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# Electrophysiological examination and high frequency ultrasonography for diagnosis of radial nerve torsion and compression

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**Abstract**

This study aims to evaluate the value of electrophysiological examination and high frequency ultrasonography in the differential diagnosis of radial nerve torsion and radial nerve compression.

Patients with radial nerve torsion (n = 14) and radial nerve compression (n = 14) were enrolled. The results of neurophysiological and high frequency ultrasonography were compared.

Electrophysiological examination and high-frequency ultrasonography had a high diagnostic rate for both diseases with consistent results. Of the 28 patients, 23 were positive for electrophysiological examination, showing decreased amplitude and decreased conduction velocity of radial nerve; however, electrophysiological examination cannot distinguish torsion from compression. A total of 27 cases showed positive in ultrasound examinations among all 28 cases. On ultrasound images, the nerve was thinned at torsion site whereas thickened at the distal ends of torsion. The diameter and cross-sectional area of torsion or compression determined the nerve damage, and ultrasound could locate the nerve injury site and measure the length of the nerve.

Electrophysiological examination and high-frequency ultrasonography can diagnose radial neuropathy, with electrophysiological examination reflecting the neurological function, and high-frequency ultrasound differentiating nerve torsion from compression.

**Abbreviations:** AMP = amplitude, CSA = cross-sectional area, EMG = electromyography, MUP = motor unit potential, NCV = nerve conduction velocity.

**Keywords:** electrophysiology, high frequency ultrasound, radial nerve compression, radial nerve torsion

## 1. Introduction

Nontraumatic radial nerve torsion is rare in clinical practice; therefore, it is less reported.[1,2] Nerve torsion may show special characteristics and pathological features, with acute onset and no history of trauma. Short-term radial nerve torsion can lead to nerve paralysis and early clinical intervention can restore nerve function. However, long-term torsion may lead to irreversible damage.[3] Therefore, accurate and timely diagnosis is of high importance. Radial nerve compression refers to the sensory or motor dysfunction because of compressed radial nerve, or specifically the radial nerve compressed by small anatomical duct or thickened tendon tissue, expressing as pain or muscle paralysis.[4] Early release of the pressure can be essential on the patient's prognosis, therefore early diagnosis is also important.[5]

Clinical diagnosis of radial neuropathy often relies on clinical manifestations, physical examinations, and electrophysiological examinations.[6] The electrophysiological examination can only show the nerve function, but not the nerve injury, location, range, and morphological characteristics.[7] Therefore, electrophysiological examination alone cannot differentiate torsion from compression. Radial nerve torsion and radial nerve compression have similar electrophysiological examination results. However, their treatment methods are different.[8] For nontraumatic radial nerve torsion, active surgical treatment is highly recommended.[9–11] If the torsion is large, nerve graft should be carried out.[12] For patients with nerve compression, nonsurgical treatment is recommended, including limiting local movement and injecting corticosteroids to reduce the inflammatory responses and relieve symptoms.[13] However, surgical treatment is commonly used. Thus, differential diagnosis between nerve torsion and compression is particularly necessary.

High-frequency ultrasound can distinguish normal nerve tissue from the surrounding muscles, tendons, fascia, and vascular tissues.[14,15] It can also clearly show the morphology, diameter and internal echo of peripheral nerve, and its anatomy relationship with the surrounding tissue,[16] and accurately predict the location and extent of neuropathy.[17] It is widely used in the evaluation of peripheral nerve lesions.[18]

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In the study, we used high frequency ultrasound to make the differential diagnosis between radial nerve torsion and compression.

## 2. Materials and methods

### 2.1. Patients

A total of 28 patients with radial neuropathy diagnosed at our hospital from November 2009 to May 2016 were consecutively selected as subjects. These 28 patients included 10 females and 18 males, aging from 18 to 42 years. All patients had unilateral involvement. The 14 patients with nerve torsion had no history of trauma, and 10 patients were heavy manual workers and manual workers. Among the 14 patients with nerve compression, 6 patients had history of injury, 5 patients had long-term compression of the upper limb, and 3 patients had no clear history of trauma. The patients had varying degrees of symptoms involving upper limb and wrist, including dysfunction of wrist and stretching thumb, muscle weakness, and sensory dysfunction. All patients underwent electrophysiological examination and high frequency ultrasonography, followed by surgical treatment and pathological examination. Surgical methods include upper arm radial nerve exploration and surgical repair. Prior written and informed consent were obtained from every patient and the study was approved by the ethics review board of Shandong Provincial Health Department.

### 2.2. Electrophysiological examinations

Electrophysiological examination was performed with MEB-9404 (Nihon Kohden, Tokyo, Japan). The nerve conduction velocity (NCV) and amplitude (AMP) of the motor nerves and the sensory nerves, and electromyography (EMG) were measured and recorded. The measurement was performed at room temperature. In detail, for measurement of the motor branch of the radial nerve, the surface electrodes were placed on the extensor of the index finger to stimulate the radial nerve in the elbow, radial nerve groove and Erb's point, respectively. The NCV and AMP of the motor nerves were recorded. The AMP < 7 mv or NCV at the elbow-radial nerve groove < 50m /s was considered abnormal. For the measurement of the sensory branch of the radial nerve, the surface electrodes were placed on the dorsal surface between the thumb and the index finger. The site at 7.5 cm above the radial styloid process was stimulated. The AMP < 8 uv or NCV <48 m/s of the sensory nerve was considered abnormal. For EMG measurement, the disposable needle electrodes were inserted into the muscle to observe whether there was spontaneous potential when the muscle was relaxed. The motor unit potential (MUP) was observed when the muscle was contracted with small force, including the duration and AMP. When the muscle was contracted with large force, recruitment responses, including recruitment frequency and AMP, were observed. If there was spontaneous muscle potential, or, MUP duration > 12 ms and MUP AMP < 550 uv, or the recruitment frequency was reduced and AMP <1.7 mv, the EMG was considered abnormal. Both the ipsilateral side and the contralateral side of the radial nerves were measured. The contralateral side of the radial nerve was used as control.

### 2.3. Ultrasound examinations

GE Vivid7 ultrasound system (GE Healthcare, Holten, Norway) was used for ultrasound examination. A high-frequency linear probe of 9 to 14 MHz was used. Briefly, patients were in supine or sitting position, to fully expose the radial nerve. The nerve was in low tension or tension-free state. The probe was perpendicular to the nerve. The diameter of the radial nerve at thinnest and thickest sites was measured on the longitudinal image. The cross-sectional area (CSA) of the radial nerve at thinnest and thickest sites was measured on the cross-sectional image. The CSA swelling rate was calculated by the formula of CSA at the thinnest site/ CSA at the thickest site of radial nerve. The morphology of radial nerve, the echo and the relationship with its surrounding tissue were observed. The location of the lesion and the involvement extent of the lesion were recorded. Both the ipsilateral side and the contralateral side of the radial nerves were measured, with the contralateral side of the radial nerve as control.

### 2.4. Statistical analysis

Statistical analysis was performed using SPSS 16.0 software. The diagnosis accuracy, sensitivity, misdiagnosis rate and Youden index were calculated. Chi-square test was used to analyze the differences in the diagnosis accuracy, sensitivity, misdiagnosis rate, and Youden index. The one way ANOVA analysis was used to compare the differences in AMP, NCV, duration, the diameter, CSA, and CSA swelling rate. $P < .05$ was considered statistically significant.

## 3. Results

### 3.1. Diagnosis of nerve torsion and compression by electrophysiological and ultrasound examination

To analyze the diagnostic value of electrophysiological and ultrasound examination, the diagnosis sensitivity, specificity, accuracy, misdiagnosis rate, and Youden index were compared. For radial torsion, the diagnosis sensitivity, specificity, accuracy, misdiagnosis rate, and Youden index of electrophysiological examination was 85.71%, 100%, 85.71%, 14.28%, and 85.72%, respectively, whereas that of ultrasound examination was 92.86%, 100%, 85.71%, 7.14%, and 92.86%, respectively (Table 1). For radial compression, the diagnosis sensitivity, specificity, accuracy, misdiagnosis rate, and Youden index of

**Table 1**

**Comparison of electrophysiological examination and ultrasound examination for diagnosis of radial torsion.**

| | | Nerve torsion (n=14) | Diagnosis sensitivity, % | Diagnosis specificity, % | Diagnosis accuracy, % | Misdiagnosis rate, % | Youden index, % |
|---|---|---|---|---|---|---|---|
| Electrophysiological examination | Positive cases | 12 | 85.71 | 100 | 85.71 | 14.28 | 85.72 |
| | Negative cases | 2 | | | | | |
| Ultrasound examination | Positive cases | 13 | 92.86 | 100 | 85.71 | 7.14 | 92.86 |
| | Negative cases | 1 | | | | | |

**Table 2**

**Comparison of electrophysiological examination and ultrasound examination for diagnosis of radial compression.**

| | | Nerve compression (n=14) | Diagnosis sensitivity, % | Diagnosis specificity, % | Diagnosis accuracy, % | Misdiagnosis rate, % | Youden index, % |
|---|---|---|---|---|---|---|---|
| Electrophysiological examination | Positive cases | 11 | 78.57 | 100 | 100 | 21.43 | 78.57 |
| | Negative cases | 3 | | | | | |
| Ultrasound examination | Positive cases | 13 | 92.86 | 100 | 100 | 7.14 | 92.86 |
| | Negative cases | 1 | | | | | |

electrophysiological examination was 78.57%, 100%, 100%, 21.43%, and 78.57%, respectively, whereas that of ultrasound examination was 92.86%, 100%, 100%, 7.14%, and 92.86%, respectively (Table 2). Statistically, there were no significant difference in diagnostic value for radial torsion and compression between electrophysiological and ultrasound examination.

### 3.2. Analysis of AMP and NCV by electrophysiological examination

The AMP and NCV of the motor and sensory nerves, and, the EMG indicators, including duration of MUP, AMP of MUP, and recruitment AMP were measured and recorded. The AMP and NCV of the motor and sensory nerves, AMP of MUP, and recruitment AMP all showed a decreasing trend in radial torsion and compression patients. However, duration of MUP was increased in radial torsion and compression patients. Statistically, these indicators of radial torsion and compression patients were significantly different from those of control ($P<.05$) (Table 3). No significant difference was found between radial torsion and compression patients. Therefore, the electrophysiological examination cannot differentiate radial torsion from radial compression.

### 3.3. Ultrasound examination

The diameter, CSA and CSA swelling rate of the radial nerve at thinnest and thickest sites were recorded and compared. As shown in Table 4, compared with control group, the diameter of the thinnest site of radial torsion and compression were significantly lower ($P<.05$). The CSA of the thinnest site of radial torsion was significantly lower than the control ($P<.05$). However, the diameter and CSA of the thickest site and the CSA swelling rate of radial torsion and compression were significantly higher than the control group ($P<.05$). Compared with radial torsion, the radial compression had significantly higher levels of the diameter of the thickest site and the thinnest site, and, the CSA of the thinnest site ($P<.05$). There was no significant difference in the CSA of the thickest site and CSA swelling rate between the torsion and the compression. Thus, ultrasound can differentiate radial torsion from radial compression

### 3.4. Surgery and results

Nerve resection was performed for radial nerve torsion patients. Two patients also received nerve transplantation. All the 14 cases of radial nerve torsion were unilateral, including 6 cases of right sides and 8 cases of left side. There were 4 cases of single torsion

**Table 3**

**Characteristics of electrophysiological examination of nerve torsion and compression.**

| | | Mean ± standard deviation | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|
| AMP of the motor branch of the radial nerve (mv) | Control | 9.26±1.45 | 8.47 | 10.05 |
| | Torsion | 2.32±1.45* | 1.53 | 3.11 |
| | Compression | 2.49±1.48* | 1.70 | 3.28 |
| NCV of the motor branch of the radial nerve (m/s) | Control | 60.86±4.29 | 58.50 | 63.21 |
| | Torsion | 36.06±4.65* | 33.70 | 38.41 |
| | Compression | 37.62±4.11* | 35.27 | 39.98 |
| AMP of the sensory branch of the radial nerve (uv) | Control | 13.39±1.48 | 12.54 | 14.25 |
| | Torsion | 8.23±3.05* | 6.46 | 9.99 |
| | Compression | 9.18±3.35* | 7.24 | 11.11 |
| NCV of the sensory branch of the radial nerve (m/s) | Control | 58.88±5.25 | 55.85 | 61.91 |
| | Torsion | 50.75±7.09* | 46.66 | 54.84 |
| | Compression | 53.08±7.22* | 48.91 | 57.25 |
| Duration of MUP (ms) | Control | 11.49±0.49 | 11.20 | 11.77 |
| | Torsion | 14.69±1.16* | 14.01 | 15.36 |
| | Compression | 14.79±1.27* | 14.06 | 15.53 |
| AMP of MUP (uv) | Control | 645.09±99.68 | 587.54 | 702.65 |
| | Torsion | 378.29±83.59* | 330.02 | 426.55 |
| | Compression | 386.76±102.76* | 327.43 | 446.10 |
| Recruitment AMP (mv) | Control | 2.03±0.33 | 1.84 | 2.22 |
| | Torsion | 1.04±0.32* | 0.86 | 1.23 |
| | Compression | 1.06±0.37* | 0.85 | 1.27 |

AMP=amplitude, CI = confidence interval, MUP=motor unit potential, NCV=nerve conduction velocity.

* $P<.05$, compared with control.

**Table 4**

**Characteristics of ultrasound examination of radial torsion and radial compression.**

| | | Mean±standard deviation | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|
| Diameter of the thinnest site (cm) | Control | 0.17±0.01 | 0.17 | 0.18 |
| | Torsion | 0.11±0.03* | 0.09 | 0.12 |
| | Compression | 0.15±0.03*,† | 0.13 | 0.17 |
| Diameter of the thickest site (cm) | Control | 0.20±0.02 | 0.19 | 0.21 |
| | Torsion | 0.31±0.03* | 0.29 | 0.33 |
| | Compression | 0.34±0.04*,† | 0.31 | 0.36 |
| CSA of the thinnest site ($cm^2$) | Control | 0.03±0.003 | 0.03 | 0.04 |
| | Torsion | 0.02±0.005* | 0.02 | 0.02 |
| | Compression | 0.03±0.008*,† | 0.02 | 0.03 |
| CSA of the thickest site ($cm^2$) | Control | 0.04±0.005 | 0.04 | 0.05 |
| | Torsion | 0.09±0.015* | 0.08 | 0.10 |
| | Compression | 0.09±0.032* | 0.08 | 0.11 |
| CSA swelling rate | Control | 1.25±0.05 | 1.22 | 1.28 |
| | Torsion | 4.86±1.94* | 3.74 | 5.98 |
| | Compression | 4.06±1.87* | 2.98 | 5.14 |

CI = confidence interval.
* $P<.05$, compared with control.
† $P<.05$, compared with torsion.

and 10 cases of multiple torsion; 10 cases of radial nerve trunk torsion, 2 cases of deep radial nerve torsion, 1 case of deep and trunk radial nerve torsion, and 1 case of radial nerve trunk with the median nerve torsion. Intraoperative observation found that the torsion of the nerve showed “sausage-like” changes.

Patients with radial nerve compression had nerve release surgery. The 14 cases of radial nerve compression patients had unilateral compression, including 9 cases of light side and 5 cases of left side. There were 4 cases of tendon compression, 3 cases of scar compression, 3 cases of compression caused by bone hyperplasia, 2 cases of compression because of internal fracture fixation, 1 case of compression caused by bone fracture, and 1 case of compression caused by traumatic neuroma. The intraoperative neurological changes caused by compression were consistent with those of the ultrasound examination.

### 3.5. Typical cases

A 32-year-old woman was admitted because of extensible wrist and numbness. Electrophysiological examination showed that the AMP of the motor branch of the radial nerve decreased to 0.6 mv and the motor NCV of the elbow-radial nerve decreased to 39.4 m/s (Fig. 1A). As shown in Figure 1B, the AMP of the sensory branch of the radial nerve decreased to 5.9 uv and the sensory NCV was 55.6 m/s (Fig. 1B). These results suggest that the left radial nerve was severely but not completely impaired. On EMG, the denervation potential was observed when the muscle was relaxed (Fig. 1C). The duration of MUP increased to 13.3 ms and the AMP of MUP decreased to 235.7 uv when the muscle contracted with small force (Fig. 1D). When the muscle contracted with large force, the recruitment AMP was 1.2 mv (Fig. 1E). These data indicates that there is neurogenic damage in the extensor nerve. Ultrasonography showed that the deep branch of the left radial nerve increased to 0.3 cm and the echo reduced (Fig. 1F, left). The right radial nerve deep branch was normal (Fig. 1F, right). The ultrasonography indicates the diagnosis of nerve compression in the left radial nerve deep branch. Surgery showed that the compression was caused by the arcade of Frohse (Fig. 1G). Therefore, deep radial nerve release surgery was performed.

A 35-year-old male was admitted because of wrist drop for a week. Electrophysiological examination showed that the AMP of radial nerve groove decreased to 0.1 mv, and the NCV of elbow-radial nerve groove decreased to 32.7 m/s (Fig. 2A). The AMP of the sensory branch of the radial nerve decreased to 3.2 uv and the sensory NCV was 42.7 m/s (Fig. 2B). This data suggests that the left radial nerve was severely but not completely impaired. On EMG, there was denervation potential when the muscle was relaxed (Fig. 2C). When the muscle contracted with small force, the duration of MUP increased to 12.5 ms and the AMP of MUP decreased to 420.2 uv (Fig. 2D). The recruitment AMP was 1.6 mv when the muscle contracted with large force (Fig. 2E). These results imply neurogenic damage of the extensor nerve. The ultrasonography showed that the deep branch of the left radial nerve was significantly thicker (Fig. 2F, left). The vertical axis of ultrasonography showed that the left deep branch of radial nerve showed hourglass-like changes, presenting as thinned torsion, reduced echo at the thickened nerve ends without compression and unclear internal structure (Fig. 2F, right). The results of ultrasonography indicate the diagnosis of nerve torsion in the deep branch of the left radial nerve. During surgery, we observed that the thickened deep branch of radial nerve had two torsions (Fig. 2G). Therefore, torsion nerve resection and sural nerve transplantation were performed.

## 4. Discussion

Upper limb radial nerve torsion and radial nerve compression all present as varying degrees of upper limb pain and limited movement, and sensory disturbances.[19,20] In the past, they were usually diagnosed as soft tissue sprain, soft tissue strain, inflammatory changes, or injury of the small nerve branch. Torsion usually has acute onset, and compression usually takes longer time.

Many clinicians had limited knowledge of radial nerve torsion of the upper arm, and misdiagnosed radial nerve torsion as radial nerve compression. However, the treatments are different, and some patients had multiple nerve or torsion sites. Stembrink et al[21] suggest that one or more nerves of the upper limb can be twisted. Yasunaga et al[22] reported a patient with 4 twisted nerve

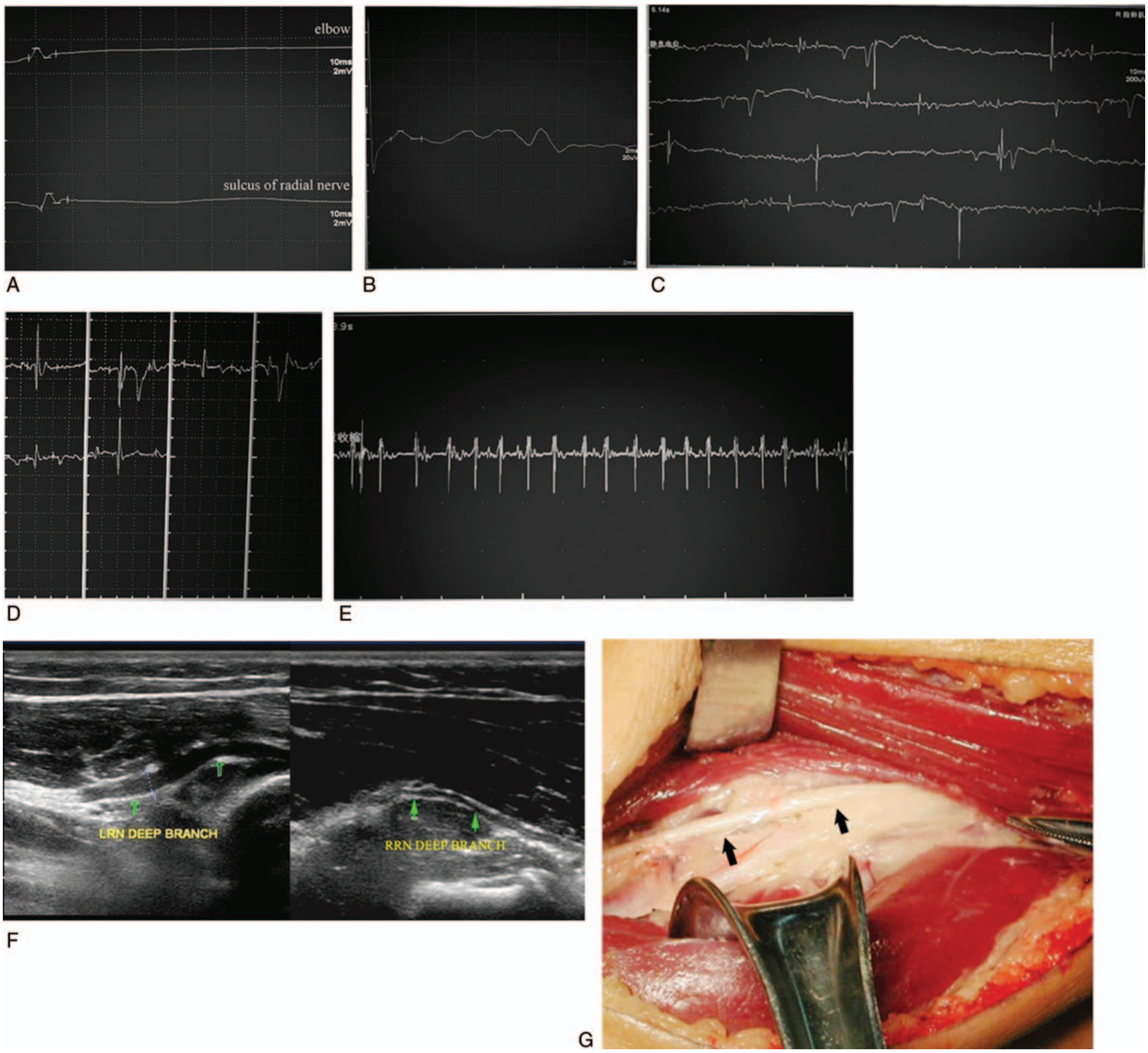


**Figure 1.** Typical case of radial nerve compression. Images were obtained from a 32-year-old woman who was admitted because of extensible wrist and numbness. A, Electrophysiological examination results of the motor branch of the radial nerve. B, Electrophysiological examination results of the sensory branch of the radial nerve. C, EMG result when the muscle was relaxed. D, EMG result when the muscle was contracted with small force. E, EMG result when the muscle was contracted with large force. F, Ultrasonography results. LRN = left radial nerve. RRN = right radial nerve. G, Deep radial nerve release surgery was performed. The arrows indicate the swelled and thickened radial nerve after compression.

of upper limb, including the median nerve, ulnar nerve, radial nerve and skin nerve, which were intraoperatively presented as 24 sites of hourglass-like changes. Preoperative ultrasound can determine the twisted site and the length of the nerve involved, which is important for choosing the surgical approach and reducing unnecessary damage of surgery.[23] In this study, among 14 patients with nerve torsion, 13 cases had unilateral radial nerve torsion, and 1 case had radial nerve and median nerve torsion. Ten cases had multiple parts of radial nerve torsion. Therefore, ultrasound should be used on multiple sites to determine the location and scope of involved nerve,[24] thus facilitating the choice of surgical approach.

Upper arm radial nerve compression has three common sites[25]: axillary arm angle, whose radial nerve is located on the inside upper end of humeral neck and humeral shaft; radial nerve groove on the outer side of upper arm, whose radial nerve is located closely on the humerus; and the penetrating part of radial nerve of the lateral medial muscle, whose radial nerve is often wrapped by tendon muscle and easily damaged after intense activity. The deep branch of radial nerve that often be compressed is located in the arcade of Frohse.[26] Radial branch of the radial nerve is often compressed by the radius or the radial stem.

Radial nerve torsion and compression are mainly diagnosed by medical history, electrophysiological examination and ultrasound examination.[6] The electrophysiological examination of torsion and compression all show decreased AMP and NCV.[27] Therefore, electrophysiological examinations can be used to determine the location and scope of nerve injury, but cannot be used for differential diagnosis or accurate location of deep injury.[28] Because of invasive nature, some patients cannot cooperate or tolerate the examination, thus affecting the test results. Ultrasound can differentiate torsion and compression based on the morphological changes. When there is radial torsion, the nerve is thinned at torsion and thickened at distal

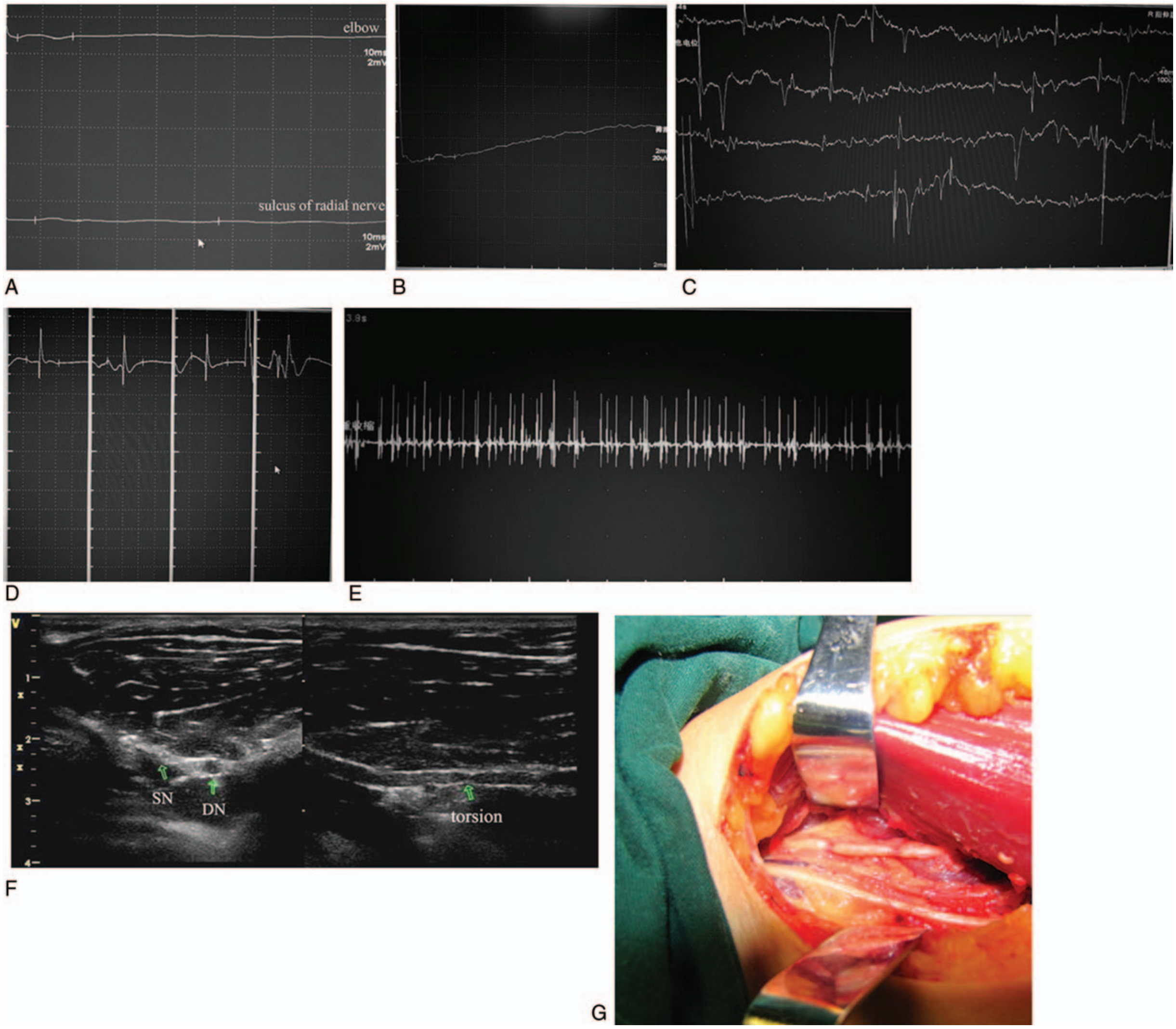


**Figure 2.** Typical case of radial nerve torsion. Images were obtained from a 35-year-old male who was admitted because of wrist drop for a week. A, Electrophysiological examination results of the motor branch of the radial nerve. B, Electrophysiological examination results of the sensory branch of the radial nerve. C, EMG result when the muscle was relaxed. D, EMG result when the muscle was contracted with small force. E, EMG result when the muscle was contracted with large force. F, Ultrasonography results. DN = deep nerve, SN = superficial nerve. G, Torsion nerve resection and sural nerve transplantation were performed. During surgery, it was observed that the thickened deep branch of radial nerve had two torsions.

ends of twisted nerve, and presents as hourglass-like changes without significant compression.[29] When there is radial compression, the nerve is thin at compression site and is thickened at the proximal end of the nerve.[30] Ultrasound can measure the diameter and CSA of the torsion or compression nerve to determine the scope of nerve injury.[31] In addition, ultrasound can detect the location and length of nerve injury, thus determining the scope of surgical operation.[32] In the small incision surgery, ultrasound can be of great importance in the choice of incision site.[9,33] Ultrasound can also detect the factors causing the nerve compression and the local anatomical relationship, which may assist selection of surgical methods and avoid increased intraoperative injury.[34]

Conservative treatment of radial nerve torsion is invalid and surgical treatment is suggested with clear results.[9–11] Radial nerve compression can be treatment by nonsurgical and surgical treatment. For patients with mild compression on ultrasound and mild clinical symptoms, local blocking treatment should be used with routine use of neurotrophic drugs and focal physical therapy, such as local infrared radiation.[35] For patients with longer compression time, nerve release surgery should be performed.[5]

Electrophysiological examination and high-frequency ultrasound have their own advantages. Electrophysiological examination can show functional status of the nerve whereas high-frequency ultrasound can show the morphological changes, which are irreplaceable.[36] In this study, 23 out of the 28 patients showed positive electrophysiological results, including 11 cases of compression and 12 cases of torsion. There were 5 cases of negative electrophysiological results, including 2 cases of compression, 2 cases of torsion, and 1 case without abnormal presentations on ultrasound. During surgery, we found that this undetected case was because of tendon tissue hyperplasia. For some patients, the electrophysiological examination was negative but the ultrasound was positive. This is mainly because of the strong compensatory ability of the radial nerve of upper arm. For patients with mildly compression or torsion, a few nerve fibers may show demyelination and conduction block within the scope of compensation, presenting as negative electrophysiological examination.[37] Therefore, ultrasound can show reduced echo and swelling of radial nerve. For patients with comparable electrophysiological examination, high frequency ultrasound should be performed to detect the type and cause of the lesion, and the location and scope of the damaged nerve, which is of great significance for the preoperative evaluation and treatment selection.

This study has some limitations. First, the sample size is relatively small. Second, the patients were not grouped by age or degree of injury.

To sum up, electrophysiological examination and high-frequency ultrasonography both can diagnose radial neuropathy with high diagnostic rate. Electrophysiological examination can reflect the neurological function. High-frequency ultrasound can determine the morphology changes of injured nerve, location of lesion, and involved scope of lesion, thus differentiating nerve torsion from compression.

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