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RESEARCH

Accuracy of ultrasound and MRI in the diagnosis of common peroneal nerve injuries

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Abstract

Background This study aimed to determine the accuracy of ultrasound (US) and MRI compared to intraoperative findings in patients who underwent surgery for their common peroneal nerve (CPN) injury.

Methods Patients who underwent surgical management of a CPN injury with preoperative US were reviewed. The status of the CPN as interpreted by the radiologist in the preoperative US and MRI were recorded. The intraoperative findings of the CPN were compared to the imaging findings. The CPN was classified as intact, partial injury, or complete transection. The location of the injury, and presence of a neuroma-in-continuity or stump neuroma were recorded. The sensitivity and specificity of US for diagnosis of a complete transection and an intact CPN were calculated.

Results Thirteen patients were included in this study. Preoperative US accurately diagnosed a complete transection in 3 out of 4 patients and an intact CPN in 4 out of 5 patients. MRI did not accurately identify the status of the CPN in any patients. US had 75% sensitivity and 78% specificity for detecting complete transection, and 80% sensitivity and 63% specificity for detecting an intact CPN. The level of injury was correctly identified in 7 out of 13 cases by US and 1 out of 8 cases by MRI. A neuroma was correctly identified in 7 of 11 cases by US and 1 out of 8 cases by MRI.

Conclusion US has a high sensitivity and specificity when diagnosing CPN lesions and was more accurate than MRI.

Keywords Knee dislocation · MRI · Peripheral nerve injury · Peroneal nerve · Ultrasound

Introduction

Peripheral nerve injuries can occur via a wide variety of mechanisms, including motor vehicle accidents, blunt trauma, burns, or iatrogenic lesions. Injury to the common peroneal nerve (CPN) is both the most common iatrogenic lesion as well as the most common peripheral nerve injury in the lower extremity in polytrauma patients [5, 18]. Treatment options for patients with CPN injuries can vary greatly, from nonoperative measures, including therapy and bracing, to surgical options, including direct nerve repair, nerve transfers, or tendon transfers [3, 15, 17, 19]. The treatment type depends on the extent of the nerve injury, as options change if the nerve is stretched but in continuity versus if there is a complete transection.

A CPN injury diagnosis begins with a thorough history and physical examination like most peripheral nerve injuries. However, patients with lesions that are in continuity and those with a complete transection may present similarly – i.e., with altered sensation over the dorsum of the foot and a foot drop. The most common diagnostic tests include electromyography (EMG), ultrasound (US), and MRI [8, 12, 16, 26]. US has become increasingly popular due to its improved resolution, availability, the ability to be performed at the bedside, and low associated risks.

The literature comparing US (with or without MRI) to intraoperative findings is sparse. Increasing knowledge of the diagnostic accuracy of US and MRI in CPN injuries can guide surgeons in treatment decision-making and patient prognostication. This study aimed to determine the accuracy of preoperative US in diagnosing CPN injuries by comparing US to intraoperative findings. Secondarily, we aimed to compare US to MRI and report on the sensitivity and specificity of both.

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Methods

After Institutional Review Board approval, all patients diagnosed with a CPN injury between 2001 to 2022 were reviewed. Inclusion criteria included a preoperative US and MRI followed by surgical intervention of the CPN injury. Patients were excluded if they did not undergo surgery for their CPN injury or if they did not have a documented preoperative US. The decision to proceed with surgical intervention was multifactorial, which included a combination of the following factors: mechanism of injury, clinical symptoms, progression over time, electrodiagnostic testing, and patient preference. Likewise, the decision to obtain additional imaging was made on a case-by-case basis.

Medical records were reviewed for demographic data (patient age, gender, and lower extremity laterality). Preoperative US and MRI findings were recorded. Musculoskeletal-specific ultrasounds were performed by a radiologist using a high frequency US probe. MRI scans were obtained using standard anatomic imaging parameters for knee imaging using a 1.5 Tesla MRI. Given the retrospective nature of this study, nerve-specific MRIs were not obtained, nor were 3.0 Tesla MRI. The time from injury to preoperative US and/or MRI and time to surgery were recorded.

Based on the US or MRI read by a fellowship-trained musculoskeletal radiologist, the CPN was classified as intact, a partial injury or a complete transection. MRIs were classified as nondiagnostic if either the original interpretation had no mention of the CPN or stated that the nerve was not well visualized (secondary to recent trauma, hematoma, etc.). These findings were compared to the operative findings, where the CPN was classified as intact, a partial injury or a complete transection. The classification of the nerve was made by the senior authors during surgical exploration based on the physical appearance of the nerve. If no fascicles appeared disrupted along the length of the visualized nerve, intraoperative testing for nerve action potentials (NAP) was performed. If NAPs were present, this was classified as intact. If NAPs were absent in one portion but present in another (some, but not all, of the fascicles were intact), this was classified as a partial injury. Nerves were also classified as partial injuries if some fascicular bundles appeared injured and some spared, in which case an internal neurolysis was performed to separate and record with NAPs across them. The nerve was classified as completely transected only if there were no remaining fascicles in direct continuity. The location of the nerve injury was detailed as in the distal thigh, popliteal crease, or fibular head on imaging and operative findings. Similarly, preoperative imaging was reviewed for the presence of a neuroma, which was compared to the intraoperative findings. Neuroma findings were classified as normal nerve (no neuroma), neuroma-in-continuity, or stump neuroma. A neuroma-in-continuity was defined as a nerve whose continuity was intact but had a loss of fascicular detail or enlargement of greater than 25% of its diameter. A stump neuroma was defined as a nerve with loss of fascicular detail or enlargement proximal to a portion with at least partial discontinuity to the distal portion.

Descriptive statistics were utilized for the demographic variables and the proportion of nerve injuries and locations accurately identified via imaging. The sensitivity and specificity were calculated for the ultrasound's ability to identify both complete CPN transection and an intact CPN. The intraoperative findings were considered the gold standard comparator for these purposes.

Results

Forty-seven patients who underwent surgical management of their CPN injury were identified. Of these 47, 13 had preoperative US evaluating the CPN and were included in this study. Patient demographics and preoperative characteristics are listed in Table 1. Eight of these 13 patients also had an MRI of the knee before surgery. Of the 13 patients included, the average age at the time of surgery was 29 years (range: 14 to 55 years), with 10 out of 13 being male and 7 out of 13 having the right lower extremity involved. The average time from injury to US evaluation was 3.8 months (range: 1 day to 6.7 months), and from injury to MRI was 2.2 months (range: 1 day to 6.8 months). The average time from US evaluation to surgery was 1.2 months (range: 1 day to 4.0 months) and from MRI to surgery was 2.8 months (range: 1 day to 5.7 months).

The details of each patient's operative and imaging findings regarding CPN injury and transection status are listed in Table 2. Intraoperatively, 5 patients were found to have an intact CPN, 4 patients had partial injuries, and 4 patients had complete transection of the CPN. Preoperative US accurately diagnosed complete transection of the CPN in 3 out of 4 patients. Similarly, US accurately identified an intact CPN in 4 out of 5 patients. Partial injuries were correctly identified by US in 1 out of 4 patients. Overall, US had a 75% sensitivity (95% CI: 19–99%) and a 78% specificity (95% CI: 40–97%) for detecting a complete CPN transection. US had an 80% sensitivity (95% CI: 28–99%) and a 63% specificity (95% CI: 24–91%) for correctly identifying an intact CPN. MRI did not accurately identify the status of a CPN injury or transection in any of the patients examined (0 out of 8) (Figs. 1 and 2).

The popliteal crease was the most common location of CPN injury. The US correctly identified the level of injury in

Table 1 Patient and injury characteristics ($n = 13$)

	n (%)
Age (y)*	29 (14–55)
Sex	
Male	10 (77%)
Female	3 (23%)
BMI (kg/m^2)*	30.7 (18.6–53.9)
Mechanism of injury	
Sports	5 (38%)
Fall	4 (31%)
Gun shot	2 (15%)
Motorcycle accident	1 (8%)
Iatrogenic	1 (8%)
Multiligament knee injury	8 (62%)
Knee dislocation	5 (38%)
Location of CPN injury	
Distal thigh	2 (15%)
Popliteal crease	5 (38%)
Fibular head	1 (8%)
Time from injury to surgery (days)*	150 (2–316)
Preoperative US available	13 (100%)
Time from injury to US (days)*	115 (1–202)
Time from US to surgery (days)*	35 (1–119)
Preoperative MRI available	8 (62%)
Preoperative MRI performed but unavailable	2 (15%)
No preoperative MRI performed	3 (23%)
Time from injury to MRI (days)*	68 (1–203)
Time from MRI to surgery (days)*	84 (1–171)

y years, *BMI* body mass index, *US* ultrasound

*Data expressed as mean (range)

Table 2 CPN transection status compared to imaging findings

US Findings	MRI Findings	Operative Findings
Intact	*	Intact
Intact	-	Intact
Intact	Nondiagnostic	Intact
Intact	Partial	Intact
Intact	Nondiagnostic	Partial
Intact	Complete	Partial
Intact	Intact	Complete
Partial	-	Partial
Complete	Complete	Intact
Complete	-	Partial
Complete	*	Complete
Complete	Nondiagnostic	Complete
Complete	Nondiagnostic	Complete

Partial and Complete refer to the type of transection noted

* MRI not available

- No MRI performed

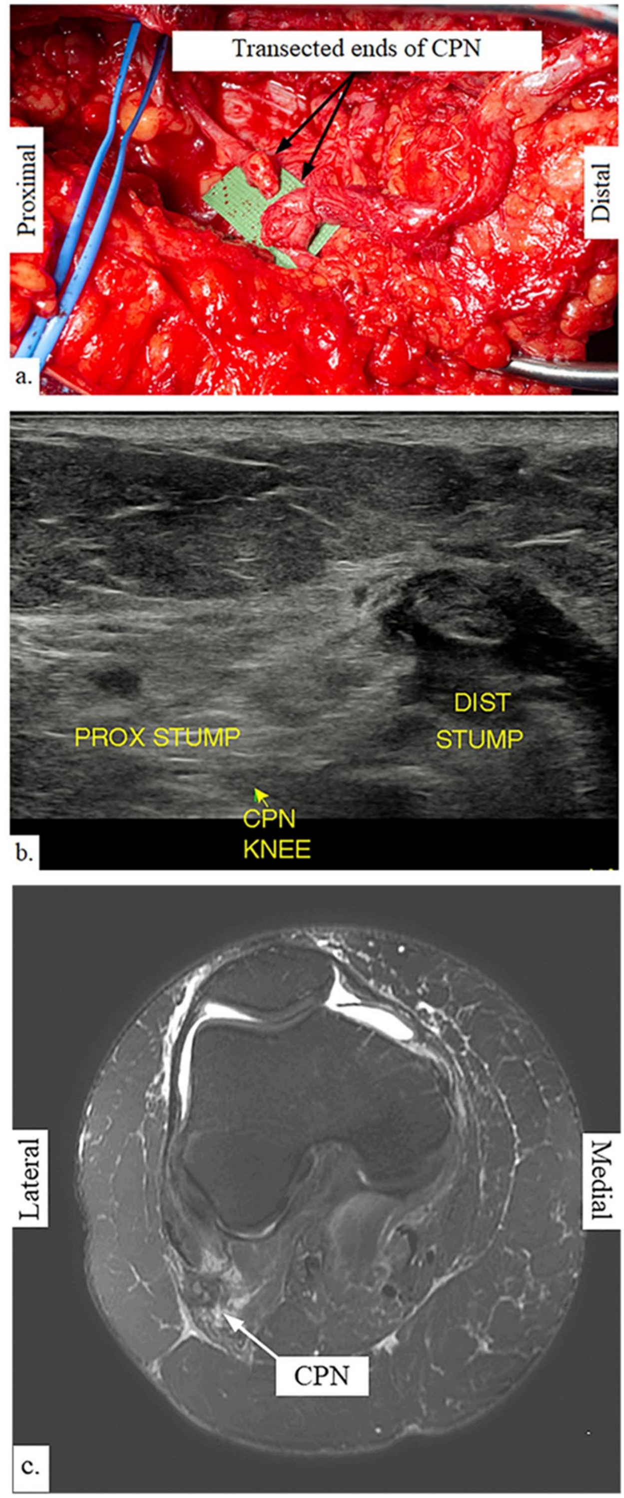

Fig. 1 Complete common peroneal nerve (CPN) transection that was accurately diagnosed via preoperative ultrasound (US), however preoperative MRI was read as "Inflammation about the peroneal nerve is likely from prior trauma." **a** Intraoperative findings of complete CPN transection. The green micro background is 3 cm total in length, with each square 1 mm x 1 mm. **b** Preoperative US showing the proximal and distal nerve stumps, consistent with complete transection. **c** Preoperative axial MRI showing increased signal about the CPN

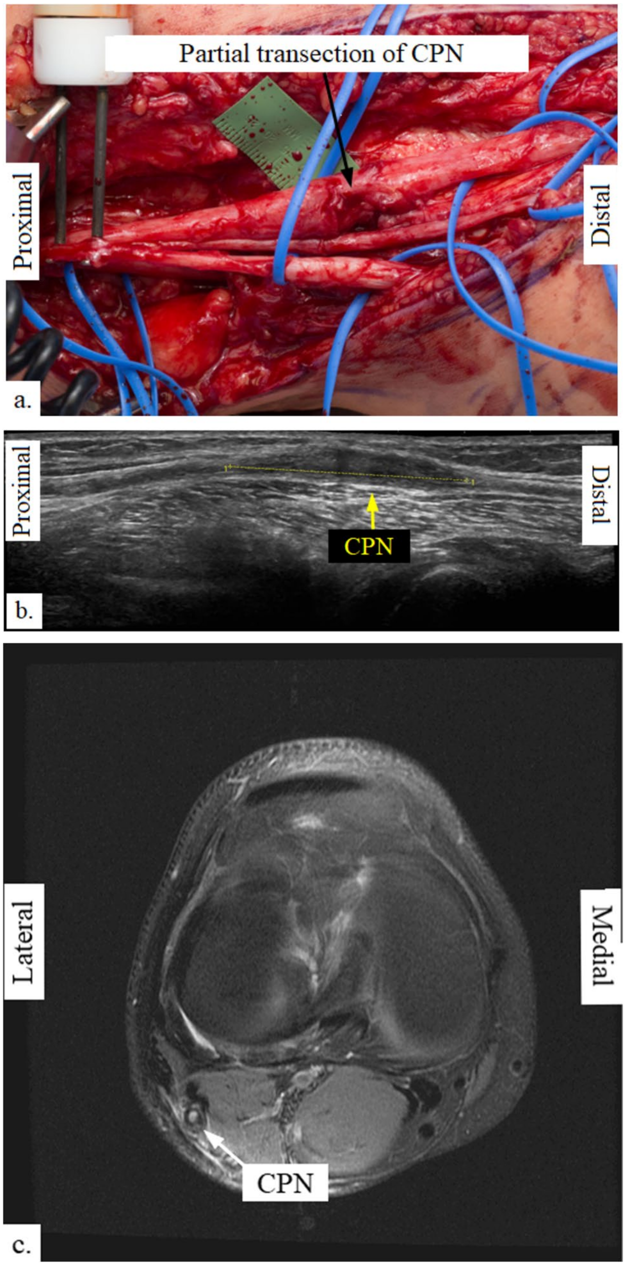

Fig. 2 Partial common peroneal nerve (CPN) injury that was not correctly identified by either the preoperative ultrasound (US) or MRI. **a** Intraoperative findings showing partial CPN injury. **b** Preoperative US showing intact CPN with neuroma-in-continuity. **c** Preoperative axial MRI showing increased signal around the CPN at the level of the knee joint, just prior to the area where it is noted to be discontinuous

7 out of 13 cases, and the MRI correctly identified the level of injury in 1 out of 8 cases.

Table 3 lists the details of each patient's CPN neuroma status. Eleven patients had intraoperative findings consistent with a neuroma. US correctly identified whether there was a neuroma-in-continuity or a stump neuroma in 7 of 11 cases.

Table 3 CPN neuroma status compared to imaging findings

Patient	US Findings	MRI Findings	Operative Findings
1	NL	*	NL
2	NL	-	NL
3	IC	Nondiagnostic	IC
4	IC	S	IC
5	IC	Nondiagnostic	S
6	IC	S	S
7	IC	NL	S
8	S	-	S
9	S	S	IC
10	S	-	S
11	S	*	S
12	S	Nondiagnostic	S
13	S	Nondiagnostic	S

NL normal/no neuroma, *IC* neuroma-in-continuity, *S* stump neuroma

* MRI not available

- No MRI performed

MRI correctly identified whether there was a neuroma-in-continuity or a stump neuroma in 1 out of 8 cases.

Of note, two patients in this study had an intact CPN intraoperatively without neuroma. Both patients underwent neurolysis and intraoperative nerve stimulation, which confirmed conduction of the CPN across the lesion. One of these patients noted spontaneous improvement in ankle dorsiflexion two months after neurolysis; however, it eventually required tendon transfer. The other patient continued to utilize an ankle–foot-orthosis postoperatively and has not undergone another surgery.

Discussion

Preoperative knowledge of the extent of nerve injury is imperative for optimal treatment decision-making and prognostication after CPN injury. Current literature evaluating the role of preoperative US and MRI in accurately diagnosing these injuries is limited. This study aimed to determine the accuracy of preoperative US and MRI compared to intraoperative findings to guide the surgeon on which imaging modality would yield the most accurate information. This study found that US was more accurate, sensitive, and specific when diagnosing CPN lesions compared to MRI obtained to assess knee injury. A prior study compared US versus MRI in patients with suspected common peroneal neuropathy. However, it did not directly compare these findings to intraoperative findings [1]. Bignotti et al.'s study does corroborate the findings of this study in that US is more accurate than MRI in patients with peroneal neuropathy, despite their patients having diagnoses of entrapment or intraneural masses, as compared to the traumatic injuries [1]. Zaidman et al. examined 53 patients who had both US and MRI for any peripheral nerve pathology and found that US was more accurate than MRI [27]. They also note that US was preferred for multifocal lesions, as MRI can often miss pathology outside the field of view, however, it is worth noting that US are also limited to the field of view scanned by the technician. This can be overcome if the technician has an adequate understanding of the clinical question and expands the field of view as necessary during testing. One recent review article suggests that MRI may be preferred over the US for larger peripheral nerves [7]. However, it does not define which peripheral nerves are large versus small. While the CPN is one of the largest peripheral nerves in the extremities, we would argue against the recommendation that MRI is the preferred study. Another study directly compared US to MRI for examining the cross-sectional area of the median nerve at the wrist. This study also found that US was more accurate than MRI, although the authors did not compare these results to intraoperative findings [10]. Interestingly, they did not believe that there was a clinically significant difference in the US versus MRI findings. This is in contrast to our study, where we would argue that knowing if a patient's CPN is intact or completely transected would have a significant clinical impact. Our study agrees with most current peripheral nerve literature and concurs that US is more accurate than MRI and is one of the few to actually corroborate these findings with a direct interoperative assessment.

The preoperative US accurately diagnosed a complete transection of the CPN in 3 out of 4 patients, an intact nerve in 4 out of 5 patients, and a partial injury in 1 out of 4 patients. Knowing the exact status of the nerve major impact on prognostication and surgical decision-making. Previous studies have demonstrated that nerve continuity is associated with improved outcomes compared to complete transection [6, 13, 22]. Patients with a complete nerve transection have no chance of spontaneous recovery. Therefore, early surgical intervention, either through direct nerve repair or nerve grafting, would ideal if it could be confirmed on preoperative imaging. US has traditionally been used to differentiate between low-grade nerve injuries (Sunderland grades I-III) and high-grade nerve injuries (Sunderland IV-V) [23, 24]. The sensitivity and specificity of US to accurately diagnose the status of the nerve has varied amongst previous literature. One cadaveric study examined complete nerve transection in the forearm and reported an 89% sensitivity and 95% specificity utilizing US [4]. Another in vivo study examined 13 patients with peripheral nerve lesions who underwent preoperative US and found that US could correctly identify the site of nerve injury and diagnosis in all cases [14]. In contrast to our study, there was no correlation to intraoperative findings, and less than half (6/13) of the patients were being evaluated after traumatic injuries. As utilized in our study, direct intraoperative nerve evaluation is considered the gold standard against which all imaging modalities should be compared. Our study found that preoperative US had a 75% sensitivity and a 78% specificity in diagnosing a complete CPN transection and an 80% sensitivity and 63% specificity in diagnosing an intact CPN.

Despite the known advantages of MRI, it did not accurately diagnose the type of CPN lesion in any patient, and only one out of 8 neuromas. This is a critical point for surgeons to understand, as MRI is often ordered after traumatic injuries. In particular, MRI is considered the standard of care after knee dislocation and is an excellent modality to evaluate ligamentous injury [20, 25]. We acknowledge that the majority of the MRIs included were done to assess knee injury, therefore the status of the CPN is often a secondary consideration. With the relatively high rate of CPN injuries associated with knee dislocation [2, 9, 11], a dedicated US study of the nerve is recommenced. A previous study found that MRI had a high sensitivity for CPN injury after knee dislocation, however this was in groups of patients with and without clinical evidence of nerve injury [21]. This discrepancy suggests that MRI alone may not be enough to definitively diagnose CPN lesions, so surgeons cannot make recommendations based on initial knee MRI alone. Given the inaccuracy of MRI obtained to assess knee injury in diagnosing CPN injuries evidenced by the findings of this study, surgeons should retain a high clinical suspicion, even when there is no mention of CPN damage in the MRI report. A low threshold to obtain a US as an adjunct to assess the CPN in patients after knee dislocation is recommended.

We recognize the limitations of this study and those inherent to retrospective evaluations. Currently, there is no institutional protocol for when to obtain US imaging for traumatic peroneal neve injuries, which creates heterogeneity in which patients are receiving this testing. Similarly, the decision to proceed with surgery is multifactorial, which may introduce unseen confounding variables, such as selection bias. While this study has a relatively small sample size, all patients had a US of the CPN compared to the intraoperative findings and MRI when available. Additionally, six patients included in this study did not have an MRI available for comparison. This limited the ability to calculate the sensitivity and specificity of the MRI. We specifically elected not to have a radiologist retrospectively read these patients' MRIs as this would likely create a confirmation bias given that all patients eventually underwent surgery for their CPN injuries. Given that this study encompassed a 20-year time period, MRI and US technology and experience with them have changed and evolved. Therefore, this study cannot report on the usage of a specific, repeated protocol. It is important to note that the quality of the US is highly dependent on the radiologist performing it, which may affect the external validity of this study. Similarly, having multiple radiologists read the images may affect the reliability of the results. The time from imaging study to surgery ranged from 1 day to 4 months in the study, which may have impacted the intraoperative findings, and we cannot rule out the notion that a partial injury may have become complete over time. Additionally, dedicated high-resolution MRI, such as the use of 3 Tesla MRI neurography, could improve the quality of the image and the ability to accurately diagnose CPN injuries. Further studies are necessary to determine if these adjustments would enhance the accuracy of MRI imaging, providing valuable guidelines.

These limitations notwithstanding, US had a high sensitivity and specificity in identifying the type of CPN lesion when directly compared to intraoperative findings. MRI obtained to assess knee injury was inferior to dedicated US of the CPN when assessing nerve injury. An accurate assessment of the CPN is crucial, as its status impacts prognostication and surgical planning. While the results of this study support the use of US to make an accurate diagnosis, additional studies are needed to further validate this. Future research should focus on a prospective study with a standardized protocol for obtaining a preoperative US in all patients with suspected peroneal nerve injuries.

Author contribution Authorship statement: LET wrote the main manuscript text and prepared the figures. CRCS collected and analyzed the data. RJS, ATB, and AYS were intimately involved in research development, supervision, and editing the final manuscript. All authors reviewed the manuscript prior to submission.

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Data availability No datasets were generated or analysed during the current study.

Declarations

This study was performed in accordance with the ethical standards described in the 1964 Declaration of Helsinki.

Ethical approval This study was approved by the Institutional Review Board under ID: 22–000581.

Informed consent Informed consent was obtained from all individual participants included in this study.

Competing interests The authors declare no competing interests.

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