A Survey of the Use of Ultrasound by Upper Extremity Surgeons

HAND
2017, Vol. 12(1) 31–38
© American Association for
Hand Surgery 2016
DOI: 10.1177/1558944716646779
hand.sagepub.com

William L. Wang¹, Kevin Kruse¹, and John R. Fowler¹

Abstract

Background: Ultrasound is a versatile imaging modality that can be used by upper extremity surgeons for diagnostic purposes and guided injections. The perceptions of ultrasound for diagnosis and treatment among upper extremity surgeons and its barriers for adoption have not been formally surveyed. The purpose of this study is to determine the current usage of musculoskeletal ultrasound for diagnostic purposes and guided injections by upper extremity surgeons and their reasons for using it or not using it in practice. **Methods:** A 22-question survey was distributed to the American Society for Surgery of the Hand (ASSH). The survey questions consisted of respondent characteristic questions and questions pertaining to the use of ultrasound. Chi-square analysis was performed to assess for a difference in ultrasound usage across respondent characteristics. **Results:** Three hundred four (43%) answered that they have an ultrasound machine in their office; Fifty-one percent (362) of the respondents use ultrasound for diagnostic purposes. Fifty-five (8%) of the survey respondents use ultrasound to diagnose carpal tunnel syndrome; 168 (23.5%) respondents reported that they use ultrasound for guided injections. There was a statistically significant difference between access to an ultrasound machine in the office by practice setting and use of ultrasound for diagnostic purposes by practice setting. **Conclusions:** The use of ultrasound by upper extremity surgeons is split for diagnostic purposes, with fewer surgeons using ultrasound to diagnose carpal tunnel syndrome and guided injections. Ultrasound machine availability and the use of ultrasound for diagnosis appear to be influenced by practice setting.

Keywords: ultrasound, hand, upper, extremity, survey

Introduction

Ultrasound is a versatile imaging modality that can be used by upper extremity surgeons for diagnostic purposes and guided injections. Previous studies have demonstrated its ability to diagnose a variety of upper extremity conditions, such as carpal tunnel syndrome^{5-7,9,10,12,21-23} and rotator cuff injuries.^{1,8,17,19} A recent prospective study found ultrasound had a better specificity and equal sensitivity compared with nerve conduction studies in a group of patients with clinical evidence of carpal tunnel syndrome.⁷ A meta-analysis performed by de Jesus et al found that ultrasound and magnetic resonance imaging (MRI) had comparable sensitivity and specificity for diagnosis of full-thickness rotator cuff tears.³ Roy et al suggested that ultrasound was a better option compared with MRI and magnetic resonance arthrography when considering accuracy, cost, and safety.¹⁶

Although accuracy of therapeutic injections is a multifactorial process that is dependent on physician experience and anatomic region, previous studies have found ultrasound-guided injections to be superior in accuracy compared with palpation-guided injections in the shoulder,^{2,4,14,15,20} elbow,² and hand joints.^{2,11} Ultrasound-guided injections also have the

benefit of being a diagnostic modality in addition to therapeutic intervention. Some studies have found that ultrasound-guided injections are associated with better clinical outcomes compared with palpation-guided injections. A randomized clinical trial demonstrated a statistically and clinically significant improvement in shoulder pain and function 6 weeks after injection with ultrasound guidance compared with landmark guidance.¹⁸ A retrospective clinical study concluded that ultrasound-guided acromioclavicular joint injections for osteoarthritis resulted in better pain and functional status at 6 months follow-up compared with palpation-guided injections.¹³

The perceptions of ultrasound for diagnosis and treatment among upper extremity surgeons and its barriers for adoption have not been formally surveyed. The purpose of this survey study is to determine the current usage of musculoskeletal ultrasound by upper extremity surgeons and

¹Department of Orthopedics, University of Pittsburgh, PA, USA

Corresponding Author:

John R. Fowler, Assistant Professor, Department of Orthopaedic Surgery, University of Pittsburgh, Suite 1010, Kaufmann Bldg., 3471 Fifth Ave., Pittsburgh, PA 15213, USA.
Email: fowlerjr@upmc.edu

Figure 1. Exclusion criteria flow chart.

their reasons for using it or not using it. We will also analyze hand surgeon responses across demographic factors to assess whether or not these factors may influence ultrasound usage. The goal of the study is to provide a cross sectional overview of the current use and perceptions of ultrasound among upper extremity surgeons.

Materials and Methods

After obtaining institutional review board approval, a 22-question survey was created using Qualtrics survey software. The survey questions consisted of respondent characteristic questions and questions pertaining to ultrasound usage (see Appendix). After approval from the American Society for Surgery of the Hand (ASSH), the survey was sent to 3720 ASSH members through email in September 2015. Participation was voluntary and access to the survey was granted through invitation only. A second reminder email was sent 7 days after the initial email. The survey was closed after 14 days. The survey results were compiled and analyzed using SPSS statistical software.

Exclusion criteria were applied after the survey was conducted. Incomplete surveys were excluded from our analysis. Since we wanted to include responses only from practicing surgeons, respondents who answered "No" on Question 1 (see Appendix) and answered "I am not currently practicing surgery" on Question 5 (see Appendix) were also excluded.

We performed chi-square analysis to compare ultrasound usage across respondent characteristics. We compared ultrasound availability, ultrasound use for diagnostic purposes, and ultrasound use for guided injections across practice setting. Respondents who answered "Other" for practice

setting were excluded from this chi-square analysis as we could assume category homogeneity. Similarly, we performed cross tabulation and chi-square analysis between ultrasound use for diagnostic purposes and ultrasound use for guided injections across number of years post-training.

Results

A total of 3720 email invitations were sent to the ASSH membership list and 3655 emails were successfully delivered. We received 801 responses, yielding a response rate of 22%. Please refer to Figure 1 for a flowchart of the exclusion criteria. After the exclusion criteria were applied, a final sample size of 714 (19%) respondents remained for further analysis.

Respondent Characteristics

Please refer to Table 1 for a description of the survey respondent residency and fellowship backgrounds. Of the 692 respondents who completed a residency, 95 (14%) of them completed their training 0 to 2 years ago, 95 (14%) 3 to 5 years ago, 74 (11%) 6 to 10 years ago, 95 (14%) 11 to 15 years ago, and 333 (48%) more than 16 years ago. Please refer to Table 2 for a description of practice type.

General Ultrasound Questions

Three hundred four (43%) answered that they have an ultrasound machine in their office. Fifty-one percent (362) of the respondents use ultrasound for diagnostic purposes. Of the 363 respondents who use ultrasound for diagnostic purposes, 32 (9%) have been using ultrasound for diagnostic purposes

Table 1. Respondent Residency and Fellowship Background.

Residency	n (%)
Orthopedic surgery residency completed	576 (81)
Orthopedic surgery residency in progress	17 (2)
Other residency completed	116 (16)
Other residency in progress	5 (<1)
Fellowship	
Fellowship completed	663 (96)
Fellowship in process	16 (2)
Fellowship not completed	13 (2)
Fellowship specialty (completed or in progress)	
Hand/upper extremity	669 (99)
Sports medicine/shoulder	1 (<1)
Other	9 (<1)

Table 2. Survey Respondent Practice Setting.

	n (%)
Small private practice (0-10 persons)	241 (34)
Medium private practice (11-20 persons)	95 (13)
Large private practice (>21 persons)	104 (15)
Academics	217 (30)
Other	57 (8)

for less than 1 year, 133 (37%) for 1 to 3 years, 55 (15%) for 3 to 5 years, 142 (39%) for more than 5 years.

Ultrasound in Diagnosing Carpal Tunnel Syndrome

Fifty-five (8%) of the survey respondents use ultrasound to diagnose carpal tunnel syndrome. Of those who use ultrasound to diagnosis carpal tunnel syndrome, 32 (58%) utilize it for patient comfort, 29 (53%) for ease of use, 27 (49%) for good accuracy, and 21 (38%) answered "Other." For those who said they do not use ultrasound to diagnosis carpal tunnel syndrome, 328 (50%) answered it was because ultrasound is not as accurate as nerve conduction studies, 210 (32%) said it was because they do not have an ultrasound machine in their office, 156 (24%) want to evaluate other nerves with the conduction studies, 144 (22%) said it was because they cannot evaluate the severity, 141 (21%) answered they are too busy to use ultrasound in the office for diagnostic purposes, and 153 (23%) answered "Other." Of the respondents who answered "Other," 48 of the respondents mentioned in the textbox that ultrasound is not necessary for the diagnosis of carpal tunnel syndrome.

Ultrasound-Guided Injections

One hundred sixty-eight (23.5%) respondents reported that they use ultrasound for guided injections. For those who do

Table 3. Question 19: If You Use Ultrasound for Guided Injections, in Which Areas Do You Use It for?

	n (%)
1st carpometacarpal joint	83 (49)
Carpal tunnel	75 (45)
Small joints of the hand	73 (43)
Long head biceps	68 (40)
1st dorsal compartment	68 (40)
Subacromial	58 (35)
Lateral epicondyle	57 (34)
Acromioclavicular joint	54 (32)
Glenohumeral joint	52 (31)
Medial epicondyle	42 (25)
Trigger finger	41 (24)
Radial tunnel	30 (18)
Cubital tunnel	27 (16)
Other	28 (17)

not use ultrasound for guided injections, 377 (69%) do not think ultrasound is necessary for guided injections, 232 (42%) answered it is because they do not have an ultrasound machine in their office, 60 (11%) reported lack of confidence in using ultrasound-guided injections, and 71 (13%) answered "Other." For those who use ultrasound for guided injections, 159 (95%) do it for improved accuracy, 72 (43%) for patient satisfaction, and 21 (13%) answered "Other." Please refer to Table 3 for a description of the anatomical areas in which ultrasound-guided injections are reported to be performed.

Ultrasound in Diagnosing Shoulder Pathology

Three hundred twenty-seven (46%) of the respondents said that they treat shoulder pathology in their practice. Of these 327 respondents, 159 (49%) answered that they would be comfortable recommending surgery for a full-thickness rotator cuff tear with ultrasound as the only soft tissue imaging. Eighty-eight (27%) were comfortable recommending surgery for a partial thickness rotator cuff tear with ultrasound as the only soft tissue imaging. For those who stated that they were not comfortable using ultrasound as the only soft tissue imaging prior to recommending surgery for full-thickness or partial thickness tears, 151 (62%) said it was because of their lack of confidence in being able to determine the reparability of the tear with ultrasound, 128 (52%) said they lack the confidence in diagnosing the tear, 67 (28%) reported it was because they did not have access to an ultrasound machine, 39 (16%) said it was because they were too busy to use ultrasound in the office, and 34 (14%) selected "Other." Finally, of the 328 respondents who treat shoulder pathology in their practice, 54 (7.5%) use ultrasound to evaluate post-operative rotator cuff repairs and 39 (5.4%) use ultrasound to evaluate the rotator cuff in post-operative shoulder arthroplasty patients.

Figure 2. Access to ultrasound machine in office between practice setting.

Figure 3. Use of ultrasound for diagnostic purposes between practice setting.

Figure 4. Use of ultrasound for guided injections between practice setting.

Chi-Square Analysis

Please refer to Figures 2 to 6 for the cross tabulated frequencies and percentages between respondent characteristics (practice type and number of years post-training) and ultrasound use. Please refer to Table 4 for the corresponding chi-square analysis results.

Figure 5. Use of ultrasound for diagnostic purposes between number of years post-training.

Discussion

Despite evidence that ultrasound is a cost-effective and accurate diagnostic modality for a variety of upper extremity conditions, the majority of respondents to our survey do not have personal access to an ultrasound machine in the office setting. Despite less access to ultrasound, academic surgeons are more likely to use ultrasound for diagnostic purposes compared with surgeons in small, medium, and large private practices. The differences however, are not particularly significant, which suggests that physician preference for the use of ultrasound does not impair diagnosis. The majority of the respondents in our survey do not use ultrasound as a modality to diagnose carpal tunnel syndrome. The primary reason that our respondents did not use ultrasound to diagnose carpal tunnel syndrome was a belief that ultrasound is not as accurate as nerve conduction studies. For the respondents who do use ultrasound to diagnose carpal tunnel syndrome, the majority selected patient comfort as the reason for using ultrasound. Finally, the majority of the respondents in the survey do not use ultrasound for guided injections.

The overall trend of the survey study demonstrates that ultrasound has not been universally embraced by upper extremity surgeons for diagnostic purposes or for therapeutic joint injections, which may be attributed to a variety of factors. There was a trend toward increased access to ultrasound in larger private practice settings. There is a substantial financial investment in owning a portable ultrasound machine and declining reimbursement for diagnostic ultrasound and ultrasound-guided injections may make ownership less feasible from a financial standpoint. With the unpredictable reimbursement trends for office ultrasound evaluation and ultrasound-guided injections, ultrasound machine investment may or may not be cost-effective depending on the region's reimbursement protocol. While questions regarding physician reimbursement with diagnostic ultrasound and ultrasound-guided injections and whether these factors influenced the adoption of ultrasound were not asked in detail in the survey, these may be interesting

Figure 6. Use of ultrasound for guided injections between number of years post-training.

Table 4. Pearson Chi-Square 2-Sided Test.

	Significance value
Access to ultrasound machine in office between practice setting	<.001*
Use of ultrasound for diagnostic purposes between practice setting	.005*
Use of ultrasound for guided injections between practice setting	.177
Use of ultrasound for diagnostic purposes between number of years post-training	.12
Use of ultrasound for guided injections between number of years post-training	.567

* $P < 0.05$.

questions to focus on in future survey studies. Furthermore, performing injections under ultrasound guidance may require a considerable amount of additional time to complete compared with traditional palpation guidance, which may ultimately delay clinic workflow.

There was no statistically significant difference in use of ultrasound for diagnostic purposes or use of ultrasound for guided injections between numbers of years post-training. One hypothesis prior to conducting this survey was that the surgeons who have been in practice many years and have not been trained in the use of ultrasound for diagnosis or joint injections may be more resistant to diverging from traditional methods and adopting the use of ultrasound. However, the survey results suggest that number of years in practice for upper extremity surgeons does not significantly influence the adoption of ultrasound. We were unable to compare ultrasound usage between different training

disciplines because the vast majority of the respondents in our sample were orthopedic residency-trained and hand fellowship-trained surgeons. For future studies, it may be interesting to compare ultrasound usage between different training backgrounds, particularly in the usage of ultrasound in diagnosis or treatment for shoulder pathology between hand fellowship-trained and sports medicine or shoulder fellowship-trained surgeons.

One limitation with this study is response bias, reflected in our survey response rate of 22%. Because our survey invites were conducted through email to a professional society and that participation was voluntary, a low survey response rate should not be unexpected. Email was the most appropriate method of invitation given the purpose of our study. Despite the relatively smaller sample size in our study, we believe we were able to capture a representative sample based on the balanced distribution between the respondent characteristics, such as practice setting and number of years they have been in practice after their residency and fellowship training. Although we do not believe that there was a compromise in survey response quality, the possibility of response bias will need to be taken into consideration when interpreting the data.

Appendix

Ultrasound Survey Questionnaire

Respondent characteristics

- Did you complete an orthopedic surgery residency?
 - Yes
 - No
 - In progress

- d. Other residency completed (Please specify)
 - e. Other residency in progress (Please specify)
2. Did you complete a fellowship after residency?
 - a. Yes
 - b. No
 - c. In progress
 3. In what specialty did you train in (or are currently training in) for your fellowship?
 - a. Hand/upper extremity
 - b. Sports medicine and/or shoulder
 - c. Other (please specify)
 4. How many years ago did you complete your fellowship (or residency, if no fellowship)?
 - a. 0-2 years
 - b. 3-5 years
 - c. 6-10 years
 - d. 11-15 years
 - e. 16 or more years ago
 5. Please select your current practice type:
 - a. Small private practice (0-10 persons)
 - b. Medium private practice (11-20 persons)
 - c. Large private practice (>21 persons)
 - d. Academics
 - e. I am not currently practicing surgery
 - f. Other (please specify)

Ultrasound survey questions

6. Do you have an ultrasound machine in your office?
 - a. Yes
 - b. No
7. Do you use ultrasound for diagnostic purposes?
 - a. Yes
 - b. No
8. How long have you been using ultrasound for diagnostic purposes?
 - a. Less than 1 year
 - b. 1-3 years
 - c. 3-5 years
 - d. More than 5 years
9. Do you use ultrasound to diagnose carpal tunnel syndrome?
 - a. Yes
 - b. No
10. For what reason(s) do you use ultrasound to diagnose carpal tunnel syndrome (select all that apply)?
 - a. Patient comfort
 - b. Ease of use
 - c. Good accuracy
 - d. Other (please specify)
11. For what reason(s) do you not use ultrasound to diagnose carpal tunnel syndrome (select all that apply)?
 - a. I don't have an ultrasound machine in my office
 - b. I don't think it is as accurate as nerve conduction studies
 - c. I can't evaluate the severity
 - d. I want to evaluate other nerves in the upper extremity with nerve conduction studies
 - e. Too busy to use ultrasound in the office for diagnostic purposes
 - f. Other (please specify)
12. Do you use ultrasound for guided injections?
 - a. Yes
 - b. No
13. What is the reason for using ultrasound-guided injection (select all that apply)?
 - a. Improved accuracy
 - b. Patient satisfaction
 - c. Other (please specify)
14. What is the reason for not using ultrasound-guided injection (select all that apply)?
 - d. I don't have an ultrasound machine in my office
 - e. I don't think ultrasound is necessary for injections
 - f. Lack of confidence in using ultrasound for guided injection
 - g. Other (please specify)
15. If you use ultrasound for guided injections, which areas do you use it for (select all that apply)?
 - a. Sub acromial
 - b. Long head biceps
 - c. Glenohumeral joint
 - d. Acromioclavicular joint
 - e. 1st carpometacarpal joint
 - f. Trigger finger
 - g. 1st dorsal compartment
 - h. Lateral epicondyle
 - i. Medial epicondyle
 - j. Cubital tunnel
 - k. Carpal tunnel
 - l. Radial tunnel
 - m. Small joints of the hand
 - n. Other (please specify)

16. Do you treat shoulder pathology in your practice?
 - a. Yes
 - b. No
17. Would you feel comfortable recommending surgery to a patient for a full-thickness rotator cuff tear repair with only ultrasound as your soft tissue imaging?
 - a. Yes
 - b. No
18. Would you feel comfortable recommending surgery to a patient for a partial thickness rotator cuff tear repair with only ultrasound as your soft tissue imaging?
 - a. Yes
 - b. No
19. What is the reason(s) for not using ultrasound as the sole imaging prior to rotator cuff repair surgery (select all that apply)?
 - a. I don't have an ultrasound machine
 - b. Too busy to use ultrasound in the office for diagnostic purposes
 - c. Lack of confidence in diagnosing tear
 - d. Lack of confidence in being able to determine the ability to repair the tear with ultrasound as the only form of soft tissue imaging
 - e. Other (please specify)
20. Do you use ultrasound to evaluate post-operative rotator cuff repairs?
 - a. Yes
 - b. No
21. Do you use ultrasound to evaluate the rotator cuff in post-operative shoulder arthroplasty patients?
 - a. Yes
 - b. No
22. Please make any additional comments about your use of ultrasound in the upper extremity

Acknowledgments

Thanks to Daniel Winger and Li Wang from the Clinical and Translational Science Institute at the University of Pittsburgh for their statistics consultation and their help in designing the survey.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation

(institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent is not applicable to this study as it does not include any patient information. Survey participation in this study was voluntary.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Funding for this study was via internal funding by the University of Pittsburgh Department of Orthopaedics and National Institutes of Health Grant UL1-TR-000005.

References

1. Cholewinski JJ, Kusz DJ, Wojciechowski P, Cielinski LS, Zoladz MP. Ultrasound measurement of rotator cuff thickness and acromio-humeral distance in the diagnosis of subacromial impingement syndrome of the shoulder. *Knee Surg Sports Traumatol Arthrosc.* 2008;16(4):408-414.
2. Cunningham J, Marshall N, Hide G, et al. A randomized, double-blind, controlled study of ultrasound-guided corticosteroid injection into the joint of patients with inflammatory arthritis. *Arthritis Rheum.* 2010;62(7):1862-1869.
3. De Jesus JO, Parker L, Frangos AJ, Nazarian LN. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. *AJR Am J Roentgenol.* 2009;192(6):1701-1707.
4. Ekeberg OM, Bautz-Holter E, Tveitå EK, Juel NG, Kvalheim S, Brox JJ. Subacromial ultrasound guided or systemic steroid injection for rotator cuff disease: randomised double blind study. *BMJ.* 2009;338:a3112.
5. Fowler JR, Gaughan JP, Ilyas AM. The sensitivity and specificity of ultrasound for the diagnosis of carpal tunnel syndrome: a meta-analysis. *Clin Orthop Relat Res.* 2011;469(4):1089-1094.
6. Fowler JR, Maltenfort MG, Ilyas AM. Ultrasound as a first-line test in the diagnosis of carpal tunnel syndrome: a cost-effectiveness analysis. *Clin Orthop Relat Res.* 2013;471(3):932-937.
7. Fowler JR, Munsch M, Tosti R, Hagberg WC, Imbriglia JE. Comparison of ultrasound and electrodiagnostic testing for diagnosis of carpal tunnel syndrome: study using a validated clinical tool as the reference standard. *J Bone Joint Surg Am.* 2014;96(17):e148.
8. Holling A. Sonography of the rotator cuff: an overview. *J Diag Med Sonog.* 2001;17(3):144-150.
9. Kele H, Verheggen R, Bittermann HJ, Reimers CD. The potential value of ultrasonography in the evaluation of carpal tunnel syndrome. *Neurology.* 2003;61(3):389-391.

10. Kwon BC, Jung KI, Baek GH. Comparison of sonography and electrodiagnostic testing in the diagnosis of carpal tunnel syndrome. *J Hand Surg Am.* 2008;33(1):65-71.
11. Lee DH, Han SB, Park JW, Lee SH, Kim KW, Jeong WK. Sonographically guided tendon sheath injections are more accurate than blind injections: implications for trigger finger treatment. *J Ultrasound Med.* 2011;30(2):197-203.
12. Nakamichi K, Tachibana S. Ultrasonographic measurement of median nerve cross-sectional area in idiopathic carpal tunnel syndrome: diagnostic accuracy. *Muscle Nerve.* 2002;26(6):798-803.
13. Park KD, Kim TK, Lee J, Lee WY, Ahn JK, Park Y. Palpation versus ultrasound-guided acromioclavicular joint intra-articular corticosteroid injections: a retrospective comparative clinical study. *Pain Physician.* 2015;18(4):333-341.
14. Patel DN, Nayyar S, Hasan S, Khatib O, Sidash S, Jazrawi LM. Comparison of ultrasound-guided versus blind glenohumeral injections: a cadaveric study. *J Shoulder Elbow Surg.* 2012;21(12):1664-1668.
15. Peck E, Lai JK, Pawlina W, Smith J. Accuracy of ultrasound-guided versus palpation-guided acromioclavicular joint injections: a cadaveric study. *PM&R.* 2010;2(9):817-821.
16. Roy JS, Braën C, Leblond J, et al. Diagnostic accuracy of ultrasonography, MRI and MR arthrography in the characterisation of rotator cuff disorders: a systematic review and meta-analysis. *Br J Sports Med.* 2015;49(20):1316-1328.
17. Rutten MJ, Maresch BJ, Jager GJ, Blickman JG, van Holsbeeck MT. Ultrasound of the rotator cuff with MRI and anatomic correlation. *Eur J Radiol.* 2007;62(3):427-436.
18. Soh E, Li W, Ong KO, Chen W, Bautista D. Image-guided versus blind corticosteroid injections in adults with shoulder pain: a systematic review. *BMC Musculoskelet Disord.* 2011;12:137.
19. Teefey SA, Hasan SA, Middleton WD, Patel M, Wright RW, Yamaguchi K. Ultrasonography of the rotator cuff. A comparison of ultrasonographic and arthroscopic findings in one hundred consecutive cases. *J Bone J Surg.* 2000;82(4):498-504.
20. Ucuncu F, Capkin E, Karkucak M, et al. A comparison of the effectiveness of landmark-guided injections and ultrasonography guided injections for shoulder pain. *Clin J Pain.* 2009;25(9):786-789.
21. Wiesler ER, Chloros GD, Cartwright MS, Smith BP, Rushing J, Walker FO. The use of diagnostic ultrasound in carpal tunnel syndrome. *J Hand Surg Am.* 2006;31(5):726-732.
22. Wong SM, Griffith JF, Hui AC, Lo SK, Fu M, Wong KS. Carpal tunnel syndrome: diagnostic usefulness of sonography. *Radiology.* 2004;232(1):93-99.
23. Ziswiler HR, Reichenbach S, Vogelin E, Bachmann LM, Villiger PM, Juni P. Diagnostic value of sonography in patients with suspected carpal tunnel syndrome: a prospective study. *Arthritis Rheum.* 2005;52(1):304-311.