PRE09: Ultrasound of the Upper Extremity

Chair(s): John R. Fowler, MD and Thomas B. Hughes, MD

Program Syllabus

77TH ANNUAL MEETING OF THE ASSH
SEPTEMBER 29 – OCTOBER 1, 2022

822 West Washington Blvd
Chicago, IL 60607
Phone: (312) 880-1900
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PRE09: Ultrasound of the Upper Extremity

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LEARNING OBJECTIVES
At the conclusion of this program, the attendee will:

- Identify potential uses of musculoskeletal ultrasound during the course of upper extremity practice
- Integrate ultrasound techniques for diagnosis of musculoskeletal conditions into your daily practice
- Apply ultrasound guided injection techniques for the treatment of upper extremity
- conditions

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commentary and add balance if “name-brands” or “only one way” to perform surgery are included in faculty presentations. Our goal is to avoid bias in ASSH programs.

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- Consulting Fees: Integra Life Sciences
- Advisor: Sonex Health, Integra Life Sciences

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Program

07:00 AM - 07:10 AM
Why You Should Use Ultrasound
John R. Fowler, MD

07:10 AM - 07:20 AM
Ultrasound for Carpal Tunnel
Richard A. Bernstein, MD

07:20 AM - 07:35 AM
Live Shoulder and Elbow Demo
Kevin Kruse, MD

07:35 AM - 07:50 AM
Live Hand and Wrist Demo
Michael T. Travis, MD

07:50 AM - 08:00 AM
Live Injection Demo
Mark Rekant, MD

08:10 AM - 10:30 AM
Hands-On Scanning and Injections
Brian M. Jurbala, MD | Adrian L. Butler, MD | Thomas Apard, MD | Edward Diao, MD | Charles S. Day, MD, MBA | Fraser J. Leversedge, MD | Ilvy H. Cotterell, MD | Isabelle David, MD | John R. Fowler, MD | Mark Rekant, MD | Olivier Mares, MD | Richard A. Bernstein, MD | Thomas B. Hughes, MD | Sebastian Kluge, MD

10:30 AM - 11:00 AM
Test your Skills!
All Faculty

PRE09: Ultrasound of the Upper Extremity

Why You Should Use Ultrasound

John R. Fowler, MD

- Consulting Fees: Integra Life Sciences
- Advisor: Sonex Health, Integra Life Sciences

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Pre-Course 09: Ultrasound Pre-Course

Why you should use ultrasound

Similar Sensitivity and Specificity compared to EMG/NCS

- Fowler (CORR 2011) – meta-analysis of 19 studies for sensitivity and specificity of ultrasound for confirmation of carpal tunnel syndrome.
    - If clinical exam reference standard: 77% sensitivity and 93% specificity
    - If EMG/NCS reference standard: 80% sensitivity and 79% specificity
- Fowler (JBJS 2014) – prospective comparison of EMG/NCS and US with CTS-6 as reference standard
    - US: 89% sensitivity, 90% specificity
    - EMG/NCS: 89% sensitivity, 80% specificity
- Fowler (JBJS 2015) – latent class analysis
    - US: 91% sensitivity, 94% specificity
    - EMG/NCS: 91% sensitivity, 94% specificity 83%

Cost-effective

- Fowler (CORR 2012) – cost-effectiveness analysis demonstrated that ordering ultrasound as the first line test is more cost-effective than ordering EMG/NCS and more cost-effective than ordered ultrasound first and then EMG/NCS if the results of the ultrasound are discordant with the clinical picture.

False positives

- Fowler (JHS 2019) – ultrasound has a lower rate of false positives when compared to EMG/NCS (23% vs 43%) in subjects with no signs or symptoms of carpal tunnel syndrome.

Efficiency of Care

- Charles (JHS 2021) - Patients who had the diagnosis confirmed by the surgeon using ultrasound underwent surgical intervention 3-4 weeks earlier, with 1.8 fewer medical visits (on average) than the number of medical visits for those who had their diagnosis confirmed using EMG/NCS.

Correlation with EMG/NCS defined levels of severity

- Aloi (HAND 2022) – Ultrasound measurements correlate well with EMG/NCS defined mild (CSA 10 mm^2), moderate (CSA 12 mm^2), and severe (14 mm^2) levels of severity.

PRE09: Ultrasound of the Upper Extremity

Ultrasound for Carpal Tunnel

Richard A. Bernstein, MD
No relevant conflicts of interest to disclose

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Ultrasound in CTS

Richard A. Bernstein, M.D.

The Orthopaedic Group

Division of Connecticut Orthopedics

Assistant Clinical Professor of Orthopaedic Surgery

Department of Orthopaedic Surgery and Rehabilitation

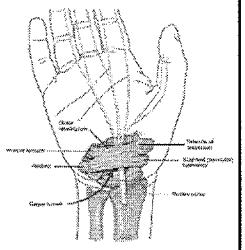
Yale University School of Medicine

New Haven, CT

ASSH Annual Meeting Las Vegas, NV September 2019

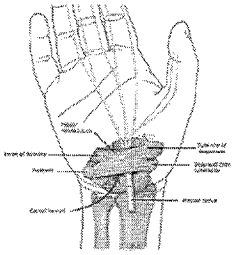
Carpal Tunnel Syndrome

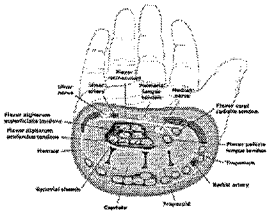
- Most common peripheral nerve entrapment syndrome
- Compression of the median nerve within the carpal tunnel
- Incidence of 3.8% in the general population
- Occupational exposure to excess vibration, increased hand force and repetition shown to increase risk of developing CTS



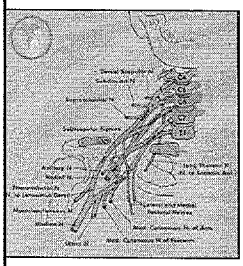
Carpal Tunnel Anatomy

- Osteo-fibrous canal in the volar wrist





Differential Diagnosis



- Cervical radiculopathy (C6 or C7 nerve root) / myelopathy
- Brachial plexopathy
- Polyneuropathy (Ex. Diabetic)
- Vascular disorders (Raynaud's syndrome)
- Soft tissue lesions in the carpal tunnel

Current Algorithm

- Current diagnosis of carpal tunnel syndrome is based on history and physical examination
  - Khalid et al. 2013 reported:
    - Phalen test: Sensitivity 94%, Specificity 78%
    - Tinel test: Sensitivity 77%, specificity 66%
- Electro-diagnostic studies serve as confirmation and to evaluate severity of disease
  - In the literature, typically used as the gold standard
    - Fowler et al. 2015 reported sensitivity of 91%, specificity 83%

NCS (Nerve Conduction Study)

- Measurement of median nerve motor and sensory distal latencies and sensory conduction velocity
- A sensory latency longer than 3.5 ms or a motor latency longer than 4.5 ms commonly is considered abnormal.

Electrodiagnostic studies

Electrodiagnostic Grade and Carpal Tunnel Release Outcomes: A Prospective Analysis

Michael Rollo, MD, Amit S. Sachanandani, MD, Mark S. Wong, MD, PhD, and Asif M. Ilyas, MD

J Hand Surg Am. • Vol. 43, May 2018

- No statistically significant differences in post operative improvement after carpal tunnel release between groups with differing EDX severity

Clin Orthop Relat Res. 2016 Aug; 474(8): 1770–1774. PMCID: PMC4925405
Published online 2016 Feb 15. doi: 10.1007/s11999-016-4692-3 PMID: 26880165

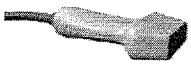
Clinical Faceoff: Routine Electrodiagnostic Testing is Not Helpful in the Management of Carpal Tunnel Syndrome

David C. Ring, MD, PhD[a]

Diagnosis of Carpal Tunnel Syndrome

- We want a test that can

1. Can help with diagnosis
2. Not painful
3. Easy to do and readily available
4. Can repeat if needed
5. Can guide treatment



What is ultrasound?

- Non-invasive imaging modality
- High frequency sound waves (above threshold of human hearing) used to create a two dimensional image

equency linear array transducer can
the resolution needed to evaluate
ligaments, tendons

Advantages of ultrasound

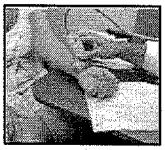
- Non-invasive
- Safe
- Painless and quick
- Reduced costs
- Good option for serial follow up
- Identify other causes of median nerve entrapment
  - Lipomas
  - Hemangiomas
  - Hematomas
- Anatomic anomalies: persistent median artery, bifid median nerve

Disadvantages of ultrasound

- User dependent
  - Requires further education and training
- Cost of acquiring ultrasound device
- Often times need a 2nd person for assistance (especially with ultrasound guided injections)

Financial Considerations

- 2010 Medicare Reimbursements:



- CPT 20526: Carpal Tunnel Injection
  - Physicians office: $70.00
  - Hospital outpatient: $54.85
- CPT 76942: Sonographic needle guidance
  - Physicians office: $176.34
  - No separate payment for hospital outpatient setting

Diagnostic Ultrasound for CTS

- How can diagnostic ultrasound help with diagnosis of carpal tunnel syndrome?

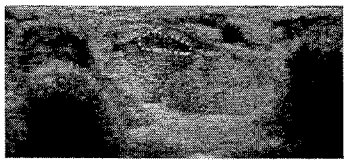
Diagnostic Ultrasound: Measurements

- Measurements

- Median nerve cross sectional area
- Flattening ratio (ratio of the nerves major to minor axis)
- Swelling ratio (CSA at the level of the pisiform to CSA at DRUJ)
- Flexor retinaculum thickness & palmar bowing
- Median nerve echogenicity and vascularity

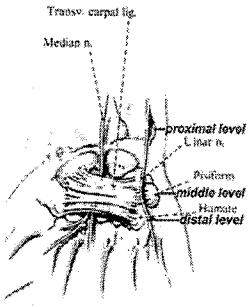
Diagnostic Ultrasound: Measurements

- Median nerve parameters evaluated
  - Median nerve cross sectional area (+ morphology)
    - Can be measured directly by tracing a continuous line around the inner hyper-echoic rim of the median nerve with electronic calipers



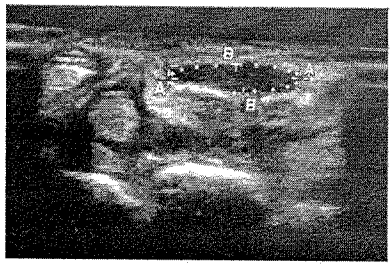
Diagnostic Ultrasound: Measurements

- Where to measure the median nerve?
- Measurements at the level of the pisiform found to be most sensitive



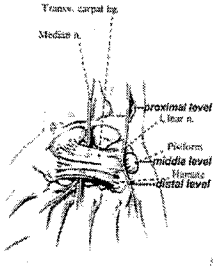
Diagnostic Ultrasound: Measurements

- Flattening Ratio: the major axis divided by the minor axis



Diagnostic Ultrasound: Measurements

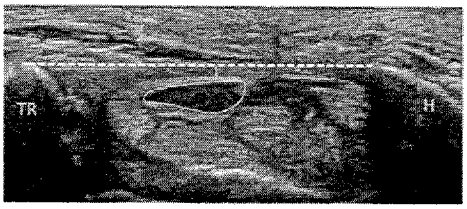
- Swelling Ratio = CSA at the level of the pisiform/ CSA at DRUJ



Diagnostic Ultrasound: Measurements

- Flexor retinaculum thickness & palmar bowing

(a)



Diagnostic Ultrasound CTS

ENLARGED MEDIAN NERVE IN IDIOPATHIC CARPAL TUNNEL SYNDROME

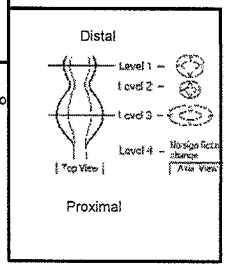
KEN-ICHI NAKAMICHI, MD, and SHINTARO TACHIBANA, MD

Department of Orthopaedic Surgery, Yokosuka Hospital, 2-36 Fukadacho, Matsuida, Yokosuka 270-8475, Japan

Accepted 7 July 2000

HIC

- Case control study
- 200 wrists with idiopathic CTS compared to 200 control wrists
- Gold standard: NCS
  - Distal median nerve latency >4.2 ms
  - Median sensory conduction velocity <45 m/s



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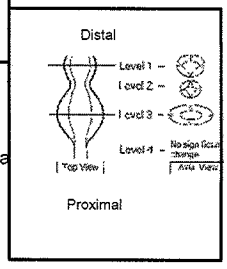
Accepted 7 July 2000

HIC

- (4) Anatomic levels
  - 1: Distal edge of flexor retinaculum
  - 2: Center of the hook of hama
  - 3: Level of wrist crease
  - 4: Distal 1/3 forearm



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Department of Orthopaedic Surgery, Tamanoue Hospital, 3-32 Tamanoue, Matsudo, Tokyo 165-0026, Japan

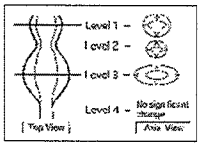
Accepted 7 July 2000

Table 1. Measurements of nerve cross-sections

Level	Patients	Controls	P-value
Cross-sectional area (mm^2)			
1	14.1 ± 4.7	10.0 ± 2.6	<0.0001
2	11.0 ± 2.4	8.3 ± 1.6	<0.0001
3	16.8 ± 6.4	10.2 ± 2.5	<0.0001
4	5.3 ± 1.0	5.3 ± 1.0	0.9512
Flattening ratio			
1	3.09 ± 0.69	3.39 ± 0.79	<0.0001
2	2.57 ± 0.48	2.81 ± 0.54	<0.0001
3	2.65 ± 0.60	2.60 ± 0.61	0.0021
4	1.83 ± 0.25	1.76 ± 0.28	0.0599

All values are means ± SD. An adjustment coefficient of 1.050 was used for the sites, and 1.089 for the area.

Higher cross sectional area levels 1-3



Diagnostic Ultrasound CTS

The Use of Diagnostic Ultrasound in Carpal Tunnel Syndrome

Ethan R. Wiesler, MD, George D. Chloros, MD, Michael S. Cartwright, MD, Beth P. Smith, PhD, Julia Rushing, MStat, Francis O. Walker, MD

From the Departments of Orthopaedic Surgery, Neurology, and Public Health Sciences, Wake Forest University School of Medicine, Winston-Salem, NC.

- 44 wrists of CTS patients and 86 wrists of asymptomatic volunteers
- Excluded patients who did not experience symptomatic relief after surgery

Diagnostic Ultrasound CTS

- Control: 9 mm^2, carpal tunnel patients: 14 mm^2, $p<0.001$
- Sensitivity analysis: cutoff of 11 mm2 cross sectional area yielded a sensitivity of 91%, specificity of 84%

Diagnostic Ultrasound CTS

- Sensitivity and specificity analysis for cross sectional area and change in cross sectional area

Table 4

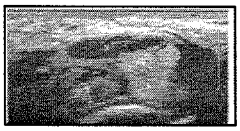
Sensitivity and Specificity of Nerve Measurements in the Diagnosis of CTS

Measurement	Sensitivity (%)	Specificity (%)
CSAn with 10-mm² threshold	100 (100/100)	57 (53/93)
CSAn with 11-mm² threshold	99 (99/100)	86 (80/93)
CSAn with 12-mm² threshold	94 (94/100)	99 (66/93)
ΔCSA with 2-mm² threshold	99 (99/100)	100 (93/93)
ΔCSA with 3-mm² threshold	98 (98/100)	100 (93/93)

Note.—Numbers in parentheses are numbers of wrists used to calculate the percentages.

Diagnostic Ultrasound CTS
Fowler, et.al JHS 44(3) 2019

- 40 Patients with a CTS-6 score of 0
- US positive in 23%
- NCS positive in 43%
- 11 Patients with False + NCS but – US
- 2 Patients with False + US
- US has lower False+ rate than US based on CTS-6 criteria



Correlation of NCS with Ultrasound in CTS
Fowler, et.al JBJS 96(17) 2014

- 85 Patients with CTS-6 >=12
- Criteria Used
  - CSA>=10 mm2 DML>=4.2ms DSL>=3.2 ms
- CTS-6 as "Reference Standard"
  - EDX sensitivity 89% specificity 80%
  - PPV US 94% PPV EDX 89%
  - NPV US 82% NPV EDX 80%
- Accuracy
  - Ultrasound 89%
  - EDX 86% (p=0.5)

Correlation of NCS with Ultrasound in CTS

Fowler, et.al JHS 41(10) 2016

- 87 Wrists in 52 Patients with clinical CTS
- Mean age 48.8 (18-86)
- Mean CSA 10.9 Mean DML 4.9 Mean DSL 3.1
- Person correlation:
  - CSA DML 0.50 ($p<0.05$)
  - CSA DSL 0.37 (p

Diagnostic Ultrasound CTS

Fowler et. al. JHS 40(10) 2015

- Moderate agreement between examiners of different levels
- Overall interobserver correlation 0.59
- An experienced ultrasonographer 0.91
- Fellow .45
- Resident .78

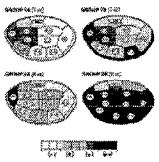
Diagnostic Ultrasound CTS

Ting, Blazer, Earp, et.al JAAOS 27(1) 2019

- 112 wrists in 78 Patients
- US and NCS
- WFR<1.5-1.7 normal
- WFR mean 2.5 mild
- WFR mean 2.8 moderate
- WFR mean 3.3 severe
- Increased cross sectional area at DWFC and wrist forearm ratio significantly correlated with severity of EDS ($p<0.0001$)

Carpal Tunnel Injections

Tenosynovial injection for carpal tunnel syndrome



Yoshitaka Minamikawa, MD, *Osaka, Japan*, Clayton A. Peimer, MD, *Buffalo, N. Y.*, Kenichi Kambe, MD, *Osaka, Japan*, Dale R. Wheeler, MD, *and* Frances S. Sherwin, MA, *Buffalo, N. Y.*

- Earliest study looking at accuracy of injections, 1992
- 16 cadaveric wrists
- 92% success rate for entering carpal tunnel

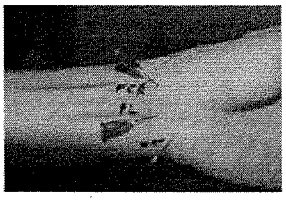
Carpal Tunnel Injections

Comparison of carpal tunnel injection techniques: A cadaver study

KAHRAMAN OZTURK[1], CEM ZEKI ESENYEL[1], MERUT SONMEZ[1], MELTEM ESENYEL[2], SINAN KAHRAMAN[3] & SERNA SENEL[2]

Departments of [1]Orthopedic Surgery and Traumatology, [2]Physical Therapy and Rehabilitation Medicine Gulhane Training and Research Hospital, Istanbul, [3]The Republic of Turkey Ministry of Justice Council of Forensic Medicine, Istanbul Medical Faculty, Istanbul, Turkey

- Cadaveric study
- 50 wrists per technique (x3)
- 23G needle with acrylic dye

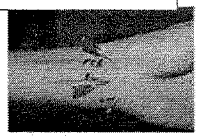


Carpal Tunnel Injections

Table I. Accuracy rates of intra-articular injections into the wrist.

Portals	Total number of injections	Placement of needle (number of injections)	
		In the carpal tunnel	Outside the carpal tunnel
		No.	No.
Injection through the flexor carpi radialis	50	48	2
Midline injection	50	41	9
Ulnar site injection	50	39	11

- Success rate: 78 – 96% depending on specific technique

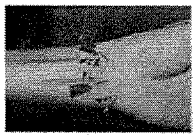


Carpal Tunnel Injections

Table II. Injuries in the carpal tunnel with the injection techniques.

Site of injection	No. of injections in the carpal tunnel	Structures injured in the carpal tunnel: Flexor digitorum superficialis	Median nerve	Sheet of the median nerve	Flexor pollicis longus
Through the flexor carpi radialis	48	1	0	0	1
Midline	41	5	8	3	1
Ulnar site	39	3	0	0	0

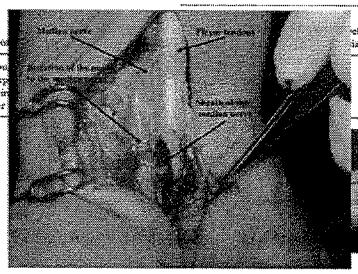
- Midline approach with highest rate of median nerve injuries: 11/41 (27%)



Carpal Tunnel Injections

Table II. Injuries in the carpal tunnel with the injection techniques.

Structures injured in the carpal tunnel



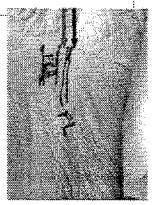
Carpal Tunnel Injections

SCIENTIFIC ARTICLE

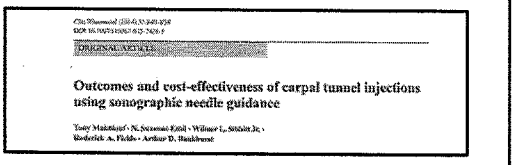
Comparison of Needle Position Proximity to the Median Nerve in 2 Carpal Tunnel Injection Methods: A Cadaveric Study

Allison MacLennan, MD, Aimee Schimizzi, MD, Kristen M. Meier, BA, G. Alton Barron, MD, Louis Catalano, MD, Steven Glickel, MD

- Cadaveric study, 15 wrists per technique
- All injections by attending hand surgeon, followed by dissection
  - #1 (black arrow): ulnar to palmaris longus tendon
  - #2 (red arrow): Ulnar to the FCR



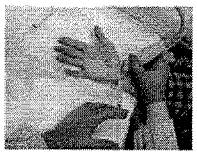
Carpal Tunnel Injections with Ultrasound Guidance



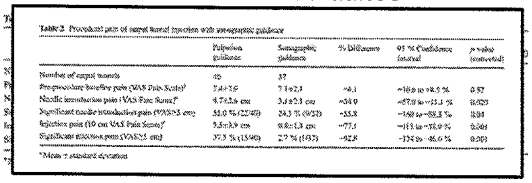
ORIGINAL ARTICLE

Outcomes and cost-effectiveness of carpal tunnel injections using sonographic needle guidance

- Randomized controlled study
- 77 wrists with clinical diagnosis of CTS randomized to ultrasound guided vs. landmark palpation based
- Injection ulnar to palmaris longus, proximal to wrist crease

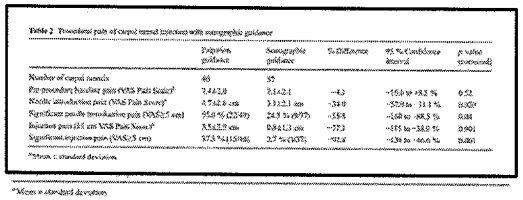


Carpal Tunnel Injections with Ultrasound Guidance



- Injection with U/S guidance resulted in
  - 34.0 % less needle introduction pain ($p < 0.02$),
  - 77.1 % less overall injection pain ($p < 0.001$)
  - 92.8 % less incidence of patients with significant injection pain ($p < 0.001$).

Carpal Tunnel Injections with Ultrasound Guidance



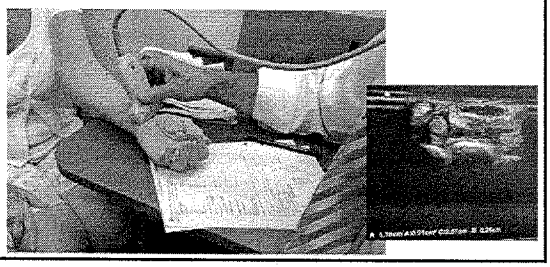
- Use of sonographic guidance was associated with a greater reduction in pain from baseline, longer duration of therapeutic effect, and longer time to subsequent injection

Study Methods:

- Prospective, non-randomized study
- Consecutive group of patients diagnosed with carpal tunnel syndrome and treated surgically with open carpal tunnel release between January 2015 – October 2016
- 200 total cases included, 108 female/ 92 male
- Single fellowship trained hand surgeon in the private practice setting
- All corticosteroid injections were ultrasound guided
- Data Collected:
  - Ultrasound measurements
  - NCV results: Sensory and motor latency
  - Pre/ Post Injection Outcome score
  - Pre/ Post Surgery Outcome score

Diagnostic Ultrasound CTS

- Ultrasound measurements collected
  - Cross sectional area
  - AP and lateral width (to calculate flattening ratio)

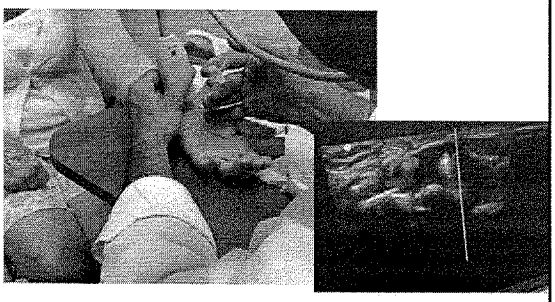


Study Methods: Outcome scores

- Boston Carpal Tunnel Questionnaire
  - Self-administered questionnaire
  - Assess the severity of symptoms and functional status
  - Two subscales:
    - Symptom severity scale (SSS, 11 items)
    - Functional status scale (FSS, 8 items).
  - Each item was assessed using a 5-point scoring system (1, no complaints; 5, very severe or continuous complaints).

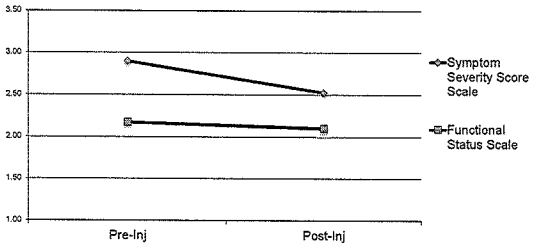
Patient Response to Treatment

- Ultrasound guided carpal tunnel injection



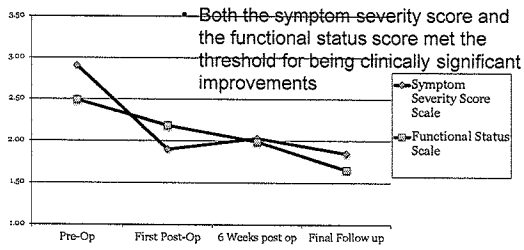
Patient Response to Treatment

- Corticosteroid Injection (BCTS pre and post injection)
  - Statistically significant decrease ($P<0.05$) in symptom severity score, but not functional status score



Patient Response to Treatment

- Carpal Tunnel Release: Pre and Post Surgery
  - ~~Both the symptom severity~~ score and the functional status score met the ~~threshold for being clinically~~ significant improvements

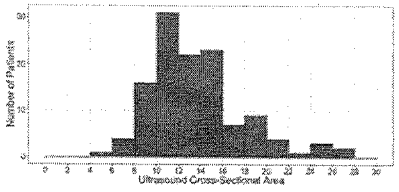


Ultrasound Electro-diagnostic Studies

Ultrasound Measurements (Average)	
AP	2.5 mm
Transverse	7.5 mm
Cross sectional area	14.0 mm^2
Flattening ratio	3.1

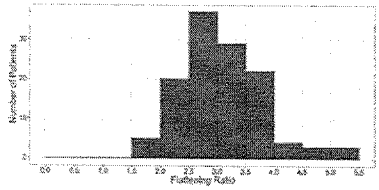
Diagnostic Ultrasound CTS

- Histogram of diagnostic ultrasound cross sectional areas:
  - 11% under 10 mm^2, but with EMG studies showing 77% of those patients with moderate NCV, 23% with severe NCV, and 8% with extreme



Ultrasound/ Electro-diagnostic Studies

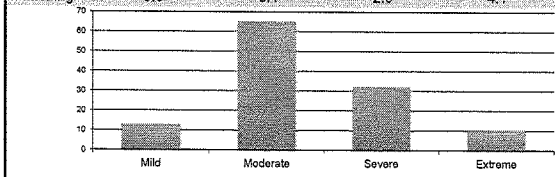
- Histogram of diagnostic ultrasound cross flattening ratio:
  - With a flattening ratio of > 3.5, odds ratio of 7.7 of having extreme nerve conduction test 95% CI (1.62,49.96), p=0.0035



Diagnostic Ultrasound CTS

- 26% of patients with severe electrodiagnostic studies (Sensory NR)
- 8% of patients with extreme electrodiagnostic studies (Motor & Sensory NR)

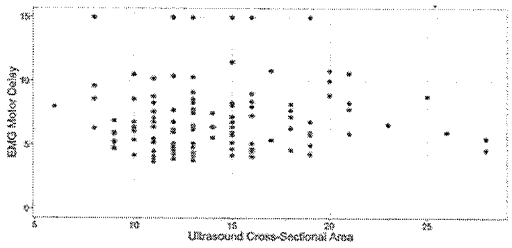
CSA	13.0 (8- 19)	14.4 (6- 29)	13.9 (8- 25)	10.3 (8- 19)
Flattening	3.3	3.1	2.9	4.1



Severity classification per criteria of Padua et al.

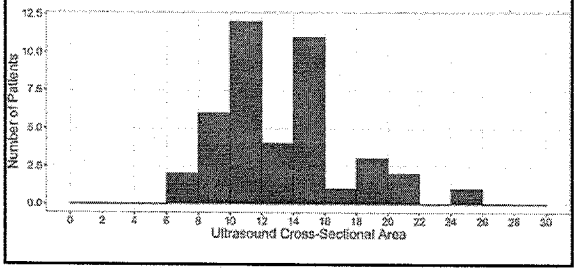
Ultrasound Electro-diagnostic Studies

- NCV results vs. ultrasound
  - No correlation found between CSA and severity of EDS



Diagnostic Ultrasound CTS

- NCV results vs. ultrasound
  - Ultrasound CSA for NR sensory and NR sensory/ motor had broad range (with 6.5% of patients having an ultrasound CSA less than 10 mm^2)



Diagnostic Ultrasound CTS

- No statistically significant differences in cross sectional area based on severity of electrodiagnostic testing
- Statistically significant difference in flattening ratio between patients with NR on motor/ sensory and those with less severe electrodiagnostic testing
  - With a flattening ratio of > 3.5, odds ratio of 7.7 of having extreme nerve conduction test 95% CI (1.62,49.96), p=0.0035

Ultrasound Response to Treatment

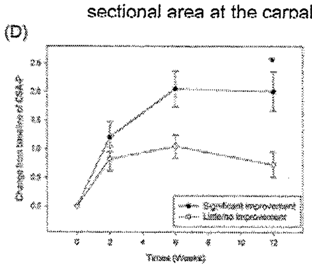
- **Does median nerve cross sectional area respond to treatment?**

Ultrasound Response to Treatment: Injection

- Wang et al. evaluated ultrasound response of median nerve to carpal tunnel injection
- 62 patients with CTS
- Ultrasound evaluation pre-injection, 2 weeks, 6 weeks, and 12 weeks after injection
- Excluded patients with severe NCS
- Divided patients into 2 groups based on level of improvement (significant vs. little/ no)

Ultrasound Response to Treatment: Injection

- Mean change from baseline of cross-sectional area at the carpal inlet



Conclusions

- Ultrasound is a readily available diagnostic modality that can be used to diagnose and treat carpal tunnel syndrome
- Use of ultrasound guidance for carpal tunnel injection may result in decreased patient discomfort, less risk for injuring the median nerve, and better outcomes
- In the real world with a complex heterogenous group of patients, median nerve cross sectional area alone may not provide relevant information regarding severity of disease (? Median nerve morphology)

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