Systematic Review of the Use of Power Doppler Ultrasound in the Imaging of Peripheral Nerve Compression Neuropathy

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Background: Power Doppler ultrasonography has been used as an adjunct in the diagnosis of peripheral nerve compression neuropathy. To better characterize its sensitivity and specificity, the authors performed a systematic review of its use in carpal and cubital tunnel syndrome diagnosis.

Methods: The authors systematically reviewed published literature on the use of power Doppler ultrasound to diagnose peripheral compression neuropathy using Ovid MEDLINE, Embase.com, Scopus, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effects, Health Technology Assessment Database, NHS Economic Evaluation Database, World Health Organization International Clinical Trial Repository Platform, and Clinicaltrials.gov. No filters for language, date, or publication type were used.

Results: After reviewing 1538 identified studies, 27 publications were included involving 1751 participants with compression neuropathy (2048 median and 172 ulnar). All but three studies examined patients with carpal tunnel syndrome. Heterogeneity between study design and methodology was a noted limitation. Sensitivity and specificity of power Doppler ultrasound in the diagnosis of carpal tunnel syndrome ranged from 2.2 to 93.4 percent, and 89 to 100 percent, respectively, whereas sensitivity for cubital tunnel syndrome was 15.3 to 78.9 percent. There was variability in power Doppler signal detection based on location, with higher sensitivities at the carpal tunnel inlet and in areas of increased nerve swelling.

Conclusions: Power Doppler ultrasound is unreliable as a screening test but appears to increase diagnostic accuracy of ultrasonography in compression neuropathies. It is most beneficial in moderate to severe disease and may be valuable in detecting early cases and in disease surveillance. (*Plast. Reconstr. Surg.* 149: 48e, 2022.)

Carpal tunnel syndrome affects 3 to 10 percent of the general population and costs over $2 billion annually in the United States,[1–4] whereas cubital tunnel syndrome affects 2 to 6 percent of the population.[5] Electrodiagnostic studies are used to confirm the diagnosis of entrapment neuropathies and distinguish severity, yet other modalities are being used to characterize neural pathology.[4] Ultrasonography is a popular diagnostic alternative given its lower cost and superiority in accessibility, ease of use, and patient comfort compared with electrodiagnostic studies.[6]

Understanding the pathogenesis of compression neuropathy is important in recognizing the value of ultrasonography features in its diagnosis. Mechanical compression leads to vascular compromise, causing venous outflow obstruction, then nerve edema, and finally arteriovenous obstruction of the epineural and intraneural vascular networks, eventually leading to ischemia and fibrosis

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in severe disease.[7,8] The relation of this process to ultrasonographic findings has been described previously, occurring in three phases: phase 1, hypervascularity caused by arteriovenous dilation and neovascularization as compensation for vascular impairment; phase 2, nerve edema causing swelling of the nerve and increased cross-sectional area; and phase 3, nerve flattening secondary to fibrosis and scarring.[7,8] Ultrasonography measurement of nerve cross-sectional area is a reliable screening test for carpal tunnel syndrome and is comparable to nerve conduction studies in sensitivity and specificity, but does not predict severity.[9,10]

Power Doppler ultrasound is more sensitive than color or spectral Doppler sonography in detection of intraneural blood flow.[11,12] In normal nerve, intraneural vessels are too small to detect; thus, identification by power Doppler ultrasound is thought to be associated with inflammation, leading to venous congestion, hyperemia, and neovascularization.[7,9,12,13] Detection of intraneural vascularity increases the accuracy of ultrasonographic diagnosis of peripheral nerve compression when combined with other parameters[9,14] but with unclear sensitivity and specificity. The aims of this systematic review are (1) to determine the sensitivity and specificity of power Doppler ultrasound in the diagnosis of peripheral compression neuropathy, and (2) to evaluate its diagnostic utility in clinical practice.

PATIENTS AND METHODS

We systematically reviewed published literature discussing the use of power Doppler ultrasound to diagnose peripheral compression neuropathy. We created search strategies using combinations of keywords and controlled vocabulary in Ovid MEDLINE, Embase.com, Scopus, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effects, Health Technology Assessment Database, NHS Economic Evaluation Database, World Health Organization International Clinical Trial Repository Platform, and Clinicaltrials.gov. No filters or limits were used. All searches were completed in January of 2020. A total of 2134 results were identified; 596 were discarded using a modified version of the deduplication processes described by Bramer et al.,[15] resulting 1538 unique records. Totals for each phase can be found in the Appendix. (**See Appendix, Supplemental Digital Content 1**, which shows fully reproducible search strategies for each database and deduplication results, ***http://links.lww.com/PRS/E774***.) Additional manual search resulted in inclusion of two articles. A limited search to identify new literature published through June of 2020 added one article.

Two author groups evaluated publications. Disagreements were settled by the senior author. All publication types were considered, including review articles and abstracts. Duplicate citations were excluded, as were abstracts with insufficient information to evaluate critically. Studies using power Doppler ultrasound to diagnose compression neuropathy of any peripheral nerve in adult human subjects were included. Articles studying special populations only, especially those associated with neuropathy (i.e., patients with rheumatoid arthritis or endocrinopathies), were excluded to minimize confounding variables. However, in one article, the control group was a population with idiopathic carpal tunnel syndrome, and results from this group were included.[16]

An expanded version of the data extraction elements presented by Wright et al. was created to identify key aspects for our review.[17] Pertinent items included details of study design, enrollment, location, population, control group, intervention, reference standard, technical aspects of power Doppler ultrasound assessment, method of evaluating power Doppler signal, and outcome measures. Study quality was graded systematically using standardized methods.[17,18] Efforts were made to identify and consider the impact of potential biases, methodology and data presentation using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement and checklist for diagnostic test accuracy.[18]

RESULTS

Our search yielded 1538 unique citations, with two added from a manual search. Of these, 1444 were excluded for not meeting inclusion criteria. The 94 remaining articles were evaluated and 26 were ultimately included in the review. Another article was included on limited search of newly published literature through June of 2020 (Fig. 1). One article is a systematic review that discusses three of the included studies.[19] Our review therefore consists of 27 publications representing 26 different studies.

Characteristics of Included Studies

Study Design

The majority of investigations were case-control, four were cohort studies,[20–23] and two were case-series design (Tables 1 and 2).[7,8,11,13,16,20–40]

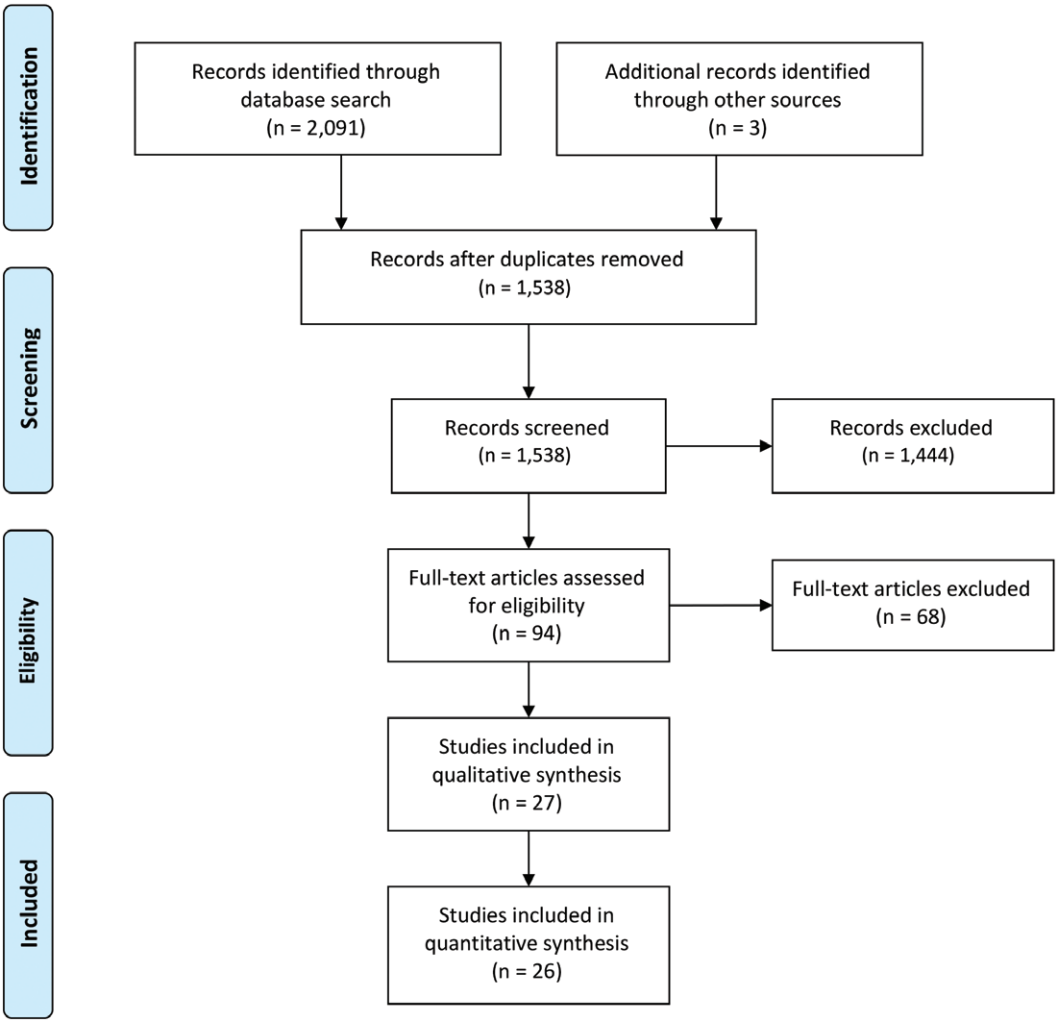

Fig. 1. Flowchart of selection of articles included in the systematic review.

Patient selection was prospective in all but three studies.[20,24,29] Four were longitudinal studies lasting 3,[20] 6,[7,35] and 36 months,[23] respectively. The rest were cross-sectional studies, and only a few were multicenter.[38,40]

Population

Studies evaluated a total of 2220 extremities in 1751 patients diagnosed with or suspected of having compression neuropathy of the median (2048 in 1582 patients) or ulnar nerve[13,39,40] (172 in 169 patients). Typical inclusion criteria were adult patients with suspected or confirmed diagnosis of idiopathic carpal tunnel syndrome or cubital tunnel syndrome. Most patients were female and aged 40 to 60 years, which is consistent with disease prevalence of carpal tunnel syndrome.[2,8] Aseem et al. studied patients with clinically suspected carpal tunnel syndrome but negative electrodiagnostic studies.[24] One retrospective study evaluated response to steroid injection therapy in patients with moderate to severe carpal tunnel syndrome.[20] Patient cohorts in at least two studies were obese.[24,31] One group used the same cohort for two similar studies.[29,30]

Control Group

Almost all control groups consisted of asymptomatic volunteers, predominantly women, although at least a few studies did not provide demographically matched cohorts.[24,29–31]

Comparator

Clinical diagnosis was the reference standard in nine studies,[16,24,27,31–33,38–40] and electrophysiologic diagnosis was the reference standard in the rest. Almost all studies compared power Doppler ultrasound with at least one other form of ultrasound, whereas some compared it to electrodiagnostic studies,[7,8,11,13,20–23,25–27,29–39] magnetic resonance imaging,[25] patient-reported outcomes,[7,20,23,35] or other measures.

Table 1. Studies Included in Systematic Review of the Diagnostic Value of Power Doppler Ultrasound in Carpal and Cubital Tunnel Syndromes

	CTS		Control					
Reference	No. of Wrists	No. of Patients	No. of Wrists	No. of Participants	PD Measure	Sensitivity	Specificity	Accuracy
Akcar et al., 2010[11]	62	42	33	33	Signal/vessel count	48.4	100	66.3
Aseem et al., 2017[24]	22	14	N/A	N/A	Semiquantitative*	7.1	100	NC
Bagga et al., 2019[25]	45	26	32	19	No explanation	2.2	100	43.4
Borire et al., 2017[26]	67	43	40	20	Quantitative software†/ semiquantitative‡	49.3	100	68.2
Chen et al., 2017[27]	50	50	25	25	Semiquantitative§	60	68	62.7
Dejaco et al., 2013[28]	270	135	40	22	Semiquantitative‡	41	90	NC
El Miedany et al., 2015[7]	233	233	112	112	Semiquantitative‡	NC	NC	NC
Evans et al., 2012[29]	83	47	83	44	+/−	NC	NC	NC
Evans et al.. 2012[30]	83	47	83	44	+/−	NC	NC	NC
Gamil et al., 2020[31]	87	61	57	30	+/−	75.8	100	85.4
Ghasemi-Esfe et al., 2011[32]	85	85	49	49	+/−	81.2	89.9	84.3
Ghasemi-Esfe et al., 2011[33]	101	101	55	55	Signal/vessel count	83.2	89.1	85.2
Guillen Astete et al., 2014[20]	166	166	N/A	N/A	No explanation	NC	NC	NC
Kapuścińska and Urbanik, 2015[21]	62	62	N/A	N/A	+/−	80.7	NC	NC
Karahan et al., 2018[22]	113	80	N/A	N/A	Semiquantitative§	70.1	NC	NC
Kutlar et al., 2017[34]	121	71	100	50	Quantitative software‖	93.4	90	NC
Marschall et al., 2016[23]	119	111	88	88	Semiquantitative‡	62.1	90.9	74.4
McDonagh et al., 2015[35]	40	29	23	12	No explanation	65.8	95.7	76.2
Mohamed et al., 2014[8]	71	51	50	50	Signal/vessel count	49.3	100	NC
Mohammadi et al., 2012[36]	90	60	54	27	+/−	54.4	100	71.5
Nam et al., 2019[37]	14	9	20	10	Quantitative software¶	64.3	80	79.5
Smerilli et al., 2019[16]	24	19	N/A	N/A	Semiquantitative‡	62.5	NC	NC
Zidan et al., 2013[38]	40	40	20	20	+/−	77.5	100	NC

CTS, carpal tunnel syndrome; PD, power Doppler; N/A, not applicable; NC, not calculated; +/−, grading signal as positive or negative.
*Vascularity rated as 2/increased if more than two areas showed flow, 1/slightly increased if one or two areas showed flow, 0/normal when there was no power Doppler signal.
†Quantitative grading of maximum pixel intensity.
‡Power Doppler signals graded 0–3 (0 = no power Doppler signal, 1 = one single vessel within the median nerve, 2 = two or three single or two confluent vessels, 3 = more than three single or more than two confluent vessels).
§Power Doppler signals graded 0–3 (0 = no power Doppler signal, 1 = one or two color spots, 2 = one linear color encoded line or more than two focal color spots, 3 = more than one linear color encoded line).
‖Quantitative grading of sum of signal area.
¶Quantitative grading of pixel count.

Intervention

All included studies used power Doppler ultrasound either alone or in combination with other diagnostic methods. Most studies used both grayscale and power Doppler ultrasound, whereas some used multiple ultrasonography settings to detect flow, including color Doppler, spectral Doppler, and superb microvascular imaging, either to confirm power Doppler signals[8,11,13,26,29,30,32,33,36,38] or compare ultrasonography techniques.[22,27,37] The majority of studies used electrodiagnostic studies for confirmation of diagnosis, stratification of patients by disease severity, or comparison with ultrasonographic results. Studies involving longitudinal follow-up evaluated power Doppler ultrasound at multiple time points, ranging from 1 week to 36 months after treatment.[7,23,24,35] The sonographer was almost always blinded to clinical examination and electrodiagnostic studies, and had experience with nerve and/or musculoskeletal ultrasonography.

There was considerable variability in the performance of ultrasonographic examinations. All studies used a linear array transducer. Most

Table 2. Studies Included in Systematic Review of the Diagnostic Value of Power Doppler Ultrasound in Carpal and Cubital Tunnel Syndromes

	CuTS		Control					
Reference	No. of Arms	No. of Patients	No. of Arms	No. of Participants	PD Measure	Sensitivity	Specificity	Accuracy
Frijlink et al., 2013[13]	137	137	24	24	+/−	15.3	95.8	27.3
Hamdy et al., 2019[39]	20	17	20	20	+/−	55	NC	NC
Kowalska, 2015[40]	19	19	N/A	N/A	+/−	78.9	NC	NC

CuTS, cubital tunnel syndrome; PD, power Doppler; +/−, grading signal as positive or negative; NC, not calculated; N/A, not applicable.

performed static evaluation at the carpal tunnel inlet, yet a few[8,11,33] used a scanning method to evaluate intraneural vessels throughout the carpal tunnel. Some took measurements at multiple levels,[23,28–30] and in others, the level of measurement was unclear.[24,25,27,35,39,40] Scan settings were typically standardized, although many articles did not provide specific ultrasonography settings. Twelve studies measured the nerve in transverse and longitudinal planes, eight measured the nerve in a single plane only,[27,28,30,36,37,39] and it was unclear in the others.[7,16,23,24,35,39] Bilateral assessment was performed in 17 studies.[8,11,16,22,24–26,28–31,34–37,39]

Evaluation of Intraneural Vascularity

Multiple sources used semiquantitative signal grading to assess vascularity,[7,8,11,16,22–24,26–28,36] although more than one scale was described. Others used computer software to quantitatively evaluate the area of vascular flow[34] or pixel intensity,[26,37] although a few investigators either counted power Doppler signals,[8,32,36] or used the presence or absence of visible signal as a binary metric.[13,21,29–32,36,38–40] One study only counted intraneural power Doppler signals visualized before signals in other structures, particularly the flexor tendons.[24]

Outcomes

Most studies were designed to evaluate the diagnostic accuracy of power Doppler signals and/or other ultrasound parameters in the diagnosis of carpal tunnel syndrome. Outcomes typically targeted measures of accuracy, such as sensitivity, specificity, and positive and negative predictive values. Some studies examined the ability of power Doppler ultrasound to classify disease severity.[7,8,11,13,22,26–28,33,34,36,38] Multivariate and linear regression analyses of diagnostic factors were performed in a few studies.[31,32,36] Some researchers looked at accuracy in detecting prognosis of treatment and patient satisfaction.[7,20,23,35]

Biases

Risks of biases were considered in the interpretation and applicability of results. Retrospective selection of patients in three studies[20,28,29] could lead to verification and detection biases. The location of study and patient enrollment could promote selection bias, as studies were performed in 13 countries and patient selection occurred in various departments, including orthopedics,[31] neurosurgery,[21] rheumatology,[16,38] neurology,[8] physical therapy,[11] and neurophysiology,[29,30] among others. Confounding bias is possible when comparing nonidentical populations. Most studies focused on idiopathic carpal tunnel syndrome with strict exclusion criteria to minimize bias from other contributory diseases, whereas others were less stringent.[25,28]

Variation in methodology is a potential source of bias, particularly in the grading of power Doppler signal. We attempted to limit publication bias by including all studies that met inclusion criteria and had sufficient detail to evaluate methodology.

Diagnostic Value of Power Doppler Ultrasound

The diagnostic accuracy of power Doppler ultrasound was satisfactory in most studies; however, the large range in sensitivity (2.2 to 93.4 percent and 15.3 to 78.9 percent for carpal tunnel syndrome and cubital tunnel syndrome, respectively) suggests a limited role as a standalone screening test (Table 1). The higher specificity (68 to 100 percent) and positive predictive value (69.2 to 100 percent), along with rare detection of power Doppler signals in confirmed healthy control subjects, reinforces its value as a confirmatory test. It adds value to other diagnostic methods, as evidenced by multiple studies showing improved accuracy when intraneural hypervascularity was combined with other diagnostic findings.[7,11,21,24–28,31–36,38] Several studies showed significant correlation with disease severity.[7,8,11,13,28,33,34,36,38,39] However, increased intraneural vascularity appears to have limited value in prolonged, severe cases with advanced neurologic disease,[7,21,24,25] which suggests that it may be related to acute or ongoing inflammatory changes. The value in monitoring treatment response and longitudinal follow-up also seems promising.

DISCUSSION

Overall, the diagnostic accuracy of power Doppler ultrasound is promising, although the wide range in sensitivity dampens enthusiasm for its reliability and reproducibility as an independent screening test. The higher specificity and positive predictive values, along with rare detection of power Doppler signals in healthy nerves, suggest that power Doppler ultrasound is a valuable confirmatory test in carpal tunnel syndrome. This should be interpreted cautiously, however, because many studies used healthy volunteers rather than patient controls, and inclusion in the analysis may artificially inflate these results. Dejaco et al. introduced a semiquantitative method of grading power Doppler signal, which elevated the threshold for confirmation to

reduce false-negative results and increase specificity but at the expense of sensitivity.[28] They evaluated 270 wrists in 135 patients, and specificity was 90 percent for power Doppler score greater than 2. They also found that power Doppler ultrasound was more sensitive at the point of maximal swelling rather than the carpal tunnel inlet. Their semiquantitative scale[7,16,23,26,28] or a similar grading method was used by multiple investigators.[8,11,22,24,27,33] Of these, Chen et al. reported the lowest specificity (≥80 percent in remaining studies), detecting power Doppler signals in eight of 25 healthy volunteers.[27]

In evaluation of carpal tunnel syndrome, the highest sensitivity of power Doppler ultrasound (93.4 percent) was reported by Kutlar et al., who evaluated 171 wrists with electrodiagnostic study–confirmed carpal tunnel syndrome and 100 control wrists from 50 healthy volunteers.[34] In contrast, two studies reported exceptionally low sensitivities.[24,25] Bagga et al. evaluated 45 wrists in 26 patients and 43 wrists in 19 healthy volunteers[25]; power Doppler flow was found in one patient with severe carpal tunnel syndrome. The low sensitivity reported could be related to the underlying cause of carpal tunnel syndrome; more than half of the patients had at least one medical comorbidity associated with carpal tunnel syndrome (e.g., hypothyroidism, diabetes mellitus, rheumatoid arthritis, presence of cysts, tenosynovitis, bifid median nerve). In addition, the range of patient symptoms was 1 month to 20 years (mean, 1.89 years), with most patients having severe disease. Although power Doppler signals are often found in moderate to severe disease,[33,38] intraneural hypervascularization occurs because of neovascularization during the acute phase of inflammation and nerve swelling, followed by ischemia and fibrosis with prolonged compression. It would seem plausible that power Doppler signal would not be detected in very early or longstanding disease, as was shown in a few studies.[7,21,24,26,38] Aseem et al. evaluated 22 wrists in 14 patients with strong clinical symptoms but negative nerve conduction studies, and noted relatively low sensitivity in this cohort using a semiquantitative grading method.[24] In the remaining studies, sensitivity of power Doppler ultrasound for carpal tunnel syndrome was 41 to 93 percent.

Power Doppler ultrasound often correlates with grayscale ultrasonography and electrodiagnostic studies in carpal tunnel syndrome diagnosis and determination of disease severity; however, there is insufficient evidence to suggest it is reliable enough to replace either of these methods.[7,8,22,26,28,31–34,38] Rather, multiple studies have shown an increase in diagnostic accuracy when intraneural vascularity identified with power Doppler ultrasound was combined with other ultrasonographic assessments (e.g., cross-sectional area, change in cross-sectional area, echogenicity) or electrodiagnostic studies.[7,11,20,21,26–28,31–36,38] Gamil et al. demonstrated agreement between power Doppler ultrasound, electrodiagnostic studies, and grayscale ultrasonographic findings, and determined that combining measurements of nerve swelling and power Doppler ultrasound increased the diagnostic accuracy to as high as 99 percent in patients with suspected idiopathic carpal tunnel syndrome.[25] This aligns with previous studies demonstrating the role of hypervascularity in combination with other findings.[9,14] Zidan et al. also found that power Doppler ultrasound improved the accuracy of ultrasonography when combined with other measures; furthermore, it was the most accurate ultrasonographic finding and the only measure that could predict median nerve compression independently.[38]

The value of power Doppler ultrasound in predicting outcomes and monitoring recovery to treatments has also been investigated[7,20,23,35] with mixed results, although there seems to be sufficient evidence to recommend its use in planning treatment and monitoring recovery. El Miedany et al. performed power Doppler ultrasound and grayscale ultrasonographic examinations of 233 wrists with carpal tunnel syndrome at baseline and at 1 week, 2 weeks, and 6 months after treatment (118 surgical and 115 nonsurgical treatment).[7] Carpal tunnel syndrome functional status and visual analogue scale pain questionnaires were completed at each visit along with electrodiagnostic studies at baseline and at 6 months. Power Doppler ultrasound was the first variable to show improvement at 1 week after treatment through 1 month, before reaching a plateau, suggesting a correlation with an acute inflammatory process. Higher power Doppler scores also predicted better response to surgical and nonsurgical treatment, which was attributed to early intervention, as both correlated with disease duration. Electrodiagnostic studies did not show significant improvement, presumably because of structural damage to the nerve compared to transient inflammation. Another study retrospectively evaluated clinical outcomes after steroid injection in 166 wrists with moderate to severe carpal tunnel syndrome to determine predictors of improved Boston Carpal Tunnel Questionnaire scores at 3 months and found that therapeutic success highly

correlated with power Doppler signal at diagnosis.[20] This agrees with findings from a prospective study of 40 wrists assessing response to treatment with ultrasonography and electrodiagnostic studies in which only power Doppler ultrasound had significant correlation with improvement in Boston Carpal Tunnel Questionnaire and visual analogue scale pain scores at 6 weeks.[35] In contrast, one study evaluated clinical outcomes using the Disabilities of the Arm, Shoulder and Hand instrument; the Boston Carpal Tunnel Questionnaire; and visual analogue scale pain and physician assessment questionnaires, finding no significant correlations with semiquantitatively graded power Doppler signals.[23]

The application of power Doppler ultrasound in cubital tunnel syndrome is less clear. Frijlink et al. studied 161 patients with clinically suspected cubital tunnel syndrome.[13] This study used color Doppler to detect intraneural vascularization of the ulnar nerve, supplemented by power Doppler ultrasound to confirm flow when presence of vascularity was uncertain. Therefore, results must be considered to reflect intraneural vascularity detected by Doppler ultrasonography, and not necessarily power Doppler ultrasound. Sensitivity and specificity were 15.3 percent and 95.8 percent, respectively. Detection of intraneural vascularity was associated with worse disease determined by electrodiagnostic studies, greater weakness and muscle atrophy, and larger ulnar nerve cross-sectional area and longitudinal diameter. Kowalska reported the use of power Doppler ultrasound to diagnose cubital tunnel syndrome in 15 patients and found a sensitivity of 78.9 percent.[40] Hamdy et al. evaluated 20 elbows, and power Doppler signal was positive in 11 (55 percent sensitive), which demonstrated a positive correlation with electrodiagnostic studies.[39] Although these studies show some utility in using power Doppler ultrasound to diagnose cubital tunnel syndrome, further investigation is warranted.

The variation in sensitivity is likely attributable to multiple factors, including technique; diverse patient populations and inclusion/exclusion criteria; and disparities in sample size, equipment, definition of power Doppler signal, operator training, and experience with power Doppler ultrasound. Obesity and decreased vascularity in advanced age are theoretical patient factors that could lower sensitivity; however, we did not find significant data to support this. Furthermore, because intraneural hypervascularization is considered pathologic, this would improve specificity in these populations. It should be noted that variables such as limb and ambient temperature, and limb position may affect results. Most investigators aimed to mitigate these effects with standardized examination methodologies.[7,8,11,13,23,24,26–34,36] A limitation of ultrasonography, especially power Doppler ultrasound, is operator-dependent accuracy. Most studies attempted to limit this effect on results by using sonographers experienced in nerve and musculoskeletal ultrasonography techniques[7,11,13,22–24,26–33,36,39,40] and comparing interobserver and/or intraobserver reliability, which ranged from 0.47 to 0.78 and 0.65 to 0.85, respectively.[7,23,26–28,32] In addition to adequate training and practice with ultrasonography, incorporating power Doppler ultrasound detection of intraneural hypervascularity may enhance the sonographer's capacity to detect disease above ultrasonography alone. A significant limitation of this systematic review is the heterogeneity of study methodologies and scoring as described previously. Although these differences preclude meta-analysis of data, we believe that this strengthens the review overall by exploring the effects of these differences and the range of utility and limitations of power Doppler ultrasound in compression neuropathy. Future efforts to define and standardize the examination and a severity-stratified scoring system will be important in making power Doppler ultrasound universally acceptable and reliable in the diagnosis of compression neuropathies.

Despite some limitations, power Doppler ultrasound is a noninvasive, cost-effective means to enhance the accuracy of ultrasonographic assessment without adding significant time to the examination. It has particular value over ultrasonography in providing some stratification of disease severity and in longitudinal assessment of treatment response. Therefore, addition of power Doppler examination may make ultrasonographic evaluation more appropriate in confirming suspected cases, stratifying disease severity, surgical planning, and monitoring posttreatment response, reducing the need for more costly and painful electrodiagnostic studies.

CONCLUSIONS

The majority of the literature on the use of power Doppler ultrasound in the diagnosis of peripheral nerve entrapment focuses on carpal tunnel syndrome, with a relative paucity for cubital tunnel syndrome. Most studies validate the use of power Doppler ultrasound as a confirmatory test, particularly in moderate to severe disease and for detecting hypervascularity in early stages of compression. Power Doppler ultrasound

is superior to electrodiagnostic studies in evaluating recovery and appears to be a sensitive method for determining response in the early posttreatment period, supporting its potential in disease surveillance. Additional investigation into the best quantification method of intraneural vascularity is needed along with guidelines to identify diagnostic thresholds for power Doppler ultrasound. Development of a standardized examination method and proper instruction of clinicians are also important steps in making power Doppler ultrasound universally acceptable and reliable in the diagnosis of compression neuropathies.

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