) shows no relation to the tumor.

Figure 3 Longitudinal 15–6 MHz US image over the proximal phalanx of the left middle finger. Distance between phalanx and tendon (*PT*), bow stringing of the flexor digitorum profundus tendon (*fdp*).

shorter examination time, lower cost, and the possibility of a dynamic real-time assessment of the corresponding structures are the major advantages of this method. Kijowski and De Smet (16) compared MRI and ultrasound imaging in the evaluation of sport medicine injuries of the upper extremity. Their study confirmed that ultrasound imaging has an accuracy comparable to MRI for the assessment of some specific injuries, mainly tears of ligaments and tendons. Further prospective studies where intraoperative findings are compared with the ultrasonographic diagnosis have to prove the quality of ultrasonographic-based diagnosis.

The assessment of ultrasound imaging in hand problems has been mainly described and published by radiologists and rheumatologists rather than by hand surgeons. Studies that have analyzed the agreement between clinical, ultrasonographic, and operative findings have, to our knowledge, not been described in the literature. The results of our study showed better agreement between ultrasonographic and operative diagnosis compared to the clinical and operative findings, although not statistically significant.

The value of ultrasound became obvious by the fact that in 21% of cases, the examination showed an influence on procedure and therapy concerning the need to do an operation or not. Unnecessary surgical interventions for exploration in case of unclear clinical findings could also be avoided. Operative procedures were directly affected in 26% in terms of adequate choice of anesthesia, surgical approach and operative technique. The ultrasonographically detected dimension of tendon adhesion or tumor mass may affect the location and length of the surgical approach. A simple division of an A1 pulley can be done with local anesthesia; in cases where an additional widespread tenosynovitis and tendon adhesion is apparent, a regional anesthesia might be preferred.

The fact that no ultrasonographic diagnosis was possible in 10% of cases could be referred to incorrect clinical indications, inexperience of the sonographers, or limits of the technique. Nevertheless, the accomplishment of ultrasound scans by the hand surgeons with a preconceived idea might influence the results. Sensitivity and specificity of ultrasound imaging could not be evaluated, since absence of a specific diagnosis is not verified with a probable unnecessary operation. With the exclusion of those patients without one of our selected diagnosis, we introduce a preselection which rules out the determination sensitivity and specificity. This fact has been taken for granted because of the specificity of ultrasound imaging for some special hand problems.

The fast, uncomplicated and non-invasive application of the ultrasound is much appreciated by the patients. The mobile application in case of emergency as well as the examination shortly before an operation or during an operation is possible. The costs for acquiring the equipment and also for the single examination are much less than MRI (in our clinic, MRI for hand is 3.75 times more expensive than ultrasonographic imaging). If necessary, the equipment can be shared with other departments (rheumatology, angiology), which supports the cost-effective use in nowadays medical practice.

Ultrasound imaging may improve quality in the treatment of specific hand problems launching a clear clinical diagnosis. It allows a focused and differentiated evaluation of specific pathologies providing high-resolution imaging of superficial structures comparable to MRI. An important advantage over the MRI consists in detecting pathological dynamic processes during provocative maneuvers like subluxation of tendons and nerves, joint instabilities, or tendon adhesions with the possibility adding bilateral comparisons. Furthermore, power Doppler imaging may show synovial vasculature and may give information about vessel flow and patency. Positive influence on procedure, therapy, and operation are the consequences. Therefore, ultrasonographic assessment of the upper extremity has its significance to become part of routine diagnostic in hand surgery. Tagliafico et al. (22) even consider ultrasound as the first-line imaging for the assessment of a wide range of pathology of the soft tissue of the wrist and hand provided that adequate equipment and training can be assured.

Furthermore, ultrasonographic-guided interventions like steroid injections and synovial biopsy in patients with tenosynovitis and arthritis (23), injections of steroid in trigger digits (12), and nerve blockade in regional anesthesia (21), may allow a more precise and safer approach improving quality of treatment.

The hand surgeon may consider adding ultrasonography to his diagnostic and imaging tools. Patient's history and clinical findings, as much as anatomical and functional knowledge combined with knowing the ultrasound tech-

nique, are important guidelines to use the ultrasound imaging appropriately. The possibility to verify the ultrasound results with the intraoperative findings will always be important in view of self control and learning curve in exploring many types of hand-specific problems. Since 2006, in Switzerland there is a 3-year training for hand ultrasonography which requires 400 supervised investigations. This training was founded by hand surgeons in collaboration with the Swiss Society of Ultrasonography in Medicine.

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