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Contribution of static and dynamic ultrasound in cubital tunnel syndrome☆

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ABSTRACT

Introduction: Electroneuromyography (ENMG) is the gold standard examination in cubital tunnel syndrome (CuTS), but sheds no light on etiology. High-resolution ultrasound (HRU) analyzes the anatomic abnormalities and physical properties of the ulnar nerve (UN) and enables dynamic study. The present non-randomized prospective study compared HRU with clinical, ENMG and intraoperative findings.
Material and methods: Sixty patients were included. The McGowan clinical classification as modified by Goldberg was employed, and ENMG lesions were ranked for severity. HRU screened for morphologic abnormalities of the ulnar nerve and cubital tunnel, measuring UN cross-sectional area (UNCSA) and flattening index (FI) in the cubital tunnel, in extension and flexion. UN stability was assessed.
Results: Ultrasound found 2 stenoses, 29 pseudoneuromas 25 dedifferentiations. There were 16 morphologic abnormalities. Mean cubital tunnel UNCSA (in cm^2) and FI were respectively 0.112 and 1.549 in extension and 0.117 and 1.827 in flexion. Nineteen cases of UN instability were found on HRU, versus 17 intraoperatively. Only 8 patients showed no abnormality on HRU. Pseudoneuroma or dedifferentiation on HRU correlated with clinical stage ($P = 0.2579$ and 0.2615, respectively). Dedifferentiation was associated with severe abnormality on ENMG ($P < 0.5$). Thirty-two stenoses, 18 pseudoneuromas and 10 *epitrochlearis anconeus* muscles were found intraoperatively, matching HRU abnormalities.
Discussion: The present findings were comparable to those of the literature. Cubital tunnel UNCSA was elevated in case of CuTS, with cut-off at 0.112 cm^2. FI was elevated in flexion ($P = 0.0063$). The rate of UN instability was 32%, compared to 21–60% in the literature. HRU findings matched the clinical and ENMG classifications. HRU proved to be an effective diagnostic tool for CuTS and its etiologies.
Level of evidence: IV.

1. Introduction

Ulnar nerve (UN) entrapment at the elbow is the second most frequent tunnel syndrome, following carpal tunnel syndrome.

CuTS can be difficult to diagnose, especially when associated with crossed thoracobrachial syndrome, and requires complementary examinations for confirmation. The gold standard here is electroneuromyography (ENMG) [1–5], which, however, is an unpleasant procedure for the patient, lasting 20 minutes on average, with waiting lists of several weeks (mean = 3 weeks); it is moreover operator-dependent and may require iterative performance. As well as establishing diagnosis, it contributes to prognosis in CuTS, specifying myelin sheath and axon involvement; it also detects associated neuropathy, but sheds no light on possible etiology.

In 2010, however, Filippou et al. [6] reported that 59.3% of cases of CuTS had identifiable causes, the most frequent of which was UN instability: subluxation and dislocation accounted for 28.6% of the total sample, at respectively 18.7% and 9.9%.

In the last 15 years, there has been considerable progress in high-resolution ultrasound (HRU) examination of peripheral nerves [1–5,7–18]. It can, for example, analyze underlying abnormalities, and also study UN physical properties. Only HRU allows dynamic study, and idiopathic CuTS is above all related to movement. HRU is non-invasive, lasting on average 15 to 20 minutes when performed by an experienced operator (10 to 30 min, depending on the radiologist's experience), and is painless. It

☆ Round Table on "Ulnar nerve disorders".

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Table 1
Descriptive statistics of the 60 ulnar nerves.

		Elbow in extension				Elbow in flexion	
	Age (years)	Proximal UNCSA[a]	Cubital tunnel UNCSA[a]	Distal UNCSA[a]	FI	Cubital tunnel UNCSA[a]	FI
Mean	52.65	0.075	0.112	0.070	1.549	0.117	1.827
Range	26–80	0.04–0.17	0.01–0.23	0.03–0.18	0.488–2.762	0.04-0.5	0.489–4.48
Standard deviation	13.20	0.027	0.054	0.024	0.532	0.068	0.845

UNCSA: ulnar nerve cross-sectional area; FI: flattening index.
[a] cm^2.

is, however, operator-dependent, especially as regards measurements.

The present study compared HRU results with clinical, ENMG and intraoperative findings and the literature.

2. Material and methods

2.1. Material

A non-randomized prospective study was performed in parallel in two French centers (Tours and Angers), with a single design. Being an observational study, it required no ethics committee approval or informed consent procedure.

Between March 1st, 2012 and April 30th, 2013, all cases of clinical CuTS were included. Preoperative ulnar nerve HRU at the elbow and ENMG were performed. Exclusion criteria were: lack of 1 of these examinations or abstention from surgery.

Sixty consecutive patients met the inclusion criteria (29 in Tours and 31 in Angers): 31 male, 29 female; mean age: 52.65 years (range, 26–80 years); 29 right and 31 left elbows.

Symptom severity was classified preoperatively following McGowan as modified by Goldberg [19].

ENMG criteria detected and classified abnormalities according to severity.

HRU with a 16 MHz probe was performed by specialized radiologists: 4 using a Toshiba™ ultrasound scanner in Angers and 2 a Siemens™ scanner in Tours.

2.2. Methods

When UN entrapment at the elbow was suspected and classified on the McGowan system, patients underwent ENMG and dynamic UN HRU, performed in random order.

For HRU, the patient was positioned seated, with the forearm in complete supination on a table or with the arm hanging down, to provide access to the cubital tunnel [1,3,4,7–12]. Examination was in 3 steps: elbow in extension; UN stability study; and elbow in flexion.

In extension, apparent UN caliber and structure were analyzed and any abnormality noted. UN cross-sectional area (UNCSA: cm^2), excluding the epineurium (to avoid measurement bias from incipient peripheral infiltration), was measured in the cubital tunnel facing the medial condyle, then 2 cm proximally in the upper arm and 2 cm distally not far from the fibrous arcade of the ulnar flexor muscle of the carpus (Osborne ligament or arcade) [1–4,7–9,12]. The transverse and anteroposterior diameters were measured in the cubital tunnel to calculate the flattening index (FI), defined by the "transverse: anteroposterior diameter" ratio [13,14].

UN stability at the elbow was assessed on active mobilization and classified in 3 types according to Okamoto et al. [8]: stable, if nerve movement was contained within the groove; subluxing if the UN reached the summit of the medial epicondyle; or dislocating if the UN moved forward of the medial epicondyle.

With the elbow in flexion, FI and UNCSA in the cubital tunnel were again measured, as were cubital tunnel depth and the distance between the triceps and the bony edge of the medial epicondyle, to assess possible cubital tunnel filling by the muscle (Fig. 1).

Finally, systematic ultrasound examination of the 1st dorsal interosseous muscle screened for amyotrophy.

The surgical report detailed UN stability, stenosis, pseudoneuroma, projecting triceps, supernumerary *epitrochlearis anconeus* muscle or other abnormality. Preoperative HRU findings were assessed by comparison with abnormalities found intraoperatively.

Statistical analysis was performed by a statistician. The tests used depended on the parameter under study, and will be detailed in the Results section.

3. Results

3.1. Descriptive statistics

Sixty UNs were studied in 60 patients. Mean age was 52.65 years (range, 26–80 years), with a significant difference between centers: 57.28 years in Tours versus 48.32 years in Angers ($P = 0.0081$; Mann-Whitney U test) (Table 1). On the McGowan-Goldberg classification, there were 12 cases of stage 1 (20%), 21 of stage 2a (35%), 18 of stage 2b (30%) and 9 of stage 3 (15%). Only 5 ENMGs (8.33%, all in Angers) found no abnormality; 21 showed moderate (35%) and 34 severe abnormality (56.67%).

HRU found 2 stenoses (3.33%), 29 pseudoneuromas (48.33%), 25 dedifferentiations (edematous infiltration inducing loss of fasciculated structure, with homogeneous hypoechogenic aspect [13]) (41.67%) (Fig. 2) and 6 peripheral infiltrations (explored for in only 44 of the patients: thus, 13.64%). Forty-four patients (73.33%) showed no abnormality of the cubital tunnel on HRU. Six had an *epitrochlearis anconeus* muscle (10%); 6 others had osteophytes (10%); 2 had associated osteophytosis and synovial pathology (3.33%); and 2 had associated osteophytes and cyst (3.33%).

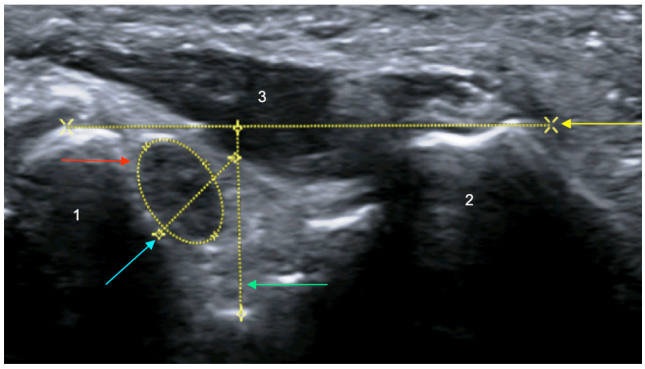

Fig. 1. High-resolution ultrasonography of the elbow in 90° flexion. 1: medial epicondyle; 2: humero-ulnar joint; 3: triceps; red arrow: ulnar nerve; blue arrow: distance between triceps and medial epicondyle bone; green arrow: depth of the cubital tunnel.

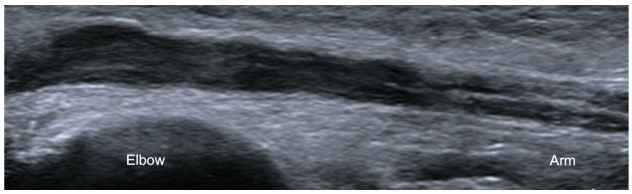

Fig. 2. Ulnar nerve dedifferentiation: edematous infiltration inducing loss of the fascicular structure of the nerve, with homogeneous hypoechogenic aspect.

Measurement in extension found a mean UNCSA of 0.075 cm^2 proximally, 0.112 cm^2 in the cubital tunnel and 0.070 cm^2 distally; mean FI was thus 1.549. There were 11 UN subluxations and 8 dislocations: i.e., 31.66% UN instability. In flexion, mean cubital tunnel UNCSA was 0.117 cm^2, FI 1.827 (Table 1), cubital tunnel depth 8.102 mm and triceps-bone distance (in 26 of the Tours patients) 4.985 mm. There were 11 first dorsal interosseous amyotrophies (25%: 13 in Tours and 2 in Angers).

Intraoperatively, 17 UNs (28.33%) were unstable. Thirty-two (53.33%) showed stenosis (Fig. 3) (23 in Tours and 9 in Angers). There were 18 pseudoneuromas (Fig. 3) (30%: 15 in Angers and 3 in Tours). The cubital tunnel was filled by the triceps in 12 of the 29 cases in Tours in which it was explored (thus 41.38%) (Fig. 3). Ten patients had *epitrochlearis anconeus* (16.67%). There were a few other abnormalities: 1 case of UN remodeling, 1 chondromatosis, cicatricial fibrous tissue, and 1 poorly contoured cubital tunnel.

3.2. Statistical analysis

UNCSA was compared on Spearman correlation tests and analysis of variance (ANOVA). In extension, cubital tunnel UNCSAs showed positive but low-intensity (I) correlation: proximally, $P = 0.0302$ and I = 4.2%; distally, $P = 0.0202$ and I = 11.2%. Cubital tunnel UNCSA in extension and in flexion showed a highly significant positive correlation ($P < 0.0001$), of considerable intensity: 22.8% of the value of one parameter was statistically dependent on the other. Elbow flexion significantly increased FI, from 1.549 to 1.827 ($P = 0.0063$; Wilcoxon signed-ranks test).

Instability showed no correlation with cubital tunnel depth ($P = 0.2863$, with no difference in distribution between groups on Mann-Whitney U test). As triceps-bone distance was measured in only 29 patients in Tours, the Mann-Whitney U test ($P = 0.2721$) was inconclusive.

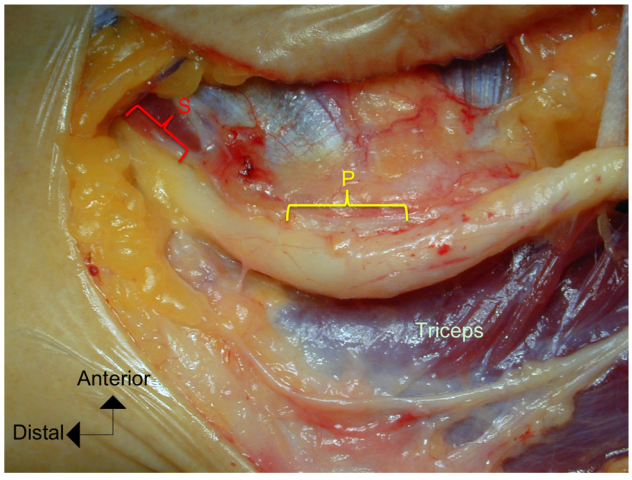

Fig. 3. Intraoperative view of right ulnar nerve. S: stenosis; P: pseudoneuroma; Triceps: distal part of triceps muscle pushing the ulnar nerve forward.

With only 2 cases, stenosis on HRU could not be analyzed statistically. For pseudoneuroma, HRU (29 cases) and intraoperative findings (18 cases) did not differ ($P = 0.8657$; Chi^2); likewise, the difference between the number of pseudoneuromas on HRU ($n = 29$) and the number of intraoperative stenoses ($n = 32$) was non-significant ($P = 0.8090$; Chi^2).

There was no significant difference between the number of dedifferentiations on HRU (25 cases) and the number of intraoperative stenoses ($n = 32$) or pseudoneuromas (18 cases) ($P = 0.3817$ and 0.3914, respectively).

There was no significant difference in UN instability between HRU (19 cases) and intraoperative observation (17 cases) ($P = 0.6083$; Chi^2), or between intraoperative projecting triceps and triceps-bone distance ($P = 0.0734$).

The incidence of pseudoneuroma and dedifferentiation on HRU did not differ from preoperative McGowan stage ($P = 0.2579$ and 0.2615, respectively; Chi^2). Only dedifferentiation could be compared with ENMG stage on Chi^2 test ($P = 0.4765$), numbers being too small in the cases of the other variables.

4. Discussion

In CuTS, high-resolution ultrasonography of the UN at the elbow has not previously been a focus of study in France. Data from the present two hand surgery centers, one in the public sector (Tours) and the other private (Angers), show that, in extension, UNCSA in the cubital tunnel was significantly elevated in case of CuTS; the present mean value of 0.1112 cm^2 was in agreement with that of the literature (0.158 cm^2) [1–3,7,12,17], for which the cut-off threshold is 0.092 cm^2 [1,3,7,12,15]. Moreover, dedifferentiation, which is a sign of neural suffering, was observed in case of severe abnormality on ENMG – a finding not previously reported.

UN entrapment in flexion induced a significantly elevated FI, by reducing anteroposterior diameter and increasing transverse diameter – an item previously taken into account in carpal but not CuTS [13,14]; a controlled comparative study could determine sensitivity and specificity.

Certain criteria could not be assessed here for lack of power: e.g., UN instability according to cubital tunnel depth or to filling by the triceps.

Ultrasonography, in which certain hand and upper limb surgeons are presently training, proved to be an effective diagnostic tool to detect CuTS and its etiologies; it showed good correspondence to the clinical and ENMG classifications. The present series and the literature demonstrate that certain ultrasound criteria (cubital tunnel UNCSA in extension, dedifferentiation) can already be implemented; others (FI, cubital tunnel depth, tricipital filling) will require studies with greater statistical power.

Thus, in case of isolated clinical CuTS, HRU, whether preformed directly in consultation or not, may replace ENMG.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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