Hypothesis
The purpose of this study is to prospectively evaluate the relationship between neurologic deficit at presentation and functional outcome in children with supracondylar humerus fractures (SCHFX) using validated outcome measures. We hypothesized that patients with nerve injury would have decreased functional outcomes compared to those who did not sustain nerve injuries.

Methods
An IRB approved prospective enrollment of consecutive patients with operative SCHFX was performed over a 3-year period. Among other injury parameters, the presence and type of any neurologic deficit was documented by the treating surgeon at presentation and throughout the follow-up period. Functional outcome was assessed at final follow-up using the Pediatric Outcomes Data Collection Instruments (PODCI) and the quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) Outcome Measure. Multiple regression analysis was used to determine the relationship between the presence/type of nerve injury and functional outcome while controlling for other injury parameters including patient age, fracture classification, fracture pattern, vascular abnormality and presence of an open fracture.

Results
752 patients were enrolled during the study period of which 199 (average age 6.7 years) completed functional outcome measures at final follow-up. Of these, 22 (11%) patients had a neurologic deficit at the time of initial presentation with 25 nerve injuries noted: 10 (40%) anterior interosseous nerve (AIN) deficits, 5 (20%) posterior interosseous nerve (PIN) deficits, 4 (16%) ulnar nerve deficits, 3 (12%) median nerve deficits, and 3 (12%) radial nerve deficits. As a group, patients with neurologic injury demonstrated significantly lower functional outcomes than those without.
differences in outcomes scores when comparing different types of nerve injuries. All nerve injuries resolved without further intervention with no residual nerve deficits in at final follow-up.

Summary Points
• In children with operative SCHFX, the presence of a nerve deficit at presentation is predictive of poorer outcomes with regards to pain, function, mobility and satisfaction at final follow-up despite complete spontaneous resolution.
• This is the first study to prospectively determine an association between neurologic deficit and functional outcome using validated outcome measures following the operative treatment of children with SCHFX.

Paper 02: The Detrimental Effect of Decentralization in Digital Replantation in the United States

*Best Papers - Thursday, September 10, 3:24 - 3:29 PM*

Treatment, Historical Information, Prognosis/Outcomes, Hand and Wrist
Level 3 Evidence

Joshua William Hustedt, MD, MHS
Patricia Klempf, MD
Lloyd P. Champagne, MD

Hypothesis
Recent reports suggest a decrease in success rates in digital replantation in the United States. We hypothesize that this may be occurring due to the decentralization of replantations away from centers of excellence.

Methods
All amputation injuries and digital replantations from the national inpatient sample database were collected from 1998-2012. Success rates at high volume and low volume centers were determined based on hospital (>20 replants per year) and surgeon volume (>5 replants per year) in the database. Univariate, correlation, and multivariate regression were used to determine statistical relationships between study variables.

Results
101,693 amputations injuries resulting in 15,821 replantations occurred during the fifteen-year study period. The overall rate of success of replantations dropped from 74.5% to 65.7% ($P < 0.001$) during the study period. The percentage of high volume centers (15.5% to 8.9%; $P < 0.001$) and high volume surgeons (14.4% to 2.6%; $P < 0.001$) has dropped significantly over the study period. High volume surgeons outperformed low volume surgeons (79.3% vs 72.2%; $P < 0.001$) and high volume hospitals outperformed low volume hospitals (77.1% vs 70.9%; $P < 0.001$) in success rates. High volume surgeons operating at high volume hospitals had significantly higher success rates than low volume surgeons operating at low volume hospitals (92.0% vs 72.1%; $P < 0.001$). In addition, high volume surgeons at high volume hospitals attempted replantations at greater rates than low volume surgeons operating at low volume centers (21.5% vs 11.0%; $P < 0.001$). Overall, an amputation injury presenting to a high volume surgeon at a high volume center has a 2.5 times greater likelihood of obtaining a successful replantation than to a low volume surgeon at a low volume hospital.
Summary Points

- Decreased success rates of digital replantation in the United States are strongly linked to the decentralization of digital replantation away from high volume surgeons at high volume centers.

- Establishment of national centers of excellence for digital replantation referral may greatly increase overall replantation success rates in the United States.

Hypothesis
The safety of elective hand surgery in women previously treated for same-sided breast cancer is controversial due to concerns of developing late onset upper extremity lymphedema. We hypothesized that the prevalence of lymphedema following elective hand surgery among breast cancer survivors would be low but may be more likely depending on the type of axillary dissection and adjuvant treatment received.

Methods
A retrospective cohort of breast cancer patients treated with axillary lymph node dissection (ALND), sentinel lymph node biopsy (SLNB) and/or radiation therapy (RT) was identified between 1997-2012. Patients with ipsilateral elective hand surgery following their breast cancer treatment were included if there was at least 1 year of follow up and no history lymphedema following breast cancer treatment. The primary outcome was documented lymphedema following hand surgery. Demographic data and clinical information pertaining to both hand surgery and breast cancer treatment and were compared between patients with and without lymphedema. Dichotomous and continuous variables were compared with Fisher’s exact and Student T-tests, respectively.

Results
The analysis included 103 patients, of which four (3.8%) had documented lymphedema following hand surgery, which developed early and was self-limited. Patient with and without lymphedema were similar in age, hand surgery procedure, and tourniquet use. Average tourniquet time was greater among women without lymphedema (23 vs. 9 minutes, P = 0.02). All patients (4/4) with late-onset lymphedema received adjuvant chemotherapy (vs. 29% in non-lymphedema group, P = .009) and RT with either ALND or SLNB (vs 41% of patients without lymphedema, P = .01). Radiotherapy or any type of axillary dissection alone was not associated with lymphedema following elective hand surgery. Lymphedema was associated with a shorter
interval between hand surgery and completion of breast cancer surgery (2.1 vs. 6.2 years, $P < .01$) and RT (2.0 vs. 3.3 years, $P = .051$).

Summary Points

- Lymphedema is uncommon and self-limited following elective hand surgery among breast cancer survivors.
- A combination of RT and ALND or SLNB and a shorter interval between hand surgery and breast cancer treatments (ALND/SLNB and RT) appears to put these women at higher risk of developing late onset lymphedema after elective hand surgery.
- Tourniquet use appears to be safe for elective hand surgery among this patient population.

Hypothesis
We hypothesize that a novel technique for all-arthroscopic fixation of capitellum osteochondritis dissecans (OCD) lesions using suture fixation and autogenous iliac crest bone grafting offers a successful alternative to open, internal fixation techniques as measured by validated, patient reported outcomes scores.

Methods
Our technique utilizes arthroscopic all-inside suture fixation with iliac crest autogenous bone grafting. The procedure was performed on four adolescents presenting with five unstable capitellum OCD lesions. The patients were all elite-level athletes: two gymnasts, one baseball pitcher, and one lacrosse player. All patients presented with elbow pain, limited range-of-motion (ROM), and decreased ability to play. MRI provided the diagnosis of an unstable OCD lesion, which was correlated with arthroscopy at the time of surgery. Postoperatively, all patients were immobilized in a long arm cast for 2 months. ROM exercises were then initiated with return to activity as tolerated over a period of 8 weeks. Patients were evaluated prospectively with DASH, Oxford Elbow and Mayo Elbow scores, VAS scores, postoperative ROM and return to play.

Results
Three females and one male aged 13 to 15 years old underwent the procedure. Three patients demonstrated a loss of preoperative terminal extension (average 28 degrees). Two patients underwent failed prior procedures at outside institutions (one retrograde drilling and one internal fixation). Average final follow-up was 2.8 years. All patients went on to union as seen
on MRI at an average of 3 months. At follow-up, the average loss of extension was 2 degrees. The average flexion was 153 degrees. There was no loss of supination or pronation. The average DASH score was 11. The average Mayo Elbow score was 88. The average Oxford Elbow score was 42. The average VAS was 2. Average return-to-play was 4 months. All patients continued to compete at an elite level. There were no infections, failure of fixation, need for conversion to open surgery, or revision surgeries.

Summary Points

- Arthroscopic all-inside fixation of unstable OCD lesions is a successful technique, facilitating athletes to return to elite level of play
- Our technique results in outcomes comparable to those reported in the literature for open fixation and arthroscopic-assisted fixation (1-3).
- Drilling from posterior to anterior through the humerus avoids the need for articular surface violation and limits the manipulation of tenuous fragments.
- Absorbable suture is used, precluding the need for hardware removal should collapse or progression of the lesion occur.

Hypothesis
Functional outcomes following peripheral nerve reconstruction for upper extremity injuries can be dependent upon the treatment option used to bridge the discontinuity. To examine these differences a control arm was added to an ongoing national nerve registry on processed nerve allografts (PNA). Based on scientific evidence and historical controls, we hypothesized that the cumulative registry would continue to demonstrate meaningful recovery for injuries spanning 5 to 65mm; and that observable outcomes for PNA would be similar to nerve autograft and significantly better than hollow tube conduit.

Methods
The RANGER registry is designed to collect injury, repair, safety and outcomes data for PNA (Avance® Nerve Graft, AxoGen, Inc), nerve autografts, and hollow tube conduits. The expanded enrollment in the registry doubled the number of PNA repairs with quantitative data, from 51 to 102 repairs since its first published reports. Outcome measures for upper extremity injuries in the cumulative PNA registry were reported and then stratified for comparison to controls; gap lengths 20mm were compared to nerve autograft. Meaningful recovery was defined as S3/M3 or greater (MRCC scale).

Results
Quantitative outcomes data for 98 subjects (mean age = 41 ± 16 [18, 77]) with 102 upper extremity repairs (80 sensory, 19 mixed, 3 motor) was available from the cumulative PNA registry. For injuries treated with PNA, recovery of meaningful sensory function was reported in 85% of the repairs (69 sensory/16 mixed) and meaningful motor function was reported in 75% of repairs (16 mixed/2 motor). The comparative analysis included 154 repairs; PNA 20 (n= 50, mgap = 30 ± 11.5) vs. nerve autograft (n=14, mgap = 40 ± 18.5). Subject demographics, medical history, and concomitant injuries were comparable between treatment groups. Meaningful levels of recovery for the PNA were statistically different from the conduit (51%), but not from the nerve autograft (64%). See Table 1 for a summary of treatment groups.

Summary Points
- Processed nerve allograft continues to demonstrate meaningful functional recovery in sensory, mixed, and motor nerve injuries between 5 and 65 mm
- Outcomes are comparable to nerve autograft and exceed those for nerve conduit in historical and registry controls ($P < 0.001$).
- The RANGER® registry including the remains ongoing; additional clinical data collected from participating sites will allow for further comparisons of these treatment options.

Hypothesis
We hypothesized that at 12 months volar locking plating (VP) would provide better clinical and radiologic outcomes than external fixation (EF) for the treatments of AO-type C2 and C3 DRFs without additional complications.

Methods
From an initial group of 92 patients with AO-type C2 and C3 distal radius fractures who were enrolled in a prospective, randomized study comparing volar plate fixation with external fixation (+/- intra-focal fixation), 74 patients were studied. Functional assessments (wrist range of motion, grip strength, Michigan Hand Questionnaire) were evaluated at each patient visit and radiographic assessment (radial inclination, volar tilt, ulnar variance, and articular congruity) were measured at month 12.

Results
The grip strength of the VP group was significantly greater than that of the EF group at 3 and 6 months. The range of motion was significantly greater in the VP group than in the EF group at 3 months. There were no significant differences in the range of motion and grip strength between the 2 groups at 12 months. The Michigan Hand Questionnaire score was higher in the VP group than in the EF group at 3 months but were same at 12 months. There was no significant difference between the 2 groups with respect to volar tilt or radial inclination. The VP group showed superior radiologic outcomes in terms of the ulnar variance. One patient in the VP group and 3 in the EF group had an intra-articular step-off deformity greater than 2mm. This difference did not reach statistical significance.

Summary
The VP group showed superior results for functional recovery and radiologic outcomes in terms of the ulnar variance. However, there were no significant differences in functional scores between the VP and EF groups at 12 months.

Hypothesis
The AAOS Appropriate Use Criteria (AUC) for distal radius fractures recommends a higher frequency of operative management of distal radius fractures than is actually performed by a group of hand fellowship-trained orthopaedic surgeons at a high-volume, level one urban trauma center.

Methods
Between August 2011 to August 2012, 829 patients presented with wrist fractures to our trauma center (identified by ICD-9 codes). We retrospectively reviewed these patients in the electronic medical record (EMR), and 112 patients met our inclusion criteria. Patients were excluded if they were younger than 16 years of age, had other significant injuries, had a delayed presentation, or were not seen by our orthopaedic hand surgeons. These 112 patients were evaluated using the AUC web-based application, which takes into account each patient’s AO/OTA fracture type (A, B, or C), mechanism of injury (high vs. low energy), activity level (normal, high functional, independent, or homebound), ASA status (1-3 or 4), and the presence of select associated injuries into its treatment recommendation. Statistical analyses included chi-square tests and post-hoc Z-tests, and statistical significance was set at a $P$-value of less than 0.05.

Results
Of the 112 patients, 64 (57%) received treatment that would have matched the AAOS AUC recommendation. After grouping fractures into AO/OTA type A, B, and C, actual management
matched the AUC recommendation 100% of the time (42/42, p55 year olds as compared to 16-40 year olds. Within the follow-up period, there was no crossover between the treatment groups. Following or not following AUC treatment recommendations would not have resulted in a statistically significant difference in the incidence of major complications.

Summary Points
• To our knowledge, this is the first clinical application of an AAOS AUC in the literature.
• AAOS AUC favors surgery for all intraarticular distal radius fractures.
• Actual treatment recommendations at our high-volume, level one urban trauma center were dependent on intraarticular fracture displacement.
• Treating clinicians may find a modified AUC that includes intraarticular fracture displacement as a variable more useful.

Hypothesis
The purpose of this general US population-based study was to estimate the incidence of scaphoid fractures and to analyze patterns in treatment and outcomes. We investigated the incidence density of scaphoid fracture treatment, the frequency of nonunion after treatment, and risk factors for nonunion. We also analyzed trends in the treatment for scaphoid fractures and the frequency of scaphoid nonunion over a 6-year period.

Methods
An administrative database of private commercial insurance beneficiaries (Truven Health MarketScan® Research Database) was queried for all treatment (casting and surgery) records of closed scaphoid fractures over a 6-year period. We examined subsequent claims to determine the frequency of undergoing additional surgical procedures for scaphoid nonunion treatment (revision fixation or vascularized bone grafting) or salvage procedures (proximal row carpectomy or radiocarpal or midcarpal arthrodesis). Trend analyses were used to determine whether changes in the frequency of surgical treatment, revision procedures, or salvage treatments occurred over the study period. Multivariable regression analysis was performed to determine the risk factors for non-union.

Results
The estimated incidence of scaphoid fracture is 10.6 per 100,000 person-years. Of the 8,923 closed scaphoid fractures from 2006 to 2012, 29% were treated surgically and 71% were treated with casting. The frequency of surgical treatment significantly rose from 22.1% in 2006 to 34.1% in 2012 \( (P < 0.001; \text{Figure 1}) \). The frequency of non-union during the study period was 10.8% after surgery and 3% after casting \( (P < 0.001; \text{Figure 1}) \). The frequency of non-union did not change over time for either the surgery or casting groups. Multivariable regression modeling indicates that younger age, male sex, and undergoing surgical treatment significantly increase
the risk of nonunion. Salvage procedures were rare, occurring in 0.29% of all scaphoid fractures during the 6-year evaluation period.

Summary
Our estimated incidence of scaphoid fracture (10.6 per 100,000 person-years) is higher than previously estimated (1.5 per 100,000 person-years)[1]. There has been increased enthusiasm in the United States to surgically treat scaphoid fractures, as reflected by our trend analysis. The frequency of non-union after surgical management for closed scaphoid fractures exceeds 10% and remained consistent during the study period. Younger patients, men, and those treated surgically are at increased risk for nonunion, all of which may reflect the higher energy mechanism of injury typically associated with scaphoid fractures. Given the increased utilization of surgery, both surgeons and patients should be aware of the frequency of nonunion to inform preoperative counseling and to guide postoperative treatment decisions.

Paper 09: Is Triangular Fibrocartilage Complex Injury Associated with Extensor Carpi Ulnaris Tendinitis or Tenosynovitis? A Case-control Comparative Study

Clinical Paper Session 01: Wrist - Friday, September 11, 8:45 - 8:52 AM

Evaluation/Diagnosis, Anatomy, Prognosis/Outcomes, Hand and Wrist
Level 3 Evidence

Toshikazu Tanaka, MD
Takeshi Ogawa, MD, PhD
Sho Kohyama, MD
Eriko Okano, MD
Naoyuki Ochiai, MD, PhD

Hypothesis
After treatment of triangular fibrocartilage complex (TFCC) injuries, the ulnar wrist may experience persisting pain, suggesting the presence of some other pathology. We compared the wrists of patients who have TFCC injuries before treatment with those of volunteers who have no ulnar wrist pain. We hypothesized that TFCC injuries are frequently complicated by extensor carpi ulnaris (ECU) tendinitis or tenosynovitis.

Methods
Altogether, 46 volunteers (21 male, 25 female; mean age 30.8 years) who had no pain in the ulnar wrist and 46 TFCC patients (22 male, 24 female; mean age 35.5 years) with a positive fovea sign and whose pain diminished after injection of 0.5ml lidocaine at the ulnar fovea were compared. In all, 20 right and 26 left wrists of the volunteers were evaluated, as were 22 right and 24 left wrists of the patients. Wrists of both groups underwent magnetic resonance imaging (MRI). Wrists were imaged with the subject prone, arms over the head, and forearm pronated. A microscopy coil was placed on the center of the ulnar head. All MRI scans were obtained using a 1.5-T system (Gyroscan NT Intera; Philips Medical Systems, Best, The Netherlands). Coronal and axial two-dimensional gradient-echo images were obtained. ECU tendon pathology (tendinopathy or tear) was classified into three categories (T1: normal; T2: multiple cracks; T3: changed intensity of tendon). Surrounding ECU tendon pathologies (e.g., tenosynovitis) were also classified into three categories (S1: normal; S2: effusion in sheath; S3 disruption of sheath)(Figure 1). There were some overlaps. The width, depth, opening angle, and radius of the curvature of the ECU groove were determined using imaging software based on a previous report(Figure 2) (reference 1). The image slice in which the ECU groove was largest was chosen
for measurement. Statistical analysis was performed with Mann–Whitney’s U-test. A $P < 0.05$ significance level was used in all cases.

Results
T2 pathology in the patient group (T1: 29; T2: 15; T3: 20) was significantly more frequent than in the volunteers (39; 4; 20, respectively). Surrounding pathology S2 was significantly more frequent in the patient group (S1: 35; S2:11; S3: 0) than in the volunteers (40; 4; 0, respectively). There were no significant differences between groups regarding the width, depth, opening angle, or radius of the curvature.

Summary
Injured TFCCs are frequently complicated by ECU tendinitis and/or tenosynovitis.


Clinical Paper Session 01: Wrist - Friday, September 11, 8:52 - 8:59 AM

Evaluation/Diagnosis, Treatment, Surgical Technique, Hand and Wrist, Elbow and Forearm, Diseases and Disorders
Level 3 Evidence

Michael Boland, MBChB
Eimear Conroy, FRCSI

Royalty: Arthrex (Boland)
Speakers Bureau: Acumed Lecture Fee (Boland)

Hypothesis
Proximal triangular fibrocartilage complex (TFC) pathology can be underdiagnosed on MRI and a normal radiocarpal view of the TFC does not exclude pathology. The Hypothesis is that pathology exists within the distal radioulnar joint that is not seen on Radiocarpal arthroscopy alone. The aim of the study is to report a retrospective review of findings of DRUJ Arthroscopy and develop a classification system of partial thickness TFC pathology.

Methods
A retrospective review of all wrist arthroscopic surgery completed by a single surgeon was performed. All cases (94) over a one year period were reviewed and all arthroscopic surgery with a normal TFC on inspection through radiocarpal portals were included. All radiology was reviewed to determine the sensitivity and specificity of MRI in helping diagnose proximal TFC pathology. All radiographs were reviewed to determine if ulnar variance had any impact on the presence of proximal TFC tears. Intraoperative findings were then reviewed and the identified pathology classified into subgroups depending on the location and type of tear.

Results
34 wrist arthroscopies were included all of whom had a normal TFC on radiocarpal arthroscopy. There was no correlation with ulnar variance and the presence of proximal TFC pathology. The sensitivity of MRI in detecting a proximal TFC tear was 70%. A Positive indentation sign was identified in 12 patients with proximal TFC pathology, while sensitivity of this finding is 35% it may be useful indicator that pathology may exist in proximal TFC.
Tears were classified according to location on the TFC, they were described as delaminating, flap lacerations or fibrillated. Chondromalacia of the ulnar head and DRUJ stability and lunotriquetral pathology was also assessed and included in the classification.

Summary
This study highlights the importance of performing distal radioulnar joint arthroscopy. MRI is a useful preoperative investigation but has poor sensitivity in the diagnosis of proximal TFC pathology. Ulnar variance is not predictive of proximal TFC pathology. Proximal TFC pathology frequently exists in the presence of an apparently normal TFC on radiocarpal arthroscopy. Subtle change in the lunotriquetral joint and TFC on radiocarpal arthroscopy that may indicate a proximal TFC pathology. The development of a classification system for describing these proximal TFC pathologies is useful for further clinical and scientific research. We recommend DRUJ arthroscopy as is useful adjunct to wrist arthroscopy and significant pathologies can be identified.
Paper 11: Importance of Computed Tomography in Determining Displacement of Scaphoid Fractures

Clinical Paper Session 01: Wrist - Friday, September 11, 8:59 - 9:06 AM

Evaluation/Diagnosis, Hand and Wrist
Level 3 Evidence

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Samir K. Trehan, MD
Krystle A. Hearns, MA
Andrew J. Weiland, MD
Michelle Gerwin Carlson, MD

Hypothesis
Scaphoid fracture displacement has been shown to correlate with higher risk of nonunion. We reviewed images from scaphoid fractures to determine if computed tomography (CT) changed the diagnosis of displacement compared to plain radiography.

Methods
Thirty-nine pre-operative radiographs and CT scans were evaluated by two blinded observers. Measurements of displacement and angular deformity were recorded. The readers were asked to judge the fracture as displaced or nondisplaced. A displaced fracture was defined as having >1 millimeter of displacement between cortices. Scapholunate, radiolunate, and intrascaphoid angles were measured. Independent samples t-tests were used to assess radiographic measures of fractures that were read nondisplaced on radiographs but displaced on CT compared to fractures reported nondisplaced on both imaging modalities. Kappa statistics were calculated to evaluate the reliability of diagnosing displacement between raters. Intraclass correlation coefficient (ICC) was calculated to determine the reliability of the intrascaphoid angle measured on radiograph and CT.

Results
Reader one identified 13 fractures (33%) as displaced on radiographs, and 26 (67%) as displaced on CT scan. Thirteen fractures were recorded as nondisplaced on radiograph, but displaced on CT scan (33%). (Figure 1) Reader two identified 16 fractures (41%) as displaced on radiograph, and 26 (67%) displaced on CT scan. Ten fractures were reported, by Reader two, as nondisplaced on radiograph, but displaced on CT scan (26%). Interobserver reliability for diagnosing displacement on radiograph was substantial (Kappa=0.73; P < 0.001), but
interobserver reliability for diagnosing displacement on CT was perfect (Kappa=1.00; \( P < 0.001 \)). None of the radiographic measurements were found to be predictors of displacement on CT scan. In addition, there was no reliability between intrascaphoid angle (“humpback deformity”) measured on radiograph and CT scan (ICC =-0.29; \( P = 0.767 \)).

Summary Points

- 26-33% of scaphoid fractures were judged nondisplaced on radiograph, but displaced on CT scan.
- Recognizing displacement and deformity is important when deciding on surgical intervention, as it may alter the treatment and surgical approach to the fracture. For this reason, we recommend CT scan to evaluate all scaphoid fractures.
- Although interobserver reliability between readers on radiographs was substantial (73%), the reliability between readers on CT scan was perfect (100%). Amongst different readers, CT scan can provide a more reliable diagnosis of displacement.
- The poor reliability of determining the intrascaphoid angle on radiograph compared to CT scan underscores the difficulty in recognizing the flexion or humpback deformity using plain radiography alone.

Paper 12: Factors Associated with Re-operation after Surgery for Scaphoid Nonunion

Clinical Paper Session 01: Wrist - Friday, September 11, 9:06 - 9:13 AM

Treatment, Surgical Technique, Prognosis/Outcomes, Hand and Wrist
Level 4 Evidence

Ali Moradi, MD
Amir Reza Kachooei, MD
Tessa Drijkoningen, MD
George S. M. Dyer, MD
David C. Ring, MD, PhD

Royalty: Wright; Medartis; Skeletal Dynamics; Biomet (Ring)
Consulting Fee: Wright; Skeletal Dynamics; Acumed; Biomet (Ring)
Fees for Non-CME Services Received Directly from a Commercial Interest or its Agent: AO (Ring)
North America; AO International (Ring)
Contracted Research: Skeletal Dynamics; Biomet (Ring)
Ownership Interest: Illuminos (Ring)

Hypothesis
To determine the rate of unplanned reoperation after surgery for scaphoid nonunion, the reasons for unplanned reoperation, and factors associated with unplanned reoperation.

Methods
Using an institutional database, we identified 190 patients that had surgery for a scaphoid nonunion from 2000 to 2013. There were 172 men and 18 women with an average age of 26±11 years (Range, 16 to 84 years). The result of the surgery was categorized as follows: no unplanned reoperation and healed fracture; unplanned reoperation for any reason; unplanned repeat surgery recommended but not done; and unknown status. We tested age, sex, affected side, interval between injury and operation, operation duration, fracture location, dorsal intercalated segment instability, surgeon perception of avascular necrosis of proximal pole, fixation device, type of bone graft, surgeon, and operative approach for association with unplanned repeat surgery.

Results
After the index operation to treat scaphoid non-union in 190 wrists, 100 (53%) had no unplanned reoperation and healed; 39 (21%) had an unplanned reoperation; in 34 (18%) unplanned repeat surgery was recommended but not done; and in 17 the status was unknown
(9%). After all subsequent surgeries, 110 patients (58%) healed (10 after one or more subsequent surgeries), 49 (26%) had persistent nonunion, 5 (3%) had a salvage procedure (e.g. excision of the distal pole of the scaphoid), and the status of 26 patients was unknown (14%). The indication for surgery in all 73 patients who had unplanned reoperation or recommended unplanned reoperation was persistent nonunion. In bivariate and multivariable analysis, the only factor related to reoperation was Kirschner wire rather than compression screw fixation of the scaphoid.

Summary Points
- Persistent nonunion is common after surgery for scaphoid non-union.
- Surgeries for persistent nonunion is even less successful.

Paper 13: Complications with the Use of BMP-2 in Scaphoid Nonunion Surgery

Clinical Paper Session 01: Wrist - Friday, September 11, 9:13 - 9:20 AM

Treatment, Surgical Technique, Hand and Wrist
Level 4 Evidence

Patrick Brannan, MD
Glenn R. Gaston, MD
Dan Lewis, MD
Bryan J. Loeffler, MD

Royalty: Biomet (Gaston)
Consulting Fee: Biomet, Smith & Nephew (Gaston)
Speakers Bureau: Auxillium (Gaston)

Hypothesis
The use of BMP-2 for revision scaphoid nonunion ORIF can increase union rate with a low incidence of complications.

Methods
We retrospectively reviewed cases of revision scaphoid nonunion ORIF (all having failed a previous scaphoid ORIF) treated with revision fixation, bone graft, and BMP-2. All patients were consented for off-label use of BMP-2. Union was determined by CT in all cases. Complications of nonunion, heterotopic bone formation, delayed wound healing, loss of motion, and need for revision surgery are reported. Final range of motion is presented.

Results
6 cases of BMP-2 use in revision scaphoid nonunion ORIF were identified between 2011 and 2014. All patients had failed an initial attempt at ORIF (all initially were cases of delayed union or nonunion). Time from injury to index ORIF ranged from 4 months to 4 years (mean 24 months). Revision surgery with BMP was performed at an average of 13 months from the index ORIF. 4 of 6 cases achieved CT proven union. There were two cases of persistent nonunion of which one underwent scaphoid excision and midcarpal fusion, while the other continues to be treated nonoperatively. 4 cases developed significant heterotopic ossification (2 of which required revision surgery). There were no cases of delayed wound healing. Only 1 of the 6 patients healed without any complications. Complications by case:

- Case 1: heterotopic ossification, final ROM 60 flexion, 40 extension
- Case 2: heterotopic ossification, final ROM 45 flexion, 45 extension
• Case 3: heterotopic ossification, persistent nonunion, 4 corner fusion, final ROM 45 flexion 20 extension
• Case 4: no complications, final ROM 70 flexion, 60 extension
• Case 5: persistent nonunion, current ROM 40 flexion, 10 extension
• Case 6: heterotopic ossification, revision HO resection, final ROM 25 flexion, 10 extension

Summary Points
• BMP-2 use in scaphoid nonunion carries significantly higher risk than previously reported.
• 1/3 of revision cases treated with BMP-2 went on to persistent nonunion.
• 2/3 of cases developed significant heterotopic ossification.
• Only 1 of 6 cases healed without complication.
Hypothesis
Contractures following neonatal brachial plexus injury (NBPI) are associated with impaired growth of denervated muscle, but the mechanism of growth impairment is unknown. Muscle growth in the neonatal period is uniquely dependent on addition of myonuclei from muscle stem cells, or satellite cells (SCs). SCs harvested from neonatally denervated muscle are capable of myogenesis *in vitro*, yet their behavior *in vivo* following neonatal denervation has not been investigated. The current study uses an established mouse model of elbow flexion contracture following NBPI to test the hypothesis that neonatal denervation-induced muscle contractures are associated with altered *in vivo* behavior of SCs.

Methods
Unilateral global (C5-T1) NBPIs were created by surgical extraforaminal nerve root excision in 5-day-old CD-1 mice under general anesthesia. At four weekly time points following denervation, bilateral biceps and brachialis muscles were harvested for analysis of *in vivo* SC activation state, apoptosis, proliferation, and activity of the Notch signaling pathway, a regulator of SC behavior. SC activation state was assessed by immunohistochemical staining for transcriptional markers of quiescence, proliferation, and differentiation. Apoptosis was assessed using TUNEL analysis. Proliferation was assessed in a subset of mice that underwent BrdU injection following denervation and prior to sacrifice. Notch signaling activity was assessed in proliferating SCs using immunohistochemical staining for the Notch intracellular domain.

Results
Following neonatal denervation, no increase in SC apoptosis was seen. In fact, SCs comprised a significantly higher proportion of myonuclei in denervated than control muscle, despite similar rates of SC proliferation. However, a significantly higher than normal proportion of the SCs in denervated muscle were in the quiescent state. Most of these quiescent SCs had undergone at least one cell division, as indicated by BrdU incorporation, suggesting that following denervation,
SCs activated and proliferated, but then most daughter cells returned to quiescence (self-renewed) rather than differentiating into myoblasts. Notch signaling is an important driver of SC self-renewal over differentiation, and a significantly higher proportion of proliferating SCs displayed activated Notch signaling in the denervated than control muscle.

Summary
Satellite cells remain abundant in vivo in neonatally denervated muscle. Following neonatal denervation, satellite cells proliferate normally, but a disproportionate number of daughter cells return to quiescence instead of differentiating into the myoblasts necessary for neonatal muscle growth. Correcting this imbalance between SC self-renewal and differentiation, potentially by manipulating Notch signaling, could allow us to harness this population of SCs to maintain muscle growth and prevent contractures following neonatal brachial plexus injury.

Paper 15: Intercostal Nerve Transfer to Restore Elbow Flexion

Clinical Paper Session 02: Brachial Plexus/Nerve - Friday, September 11, 8:52 - 8:59 AM

Treatment, Surgical Technique, Prognosis/Outcomes, Elbow and Forearm, Congenital and Pediatric Problems, Nerve, General Principles

Level 3 Evidence

Eric Wagner, MD
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Salary: Mayo Clinic (Shin)
Royalty: Trimed (Shin)
Contracted Research: Bacterin International (Shin)
Other (Please describe): editor Techniques Hand Upper Extremity (Shin)

Hypothesis
The purpose of this study is to evaluate the outcomes of intercostal nerve transfer to the musculocutaneous motor branch for restoration of elbow flexion.

Methods
Over a 10-year period, 85 patients underwent intercostal nerve transfers to the musculocutaneous nerve at a single institution. The average age at surgery was 30.5 years (17-65), mean BMI 29, with 11 females, and were 18 smokers. All patients had brachial plexus injuries with 19 having C5-C7 avulsions while most had C5-T1 avulsions (n=66). All (n=85) patients had grade 0 biceps strength preoperatively. Patients underwent intercostal nerve (ICN) transfer involving combinations of ICN 3-7 to the musculocutaneous nerve. Fifty-five (65%) patients underwent a simultaneous free gracilis muscle transfer to augment elbow flexion (n=24) or obtain wrist/finger flexion (n=31). Eleven patients had a preexisting arterial (subclavian or axillary) injury.

Results
At an average follow-up of 2.8 years (range, 1.0-9.2), 46 (54%) of patients recovered at grade III or better elbow flexion strength. 69 (81%) of patients demonstrated signs of muscle recovery on EMG at last follow-up. The mean elbow flexion was 88 degrees (range, 0-150). The patients DASH scores improved from 48.5 preoperatively to 36.5 postoperatively ($P < 0.001$), and VAS
scores decreased from 5.9 (out of 10) to 4.8 postoperatively ($P = 0.03$). The number (2, 3, or 4) intercostal nerves used did not have a significant impact on any of the final outcomes. The use of a free muscle transfer improved postoperative elbow flexion strength, with 33 (total n=55, 60%) having greater than or equal to III muscle strength, compared to 12 (total n=30, 40%) of those without a free muscle transfer ($P = 0.04$). There also were improvements in elbow range of motion (92 vs 78) and EMG signs of recovery (85% vs 70%), but these did not reach statistical significance. Free muscle transfer did significantly improve DASH scores (33 vs 44, $P = 0.03$).

Patients with vascular injuries (n=11) had significantly worse rates of elbow flexion recovery, including worse muscle strengths ($P < 0.01$), DASH scores ($P < 0.01$), and rates of EMG recover ($P < 0.03$). 45/75 (61%) of patients without vascular injuries obtained grade III elbow flexion or greater.

Summary Points

- Intercostal nerve transfer in the setting of a complete or near complete brachial plexus injury leads to reasonable rates of recovery of elbow flexion.
- Preexisting vascular injuries portend a poor outcome.
- In these patients with very limited options, intercostal nerve transfer represents a reasonable nerve transfer option.
Hypothesis
Contralateral C7 (CC7) transfer has been widely applied for treatment of traumatic brachial plexus injury. However, the effectiveness and safety of the procedure remain controversial. The purpose of this systematic review is to study the overall outcomes of CC7 transfer and investigate the donor-site morbidity after CC7 transfer in traumatic brachial plexus injuries.

Methods
Using PubMed and EMBASE databases, we identified original articles related to CC7 transfer for traumatic brachial plexus injury. For outcomes study, we extracted the objective outcomes of CC7 transfer to the recipient nerves, and normalized modifications of MRC and other outcome measures into an MRC-based outcome scale. For donor-site morbidity study, the incidence, recovery rate and time of sensory abnormality and motor deficit were extracted. The sensory abnormality areas and muscles involved in motor weakness were also summarized.

Results
Thirty-nine studies were identified in outcome study. The outcomes were categorized based on the three major recipient nerves. In the median nerve group, 11% of patients regained MRC grade M4 wrist flexion and 38% achieved M3 (Table 1). Grade M4 finger flexion was achieved by 7% of patients whereas 36% achieved M3. Finally, 56% of patients regained S3 or greater in the median nerve territories. In the musculocutaneous nerve group, 38% of patients achieved grade M4 elbow flexor strength and 37% regained M3. In the radial/triceps nerve group, 25% regained elbow or wrist extension strength to grade M4 and 25% regained to M3. A total 904 patients from 27 studies were included in donor-site morbidity study. Overall, 74% of patients experienced sensory abnormalities after CC7 transfer, and 98% of patients recovered to normal; the mean recovery time was 3 months (Table 2). For motor function, 20% of patients had motor deficits and 91% regained normal motor functions; mean recovery time was 6 months. Sensory abnormality mainly occurred in the median innervated area of the hand, whereas motor deficit
most often involved radial nerve innervated muscles. There were 2% of patients with long-term morbidity.

**Summary Points**
- Outcome measures in the included studies were not consistently reported to uncover true patient-related benefits from the CC7 transfer. Reliable and validated outcome instruments should be applied to critically evaluate patients undergoing CC7 transfer.
- The incidence of donor-site morbidity after CC7 transfer was relatively high, and severe and long-term defects occurred occasionally. CC7 transfer should be indicated only when other donor nerves are not available, and with a comprehensive knowledge of the potential risks.

*Paper 16_Image01*
*Paper 16_Image02*
Paper 17: Comparison of Functional Recovery Outcomes by Gap between Processed Nerve Allograft and Hollow Tube Conduits for Digital Nerve Repairs

Clinical Paper Session 02: Brachial Plexus/Nerve - Friday, September 11, 9:06 - 9:13 AM

Treatment, Surgical Technique, Prognosis/Outcomes, Hand and Wrist, Nerve

Level 2 Evidence

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Mitchell A. Pet, MD
Wesley P. Thayer, MD, PhD
Harry Hoyen, MD
Gregory M. Buncke, MD

Speakers Bureau: AxoGen, Inc. (Ko, Buncke)
Contracted Research: Received research grant from Axogen (Thayer, Buncke)
Consulting Fee: Synthes, Axogen, Stryker (Hoyen)

Hypothesis
Processed nerve allograft and tube conduit both offer convenient options for digital nerve gap repair. Despite their wide availability, no consensus exists as to the optimal treatment for digital gaps up to 2 cm. To evaluate for potential differences in recovery outcomes with these repair methods, we added contemporary control cohorts to a national nerve registry. We hypothesized that processed nerve allografts would perform consistently well while the quality of recovery with conduit would decrease as gap length increased.

Methods
The RANGER registry is an active database designed to continuously monitor and collect injury, repair, safety and outcomes data for processed nerve allografts (Avance® Nerve Graft, AxoGen, Inc). In 2013, a contemporary control was added to allow for comparisons of recovery outcomes to tube conduits. The database was queried for digital nerve injuries with gaps up to 20 mm. The dataset was stratified into two gap length groups, gaps < 10 mm and 11-20 mm. Meaningful sensory recovery was defined by the MRCC scale at S3 or greater. Comparisons of meaningful recovery outcomes were completed by repair method between and across the gap length groups.
Results
Four sites contributed data for both types of repairs. Thirty nine subjects with 63 injuries were included. The < 10mm gap group consisted of 20 PNA and 8 conduit repairs. The 11-20mm gap group consisted of 20 PNA and 15 conduit repairs. Subject, medical history, and concomitant injuries were comparable between treatment groups. Overall meaningful levels of recovery were reported in 90% for the PNA group as compared to 44% for the conduit. In the < 10mm gap group, PNA and conduit reported 100% and 75% meaningful recovery respectively with no revisions. In the 11-20mm gap length group, PNA and conduit reported 80% and 33% recovery respectively (P < 0.0132) with four revisions reported in the conduit group. See Table 1 for a group demographics and summary of outcomes. See Figure 1 for a distribution of MRCC scores by group.

Summary Points
• Processed nerve allograft performed consistently well across both gap length groups.
• Reported levels of meaningful recovery for processed nerve allografts exceed that of tube conduits across all gaps and groups.
• Conduits reported a statistically significant difference by gap length with < 10mm repairs reporting more consistent levels of recovery as compared to gaps at 11-20mm.
• The RANGER registry remains ongoing; additional clinical data collected from participating sites will allow for further comparisons of PNA to conduit.


Clinical Paper Session 02: Brachial Plexus/Nerve - Friday, September 11, 9:13 - 9:20 AM

Treatment, Prognosis/Outcomes, Nerve
Level 2 Evidence

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Speakers Bureau: AxoGen, Inc. (Safa, Buncke)
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Hypothesis
The historical standard for peripheral nerve gap repair has been the nerve autograft. Recently processed nerve allografts have been established as a viable alternative. To examine the differences we added contemporary control cohorts to a national nerve registry. Based on scientific evidence and historical controls, we hypothesized that processed nerve allografts would perform similar to nerve autograft in mixed nerve injuries of the upper extremity.

Methods
The RANGER registry is an active database designed to collect injury, repair, safety and outcomes data for processed nerve allografts (Avance® Nerve Graft, AxoGen, Inc) according to an IRB approved protocol. Contemporary controls added to the established registry allow for comparisons of recovery outcomes between treatment groups. The database was queried for subjects presenting with mixed nerve gap injuries up to 70 mm repaired with either processed nerve allograft (PNA) or nerve autograft. Identified subjects reporting quantitative outcomes with a minimum of nine months follow up were included in the dataset. Subject demographics and repair characteristics, and recovery of function were compared. Meaningful recovery was defined as S3/M3 or greater (MRCC scale).
Results
Twenty subjects with 22 injuries were included. The groups consisted of PNA (n=14) and nerve autograft (n=8). Subject demographics, medical history, and concomitant injuries were comparable between treatment groups. The PNA group reported a higher incidence of high energy traumatic injuries. Repair techniques varied between the groups. The PNA repairs included size matched fascicular or caliber matched epineural repairs while all the nerve autografts were multi-strand cabled repairs. The average nerve gap between the groups varied at 30±14 mm and 44±11 mm for PNA and nerve autograft respectively. Available quantitative data reported meaningful recovery in 86% in PNA group as compared to 88% for nerve autograft. See Table 1 for a summary of treatment groups. See Figure 2 for a distribution of sensory and motor MRCC scores by repair group. There were no reported adverse events related to the treatment groups.

Summary Points
- Processed nerve allografts can be used to repair mixed nerve injuries for return of both sensory and motor function.
- Reported levels of meaningful recovery for processed nerve allografts are comparable to nerve autograft.
- Outcomes from both groups were comparable to those reported in historical controls.
- The RANGER registry remains ongoing; additional clinical data collected from participating sites will allow for further comparisons of repair modalities.

Hypothesis
Osteoporosis may result in increased distal radius fracture severity and the need for surgical intervention. We hypothesized that patients who have a lower bone density will have a tendency toward operative management of a distal radius fracture when compared to patients of similar age with higher bone density scores.

Methods
A retrospective cohort study was performed, including all Kaiser Permanente Southern California (KPSC) enrollees who were aged 55 years or older between January 1, 2007 and December 31, 2012 and underwent treatment for a distal radius fracture. IRB approval was obtained. All patients over the age of 50 who sustain a distal radius fracture are evaluated with a DXA scan within 3 months of the injury within KPSC. Of the non-operative patients, 48 did not have DXA data and were excluded from analysis. Radiographs were classified using the AO classification for distal radius fractures. 761 non-operative cases were included in the analysis. The total study population (operative and non-operative) was 890. Demographic data and T-scores were recorded from the distal radius fracture operative registry, administrative databases and the medical record.

Results
There were 737 fractures in women and 153 fractures in men. The mean age was 69.9 years (range, 55-96). The mean T-score was -1.95 (SD 0.97). There were 283 AO type A fractures, 150 type B fractures, and 381 type C fractures. Treatment was non-operative for 761 fractures (86%), and surgical for 129 fractures (14%). There was no difference in T-score between fractures in the surgical and non-operative cohorts, but patients treated surgically were younger than patients treated non-operatively. T-scores were higher in men than women, and higher in type B fractures than in type A or C fractures. Increasing age and AO fracture type B were associated with lower odds ratio for surgical treatment. Age and sex significantly influenced T-score, and
age significantly influenced treatment group (decreasing surgery with increasing age), but that AO fracture classification was not sequentially increased by decreasing T-score and did not itself influence treatment group.

Summary Points
• Non-operative treatment of distal radius fractures is more common in elderly patients despite lower T-scores.
• T-scores decline at a faster rate in men as compared to women as one ages.
• T-score did not predict surgical intervention when controlling for age, gender and AO classification.
• Fracture severity (AO classification) was independent of T-score.
• Decision making for surgery may include subjective factors such as patient/physician preference and objective fracture characteristics not accounted for by the AO classification.

Clinical Paper Session 03: Distal Radius - Friday, September 11, 10:12 - 10:19 AM

Evaluation/Diagnosis, Treatment, Anatomy, Prognosis/Outcomes, Hand and Wrist
Level 3 Evidence

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Hypothesis
We evaluated the fragment specific articular surface reduction with computed tomography (CT), and determined which joint fragment is mostly related to the outcome of distal radius fracture surgically treated with volar locking plate (VLP).

Methods
Total 124 patients with surgically treated distal radius fracture using VLP were eligible for current study. At final, 99 patients had met the selection criteria and permitted to participate in current study, and their wrist was evaluated with CT at final follow-up. To evaluate the fragment specific articular surface reduction, it was divided into six specific fragments; scaphoid, volar lunate and dorsal lunate facet, central portion, dorsal and volar rim. The articular surface mismatch within each fragment were evaluated with three-grade ordinal scale; “no mismatch”, “mismatch less than 2mm”, “mismatch more than 2mm”. To evaluate the alignment of the distal radius, simple radiograph were examined. For clinical evaluation, the Disability of the Arm, Shoulder and Hand (DASH), and modified Mayo wrist score (MMWS), were completed at final follow-up. Subjects were divided into two groups according to final DASH and MMWS score, and compared. Correlation analysis between several parameters and DASH, MMWS were performed. Multiple logistic regression analysis was performed to evaluate cause-effect relationship between surgical outcome and various parameters, and to control confounding effect of each parameter.

Results
Mean follow-up period was 13.9 (range, 12 to 52) months. There were no parameters showing significant difference between two groups divided by the result of DASH score. Parameters
showed significant correlation with DASH score were dorsal lunate facet, central depression. The dorsal lunate facet showed the strongest correlation with DASH score (spearman’s rho= 0.218, \( P = 0.030 \)). Articular surface mismatch at dorsal lunate facet, central depression, and volar rim were significantly greater in the group with worse MMWS score (\( P < 0.001, 0.036, 0.042 \)). Variables showed significant correlation with MMWS were the articular surface mismatch at scaphoid facet and dorsal lunate facet, and central portion. The mismatch of dorsal lunate facet also showed strongest correlation with MMWS (spearman’s rho= -0.367, \( P < 0.001 \)). The result of multiple logistic regression analysis showed that the mismatch of the dorsal lunate facet has significantly high odds ratio of having worse result of MMWS.

Summary Points
• The degree of articular surface mismatch within dorsal lunate facet seems to the surgical treatment of distal radius fracture.
• With the case involved the dorsal lunate facet, surgeons should be cautious about its reduction during surgery using VLP.

Hypothesis
Malunited distal radius fractures (DRFs) occasionally limit forearm rotation; however, the relationship between deformity and forearm rotation restriction is unclear. This study assessed in vivo three-dimensional (3D) forearm motion with malunited DRF to elucidate the relationship between deformity and restricted rotation.

Method
Sixteen malunited DRFs with restricted forearm rotation were investigated (10 females, six males). The mean patient age was 45 years (range 10–77 years), and the average interval from first injury to examination was 11 months. Computed tomography of the bilateral forearm was performed for two rotational positions (maximum pronation and supination), and 3D bone surface models of the radius and ulna were created. Kinematic variables were measured by superimposing the ulna in a supinated position on the images of pronated position using a surface-based registration technique. The rotation axis of the radius relative to the ulna was calculated using a screw displacement axis system. The path of the distal radioulnar ligament (DRUL), which consists of four limbs (palmar/dorsal and deep/superficial), were created based on anatomical locations; each shortest path length avoiding bone obstacles was calculated. Each limb length was compared with the contralateral side in neutral position (Fig. 1.). The 3D deformity, forearm motion range, and DRUL length were quantitatively analyzed.

Results
The average pronation and supination were 55.4° and 50.2°, respectively. Eleven cases had dorsal angulation deformity (average 25.8°), and 11 cases had internal rotation deformity (average 16.3°). The deformity in the direction of volar flexion and internal rotation related to
the restriction of supination [correlation coefficients (R) 0.70 (P < 0.01) and 0.57 (P = 0.02)]. The dorsal angulation and external rotation deformity correlated with limited pronation [R = 0.86 (P < 0.01) and R = 0.60 (P = 0.01)]. In cases with limited pronation, the length of the deep dorsal and superficial dorsal limbs were elongated in the maximum pronated position [R = -0.63 (P < 0.01) and R = -0.66 (P < 0.01)]. In cases with limited supination, relationships between deep palmar and superficial palmar limbs and maximum supination range were similar [R = -0.85 (P < 0.01) and R = -0.78 (P < 0.01)].

Summary
Limited forearm rotation with malunited DRF is related to the direction and amount of radius deformity. Limited pronation and supination are considered to result from the effect of radius deformity on overstretching dorsal and palmar ligaments (Fig. 2).
Hypothesis
Fracture specific parameters can predict loss of fixation after volar locked plating of AO classification 23-C3 distal radius fractures

Methods
We designed a case-control study to examine variables associated with early failure of volar locking plate fixation. All intra-articular distal radius fractures treated surgically at our institution between 2005-2013 by three board certified hand surgeons were screened. We identified 187 patients with AO classification 23-C3 fracture (multifragmentary, complete articular) treated with volar locked plating and with adequate imaging and follow-up through fracture healing. Our failure of treatment cohort consisted of 19 patients who experienced postoperative loss of reduction sufficient to result in intra-articular screw penetration and/or joint subluxation. Our control cohort consisted of 19 age and gender matched patients with AO 23-C3 fractures treated with volar locked plating who maintained radiographic reduction at final followup. Injury, immediate postoperative, and follow-up radiographs were examined for radial inclination, radial length, ulnar variance, volar tilt, teardrop angle, radial subsidence, carpal subluxation, articular displacement and dimensions of the primary styloid and lunate fragments. Differences in mean values between cohorts were assessed using a two-tailed students t-test.

Results
There were no significant differences between demographic characteristics between cohorts. Significant differences were observed between cohorts for several variables on injury radiographs. The average length of the radial styloid fragment, measured longitudinally from the styloid tip to the fracture line on PA views, was smaller in the failure cohort (15.8mm (failure) vs 20.3mm (control), P = 0.034). The articular width of the volar lunate facet fragment, measured from the ulnar corner of the lunate facet to the edge of the fracture on PA view, was smaller in the failure group (11.6mm (failure) vs 15.1mm (control), P = 0.019). Ulnar variance on injury films was greater in the failure group (+5.6mm (failure) vs +3.4mm (control), P = 0.021).,
Residual articular displacement on immediate postoperative radiographs was greater in the failure cohort. (2.1 mm (Failure) vs 0.5mm (control). No significant differences were observed between cohorts for the remaining variables.

Summary Points

- Significant differences were observed between failure and control cohorts for the following variables: pre-reduction ulnar variance, length of the radial styloid fragment, articular width of the lunate facet fragment, and articular displacement on immediate postoperative films.
- Distal fracture lines, small key articular fragments, and radial shortening on injury radiographs, as well as non-anatomic articular reduction represent risk factors for loss of reduction following volar plate fixation of AO C3 distal radius fractures.
Hypothesis
The purpose of this study was to determine the Minimal Clinically Important Difference (MCID) of the Patient-Rated Wrist Evaluation (PRWE) score in patients with distal radius fractures. The MCID of the PRWE was examined previously in patients suffering from chronic wrist conditions. However, the MCID of the PRWE has never been determined in patients with a distal radius fracture. We hypothesised that the MCID in patients with this acute condition is not necessarily similar to the MCID for patients who suffer from a chronic condition.

Methods
We prospectively included 102 patients with a median age of 59 years (Interquartile Range 48 – 66). All participants completed the PRWE questionnaire during two separate visits. Additionally, patients were asked to indicate the degree of clinical change they appreciated on a scale from -5 (much worse) to +5 (much better) through 0 (no change). Accordingly, patients were categorized into two groups: (1) minimally improved; or (2) no change. These groups were used to ‘anchor’ the changes observed in the PRWE to patients’ perspective of what is clinically important. We determined the MCID according to the ROC method. In this context, the change in PRWE is considered a diagnostic test and the anchor (minimally improved or no change) is the gold standard. The optimal ROC cut-off point reflects the value of the MCID.

Results
The majority of patients indicated to experience marked improvement and the PRWE score between the first and the second measurement differed significantly ($P < 0.001$, Wilcoxon Signed Rank Test). The MCID of the PRWE was 11.5 points.
Summary Points

- A change of 11.5 points on the PRWE represents a clinically important difference for patients with distal radius fractures.
- We recommend using this value to interpret treatment effects and for sample size calculations.
Hypothesis
The purpose of this study was to investigate the biomechanical properties of modified repair techniques for flexor tendon reconstruction and the effects of surface modification using carbodiimide-derivatized synovial fluid plus gelatin (cd-SF-G), compared to the traditional repair techniques.

Methods
The second and fifth digits from 16 canine forepaws were randomly divided into 4 groups: 1) traditional graft repairs (TGR group) including distal Bunnell repair and proximal Pulvertaft weave repair; 2) modified graft repairs (MGR group) including distal graft bony attachment repair and proximal step-cut repair; 3) Group TGR coated with cd-SF-G (TGR-C group); and 4) Group MGR coated with cd-SF-G (MGR-C group). Digit normalized work of flexion (nWOF), ultimate failure strength, and stiffness were measured.

Results
The nWOF in MGR group was significantly less than TGR group ($P < 0.05$). The nWOF in groups treated with cd-SF-G was significantly less than their untreated counterparts ($P < 0.05$). Ultimate load to failure of the MGR-C group was significantly greater than the TGR-C group ($P < 0.05$), but no significant difference in stiffness was found between these two groups.

Summary
The modified techniques can not only improve tendon gliding abilities but can also improve breaking strength. Additionally, surface modification with cd-SF-G significantly decreased the work of flexion.

Paper 25: Tenocyte Transdifferentiation Underlies Enthesis Regeneration

Clinical Paper Session 04: Tendon - Friday, September 11, 10:12 - 10:19 AM

Anatomy, Basic Science, Hand and Wrist, Elbow and Forearm, Shoulder and Arm, General Principles
N/A - Not a clinical study

Rowena McBeath, MD, PhD
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Hypothesis
The structure attaching tendon to bone – the enthesis -- comprises four distinct zones: tendon, fibrocartilage, mineralized fibrocartilage, and bone (1). The molecular and cellular signaling events responsible for human enthesis formation are unclear. Prior in vitro studies of human tenocytes have demonstrated tenocytes transdifferentiate into fibrochondrocytes (2). We hypothesize that tenocytes transdifferentiate to mineralized fibrocartilage and bone depending on changes in their microenvironment, and use our results to develop an enthesis-like construct.

Methods
Human tendon tissue was isolated from patients undergoing revision amputation from traumatic hand injury (3). Tenocytes were isolated, then cultured in hypoxic (1% O2) and normoxic (22% O2) environments in low, medium and high cell densities. Tenocyte cultures were harvested and underwent immunofluorescent staining for collagen I, collagen II, and aggrecan; and light microscopic staining for mineralization (alkaline phosphatase and alizarin red) and lipid droplet formation. Tenocytes were also harvested for quantitative RT-PCR analysis of tenocyte markers (tenomodulin, scleraxis), fibrochondrocyte markers (collagen II, aggrecan) mineralized fibrochondrocyte markers (collagen X, alkaline phosphatase) and lipids (LPL). Biochemical assays for RhoA and Rac1 GTPase activity are as described (4). Activation of RhoA and Rac1 GTPase using adenoviral transduction is as described (5). Tenocyte implantation in electrospun nanofiber constructs is as described (6).

Results
In a hypoxic environment (1% O2), tenocytes cultured at low cell density displayed increased stress fibers, increased aggrecan production, and time-dependent matrix mineralization via alizarin red staining, consistent with transdifferentiation to mineralized fibrochondrocytes. Tenocytes cultured at medium cell density retained the tenocyte phenotype. Interestingly, tenocytes cultured at high cell density formed lipid droplets. When analyzed for biochemical activity, tenocytes that had transdifferentiated into mineralized fibrochondrocytes displayed concomitant high RhoA and low Rac1 GTPase activity. Conversely, tenocytes that displayed
characteristics of intramedullary bone (e.g. adipocyte formation) displayed concomitant low RhoA and low Rac1 GTPase activity. These differential tenocyte phenotypes were maintained when cultured in a three dimensional electrospun nanofiber construct.

Summary Points
• Depending on the microenvironment, human tenocytes transdifferentiate into the cells of the enthesis.
• Mineralization of fibrochondrocytes occurs in a time-dependent fashion, and is controlled by differential activity of the RhoA and Rac1 GTPases.
• Manipulation of RhoA and Rac1 GTPase activity via adenoviral transduction, and three-dimensional control via an electrospun nanofiber construct, maintains the transdifferentiated phenotype.
• Recreation of the human enthesis through tenocyte transdifferentiation in vitro represents a novel mode of cellular therapy, applicable to finger, wrist, elbow and shoulder pathology.

Hypothesis
Current strategies to enhance tendon healing are limited by the inability to retain therapeutic cells within the injury site, presenting challenges regarding the safety and efficiency of cellular-based treatments. Previously, our laboratory has demonstrated that a novel tissue engineered cellular construct, expressing an inducible Artificial Collagen-Specific Anchor (ACSA), decreases cellular migration and improves cellular attachment to collagen-rich sites, without disrupting cell survival. The purpose of this Study is to 1) evaluate the performance of this Collagen Specific Anchor in an Ex Vivo Tendon Injury Model, and 2) determine whether its expression improves cellular integration into the injury site, enhancing tendon laceration healing. Potential advantages of this construct may include improved safety and efficiency of future cellular therapies, with enhanced tissue healing.

Methods
Our previously engineered cellular construct exhibits these features: Murine fibroblasts (NIH 3T3), anchored to human type I collagen (C-terminus, a2 chain), tetracycline (Tet)-responsive promoter, and GFP tag (Fig 1A). Stable expression of the ACSA-GFP construct in transfected cells, has previously been established (Fig. 1B). This construct was tested in a bioreactor system (LigaGen), utilizing an ex vivo rabbit Achilles tendon injury model. Cells expressing ACSA-GFP were seeded on a polyglycolic acid (PGA) scaffold, inserted into defect sites, maintained under mechanical stimulation, in the presence or absence of Dox. Histological analysis was performed on samples treated with both engineered and control cells. Fluorescence microscopy confirmed ACSA-GFP expression of integrated cells at the tendon defect sites.

Results
Tissue engineered cellular constructs expressing ACSA-GFP demonstrated efficient integration of cells at the injury defect site, and within collagen-rich elements of the native tendon (Fig 2). Fluorescent microscopy exhibited GFP signal at the tendon injury interface and the surrounding native tissue. Cellular constructs not expressing ACSA-GFP demonstrated poor integration at the
scaffold-tendon junction, with no significant evidence of cellular penetration into the surrounding tissue. Fluorescent microscopy corroborated these findings.

Summary Points

- Existing strategies of tendon healing are limited by the inability to retain therapeutic cells within the injury site, resulting in their inefficient and non-specific delivery.
- We propose a novel strategy enabling the controlled expression of collagen specific anchors at the surface of therapeutic cells, facilitating cellular retention within collagen-rich sites.
- Tissue engineered constructs expressing ACSA-GFP exhibited improved cellular integration at the scaffold-tendon junction, with increased penetration into the surrounding collagen-rich native tendon tissue.
- Potential benefits may include improved safety and efficiency of future cellular therapies, with enhanced tissue healing.

References:

Hypothesis
The interlacing weave suture technique is generally used for strong tendon transfer fixation, but is difficult to use when a tendon is short and the area of overlap is small. In that case, we often use a side-to-side tendon repair with a simple mattress suture technique, which is weaker than the interlacing weave technique. We sought to compare the mechanical strength of side-to-side tendon repairs using a modified Krackow method, traditionally used as a pull-out suture, and side-to-end tendon repairs using the interlacing suture technique for flexor tendon repair. Our hypothesis was that in clinical practice a modified Krackow method is likely to be as strong as the interlacing suture technique.

Methods
We harvested tendons from the flexor digitorum superficialis (FDS), flexor digitorum profundus (FDP), and flexor pollicis longus (FPL) from 8 unembalmed frozen cadavers. We compared the load to failure (N) of 41 repairs between 3 groups: repairs with the modified Krackow method involving 8 locking loops on the overlap space (K repairs); repairs with the interlacing suture technique consisting of 2 weaves (I repairs), with 2 mattress sutures for each weave and 2 mattress sutures on each side of the overlap region; and repairs with 8 mattress sutures placed on the overlap (M repairs). For all repairs, the length of the overlap region was 25 mm and suture material was 4-0 nylon. Subsequently, we compared displacement (mm) between 31 K and I repairs with a cyclic loading test. The load in cyclic loading test was 5 N to 75 N for 200 cycles. We defined displacement on this test as that from the second cycle to 200 cycles. Biomechanical testing data were analyzed using an ANOVA followed by an SNK test and a paired or unpaired t test. Significant difference was assumed for $P < 0.05$. 

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Clinical Paper Session 04: Tendon - Friday, September 11, 10:26 - 10:33 AM
Results
The peak load to failure for the K repairs was 155 ± 45 N, for I repairs was 122 ± 18 N, and for M repairs was 94 ± 36 N. There was a significant difference in the peak load to failure between K repairs and I repairs, and K and M repairs. K repairs showed significantly less displacement (2.9 ± 1.4 mm) than I repairs (4.0 ± 0.8 mm).

Summary
Side-to-side repair using the modified Krackow method is likely to be better in clinical practice than the interlacing suture technique given similar small areas of overlap.


*Clinical Paper Session 04: Tendon - Friday, September 11, 10:33 - 10:40 AM*

Shalimar Abdullah, MD

**Hypothesis**
A three dimensional synthetic tendon scaffold allows ingrowth of adjacent human tenocyte cells from human tendon.

**Methods**
Upper limb tendons are harvested from patients indicated for upper limb amputation after consent has been obtained. Upper limb tendons are sutured to the synthetic tendon (both sides of 0.5 cm of synthetic scaffold will be sutured to 1 cm of extensor or flexor tendon and specimen is cultured in growth medium). Eight samples will be prepared and maintained in CO2 incubator with medium change 3 times a week. At the end of 2, 4, 6, and 8 weeks, samples of the tendon from the designated weeks will be fixed with formalin overnight, embedded in paraffin and cut from paraffin blocks using a microtome. Haematoxylin and Eosin staining are performed. Tissue characteristics and percentage of growth of tenocytes are examined by a pathologist.

**Results**
There is no tenocyte growth seen in the first 2 weeks of incubation. However at 4 weeks, tenocytes are seen migrating towards the junction between the tendon and synthetic scaffold. At 6 weeks, more tenocytes are seen growing into the synthetic scaffold and at 8 weeks, tenocytes are seen in abundance in the synthetic tendon.

**Summary**
Tenocytes from human tendons of the hand can proliferate into adjacent synthetic tendon. There is potential for synthetic tendon to slowly acquire characteristics of natural tendon. Synthetic tendon which can mimic normal tendons can solve problem of limited donor tendon availability.
Hypothesis
Time to return to play after hand injuries in elite athletes has not been described. We report the return to play from metacarpal fractures, phalangeal fractures, and thumb ligament tears over a five-year period in the National Basketball Association (NBA).

Methods
The NBA transaction report was analyzed from January 2009 to May 2014. Players were identified who were added to the injured list (IL), missed games due to injury, or underwent surgery for a hand injury. Games missed, days spent on the IL, and age at injury were calculated by injury type and location. Associations between position and injury type were analyzed using Chi-square tests. Independent samples t-tests were used to compare return to play between surgically treated and non-surgically treated injuries. Welch’s Robust ANOVA with Games-Howell correction was used to compare return to play between injury type and position. A Pearson correlation was used to correlate age with return to play. Statistical significance was defined as p<0.05.

Results
One hundred and thirty seven injuries were identified, including 39 hand injuries 98 finger injuries. Three frequent injuries were identified and analyzed: metacarpal fractures, phalangeal fractures, and thumb ligament tears. (Table 1) Return to play was calculated from the date of injury to the date of return. Thumb ligament tears were treated surgically and had the longest return to play of 67.5±17.7 days (p<0.05). Return to play for metacarpal fractures treated surgically (56.7±26.3 days) was significantly greater than non-surgically repaired metacarpal fractures (26.3±12.1 days, p<0.01). Return to play for surgically repaired phalangeal fractures (46.2±10.8 days) trended greater, but was not significantly different than phalangeal fractures that were not treated surgically (33.3±28.5 days, p>0.05). Player position and age were not related to injury type or time to return to play (p>0.05).
Summary Points

- Hand injuries in professional basketball players can lead to prolonged periods of time away from competition, especially following surgery.
- Thumb ligament tears resulted in the longest return to play (67.5 days) compared to phalangeal fractures and metacarpal fractures.
- Return to play was twice as long for metacarpal fractures treated surgically than for metacarpal fractures treated non-surgically (56.7 vs 26.3 days), contradicting anecdotal information stating surgical fixation speeds return to play.
- Return to play was not significantly different between phalangeal fractures treated surgically and those not treated surgically.
- This study provides guidelines on expected return to play in the NBA for these common injuries.
Hypothesis
Hypotthenar hammer syndrome (HHS) is an uncommon cause of digital ischemia, and many patients ultimately require vascular reconstruction to alleviate critical ischemia. Long-term patency rates and related outcomes are not well established, and purpose of this study is to evaluate these endpoints following vascular reconstruction of HHS. Additionally, we aim to identify any patient or treatment related factors that may contribute to differences in outcome.

Methods
Color flow ultrasound was utilized to determine the patency of 18 vein graft reconstructions of the ulnar artery at the wrist in 16 patients. Validated questionnaires evaluated patients’ functional disability with the Disabilities of the Arm, Shoulder and Hand (DASH) score, pain with the Visual Analog Scale (VAS), and cold intolerance with the Cold Intolerance Symptom Severity survey (CISS). Patient demographics, clinical data, and surgical factors were analyzed for association with graft failure. Patients were asked to grade the result of treatment on a 0-10 scale.

Results
Fourteen of 18 grafts (78%) were occluded at a mean 118 months postoperatively. Patients with patent grafts had significantly less disability related to cold intolerance according to the CISS survey (mean 21.8 versus 55.0) in addition to significantly less pain on the VAS scale. There was no statistical difference in DASH scores between patent and occluded grafts. Patients graded the result significantly higher in patent reconstructions (9.5 versus 6.8).

Summary
The present study demonstrates a higher rate of graft occlusion than previously reported at a mean follow-up of 9.8 years, which represents one of the longer duration follow-up studies of surgical treatment of HHS to date. Despite a high percentage of occlusion, patients overall remained very satisfied with low functional disability, and all patients would recommend surgical reconstruction. This study suggests that improved outcomes may result from patent grafts long-term.
Hypothesis
Simultaneous loss of the A-2 and A-4 pulleys can cause significant bowstringing of the flexor digitorum profundus. Pulley repair is commonly done with a palmaris tendon loop about the proximal or middle phalanx. The number of loops and the location of the loops can effect the degree of bowstringing. The purpose of this study was to investigate whether repair of the A2 pulley alone in a digit having A2 and A4 pulley incompetence could lead to a good functional outcome and to determine the number of graft rings necessary for proper repair.

Methods
A motorized apparatus was constructed using potentiometers to measure angular rotation of the digit as a function of tendon excursion. After control (undamaged pulleys) testing, we recorded finger angular rotation as a function of tendon excursion of eleven cadaveric fingers after the following interventions: 1) complete excision of A2 and A4 pulley, 2) repair of distal part of the A2 pulley with one ring of tendon graft, 3) repair of the A2 pulley with two rings of tendon graft, 4) repair of the A2 pulley with two rings of tendon graft and the A4 pulley with one ring. The loss of flexion at full tendon excursion was measured both at the PIP and MCP joint and was calculated as a percentage loss as compared to controls.

Results
The loss of the A-2 and A-4 pulleys caused a loss of 32% angular excursion at the MCP joint and 19.6% at the PIP joint. At the PIP joint One ring showed a 14% loss in PIP rotational angle compared to control, 2 rings showed a 17% decrease while the use of three rings, that is, two at A2 and one at A4, had a decrease of 5%. At the MCP joint, with one ring, the decrease in rotational angle was 12% with a second ring 16% whereas with the 3 ring scenario it was 14%.
Summary Points
There is significant loss of rotation at both the MCP and PIP associated with loss of the A-2 and A-4 pulley. A double loop at the proximal phalanx fostered no advantage to the single loop. This may involve issues of increased tendon drag. The best reconstruction was the 2 plus 1 pulley reconstruction. The study indicates clinically that in cases of loss of both the A-2 and A-4 pulley, reconstruction of both pulleys should be considered.

Hypothesis
Chronic fractures affecting the PIP joint present a big challenge for hand surgeons. There is no classification for this problem. The purpose of the study is to classify this chronic fracture. We hypothesize that each stage of chronic PIP joint fractures have different appropriate treatment.

Methods
Consecutive patients with chronic PIP joint fractures presented to our center from May 2007 to Dec 2014 were included in the study. Patients who were indicated for reconstructive surgery were divided into 5 different groups according to severity of the joint injuries, and received relevant reconstructive procedures. Outcome measurements included radiographic evidence of bone healing, joint alignment and/or collapse, ROM of PIP joint, and the donor site morbidity.

Results
There were 36 patients with chronic PIP joint fractures presented to our center during the period. Among them, 23 patients received reconstructive surgery. The average age was 32 (15-54) years, with 21 males. These patients were divided into 5 groups: 2 cases of nonunion, 6 cases of malunion, 9 cases of partial osteochondral defect, 3 cases of posttraumatic arthritis, and 4 cases of joint collapse. Surgeries were performed 1 months to 3 years after the fracture or previous surgery. Following procedures were performed: ORIF + BG for nonunion, corrective osteotomy for malunion, osteochondral graft for partial osteochondral defect,vascularised joint transfer for posttraumatic arthritis, and vascularised joint transfer following distraction for joint collapse. The average arc of motion for the involved PIP joint was 79° (35°—95°). The distal interphalangeal (DIP) joint average arc of motion was 50° (0°—65°). Bony union was obtained in 22 patients. There was one painful degenerative arthritis after osteochondral bone graft and one refraction after vascularized joint transfer who converted to a revision surgery. Twenty-one patients had no pain, and 20 patients were satisfied with their function.
Summary Points

- Treat PIP joint nonunion and malunion as soon as it is recognized, excellent recovery can be achieved with minor donor site sacrifice.
- For partial articular defect, anatomical reconstruct can be achieved by osteochondral grafts with satisfactory outcome.
- If vascularised toe joint transfer is performed, donor site can be well preserved by IC bone graft and canulate screw.

Hypothesis
Ulnar collateral ligament (UCL) reconstruction is commonly performed on professional baseball pitchers to address UCL insufficiency. Some pitchers have elected to undergo revision UCL reconstruction to prolong their careers after suffering recurrent UCL insufficiency. With recent improvements in surgical techniques and rehabilitation protocols we hypothesize that UCL revision reconstruction rates in professional baseball players have decreased in recent years.

Methods
Data were collected on 271 professional baseball pitchers who underwent primary UCL reconstruction from 1974 until 2014. Each player was evaluated retrospectively for occurrence of revision UCL reconstructive surgery. Data on players who underwent revision UCL reconstruction were compiled to determine 1) total surgical revision rate and 2) revision rate by year. Yearly revision rates were analyzed for trends. Dates of primary and revision surgery, as well as ages of the players at these times and at retirement, were recorded. Average career length after primary UCL reconstruction was calculated and compared to that of players who underwent revision surgery. Logistic regression analysis was performed to assess risk factors for revision including handedness, pitching role, and age at the time of primary reconstruction.

Results
The annual rate of primary reconstructions amongst professional pitchers increased from 1974 to 2014, while the rate of revision UCL reconstructions has recently decreased. Of the 271 pitchers included in the study, 40 (14.8%) required at least one revision procedure during their playing career. Three (1.1%) cases required a second UCL revision reconstruction. The average time from primary surgery to revision was 5 years (Range: 1-13 years). The average length of career following primary reconstruction for all players was 5 years (Range: 0-22 years). The
average length of career following revision UCL reconstruction was 3 years (Range: 0-8 years). No risk factors for needing revision UCL reconstruction were found.

Summary Points

- The rate of primary UCL reconstructions amongst professional pitchers is increasing.
- The rate of revision UCL reconstructions appears to be decreasing.
- Explanations for the decreased revision rate may include improved surgical technique and improved rehabilitation protocols.
- The average length of career following primary reconstruction is 5 years compared to only 3 years following revision.
Hypothesis
The use of a laser pointer on a mini C-arm fluoroscopic unit helps to decrease the number of shots required, the time it takes to accomplish the task at hand, and decreases the radiation exposure to the surgeon and patient.

Methods
25 surgeons were tasked with obtaining "perfect circle" views of two cannulated screws placed into a cadaveric wrist while multiple parameters, including time to complete the task, number of shots required to complete the task, radiation exposure as recorded on the mini C-arm fluoroscopic unit, and the number of blank shots taken, were recorded.
A one-tailed paired Student’s t-test ($P < 0.05$) was used to determine difference between the time to complete the task, the number of shots required to complete the task, radiation exposure, and total exposure time as recorded on the mini c-arm fluoroscopy unit. A Z-test was used to determine the difference in percentages of blank shots taken by the surgeon. A post-hoc power analysis was performed and statistical analysis was also completed.

Results
An average +/- SD of 81.6 +/- 41.3 seconds were required to complete the assigned task when laser guidance was used compared to 104.6 +/- 68.2 seconds without laser guidance. ($P = 0.074$)
An average of 17 +/- 11.3 shots with the use of laser guidance and 21.8 +/- 10.4 shots without laser guidance. ($P = 0.056$) The total exposure time and total dose area product (DAP) with and without laser guidance were 24.5 +/- 19.9 compared to 29.0 +/- 15.4 and 2.4 +/- 3.5 respectively. ($P = 0.18; P = 0.26$, respectively) Lastly, the number of blank shots was significantly reduced from 88% to 12% with the aide of laser guidance. ($P < 0.001$)
A post hoc power analysis to detect a difference in the number of shots taken was 69%, 62% to detect the difference in time to accomplish the task, 33% to detect the difference in total
exposure time, 22% for difference in DAP and 100% for difference in number of blank shots taken.

Summary
The use of a laser pointer on a mini C-arm fluoroscopic unit helps to decrease the number of shots required, the time it takes to accomplish the task set at hand, and decreases the incidence of blank shots taken.

Hypothesis
The primary aim of this study was to evaluate online patient ratings (OPRs) of hand surgeons. We hypothesized that (1) the majority of hand surgeons would be rated online, (2) surgeons with greater online presence would have higher OPRs, and (3) positive comments posted on rating websites would more likely reflect surgeon-dependent factors, while negative comments would more likely reflect surgeon-independent factors.

Methods
250 US hand surgeons were randomly selected from the ASSH online member directory. We reviewed surgeon profiles on three of the most commonly visited OPR websites: HealthGrades.com, Vitals.com and RateMDs.com [1]. Written comments were categorized into 6 groups: professional competence, communication, cost, overall assessment, staff and office practice [2]. Surgeon-specific data were also collected from Google, Facebook and Twitter. Independent sample t tests were used to compare OPRs between surgeons who had a website, Facebook or Twitter page. One way ANOVA was used to analyze the mean number of written comments between groups. Analyses were conducted with SPSS version 22.0.

Results
250 hand surgeons from 43 states were included in this study. 245 hand surgeons (98%) had at least one OPR among the three websites. The number and magnitude of OPRs are presented in Figure 1. When Google searching hand surgeons, the mean number of top 10 results dedicated to OPR websites was 3.4.
220 hand surgeons (88%) had a professional website. Links to professional Facebook and Twitter pages were listed on 113 (45%) and 50 (20%) surgeon websites, respectively. Surgeons with an increased online presence (i.e. website, Facebook or Twitter pages) had significantly higher OPRs on RateMDs.com ($P < 0.01$, 0.02, 0.02, respectively) and Vitals.com ($P < 0.01$, 0.80, 0.08, respectively).
Positive online comments were found to be more likely associated with surgeon-dependent factors (i.e. clinical outcomes), while negative comments more likely reflected surgeon-independent factors (e.g. wait time, office staff, cost) (Figure 2).

Summary Points

- OPR websites are increasingly utilized by patients to inform decision-making, despite potential concerns regarding validity [3-6].
- OPR websites feature prominently on Google and 98% of hand surgeons are reviewed online.
- This is the first study to evaluate hand surgeon OPRs, assess factors associated with positive OPRs in orthopedic surgeons, and/or correlate physician online presence with OPRs.
- This is the first study to distinguish between physician-dependent and physician-independent factors with respect to positive and negative written OPRs, respectively. This finding highlights a fundamental difference in how patients and physicians assess care quality.

Paper 36: A Prospective Comparison of Large vs Mini C-Arm Fluoroscopy and Resultant Eye Radiation Exposure

Clinical Paper Session 06: Practice Management - Friday, September 11, 11:39 - 11:46 AM

Hand and Wrist
Level 2 Evidence

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Hypothesis
The WHO recognizes cataract as the most prevalent eye disease in the world, and the association of eye radiation exposure with the premature development of cataracts has been reported. The current concept in the pathogenesis of radiation-induced cataract formation suggests elevated radiation levels lead to the generation of reactive oxygen species and increased DNA damage at the lens epithelium, resulting in cataractous lens. During routine Hand Surgery, fluoroscopic radiation exposure is a potential occupational health hazard, given operator proximity and the relative lack of eye shielding. The purpose of this study is to 1) perform a prospective comparison of Large versus mini C-Arm Fluoroscopy and resultant eye radiation exposure, and 2) test the hypothesis that mini C-Arm use yields lower radiation loads, which do not exceed the critical eye radiation dosages associated with cataractogenesis.

Methods
Over a six month period, eye radiation exposure was measured in a Board-Certified Hand Surgeon (CFL) utilizing both Large and mini C-Arm fluoroscopy during routine surgical procedures. Eye dosimeters were secured to surgical loupes at the level of the orbit. Specific dosimeters were designated for Large and mini-C-Arm use. Accumulated radiation dosage was analyzed and compared to control badges on a monthly basis, and background exposure was eliminated (Landauer). For each procedure, radiation output was logged, including the dose rate, total accumulated dosage, and total exposure time.

Results
During the collection period, 38 cases used Large C-Arm fluoroscopy, and 11 cases used the mini C-Arm. Common procedures included ORIF distal radius fractures, removal of hardware, closed
reduction and percutaneous pinning of metacarpal and phalangeal fractures. Average monthly mini C-arm radiation output: dose rate: 4.68±2.09 mGy/sec, total accumulated dosage: 10.58±4.86 mGy, and total exposure time: 38.62±6.83 sec. Average monthly Large C-arm radiation output: dose rate: 2.94±1.90 mGy/sec, total accumulated dosage: 5.44±4.27 mGy, and total exposure time: 42.56±7.99 sec (Fig. 1). For both Large and mini C-Arm Fluoroscopy, average monthly eye radiation exposure was undetectable (<30 mrem). These values were significantly less than the previously reported maximum radiation dosage to the eye (1,250 mrem/month).

Summary Points
• Routine use of protective lead lining eyewear among Hand surgeons remains rare.
• No significant differences in eye radiation exposure were noted between Large or mini C-Arm use, suggesting that accumulated eye radiation dosage does not approach previously reported levels of critical radiation loads.
• Further investigation into C-arm radiation exposure may validate the safety associated with its routine use during Hand Surgery.
Hypothesis
Despite federal legislation, wide variation persists in the referral patterns of upper extremity trauma patients. We sought to understand the differences in transfer rates for patients with upper extremity trauma by hospital trauma center designation, and hypothesized that uninsured and underinsured patients are more likely to be transferred to another facility compared with privately insured patients.

Methods
Trauma centers are designated by local authorities and verified by the American College of Surgeons. Using the 2012 National Trauma Data Bank, we examined the probability of a patient with isolated upper extremity trauma to be transferred from one center to another. We used multivariable logistic regression to compare risk-adjusted transfer rates for patients with upper extremity injuries by trauma center designation and clustered variance method to adjust for intra-hospital correlation.

Results
In 2012, 6,295 adult patients ages 18-64 with isolated upper extremity trauma presented to 477 hospitals. Overall, transfer rates were significantly higher among level III trauma centers (26%) compared with level I (2%) or level II (11%) trauma centers ($P < 0.001$). Adjusting for patient and hospital characteristics, patients with public insurance were more likely to be transferred from level III trauma centers to another center (OR=1.76, CI: 1.07-2.88) compared with being privately insured.

Summary Points
• Underinsured patients with upper extremity trauma injuries were more likely than privately insured patients to be transferred from level III trauma centers.
• Lack of transfer guidelines for upper extremity trauma, scarcity and unbalanced distribution of hand and plastic surgeons in level III trauma centers and financial considerations of smaller community hospitals may explain substantial hospital-level variation in upper extremity trauma care in the U.S.
• Current regulations may not prevent unnecessary patient transfers based on insurance status among level III trauma centers.
• Policy makers may need to provide compensation or incentive to overcome the financial burden of providing care for underinsured patients among smaller and less financially secure hospitals.
Hypothesis
No previous study has examined factors within a large population of hand surgeons that may contribute to variability in Medicare reimbursement. We hypothesize that a significant variation in Medicare reimbursement exists among hand surgeons based on factors including number of years in practice and geographic location.

Methods
We queried data from all surgeons with active membership in the American Society for Surgery of the Hand (ASSH) in 2012. Identifying data for active ASSH members were matched with provider information from the Medicare database as produced by the United States Centers for Medicare and Medicaid Services (CMS). Members with inconsistent or missing data between the two databases were excluded. A total of 1,667 hand surgeons satisfied inclusion. For each surgeon, we obtained total CMS reimbursement, as well as individual reimbursements for each service provided. Surgeons were sub-categorized based on the number of years they had been ASSH members and by their primary state of practice. Average reimbursements were compared between sub-groups using ANOVA analysis.

Results
Mean and median total CMS reimbursements for all ASSH members were 68,139.63 and 49,236.84, respectively (range 262.73 to 919,128.92). Of the four states with at least 90 hand surgeons, Florida had the highest reimbursement per surgeon ($131,781.00 per 93 surgeons) followed by New York ($72,401.80 per 104), Texas ($60,857.34 per 94) and California ($60,345.85 per 162). There was no significant correlation between number of hand surgeons per capita and mean reimbursement. When reimbursement was compared across groups based
on years as ASSH members, there was a significant difference between all three age groups with the highest mean reimbursement among the 8-20 year group (mean 74,952.34, median 52,764.02) followed by the over-20-year group (mean 64,352.63, median 45,499.51) and the 0-7 year group (mean 60,501.16, median 46,471.20).

Summary
We believe this to be the first study to examine factors exclusively among a large cohort of U.S. hand surgeons that may contribute to variability in reimbursement from Medicare. The non-linear relationship between hand surgeons’ time in practice and their total reimbursement from Medicare suggests that higher reimbursements parallel surgeons’ prime period of surgical volume rather than a predilection for or against treating the Medicare population.

The geographic variations in reimbursement do not correlate with state population or hand surgeons per capita. This may suggest that these geographic variations are more closely tied to their respective patient demographics, as opposed to a “supply and demand” model of surgeons, as suggested in other studies.

Hypothesis

In treating carpometacarpal (CMC) osteoarthritis, it is currently unclear whether ligament reconstruction and tendon interposition (LRTI) or suture button suspensionplasty is more effective at restoring native biomechanical range of motion (ROM). Our goal was to test if suspensionplasty is equivalent to LRTI utilizing a custom CMC joint simulator in an in-vitro cadaveric model.

Methods

A novel robotic linear actuator simulator system was devised to generate CMC circumduction via tendon excursion in cadaveric arms under load control. Six tendons (Flexor Pollicis Longus, Abductor Pollicis Brevis, Abductor Pollicis Longus, Extensor Pollicis Brevis, Extensor Pollicis Longus, Adductor Pollicis) were sutured to the actuator system at their proximal muscle origins, utilizing minimal exposure of the tissue to promote hydration and native force vectors of the tendons. Intrinsic tendon physiologic vectors were maintained by redirecting the attached suture through eyelets secured to bony landmarks (the scaphoid tubercle and third metacarpal for the Flexor Pollicis Longus and Adductor Pollicis, respectively). The actuators pulled on individual tendons to a maximum tensile force of 20N, in addition to controlled releasing of each tendon in a specific and repeatable sequence that allowed mobilization of the joint. Motion of the joint in the flexion/extension, abduction/adduction, and circumduction planes was quantified using opto-electric tracking. The metacarpophalangeal and interphalangeal joint were pinned with a
Kirschner wire while the thumb was fully extended in order to prevent joint articulation distal to the CMC. Motion was analyzed for seven matched pairs of cadaveric specimens (n = 14), with each pair receiving a LRTI and suspensionplasty intervention. Circumduction data was calculated using the closed area of motion data points, projected on the fitted plane using custom Matlab software. Data was statistically compared between both interventions using non-parametric analysis (Mann-Whitney U) with significance set at $P = 0.05$.

Results
Results are presented on Table 1. There was no statistical difference between interventions for all motion planes ($P = 0.277$ for all cases). The standard deviation for suspensionplasty circumduction was much lower, indicating that this particular intervention had a more reliable outcome.

Summary Points
- CMC circumduction in a cadaveric model was accomplished using tendon excursion and robotic actuation with force feedback.
- Matched pair-comparison of an LRTI and suspensionplasty found that there was no statistical difference between the kinematics of both interventions.
- Suture button circumduction motion was found to have a much lower standard deviation, and thus a more reliable outcome.

Hypothesis
We hypothesize digital X-rays, similar to the analog counterparts, have poor accuracy and reliability in determining bone mineral density relative to DEXA scan.

Methods
We prospectively evaluated female patients older than 65 years who presented to our hand clinic and had digital hand and wrist X-rays as part of their evaluation. Patients who had a fracture and those who had not had a DEXA scan within the past two years were excluded from the study. The remaining 34 patients form the basis of this study. Five fellowship-trained hand surgeons, blinded to DEXA scores, evaluated the x-rays and classified them as osteoporotic, osteopenic, or normal bone mineral density. The surgeons viewed the images on a standard PACS terminal and were permitted use of the digital manipulation tools to replicate the common clinical scenario. Four weeks after the initial assessment, the X-rays were again randomized and a second assessment was performed. Accuracy relative to DEXA score was tabulated, and interobserver and intraobserver agreement were also calculated.

Results
The observers performed a total of 340 assessments. The assessments relative to DEXA scores were correct in 169 of the assessments (49%). Only one x-ray was correctly diagnosed by all physicians over both assessments while two x-rays were never correctly diagnosed. Analysis of the incorrect assessments revealed that observers tended to underestimate or overestimate bone mineral density at an approximately similar rate (49% and 51% respectively). When the observations were inaccurate, reviewers were off two grades (normal vs. osteoporosis and vice versa) in 17% of the evaluations and 1 grade (normal vs. osteopenia, osteopenia vs. osteoporosis...
and vice versa) in 83% of the evaluations. A mean weighted kappa coefficient of agreement between observers was 0.29 (range 0.02-0.41) indicating fair agreement. The mean weighted kappa coefficient for intraobserver agreement between the first and second assessment for all five physicians was 0.46 (range 0.19-0.78) indicating moderate agreement.

Summary Points
- Abnormally low bone mineral density is a common occurrence in patients treated for upper extremity disorders.
- There is poor accuracy and only fair agreement in diagnosing osteoporosis compared to DEXA using visual assessments of digital hand and wrist x-rays.
- Digital hand x-rays have significant limitations as a tool for evaluating bone mineral density.

Paper 41: The Relationship Between the Bony Morphology of First Metacarpal Base and the Stability of the Thumb Carpometacarpal Joint in a Normal Female Population

Clinical Paper Session 07: CMC Joint - Friday, September 11, 1:59 - 2:06 PM

Evaluation/Diagnosis,Treatment,Prognosis/Outcomes,Hand and Wrist,Diseases and Disorders
Level 1 Evidence

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Hypothesis
Instability of the thumb carpometacarpal joint (CMCJ) is considered as a major cause or an early stage of CMCJ osteoarthritis. We evaluated the effect of the bony morphology of first metacarpal base on the stability of thumb CMCJ.

Methods
We evaluated 108 female hands without generalized ligament laxity or CMCJ osteoarthritis. We evaluated bony morphology of the first metacarpal base using the first metacarpal slope (MS) measured in true lateral radiographs of the first metacarpal, and evaluated radiologic instability of the thumb CMCJ using the subluxation ratio (SR) measured in CMCJ stress view radiographs. After dividing the subjects into 4 subsets according to age or MS, we compared the CMCJ instability (SR) between those in the upper and lower quartile groups. We also performed correlation analyses among age, MS, and SR.

Results
The mean age was 57 years. The mean MS was 82.3 degrees (standard deviation (SD), 4.2 degrees; range, 71.2 to 89.8 degrees), and the mean SR was 0.27 (SD, 0.13; range, 0 to 0.57 degrees). There was statistically significant difference in the mean SR between those in the upper and lower quartiles of MS (0.24 vs. 0.32, $P = 0.013$), meaning those with smaller MS are more likely to have radiologic instability of the CMCJ. The mean SR did not differ between those in the upper and lower quartile of age ($P = 0.79$). There was no statistically significant relationship among age, MS, and SR in Pearson’s correlation test.
Summary
This study found that radiologic instability of the thumb CMCJ was larger in women with smaller metacarpal slopes than in women with larger metacarpal slopes. However, there was no relationship between the age and the metacarpal slope or radiologic instability of the CMCJ. These finding suggest that age does not affect the first metacarpal morphology or radiologic instability of the CMCJ, but that the first metacarpal base morphology may affect the joint’s radiologic instability, which may be associated with the development and progression of thumb CMCJ osteoarthritis.

Hypothesis
A simple reconstructive method for treating advanced arthritis of the thumb carpometacarpal (CMC) joint with suture suspension arthroplasty (SSA) is a reliable, low morbidity procedure, providing a simpler alternative with similar long-term outcomes, compared to trapeziectomy procedures, with or without ligament reconstruction.

Methods
SSA technique for thumb CMC arthritis reconstruction consists of trapeziectomy via a single volar incision and a four-strand intra-articular suture (0 gauge non-absorbable) suspension sling, creating a “hammock” between the distal-most insertions of the abductor pollicis longus and the flexor carpi radialis. This construct is pulled firmly, tethering the base of the thumb towards the base of the index metacarpal, correcting the subluxation deformity and maintaining arthroplasty space. All procedures were performed by the senior author, averaging 22 minutes operative time, followed by 14 days of post-operative immobilization, then short opponens splinting for four weeks and rehabilitation protocol (1), progressing to unrestricted use by 12 weeks. Long-term evaluation of 117 thumbs (average 89.4 months) with strength measurement and QuickDASH questionnaire, were analyzed with a paired t test. Final Xrays were obtained.

Results
117 out of 153 thumbs in 110 patients (76% recall) were available for long-term follow up averaging 89.4 months (80-104 months). 96 patients were female, 21 male. Statistically significant ($P < 0.05$) improvement in pain relief, patient satisfaction, grip, key and tip pinch strength, and functional improvement was noted in the majority of patients. Average QuickDASH score (0.3) at final follow up indicated good to excellent satisfaction and functional use in the majority of patients. Xray evidence of subsidence averaged 30% (0-90%). One patient (0.8%) required revision surgery. Flexor carpi radialis rupture occurred in 7 (6%) thumbs after a sudden stress activity around 4-6 weeks post op, requiring no additional treatment.
Summary Points

• Suture suspension arthroplasty for thumb CMC arthritis reconstruction is a simple, reliable method. Patient advantages include lower morbidity as a result of a single incision without tendon sacrificing, and avoidance of potential complications related to multiple incisions, tendon harvesting, drill hole formation, hardware implantation, pin fixation, or prolonged immobilization. Most patients are able to resume normal, unrestricted use at 12 weeks post-operative.

• This method is cost-effective, utilizing less operative time, and does not require additional cost of implants or anchors.

• Long-term results of suture suspension arthroplasty show similar outcomes as described with other methods of trapeziectomy, with or without ligament reconstruction (2), resulting in a very high degree of patient satisfaction, with a simple, minimally invasive, and cost-effective option.

Hypothesis
The medical management of rheumatoid arthritis has dramatically changed with the approval of biologic disease-modifying anti-rheumatic drugs (DMARDs). Today, early initiation of DMARDs is considered standard of care and a quality indicator by many professional societies. Among rheumatologists, surgical intervention is often considered a treatment failure. In contrast, surgeons fear that surgical referrals are delayed, potentially losing the opportunity to achieve a functional and aesthetically pleasing reconstruction for advanced deformities. This study examines the effect DMARDs (biologic and non-biologic) on the rates of RA-related procedures among older adults. We hypothesized that rates of surgery are lower among patients who receive biologic DMARDs.

Methods
We examined all fee-for-service claims drawn from the Medicare Beneficiary Summary files between 2006 to 2012, including Part A, Part B, and Part D prescription drug events. We used National Drug Codes to identify the receipt of biologic and non-biologic DMARDs. We applied Current Procedural Terminology and ICD-9 codes to identify RA-related upper extremity procedures for the shoulder, elbow, wrist and hand. We used hierarchical logistic regression to examine the effect of patient-level factors, including the receipt of DMARDs and annual number of rheumatologist visits, and regional factors, including provider density, on rates of upper extremity reconstruction for RA (defined as number of RA patients who received the surgery per 10,000 RA patients per year).

Results
In this cohort of 250,453 Medicare Beneficiaries with RA, 2.4% underwent upper extremity procedures, with wide variation across hospital referral regions (0.1% - 2.57%; national average rate=0.9%). (Figure 1) After controlling for other patient and regional-level factors, patients who received biologic DMARDs by infusion (OR=1.63; 95%CI: 1.39-1.93) or injection (OR=1.66; 95%CI: 1.51-1.83) were more likely to undergo upper extremity reconstruction compared with patients who received non-biologic DMARDs or no DMARD therapy (Table 1). Additionally, patients who visited rheumatologists more than 3 times per year were more likely and were maintained on biologics were twice as likely to undergo surgery compared with patients maintained on non-biologic DMARDs or without DMARDs and fewer rheumatologist visits (OR=2.12; 95%CI: 2.01-2.33).

Summary Points
• Among older patients, biologic DMARDs do not reduce the need for upper extremity reconstruction.
• Given the substantial cost and immunosuppression risk associated with biologic DMARDs, comparative evidence is needed to discern which patients will derive benefit from medical or surgical intervention, and surgeons should continue to play an integral role in the multidisciplinary care of RA patients.
Hypothesis
It is currently unknown whether time from injury affects outcomes following repair of dorsal scapholunate ligament (SLL) tears. We tested the null hypothesis that the outcomes of SLL repair are similar when performed within 6 weeks of injury (acute repair) versus when repaired from 6 to 12 weeks following injury (subacute repair).

Methods
This case-control study examined 22 patients (12 acute repair, 10 sub-acute repair) who underwent dorsal SLL repair for isolated complete tears of the SLL, with or without supplementary capsulodesis. Patients who underwent SLL repair for complete rupture of the dorsal SLL between 1996 and 2012 were identified from an electronic billing database. Demographic data (age, sex, BMI, occupation, tobacco use) was recorded and radiographic measurements (SL angle and SL gap) were determined from preoperative radiographs. All patients returned to clinic for a study-related visit including radiographic examination of the injured wrist (PA, lateral, supinated PA grip view), physical examination (wrist range of motion, strength testing) and standardized questionnaires (Michigan Hand Questionnaire, VAS-function and pain, SF-12). Analyses were performed on all categorical and continuous data to compare acute and subacute repair groups ($P < 0.05$).

Results
The median length of follow-up for the acute and sub-acute groups were 5.5 and 6.1 years, respectively (Table 1). There was no significant difference in any of the variables between the two groups. The groups were near identical with regard to final SL angle (acute: 66°, subacute: 65°), final SL gap (3.0 mm, 2.9 mm), and proportion of cases that progressed to scapholunate-advanced collapse (2/12, 2/10). Patient-rated outcomes were not different between patient groups (Table 2). Wrist motion ($P = 0.20$) and forearm motion ($P = 0.21$) were also comparable.
for the acute and subacute repairs. Both acute and subacute repairs demonstrated well-preserved grip strength (98% of unaffected versus 90%) ($P = 0.29$).

Summary Points
- At a median follow-up of 5.5 and 6.1 years, respectively, no statistically significant or clinically relevant differences were found when comparing radiographic findings, patient rated outcomes and wrist motion following acute and subacute SLL repair.
- Acute and subacute repairs of the SLL demonstrate similar rates of progression to end-stage arthritis.
- Whether treated within 6 weeks or 12 weeks of injury, SLL repair may produce a similar outcome when reparable ligamentous tissue exists.

Reference 2: Pomerance J. Outcome after repair of the scapholunate interosseous ligament and dorsal capsulodesis for dynamic scapholunate instability due to trauma. J Hand Surg Am. 2006;31:1380–1386
Hypothesis
The biomechanical property of the capitohamate (CH) ligament is equivalent to the SL ligament. We reconstructed torn SL ligament using the bone-CH ligament-bone substitute.

Methods
Indications of this procedure are unreparable complete disruption of the SL ligament (Fig 1A). Scapholunate joint was reduced by manual or joystick maneuver, then temporary fixed with 2 K-wires and the scaphocapitate interval was fixed with 1-2 K-wires. The dorsal portion of the SL ligament was refreshed and the 5 mm×10 mm×5 mm (width, length, depth) cubic gutter was made at the exact position of the dorsal portion of the SL ligament by a chisel. Proximal half of the CH ligament with capitate bone and hamate bone (bone-CH ligament-bone) was harvested as same size as the gutter made at the SL ligament, then grafted, fixed firmly with 1.2 mm diameter titanium screws to the scaphoid and lunate to reconstruct the SL ligament (Fig 1B and C). Since 2008, 15 wrists of 14 patients with an age of 38 years (range 25 to 75) underwent this procedure with at least 1-year follow. There were 14 male and 1 female, 11 rights, 2 left and 1 bilateral wrists. Thirteen wrists indicated dissociation of SL joint gap more than 3 mm and two indicated complete SL ligament disruption with severe DISI deformity. K-wires were removed 8 weeks after the surgery and active ROM exercise began. We evaluated pain (VAS), wrist motion (angle), radiographic characteristics, such as SL gap (mm), SL angle, and modified Mayo wrist score.

Results
VAS was improved to postoperative 77 from preoperative 12. We obtained average wrist extension/flexion of 74/60 degrees. There was no ossification of reconstructed SL. SL gap was improved average 4.8 mm to 2.1 mm and SL angle was changed from 67 to 55 degrees (Fig. 2).
Modified Mayo wrist score was improved to 82 points postoperatively from preoperative 47. Clinical outcome was 8 excellent, 6 good and 1 fair with modified Mayo-wrist score.

Summary
We obtained excellent radiographic and clinical results of complete disruption of the SL ligament by reconstruction using bone-CH ligament-bone substitute.

Hypothesis
A biomechanical study was performed to determine the efficacy of an articulating intercarpal screw for restoring normal scapholunate kinematics following sectioning of scapholunate interosseous ligament (SLIL). We hypothesized that the screw would resist scapholunate (SL) gapping while permitting normal rotational motion of the scaphoid and lunate during simulated wrist motion in a cadaver model.

Methods
Optoelectronic motion sensors were placed on the scaphoid, lunate, distal radius and 3rd metacarpal of 10 young cadaver wrists. The wrist tendons were loaded with 100N. Cyclic testing of the wrist was performed in flexion/extension (FE), radial/ulnar deviation (RUD) and dart-throwing motion (DTM). Kinematic data was analyzed to determine differential movement of the scaphoid and lunate with 1) SLIL intact, 2) after sectioning the SLIL, 3) after sectioning the SLIL and cycling the wrist through 1000 cycles of flexion/extension, and 4) after SL reduction and placement of the articulating intercarpal screw. Scaphoid and lunate motion for each testing state were compared using repeated measures ANOVA with statistical significance set at $P < 0.05$.

Results
After cutting the SLIL, changes of scaphoid and lunate motion were observed. During FE the scaphoid moved into radial deviation ($P = 0.02$) and the lunate moved into flexion ($P = 0.01$). During wrist RUD, the scaphoid moved into ulnar deviation ($P = 0.016$) and the lunate moved
into extension ($P = 0.012$). During DTM, the scaphoid moved into ulnar deviation ($P = 0.03$), and the lunate moved into extension ($P = 0.04$) and ulnar deviation ($P = 0.018$).

After cycling the wrist through 1000 cycles, further changes in motion were observed. During FE, the scaphoid moved into further radial deviation ($P = 0.02$) and during DTM the scaphoid and lunate both moved into further ulnar deviation ($P = 0.046$ and 0.042 respectively).

Placement of intercarpal screw across the SL joint corrected the motion changes that were observed after SLIL sectioning and motion through 1000 cycles. There was no significant difference in the motion of the scaphoid or lunate during FE, RUD, DTM with the screw in place compared to motion with an intact ligament.

Transecting the SLIL and cycling the wrist through 1000 cycles of FE did not produce an SL gap during FE ($P = 0.364$), RUD ($P = 0.290$), or DTM ($P = 0.524$).

Summary Points
- Sectioning the SLIL and repetitive cycling of the wrist created significant changes in motion of the scaphoid and the lunate during wrist range of motion.
- Placement of an articulating intercarpal screw corrected the changes in scaphoid and lunate motion while permitting independent intercarpal motion.

Hypothesis
In a survey of yoga professionals, the wrist accounted for 11.5% of reported injuries. The purpose of this study was to evaluate how modifications may decrease strain and prevent injury in three common yoga positions - downward dog (DD), chaturanga (Ch), and side plank (SP).

Methods
The participants were 43 healthy volunteers, 23 females and 20 males. Mean age was 27 years. Peak pressure, maximum force and load distribution were measured in standard and modified positions in DD, Ch, and SP using a pressure-measuring device. Wrist extension was also measured in these same positions. Modification to the DD position consisted of placing the palms on an elevated platform. Ch and SP were modified by permitting the participants to have their knees on the floor rather than balance on their toes. Modified positions shifted the center of gravity further toward the lower torso, decreasing both load forces on the wrist and degree of wrist extension. A two-way ANOVA was performed to assess the effect of standard and modified positions on peak pressures.

Results
Peak pressures decreased from 379.4 to 308 kPa and 483.1 to 401.9 kPa in the modified Ch and SP positions, respectively ($P < 0.001$). The modifications in DD did not significantly affect the peak pressure ($P = 0.713$). Similarly, maximum force was decreased in modified Ch and SP positions, with Ch decreasing from 290.0 to 244.2 N and SP from 433.0 and 360.1 N ($P < .001$). The modifications in DD did not significantly affect maximum force ($P = 0.518$). Analysis of load distribution mapping showed that peak pressure and maximum force were highest in the thenar area in the palms in DD and SP positions. In Ch, peak pressure and maximum force were highest in the hypothenar area. The angle of wrist extension increased in Ch and SP from 70.3 to 70.7 and 82.3 and 83.3. Wrist extension decreased in the DD position from 57.5 to 52.0.

Summary Points
• Modified SP and CH yoga positions resulted in a significant decrease in peak pressure and maximum forces by shifting the center of gravity toward the lower torso.
• Modifications to the DD pose resulted in a significant decrease in wrist extension angle potentially adding protective benefits.

Reference 2: Suprak DN, Dawes J, MD S. The effect of position on the percentage of body mass supported during traditional and modified push-up variants. J Strength Cond Res. 2011 Feb;25(2):497-503
Hypothesis
Wrist denervation has been shown to be a good option for patients with chronic wrist pain related to articular degeneration or chronic instability. Removal of the sensory innervation to the wrist joint provides relief of pain; however denervation does not address the underlying pathology. Patients continue to undergo degenerative changes and may need revision procedures. This study reviews the 20 year long term outcomes of patients treated with partial wrist (anterior and posterior interosseous nerve) denervation focusing on need for and time to salvage procedure.

Methods
We conducted an IRB approved retrospective study over a 20 year period of all patients undergoing wrist denervation by the lead authors between 1994 and 2014. At latest follow up, data including range of motion, grip strength, radiographic degeneration and need for revision surgery were recorded.

Results
The series includes 106 patients (68 male, 38 female) with an average age at surgery of 52 (range 14 to 80). Average follow up was 78 months (range 3 to 212). The main diagnoses in this series were SLAC degenerative arthritis (43%) and radiocarpal arthritis (40%). Average flexion to extension arc was 93 degrees on the affected extremity (76% of the contralateral) and average grip strength was 83% of unaffected extremity. Seventy one percent of patients (75/106) had satisfactory outcomes and did not require revision procedures at average follow up of 78 months (range 3 to 212). Twenty nine percent (31/106) of patients underwent revision surgery including four corner fusion (11), total wrist fusion (6),
proximal row carpectomy (4), radiosapholunate fusion (3), total wrist arthroplasty (1), Sauve-Kapandji (1), ulnar shortening procedure (1), Darrach (1), radial styloidectomy (1) and ulnar head hemiresection interposition arthroplasty (1). Time to salvage surgery was on average 25 months after denervation (range 2 to 165).

Summary Points
- Partial wrist denervation is a reliable motion preserving procedure for patients with chronic wrist pain. In this series, 71% of patients experienced pain relief and did not require further salvage procedures at an average of 78 months of follow up.
- Twenty nine percent of patients ultimately underwent salvage procedure. On average, the patients experienced pain relief for 25 months (range 2 to 165) prior to ultimately undergoing a salvage operation.
- The significance of these results better enable surgeons to give time estimates and expectations regarding pain control following wrist denervation in the patient with chronic wrist pain.
Paper 49: Hydrophilic Polymers Immediately Restore Axonal Continuity as Assessed by Retrograde Tracer

**Clinical Paper Session 09: Basic Nerve - Saturday, September 12, 8:45 - 8:52 AM**

Basic Science, Hand and Wrist, Elbow and Forearm, Shoulder and Arm, Nerve

N/A - Not a clinical study

David C. Riley, BS

**Hypothesis**
Polyethylene glycol (PEG) immediately restores axonal continuity using an in-vivo rat sciatic nerve injury model.

**Methods**
Female Spraque-Dawley rats were anesthetized with inhaled 2% isoflurane. The left sciatic nerve was exposed by making a clean 25 mm transection through the biceps femoris. Pre-injury compound action potentials (CAPs) were recorded. The nerve was transected and repaired using standard microsurgical techniques. Polyethylene glycol (PEG) was delivered into the neurorraphy using a novel application device. Post-repair compound action potentials were recorded immediately following repair. The sciatic nerve was then cut 4-5 mm distal the repair site. The proximal stump was exposed to 5 µL of 2% fast blue tracer for 1 hour. The biceps femoris was sutured using horizontal mattress sutures and the skin re-approximated using a running subcuticular suture. Animals were sacrificed on post-operative day 7 by perfusion fixation. Thirty evenly spaced cross-sections of the lumbar spinal cord were taken from L2-L4. Experimental animals were treated with Plasmalyte A, 1% methylene blue, 50% by weight solution of polyethylene glycol (PEG), and Lactated Ringers; control animals did not receive PEG.

**Results**
We found that PEG rapidly restores axonal continuity as assessed by compound action potential conduction and intracellular retrograde tracer across the injury site. In our study, we found that 83.33% (5/6) of PEG fused animals had restored CAP function immediately following repair while 0% (0/6) of control animals had any signs of CAP recovery. Additionally, PEG treated animals were associated with a statistically significant increase in the number of fluorescently labeled motor neurons from L2-L4 of the spinal cord compared to negative control animals. Finally, we found a significant decrease in the number of fluorescently labeled cells for PEG vs positive control which indicates that not all axons are being fused in PEG treated animals.

**Summary Points**
• We believe PEG fusion techniques may drastically improve the long-term recovery of more proximal nerve injuries where poor outcomes are more common.
• The ability to record through conduction action potentials following repair in PEG treated animals suggest that axonal continuity is immediately restored following application of PEG.
• The increased number of fluorescently labeled motor neurons in PEG vs negative control animals suggests that restored axonal continuity following PEG fusions is maintained for days following surgery.
• The decreased number of fluorescently labeled motor neurons in PEG vs positive control animals suggests that the efficacy of PEG fusion procedures could be increased.

Hypothesis
In previous animal studies commercially available processed nerve allografts have been inferior to autograft nerve for motor recovery. The goal of this study is to create an optimized nerve allograft (in vitro) and subsequently challenge it to the nerve autograft regarding motor nerve regeneration (in vivo).

Methods
For the in vitro experiment 50 rat nerves were processed. Based on previous research, standard decellularization protocols were used with different modifications and the addition of an highly potent enzymatic step Elastase. Subsequently, the nerve segments were stored at either 4 or -80°C for the duration of two weeks. Both processed and fresh control nerves were analyzed with confocal microscopy using immunohistochemical stainings on the basal lamina (laminin ?, S100 protein) and immunogenicity (major histocompatibility complex class I). Morphology of the ultrastructure and amount of cellular debris was analyzed on cross sections of the nerves stained with toluidine blue and analyzed under electronmicroscopy. The superior method of this in vitro project was used for implementation in vivo to test the motor functional outcome of the nerve allograft in a rat. In the in vivo project, 60 rats sustained an 1 cm sciatic nerve reconstruction with either autograft(I), non-frozen allograft(II), or frozen allograft (III). Twelve and 16 weeks post-operatively motor functional outcome was determined with ankle angle, electrophysiology, isometric tetanic force, muscle mass and histomorphometry.

Results
Nerve ultrastructure was preserved with all decellularization protocols. Storage at -80°C severely altered nerve ultrastructure after any decellularization method. Elastase was found to
significantly reduce the immunogenicity (MHC-I) and the amount of Schwann cells (S100), while maintaining good structural properties. When tested in vivo, significant differences were found between the three groups with regard to motor function at both 12 and 16 weeks. Cold storage of the processed allograft shows better results than the frozen stored allograft and reached the level of the nerve autograft.

Summary Points
- Elastase, when added to nerve processing, reduced immunogenicity, diminished cellular debris and removed Schwann cells better while maintaining ultrastructure.
- Storage at -80°C after the decellularization process heavily damaged nerve ultrastructure compared to cold storage.
- The in vivo study, the optimized processed nerve allograft showed comparable to the golden standard, the nerve autograft, at both 12 and 16 weeks postoperatively.
Hypothesis
Several alternative approaches to autologous nerve grafting have been developed. Nevertheless, current regenerative medicine-based techniques are severely limited and do not provide satisfactory results. Currently used allograft conduits require immunosuppression and demonstrate poor motor recovery. The aim of this study was to test the feasibility of Epineural Sheath Conduit (ESC) Supported with Bone Marrow-derived Stromal Cells (BMSC) on restoration of 6 cm long nerve defect in sheep model.

Methods
Sheep model was used due to morphometrical resemblance of sheep peripheral nerves to human nerves and ability for long nerve defects creation. ESC was created from the median sheep nerve by removing all fascicles. Sheep BMSC were purified by the buffy coat method and cultured for 14 days. Next, cells were fluorescently labeled with PKH-26 dye and injected into the empty ESC (70-80 x 106 cells). Restoration of 6cm median nerve defect was performed in 6 experimental groups (n = 6): Group 1: autograft controls, Group 2: autogenic ESC filled with saline control, Group 3: autogenic ESC filled with autogenic BMSC, and Group 4: Allogenic ESC filled with autogenic BMSC. At 3 and 6 months follow up, nerve conduction velocity (NCV) and somatosensory evoked potential (SSEP) measurements and nerve samples were collected for immunohistochemistry.

Results
All animals recovered from the surgery without complications. The shape and integrity of the conduit was preserved in all groups. The NCV and SSEP assessments confirmed presence of
neurosensory responses in both saline and BMSC-filled conduit groups. Smaller diameter fascicles were observed in BMSC filled conduits (Group 3 and 4) in comparison to saline filled conduit (Group 2). Immunofluorescent staining at 3 months in saline filled conduit showed presence of fascicle-like structure in the proximal, middle, and distal parts of the conduit. Toluidine blue staining revealed the presence of myelinated axons in all of the groups. Migratory potential of BMSCs in lymphoid organs was analyzed by fluorescent staining. No presence of BMSCs was detected in liver, lymph nodes, spleen and thymus 6 months after SCEC transplantation.

Summary
The feasibility of creation and application of ESC to restore 6 cm nerve defects in sheep model was confirmed. Immunohistochemical and neurosensory assessment confirmed regenerative properties of the ESC. ESC is a novel promising bio-construct of naturally occurring epineural sheath and BMSCs and has potential for successful regeneration of long nerve defects. In the future it can be included into the armamentarium of regenerative medicine.
Hypothesis
We hypothesized that Erythropoietin (EPO) would accelerate neuronal recovery after surgical decompression in a murine model of chronic nerve compression. Moreover, we hypothesized that the positive effect of EPO treatment would correlate to the myelination status of the nerve, in a model where demyelination is a direct result of compression injury.

Methods
A 3-mm biologically-inert tube was used to induce compression neuropathy for 10 weeks in mice which then underwent surgical decompression. One group of mice (n=5) received erythropoietin throughout the experiment (EPO/EPO), while a second group received saline throughout the experiment (saline/saline), and a third group received saline during compression and erythropoietin after decompression (saline/EPO) and a control group underwent sham surgery. Electrophysiological and immunohistochemical evaluations were utilized to assess the recovery of the injured nerves. Nerve conduction velocity (NCV) and myelin density were compared within the experimental sham surgery control groups using appropriate parametric statistics (Student t-test and one-way ANOVA).

Results
During compression, electrophysiological evaluation revealed a progressive decline in NCV. This decline was attenuated in the group receiving EPO. In the saline-treated compression groups, the NCV progressively decreased from a baseline of 50.82 ± 3.34 m/s to 34.46 ± 3.1 m/s at 10 weeks of compression (P = 0.02). In the EPO-treated compression group, the decrease in NCV was diminished, from a baseline of 53.14 ± 7.66 m/s to 38.36 ± 3.39 m/s at 10 weeks of compression (P = 0.10). After decompression, all experimental groups showed a progressive
increase in NCV with mice receiving EPO treatment as an adjuvant to decompression showing an accelerated rate of recovery \((P = 0.02)\). The average myelin density was calculated from nerves harvested three weeks post-decompression. Untreated compressed animals (saline/saline) showed statistically significant decreases in myelination as compared to the sham surgery group \((P = 0.003)\). Erythropoietin treatment, whether continual (EPO/EPO) or only after decompression (saline/EPO), significantly improved myelin content to a level indistinguishable from the sham surgery group \((P = 0.99\) and \(P = 1.00\), respectively).

Summary

Erythropoietin treatment as an adjuvant to surgical decompression facilitates the recovery of nerves in a standard murine model of compression neuropathy. Erythropoietin may also demonstrate a neuroprotective effect during chronic nerve compression, in the absence of surgical intervention, although additional study is needed. The clinical use of erythropoietin, as an adjuvant to surgical decompression, may have therapeutic potential in the treatment of chronic nerve compression injuries.

Hypothesis
Schwann cells are key players in the setting of peripheral nerve injury and improve clinical outcomes by accelerating nerve regeneration across nerve gaps. However, the relatively slow growth rate and large amount of Schwann cells required for effective neurite outgrowth limit their use in a feasible time period. Amniotic fluid derived stem (AFS) cells have demonstrated multi-potency with neurogenic potential and have been suggested to produce angiogenic and neurogenic growth factors in their undifferentiated form \textit{in vitro}. Thus, we hypothesize that co-culturing amniotic membrane and amniotic fluid stem cells will accelerate the proliferation of Schwann cells \textit{in vitro}.

Methods
Primary rat Schwann cells (rSC, isolated from sciatic nerves of 2 month old Sprague Dawley rats, (P2-4)) and human NF1 Schwann-like cells (CRL-2884, ATCC®, Manassas, VA (P3-5)) were cultured at 5000/well in 96 well plates and divided into eight test groups: I. rSC control II. rSC co-cultured with live amniotic membrane III. rSC co-cultured with dehydrated amniotic membrane IV. rSC co-cultured with ground amniotic membrane and amniotic fluid stem cells. V. human Schwann cells (hSC) control VI. hSC co-cultured with live amniotic membrane VII. hSC co-cultured with dehydrated amniotic membrane VIII. hSC co-cultured with ground amniotic membrane and amniotic fluid stem cells. Cell Counting Kit-8 assays were performed on day 1, 7 and 14 to determine cell proliferation and viability with the co-culturing. Six technical replicates and three independent experiments were performed for each group. All data were expressed as mean ± SEM and differences between the experimental and control groups were assessed by two-tailed Student’s \textit{t}-test. Results with $P < 0.05$ were considered statistically significant.

Results
Both rat and human Schwann cells were viable with each co-culturing at the end of 14 days. All treatment groups (II, III, IV, VI, VII, VIII) showed a significant increase in proliferation compared to the control groups (I and V) at 7 and 14 days. (fold change with co-culturing groups at 7 days: Group II: 3.22 ± 0.26; Group III: 3.22 ± 0.20; Group IV: 2.01 ± 0.15; Group VI: 3.84 ± 0.28; Group
VII:1.51± 0.38; Group VIII: 1.94 ± 0.21, P < 0.01 in all groups compared to control). Results were similar with 14 days of treatment.

Summary
Co-culture with amniotic membrane and amniotic fluid stem cells supported and facilitated Schwann cell growth. Similar co-culture may have the potential to improve the regeneration of peripheral nerve and nerve bed following injury.

Hypothesis
Contemporary studies analyzing final neurologic recovery after cubital tunnel syndrome surgery have not demonstrated the superiority of any one surgical approach. Assuming similar ultimate outcome, differences in the relative risks and the morbidity between potential procedures plays a pivotal role when recommending a surgery. The purpose of this study was to compare the morbidity of common cubital tunnel surgeries. Our working hypothesis was that in situ decompression would impart less surgical morbidity (surgical site pain, narcotic usage, functional impairment) when compared to transposition or epicondylectomy.

Methods
This prospective cohort study enrolled 102 adult patients indicated for cubital tunnel surgery at a tertiary institution. In situ decompressions (n=29), ulnar nerve transpositions (n=56), and medial epicondylectomies (n=17) were performed. No significant preoperative differences in age, sex, or the presence of pain existed between each surgical group (Table 1). Data were collected by independent clinicians at 3 postoperative intervals: 2 weeks, 6 weeks, and >8 weeks. Postoperative data quantified surgical morbidity: Visual Analog Scale (0-10) surgical site pain (at rest, moving, placing on surface), narcotic consumption (morphine equivalents), olecranon paresthesia, and wound complications (hematoma, drainage, infection). Patient-rated disability was quantified with the Levine-Katz functional score. Statistical analyses compared morbidity data between surgical groups.

Results
Surgical site tenderness was the least after in situ release although statistical significance was only noted at 2 weeks. The frequency of narcotic use by patients decreased for all surgical
groups at each subsequent followup. In situ decompression resulted in fewer patients using narcotics and fewer morphine equivalents consumed by users at all time points to a degree that was judged clinically relevant but not statistically significant. Olecranon paresthesias were frequent in all surgical groups but had only resolved by the final follow up interval in the in situ decompression group (Table 1). Three hematomas occurred following transposition (5%) with 1 requiring operative debridement. No other wound complications occurred. Levine Katz functional scores indicated initial disability that increased following transposition, although this improved similarly to in situ decompression by the final follow up (Figure 1).

Summary Points
- Ulnar nerve transposition and medial epicondylectomy are associated with greater narcotic requirements, surgical site tenderness, and olecranon paresthesia during early recovery than in situ decompression.
- In the 3rd month after surgery, differences in patient-rated function following in situ decompression and ulnar nerve transposition have normalized.

Evaluation/Diagnosis, Prognosis/Outcomes, Nerve, Diseases and Disorders
Level 3 Evidence

Justin J. Koh, MA
Prosper Benhaim, MD
Kodi K. Azari, MD, FACS

Hypothesis
Patients with coincident cubital tunnel syndrome can be diagnosed among patients presenting with carpal tunnel syndrome based on demographic factors, presenting symptoms, physical exam findings, and nerve conduction study results.

Methods
A retrospective chart review of 515 patients was performed from patients treated for carpal tunnel release and cubital tunnel release by two university-based hand surgeons. These patients were divided into cohorts as patients with isolated carpal tunnel syndrome (n=337) and patients with coincident carpal and cubital tunnel syndromes (n=178). These patients were characterized according to demographic factors, past medical history, physical exam findings, and nerve conduction study results. Univariate and multivariate logistic regression were used to select significant predictors of coincident nerve compression. The “K-B score” was constructed by converting the regression coefficients of independently predictive factors in the multiple regression model to integers for diagnosis of coincident nerve compression, after which a simplified 5 point model was chosen. A receiver operating characteristic curve was generated for each iteration of the K-B score, after which sensitivities, specificities, positive, and negative predictive values were calculated for each potential score threshold to identify the best cutoff value.

Results
Loss of intrinsic hand strength, ulnar sensation loss, positive elbow flexion test, positive cubital tunnel Tinel’s sign, and abnormal ulnar nerve NCS result were selected. The cutoff value for the K-B score was 2 points, with a sensitivity of 86.6% and a specificity of 86.5% in the developmental cohort. Area under the receiver operating characteristic curve was 0.9217.

Summary Points
• Given the limited sensitivity and relatively high false negative rate of the NCS at the cubital tunnel, physical exam findings should weigh heavily in a diagnosis of coincident cubital tunnel syndrome in carpal tunnel syndrome patients.

• Patients with a K-B score of 2 or greater should be carefully evaluated for coincident compression neuropathy.

• In this developmental cohort, the K-B score was a robust method for detecting coincident cubital tunnel syndrome in carpal tunnel syndrome patients. The variables involved are routinely used to assess compression neuropathy at the cubital tunnel.

• Importantly, all component factors of the K-B score (i.e. loss of intrinsic hand strength, ulnar sensory loss, positive elbow flexion test, positive cubital tunnel Tinel’s sign, and abnormal ulnar nerve NCS result) were determined to be of equivalent clinical weight in assessing patients with potential coincident compression neuropathy.


Paper 56: The Efficacy of In-Situ Cubital Tunnel Release in Management of Elbow Ulnar Compression Neuropathy in McGowen Grade 3

Clinical Paper Session 10: Neuropathy - Saturday, September 12, 10:19 - 10:26 AM

Evaluation/Diagnosis, Treatment, Surgical Technique, Prognosis/Outcomes, Elbow and Forearm, Nerve
Level 3 Evidence

Ali Izadpanah, MD, MSc
Robert Spinner, MD
Sanjeev Kakar, MD, MBA

Royalty: Skeletal Dynamics (Kakar)
Consulting Fee: Arthrex, Skeletal Dynamics (Kakar)
Contracted Research: Arthrex (Kakar)

Hypothesis
Cubital Tunnel syndrome is the second most common compression neuropathy of the upper extremity with an incidence of 24.7 in 100,000. Numerous surgical modalities have been proposed for management of this entity in the face of failure after conservative management. However, up to this date, there has been no data demonstrating one method being superior to another for management of this common compression neuropathy leading to considerable pain and disability in patients. Thus, we sought to determine the efficacy and complication profile of in-situ release compared to subcutaneous and submuscular or intramuscular ulnar nerve transposition in McGowen grade 3 (constant numbness and evident weakness).

Methods
A retrospective chart review of 100 consecutive patients with McGowen grade 3, undergoing surgical decompression from May 2008 to May 2009 was performed. All patients had a minimum of one-year follow up. Patients’ demographics such as age, sex, and associated comorbidities were collected. Electromyogram and nerve conduction studies were reviewed. Postoperative course, any evidence of recurrence or incomplete relief of symptoms and data regarding the perioperative complication profile were collected. Statistical analysis and comparison between in-situ release versus subcutaneous and submuscular transposition was performed using SPSS 22.0.

Results
There were a total of 38 (38%) females and 62 males (62%) with a mean age of 52±17.1 years old (16 years to 94 years). Twelve patients underwent submuscular or intramuscular transposition,
48 patients underwent subcutaneous transposition and 40 patients underwent in-situ release. The average duration of symptoms for our patients was 12.1±5.8 months (3 months to 60 months). There were two patients with wound healing complications (dehiscence), one in submuscular transposition and one in intra-muscular transposition. Five patients had recurrence or incomplete relief of symptoms. Out of these five, two had undergone in-situ release, two had undergone subcutaneous release and one had a submuscular release. A Chi-square analysis was performed which demonstrated no statistical significance in recurrence rate requiring revisional surgery between in-situ compared to subcutaneous or submuscular release (P = 0.4).

Summary
In conclusion, our results demonstrate that in surgical management of McGowen grade 3, the in-situ release had similar success rate as subcutaneous or submuscular transposition with lower complication rate (none versus 2%). Thus, in-situ release could be an alternative in management of patients with McGowen grade 3 ulnar nerve compression neuropathy at the elbow with a similar success rate as the submuscular and intramuscular transpositions with a lower complication rate.
Paper 57: Does BMI, Age, Gender, or Diabetes Affect Cross-Sectional Area of the Median Nerve in Asymptomatic Patients?

Clinical Paper Session 10: Neuropathy - Saturday, September 12, 10:26 - 10:33 AM

Evaluation/Diagnosis, Anatomy, Hand and Wrist, Nerve, Diseases and Disorders

Level 2 Evidence

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Hypothesis
BMI, age, gender, and diabetic status affect the baseline cross-sectional area (CSA) of the median nerve at the wrist of asymptomatic individuals.

Methods
Consecutive patients without a history of carpal tunnel release were recruited. CTS-6 was completed in all patients; those with a score of 0 were included. Ultrasound examination was performed on both wrists and CSA of the median nerve at the carpal tunnel inlet recorded. Trends and differences in median nerve CSA and CTS-6 score were analyzed with regard to hand dominance, age, gender, BMI, and presence or absence of diabetes. Within each group, wrists were separated into subgroups based on hand dominance. Statistical analysis was performed using correlations and independent T-tests.

Results
A significant difference was seen between patients with BMI <30 (dominant side mean = 6.5 mm2, non-dominant side mean = 6.1 mm2) and those ≥30 (dominant side mean = 7.6 mm2, non-dominant side mean = 7.2 mm2). CSA correlated with BMI (dominant side r=0.30, non-dominant side r=0.35) and age (dominant side r=0.27, non-dominant side r=0.24). Side to side difference reached marginal significance (P = 0.049). Mean CSA was significantly higher in the non-dominant hand of diabetics (mean = 8.0 mm2) compared to non-diabetics (mean = 6.3 mm2, P = 0.002) but not in the dominant hand (mean = 7.9 mm2 in diabetics, mean = 6.7 mm2 in non-diabetics, P = 0.13). CSA was not significantly different with respect to gender. Females trended toward a smaller mean CSA than males for both the dominant (mean = 6.5 mm2 for
females, 7.1 mm² for males, \( P = 0.1 \) and non-dominant hands (mean = 6.4 mm² for females, 6.5 mm² for males, \( P = 0.69 \)), though the differences did not reach statistical significance. (Table 1)

Summary Points

• Patients who are obese have a significantly larger median nerve CSA at baseline, even in completely asymptomatic individuals.
• Median nerve CSA shows a positive correlation with both BMI and age.
• In a side to side comparison, CSA was larger for the dominant wrist compared to the non-dominant wrist.
• Diabetics had a significantly larger median nerve CSA in the non-dominant hand but not the dominant hand.
• Females trended toward a smaller mean CSA than males, but this did not reach statistical significance.
Hypothesis
An hourglass-like fascicular constriction, which is a focal fascicular lesion observed at one or a few places in one or a few fascicles of a peripheral nerve trunk, and usually affects the anterior interosseous nerve (AIN) or posterior interosseous nerve, is improved with the relief of symptom.

Methods
Seven consecutive patients who were diagnosed with idiopathic AIN palsy based on clinical findings and had hourglass-like fascicular constrictions in the AIN revealed by the ultrasonographic examination were included. We used the high-resolution device with a 14-6 MHz linear probe, and observed nerve fascicles in the median nerve trunk in a transverse and longitudinal fashions around the site of tenderness at the elbow joint level confirming the presence of fascicular constriction.
The age at the time of diagnosis ranged from 19 to 56 years old. The duration between onset of symptoms and ultrasonographic examination ranged from 7 days to 8 months, and the duration between examination and operation ranged from 3 days to 1 month.
All but one case took interfascicular neurolysis, and we followed up all cases clinically and ultrasonographically every one month. At the time of examination, we calculated constriction ratio, which was obtained by the division of the involved fascicular diameter at the constriction by that at the proximal non-constricted site.

Results
The number of constrictions ranged from one to eight, and all constrictions revealed ultrasonographically were confirmed intraoperatively. In the five cases with the operative treatment, recovery from paralysis began from 3 weeks to four months after surgery, and was completed (M0 to M4 or M5) five to seven months after surgery. Postoperative ultrasonography revealed the constrictions subsided. The other one treated operatively got little recovery (M0 to
M2) at 10 months after surgery, and the severe constriction still remained. In the one conservative treated case, the paralysis began to recover at 9 months and recovered completely (M0 to M5) at 14 months after the onset. On the ultrasonographic examination, its constriction incompletely subsided.

Summary
The hourglass-like fascicular constriction subsided with the relief of the paralysis both in the operatively and conservatively treated cases. The cause of constriction is still unknown, however, it may play a significant role on this type of paralysis.

Hypothesis
Unnecessary inter-facility transfers for evaluation by a hand surgeon create significant human and economic burden for patients, providers, and the healthcare system. However, emergency hand care standards to guide treatment, consultation or transfer to a tertiary care center are lacking. Diagnosis-specific guidelines for emergency providers may improve both the quality and cost of care for upper extremity (UE) emergencies.

Methods
We created a framework to group common UE emergency diagnoses based on ASSH standards and other published guidelines from the literature. Based on this framework, we designed a survey to evaluate the level of training – emergency medicine (EM), general orthopedic or plastic surgery, or hand fellowship – most appropriate to provide definitive, point-of-care service for each of the diagnostic groupings. As both educational leaders and key partners for developing consensus standards, EM and hand fellowship program directors (PDs) were chosen as the study population.

Results
We received 79 responses from hand fellowship PDs (89.7% return rate) and 151 responses from EM PDs (49.3% return rate). EM physicians were less likely than hand surgeons to report that specialized training was necessary to care for most of the diagnoses evaluated. (Table 1) Despite these differences, we identified consensus (>50% agreement with non-overlapping 99% confidence intervals) for the level of training that PDs felt was most appropriate to care for nearly all of the diagnosis groups in our framework. (Table 2)

Summary Points
This survey demonstrates variable levels of consensus (56.1% - 100%) between EM and hand surgery PDs regarding the level of training necessary to care for common urgent or emergent UE diagnoses. The program directors reported:

- Emergency medicine physicians, with outpatient hand surgery follow up available, should provide point-of-care service for uncomplicated cellulitis, simple abscesses, paronychia or felon, simple lacerations without deep tissue involvement, non-displaced distal radius or ulna fractures, and reducible hand fractures.
- General orthopedic or plastic surgery coverage should care for osteomyelitis, septic wrist, open fractures of the hand or wrist, and compartment syndrome.
- Specialty hand coverage should be available for necrotizing infections, flexor tenosynovitis, crush injuries and complex lacerations, complicated dislocations, and high pressure injection injuries.

This diagnostic framework may improve triage in emergency hand care, specifically regarding the need for specialty consultation. Using these guidelines, unnecessary inter-facility transfers may be avoided by identification of patients who do not require a provider with more specialized training, and therefore are not appropriate for transfer.

Hypothesis
To date there has never been a national or international study designed to compare the functional outcomes of individuals who have been recipients of hand transplants, amputees fit with electric multi-articulating hands, and those with toe-to-hand transfers. Can a Functional Baseline Index score be defined and what does it tell us about the objective and subjective outcomes these individuals experience?

Methods
The subject population included 3 study groups- 5 individuals with unilateral and bilateral hand transplants, 14 unilateral and bilateral prosthetic users of electric multi-articulating hands and digits, and 6 individuals with unilateral and bilateral toe-to-hand transfers. Each subject in the study was evaluated with the following validated and standardized tests: Box and Blocks Test (BBT), Nine Hole Peg (NHP), Southampton Hand Assessment Procedure (SHAP) and the Disabilities of the Arm, Shoulder and Hand (DASH). Because of the differences in the subject group size and overall sample size, the data was calculated by Cohen’s d- effect size, to represent group differences.

Results
When evaluating the subjective, patient perception of disability, calculated by the DASH, subjects who utilized electric multi-articulating hands and digits perceived themselves “less disabled” when compared to hand transplant subjects (d=.96). The individual with bilateral multiple toe-to-hand transfers however, considered himself to be the “least disabled” as recorded by the DASH. Subjects who utilized electric multi-articulating hands and digits scored slightly higher (d=.12) in their overall “index of function” recorded by the SHAP. Bilateral hand transplant subjects scored slightly better in manual dexterity, based upon their Box and Blocks Test score, and bilateral prosthetic users scored better in fine motor dexterity based upon the Nine Hole Peg scores.
Summary Points

- As dramatic advances are being made in the field of reconstructive, microvascular and hand transplantation, the field of electric multi-articulating hand and digit technology has experienced significant success as well.
- An ability to quantify the “success” of these individuals needs to be defined through a Functional Baseline Index score that will enable hand procedure subjects to be compared to the functional score of those fit with advanced prosthetic components.
- Early results reveal that the outcomes of hand transplants, 2 years or more post-procedure, demonstrate similar outcomes of prosthetic users of advanced hand technology, as it relates to activities of daily living, fine motor and manual dexterity.
Hypothesis
The purpose of this study was to determine reliability parameters (inter-rater reliability, response stability and responsiveness) of the "Ten Test" (TT), a clinical measure of discriminative sensation whereby the magnitude of abnormal sensation is normalized to an area of normal sensation on a 10-point Likert scale, in a sample of hand trauma patients. A secondary purpose was to compare the reliability of TT to that of the Weinstein Enhanced Sensory Test (WEST), a semi-quantitative monofilament test that is commonly used in this setting. We hypothesized that TT would display good reliability and that reliability parameters would be similar to those of WEST.

Methods
Patients (n=29, mean age=37±12) with self-reported abnormal hand sensation, presenting to an outpatient hand trauma clinic within seven days of injury, underwent TT and WEST by two separate raters on the same day. The order of test and rater were randomized to reduce systematic error. Levels of WEST were transformed into a 5-point ordinal scale corresponding to the coloured monofilaments, which represent progressively impaired sensation. Bland-Altman plots were constructed to provide a visual representation of agreement. Inter-rater reliability, response stability and responsiveness of each test were determined by the intraclass correlation coefficient (ICC: 2, 1), standard error of measurement (SEM) with 95% confidence intervals (CI) and minimal clinical difference score (MCD), respectively.

Results
Inspection of the Bland-Altman plots revealed greater inter-rater agreement for TT than for WEST (Figure 1). TT displayed excellent inter-rater reliability (ICC=0.95, 95% CI 0.89-0.97) compared to good reliability for WEST (ICC=0.78, 95% CI 0.58-0.89). The range of true scores expected with 95% confidence based on the SEM (i.e. response stability), was ±1.05 for TT and
MCD scores reflecting test responsiveness were 1.50 and 1.60 for TT and WEST, respectively.

Summary Points

- TT displayed excellent inter-rater reliability, response stability and responsiveness in a sample of patients presenting to an outpatient hand trauma clinic.
- Reliability parameters were stronger for TT compared to WEST.
- The range of scores expected on repeated measurements of WEST encompassed a wide range of sensory impairment (±1.10). For a patient with a score of 3, the true score would lie between 2-4, reflecting a range of sensory impairment from mild-to-severe.
- These results provide support for the utility of TT in this population. Considering the ease of implementation and excellent reliability of TT, it may be a practical alternative to monofilament testing.

Hypothesis
The hypotheses of this study was that in distal radius fractures with displaced volar lunate facet fragments, disruption of the dorsal radiocarpal (DRC) and the dorsal intercarpal (DIC) ligaments will significantly increase volar lunate translation and that cyclic grip loading will further increase translation.

Methods
6 matched pair cadaveric specimens from the mid-forearm to hand were tested on a custom dynamic hand testing system. In group 1, testing was performed on the intact wrist, the wrist with a volar lunate facet fracture, and the fractured wrist after 500 cycles of grip. In group 2, in addition to the intact and fractured wrist, the fractured wrist with the DRC and DIC cut, and the fractured wrist with the dorsal ligaments cut after 500 cycles of grip were tested.

Results
Volar-dorsal, proximal-distal, radial-ulnar, and total displacement of the lunate was calculated from 45° wrist flexion to 45° wrist extension in 22.5° increments with the wrist flexors/extensors loaded. Statistical comparisons were performed using repeated measures ANOVA with a Tukey post-hoc test with a $P$-value 0.189 or radial-ulnar translation ($P > 0.128$) with the fracture alone. Grip cycling further increased proximal translation at 22.5° of extension ($P = 0.013$) and neutral wrist positions ($P = 0.045$) but had no additional effect on other translations ($P > 0.056$). In the wrist extension positions, significant increases ($P 0.328$) or radial-ulnar ($P > 0.15$) translations after the dorsal ligaments were cut. Grip cycling significantly increased ($P < 0.048$) resulting displacements after dorsal ligament cutting.

Summary Points
- Volar radiocarpal instability after distal radius fractures with displaced volar lunate facet fragments is exacerbated by injury to the DRC and DIC ligaments.
- These findings suggest that patients with volar radiocarpal subluxation are likely to have disruption of the dorsal capsuloligamentous structures.
• Radiocarpal instability further worsened with grip cycling only after the dorsal capsuloligamentous structures were cut suggesting that unrecognized dorsal sided injury may be a contributing factor to why fixation of volar lunate facet fragments remains problematic.

Hypothesis
Peripheral triangular fibrocartilage complex (TFCC) tears may be treated with several methods that have a high variability in outcomes. We believe that a combination of extensor capsulorrhaphy using the Herbert Sling (HS) and all-inside arthroscopic suture repair (SR) provides greater ulnocarpal joint (UCJ) and distal radioulnar joint (DRUJ) stability when compared to either procedure in isolation.

Methods
Twelve fresh-frozen, age-matched specimens intact from the proximal humerus to the fingertips were used for this study. Non-destructive testing was performed for each arm to assess the native UCJ and DRUJ stability. Each specimen was secured to a mechanical testing machine, and an actuator was then sinusoidally cycled dorsally and volarly until a neutral zone was displayed. The slope of the load-displacement curve at the maximal dorsal displacement was defined as “stiffness”.

An ulnar-sided, peripheral TFCC injury (Palmer 1b) was created in each specimen using an arthroscope, and mechanical testing was repeated. Six specimens were treated with SR, six were treated with HS, and testing was repeated. The six specimens treated with SR were then treated with HS, and testing was repeated again. Paired Student’s t-tests were used for statistical analysis within cohorts.

Results
All three reconstructions demonstrated improvements in UCJ and DRUJ stability. When combining all cohorts, there was a decrease in UCJ ($P = 0.020$) and DRUJ stiffness ($P = 0.079$) after the creation of a peripheral TFCC injury, and after repair there was a significant increase in
UCJ ($P = 0.0077$) and DRUJ ($P = 0.0056$) stiffness. With regards to the UCJ stiffness, HS recovered 47% ($P = 0.030$), SR recovered 32% ($P = 0.32$), and SR+HS recovered 124% ($P = 0.040$) (Fig. 1). When comparing DRUJ stiffness, HS recovered 133% ($P = 0.021$), SR recovered 48% ($P = 0.36$) and SR+HS recovered 88% ($P = 0.16$) (Fig. 2).

Summary Points
• All repair constructs increase both DRUJ and UCJ stability after the creation of a peripheral TFCC tear; however, SR demonstrates the least improvement with the most inconsistency in recovery.
• The addition of HS after SR provides greater improvement in both DRUJ and UCJ stability when compared to SR alone.
• Consideration should be made for HS as an adjunct procedure in cases where stability cannot be fully restored with just SR.

Hypothesis
In hand surgery, the optimal epinephrine effect from local anesthesia - producing maximal vasoconstriction and prime visualization- is achieved by waiting significantly longer than the traditionally quoted 7 minutes from the time of injection.¹ ² ³

Methods
In this prospective comparative study, healthy patients undergoing unilateral carpal tunnel surgery waited either 7 minutes versus 33 minutes - between the time of injection of 1% lidocaine with 1:100,000 epinephrine, and the time of incision. A standardized incision was made through dermis and into the subcutaneous tissue followed by exactly 60 seconds of measuring the quantity of blood loss using sterile micropipettes (Fig 1).

Results
There was a statistically significant reduction in the mean quantity of bleeding in the group that waited a mean of 33 minutes after injection and before incision compared to the group that waited only 7 minutes ( 95% Confidence intervals of 0.06 +/- 0.03 ml/cm of incision, compared to 0.17 +/- 0.08 ml/cm respectively) (P = 0.03).

Summary Points
• No studies to date have measured micro quantities of intraoperative bleeding in order to directly quantify the effects of local anesthetic and epinephrine on vasoconstriction in humans; previous studies have instead used indirect measurements such as laser doppler and near-infrared spectroscopy (4,5).
• Waiting roughly 33 minutes for the optimal epinephrine effect will result in less intraoperative bleeding than the traditionally quoted 7 minutes for all hand surgery
procedures using wide awake local anesthesia & no tourniquet (WALANT). Achieving the optimal epinephrine effect is crucial in order to obtain hemostasis and visualization in WALANT hand surgery (60). The benefits of WALANT hand surgery include: intraoperative active movement examinations, as well as a reduction in the cost, waste, and complications which are associated with the main operating room and general anesthesia (7,8).

Hypothesis
The purpose of our study was to perform a case-control analysis of two sources of nerve graft; the denervated superficial branch of the radial nerve (SBRN) in patients with ipsilateral brachial plexus injuries and the normal sural nerve in nerve grafting to restore function in the upper extremity.

Methods
Over a 10-year period, 25 patients underwent SBRN nerve grafting with a dennervated ipsilateral nerve for brachial plexus injuries, which were T matched 2:1 with 50 patients who underwent sural nerve grafting by age, gender, and BMI (Comparisons are summarized in Table 1).

Results
The average follow-up for the use of ipsilateral dennervated SBRN patients was 2.5 years (1-7) and for the sural patients was 2.8 years (1-9). In the dennervated SBRN group, only 3 (12%) of patients experienced grade III or higher muscle function. All 3 of these patients underwent a grafting of the spinal accessory to triceps motor branch. This is in contrast to 20 (36%) of the patients who underwent sural nerve grafting achieving grade III or higher muscle recovery ($P < 0.01$), including C5, C6, or upper trunk to axillary ($n=5$) and musculocutaneous ($n=7$); or spinal
accessory to axillary (n=1), musculocutaneous (n=2), and triceps motor branch (n=5). Only 12% of the denervated SBRN group had EMG signs of muscle recovery compared to 61% of the sural nerve group ($P < 0.01$). Smoking had a negative impact on muscle recovery, decreasing the rate of grade III or higher recovery in the denervated SBRN group ($P < 0.01$) and the sural group ($P = 0.01$). No other factors had an impact on muscle recovery. Overall, patients in both groups had significant improvements in their preoperative to postoperative pain and DASH scores ($P < 0.04$).

Summary Points

- Use of ipsilateral denervated SBRN nerve grafts in patients with brachial plexus injuries has significantly poorer outcomes when compared to sural nerve grafts in the treatment of brachial plexus injuries in a matched series.
- The use of this deinnervated nerve should be saved for situations when no other nerves grafts are available and should be avoided when sural nerve grafts are available.
- Patients also should be counseled on the risks of smoking when choosing to undergo brachial plexus reconstruction.
Hypothesis
The purpose of this study was to report the patient-rated outcome measures (PROMs) using the Hand20 questionnaire (Suzuki et al. JBJS 2010) before and after surgery of the benign upper limb tumor. We hypothesized that benign upper limb tumors have a clear indication for surgery according to the PROMs.

Methods
This study included 301 consecutive patients with histories of benign bone and soft tissue tumors of the upper limb, who had undergone surgery. There were 130 male and 171 female patients with a mean age of 45 years (range, 11–87 years). The diagnoses included 72 ganglions, 37 vascular tumors, 31 giant cell tumors of tendon sheath (GCTTS), 24 schwannomas, 21 lipomas, 21 enchondromas, 17 glomus tumors, 16 fibromas, 15 exostoses, 12 epidermoid cysts, 6 vascular leiomyomas, 6 granulomas, and 23 others. The tumors were located on the finger in 147 cases, hand in 51 cases, wrist in 61 cases, forearm in 18 cases, elbow in 16 cases, and upper arm and axilla in 8 cases. Tumor size was classified into 3 groups: smaller than 1 cm (45 cases), between 1 and 3 cm (157 cases), and larger than 3 cm (99 cases). We have prospectively assessed PROMs using Hand20 questionnaire before and after surgery. The mean period from surgery to assessment was 21 months (range, 6–78 months).

Results
The mean Hand20 and pain scores significantly improved in patients with ganglions, vascular tumors, GCTTS, schwannomas, enchondromas and lipoma. The mean pain scores in patients with glomus tumors improved significantly, but the mean Hand20 scores improved without significance. In patients with fibromas, exostoses, epidermoid cysts, granulomas, and vascular
leiomyomas, both the mean Hand20 and pain scores improved without statistical significance. (Figure 1 and 2)
As to the size of the tumors, the mean Hand20 and pain scores significantly improved in all 3 groups.
The mean Hand20 scores were significantly improved in patients with tumors located in the finger, thumb, hand, and wrist. However, the mean Hand20 scores were improved without statistical significance in patients with tumors located in the forearm, elbow, upper arm, and axilla.

Summary
Upper limb tumors are frequently encountered by hand surgeons. Surgery is indicated not only to sample the tumor tissue for definitive diagnosis, but also to improve the function and aesthetic outcome of the hand. According to the results of PROM, benign hand tumors located within the distal upper limb have a clear indication for surgery.

Paper 67: av integrin is a Crucial Regulator in the Development of Dupuytren Contracture

Clinical Paper Session 12: Hand 2 - Saturday, September 12, 2:36 - 2:43 PM

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Hypothesis
Although Dupuytren contracture is characterized by myofibroblast development and increased cytokines including transforming growth factor-ß1 (TGF-ß1) in the palmar fascia, the relationship between TGF-ß1 and av integrin, which is considered to be related to fibrosis, has not been clearly elucidated. We hypothesized that av integrin would play an important role in the development of Dupuytren contracture.

Methods
Seven male patients whose mean age at the time of surgery was 70.7 years (range, 68 to 73) underwent partial fasciectomy as treatment for Dupuytren contracture. The nodule and cord were isolated from the palmar fascial tissues of the patients. Normal palmar fascia was obtained from seven control patients with carpal tunnel syndrome undergoing carpal tunnel release. These included two male and five female patients whose mean age at the time of surgery was 67.0 years (range, 36 to 88). Histologic and immunohistochemical analyses were performed to investigate the expression patterns of the myofibroblast and integrins. The expression of TGF-ß1 and av-, a4-, ß6-, ß8-integrins were assessed by real-time PCR reaction. Statistical comparisons were performed using paired t-tests (P < 0.05).

Results
The spreading and proliferation of fibroblasts were found in nodules, while few fibroblasts were detected in cords and normal palmar fascia. In immunohistochemical analysis, alpha-smooth-muscle-actin (a-SMA)-positive cells were mainly observed in nodules, while few a-SMA-positive cells were found in normal palmar fascia. Among the a-SMA and integrins, a-SMA and av integrin were markedly induced and co-localized in nodules. Real-time PCR analysis confirmed that the
expression of TGF-β1 and αv integrin genes were significantly increased in nodules, as compared to those in normal palmar fascia (P = 0.004 and P = 0.006, respectively) (Figure 1A and 1B).

Summary
Henderson et al. showed that αv integrin controls a core molecular pathway that regulates fibrosis in several organs. In fact, we found the expression of TGF-β1 and αv integrin were significantly increased in nodules, as compared to those in normal fascia. The obtained results indicate that αv integrin is a critical intrinsic regulator of the growth of fibrous tissue in Dupuytren contracture via regulating TGF-β1 expression. αv integrin will become a target molecule for the injection treatment of Dupuytren contracture.

Paper 68: The Effect of Corticosteroid Concentration on Glycemic Control in Patients with Diabetes Mellitus

Clinical Paper Session 12: Hand 2 - Saturday, September 12, 2:43 - 2:50 PM

Hypothesis
Corticosteroid injections have proven to be less effective in diabetic patients and may result in transient elevations in blood glucose levels. We hypothesize that triamcinolone injected at a concentration of 10 cc/mg (T-10) is equally successful, safer, and more cost-effective than triamcinolone 40 cc/mg (T-40).

Methods
All patients with type II diabetes mellitus and presenting to a university-based hand surgery clinic were prospectively enrolled in this study if they were candidates for a corticosteroid injection. Either T-10 or T-40 was administered based on surgeon preference. Fasting glucose the morning of injection, QuickDash scores prior to injection, and location of pain were recorded. Blood glucose was recorded the evening of the injection, and the fasting glucose was recorded each morning until it normalized back to the pre-injection levels. QuickDash and VAS scores were recorded at 6 weeks. Statistical analysis was represented with means, standard deviations, and student’s T-test for comparisons when needed.

Results
Patients in both cohorts on average had improvements in their QuickDash and VAS scores after the injection, and there was no significant variation between cohorts. There was a significant elevation in blood glucose regardless of injection type ($P = 0.005$). The T-10 group had an average maximum glucose elevation of 53 (41%) points, which returned to baseline at 21 hours. In contrast, T-40 had a maximum glucose of 50 (40%) points returning in 54 hours to baseline. The difference in time to return to baseline trended towards statistical significance ($P = 0.07$). No patients in either cohort had glucose elevations that required adjunct insulin treatment or
evaluation in the emergency room. T-10 was also 4 times cheaper ($2.40 versus $9.96 per cc) than T-40 per injection administered.

Summary Points
- Both T-10 and T-40 are effective in relieving painful symptoms and improving patient functionality after injection.
- A lower concentration of triamcinolone steroid is associated with a quicker return of blood glucose to baseline.
- T-10 is a cheaper and more cost-effective alternative to T-40.

Hypothesis
Readmission following surgery is a quality metric tracked by many institutions including Government agencies. The incidence of readmission following outpatient hand and elbow surgery is not reported. We utilized the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database to determine the incidence of unplanned thirty-day readmission and the associated perioperative characteristics of patients undergoing outpatient hand and elbow surgery.

Methods
The ACS-NSQIP database was queried to identify patients undergoing outpatient hand and elbow surgery between 2011 and 2013. The patients were identified using 407 hand-and-elbow-specific CPT codes. NSQIP captures 30-day readmissions that take place at the index hospital as well as any other hospital. Patients who underwent any other concomitant surgery were excluded from the analysis. Patients who required an unplanned readmission were compared with those who were not readmitted. Preoperative patient characteristics, intraoperative variables, days from procedure to discharge, 30-day complication rates, and mortality were compared between the cohorts. An α = 0.001 denoted statistical significance due to the large sample size.

Results
A total of 18,174 outpatient hand and elbow surgeries were identified between 2011 and 2013 of which 202 patients (1.1%) required an unplanned readmission. Patients who required readmission were significantly older (58 vs. 50 yr; P < 0.001) and experienced longer operative
time (80 vs. 64 mins; $P < 0.001$). Pre-operative comorbidities including diabetes, hypertension, COPD, renal dialysis, and steroid use were more prevalent in the readmitted cohort ($P < 0.001$). Likewise, ASA class 3 and 4 were more prevalent in the readmitted cohort ($P < 0.001$). These patients had greater incidences of postoperative morbidity and mortality ($P < 0.001$).

Summary
The incidence of unplanned readmission following outpatient hand and elbow surgery is low. Nevertheless, patients who were readmitted experienced higher incidences of postoperative complications and mortality. These data may be helpful for risk stratification of these patients prior the surgery. Further analysis is warranted to characterize the independent predictors of readmission following outpatient hand and elbow surgery.
Hypothesis
Olecranon fractures is most commonly found in elderly patients with multiple comorbidities, low demands and a diminished bone quality, which sometimes makes fixation difficult. Although good surgical outcomes have been reported in elderly patients, some authors presented complications in up to 30% of the cases. Given the number of elderly patients sustaining these injuries, research is required to determine the role of non-operative treatment for displaced fractures, since there is not much literature that compares surgical and non-surgical treatments. The purpose of this study was to evaluate retrospectively the clinical and radiological outcomes of a consecutive cohort of patients over 70 years old with displaced olecranon fractures functionally treated.

Methods
During a 30-months period, we collected data on all patients with olecranon fractures who presented in our service. Inclusion criteria were: patients with displaced fracture older than 70 years old, acceptance and completeness the proposed protocol of treatment and more than one-year follow-up. An articular gap or a gap at the level of the posterior cortical of the olecranon bigger than 5mm was considered a displaced fracture. Twenty-eight patients were included. The elbow was immobilized with a long arm cast at 90° of elbow flexion for an average of five days (4 to 7). Then, the cast was removed and a sling placed. Active mobilization was indicated as tolerated. No patients were lost in this study. Twenty-seven were female. Average age was 82 years (71 to 91). Twenty-two patients had osteoporosis. According to Mayo Clinic’s Classification, 18 fractures were type IIA and 10 were IIB.

Results
At a mean follow-up of 16 months (range 12-26), the average flexo-extension was 140°-15° (92% of the contralateral side). The average pain was 1 (0 to 8) and the average degree of satisfaction
was 9 (8 to 10), according to VAS. Elbow extension strength was M5 in 17 patients and M4 in nine. Average MEPI score was 95. Twenty-two patients evolved into a non-union. No patient required surgical treatment.

Summary Points

- Non-surgical functional treatment of displaced olecranon fractures in the elderly showed a functional range of motion with a high rate of satisfaction.
- Although an important number of non-unions were present, most were well tolerated and it was not necessary to operate on any of the patients.

Hypothesis
Is it possible to minimize the dissection necessary to completely release severe elbow contractures in a less complicated manner than traditional open or arthroscopic techniques? The purpose of this study is to evaluate the safety and efficacy of a new surgical technique which releases elbow contractures through the exposure of an olecranon osteotomy.

Methods
21 consecutive patients with established elbow contractures and who had failed to respond to nonoperative treatments underwent an osteotomy-facilitated elbow release (OFER). Average preoperative arc of motion was 28 degrees (ranged from 0 degrees to 45 degrees). Minimum follow up was 24 months. Average patient age was 35 years (range: 28 to 53yrs). Average time between the initial injury or most recent surgery and OFER was 14 months (ranges: 6 to 22 months). Conditions resulting in contracture include supracondylar humerus fracture treated with ORIF (14 patients), terrible triad fracture-dislocation (4 patients), spontaneous heterotopic ossification following head injury (2 patients), and olecranon malunion (1 patient). Average flexion-extension arc was 35° (range: 0-60°). All patients received rehabilitative services begin within the first postoperative day. Following the OFER procedure, patients were evaluated in terms of motion, pain, DASH scores, and complications. No patients were lost to follow up.

Results
Average operative time was 45 minutes and average incision length was 10 cm. At final follow up, average flexion-extension arc increased 110°. Average pain was reported to be 1 out of 10 (range: 0-2). DASH scores demonstrated high functioning abilities compared to control populations. All olecranon osteotomies healed. There were no nonunions, malunions, or problems with joint instability. One patient developed ulnar neuritis four weeks after surgery that spontaneously resolved.

Summary Points
- Osteotomy-facilitated elbow release (OFER) appears to be a safe and effective alternative to more invasive open release or more technically demanding arthroscopic elbow releases.
- All intrinsic and extrinsic causes for the contracture, including extensive heterotopic bone, may be addressed through this exposure.
- Results of the OFER are similar or better than those reported for more traditional open or arthroscopic procedures.
- Anecdotal observations suggest that the OFER procedure may be faster, easier, safer and results in less postoperative swelling and consequently facilitates rehabilitation over more traditional techniques.
Paper 72: Phase 2a Study of Safety/Efficacy of Collagenase (CCH) in Patients with Adhesive Capsulitis

Clinical Paper Session 13: Elbow - Saturday, September 12, 2:36 - 2:43 PM

Treatment, Shoulder and Arm
Level 1 Evidence

Edward D. Wang, MD
Marie A. Badalamente, PhD
Sean MacKenzie, MD
Michael Skyhar, MD
Greg Kaufman, MD
James Tursi, MD

Contracted Research: Auxilium Pharmaceuticals (Wang, MacKenzie, Skyhar)
Royalty: Biospecific Technologies Corp. (Badalamente)
Consulting Fee: Cayenne Medical (Skyhar)
Salary: Auxilium Pharmaceuticals, Inc. (Kaufman, Tursi)
Fees for Non-CME Services Received Directly from a Commercial Interest or its Agent:
            Auxilium Pharmaceuticals, Inc. (Kaufman)
Other (Please describe): Stock options, Auxilium Pharmaceuticals, Inc. (Tursi)

Hypothesis
This phase 2a, open-label, controlled, dose-ranging, multicenter study was designed to assess the safety and efficacy of CCH compared to an exercise-only control group in patients with Stage 2 (frozen) unilateral idiopathic adhesive capsulitis.

Methods
Four cohorts of 10 patients each received up to 3 ultrasound-guided extra-articular injections (Figure 1) directed on to the anterior capsule, midway between the tip of the coracoid and the bicipital groove, of 0.29 mg or 0.58 mg of CCH (in varying volumes: 0.5, 1, or 2 mL), separated by 21 days. Cohort 5 (n=10) performed home shoulder exercises only. The primary endpoint was change, in degrees, from baseline to Day 92 in AROM forward flexion compared to the exercise-only cohort. Secondary endpoints were change in passive ROM forward flexion and changes in AROM and PROM of 3 additional planes (abduction, external/internal rotation). Function and pain were assessed. Adverse events (AEs) were assessed. Baseline and end of study MRIs were obtained for all patients.
Results
50 patients (10 male, 40 female) at 11 sites throughout the US with a mean age of 54 years (range, 41-74) were enrolled. The 0.58mg/1mL and 0.58mg/2mL dosing arms showed significant improvement from baseline in AROM forward flexion vs. the exercise-only group ($P = 0.0131$ and $P = 0.0385$, respectively). Trends with improvement in AROM were also seen in the other CCH treated cohorts. PROM forward flexion was significantly improved in the 0.58mg/1mL and 0.58mg/2mL dosing arms compared to exercise only. The 0.58mg/1mL treatment group also showed significant improvements in passive ROM abduction and external rotation compared to exercise only. Passive ROM internal rotation was significantly increased in the 0.58mg/0.5mL cohort compared to exercise only. Twenty-nine patients (72.5%) received 3 CCH injections, 5 patients received 2 injections, and 6 received 1 injection. Both the 0.58mg/1mL and 0.58mg/2mL cohorts had significant improvement in pain and function from baseline vs. the exercise-only group ($P < 0.05$). Treatment-related AEs with CCH were transient and confined to the local injection site and ipsilateral arm/shoulder. AEs of injection site pain and injection site swelling resolved in ~7 days without intervention. There were no serious AEs. Baseline and Day 92 MRI evaluations indicated no clinically significant rotator cuff injuries or other safety findings.

Summary Points
• Extra-articular injection of CCH (1mL and 2mL) significantly improved ROM, shoulder function, and pain compared to an exercise-only treatment regimen in patients with adhesive capsulitis.
• The safety profile was consistent with prior studies(1,2) and CCH use in other indications.

Paper 73: Prospective Evaluation of Opioid Utilization After Upper Extremity Surgery: Determining Consumption Patterns and Developing Prescribing Guidelines

Clinical Paper Session 13: Elbow - Saturday, September 12, 2:43 - 2:50 PM

Evaluation/Diagnosis, Treatment, Surgical Technique, Prognosis/Outcomes, Hand and Wrist, Elbow and Forearm, Shoulder and Arm, General Principles
Level 2 Evidence

Nayoung Kim, BS
Jonas L. Matzon, MD
Asif Ilyas, MD
Mitchel Maltenfort, PhD

Hypothesis
While adequate management of post-operative pain with oral analgesics is an important aspect of surgery, it remains unclear how many pills are necessary to appropriately manage post-operative pain. The purpose of our prospective study was two-fold: (1) to evaluate opioid consumption after outpatient upper extremity surgery, and (2) to evaluate opioid utilization patterns in order to develop prescribing guidelines.

Methods
Nine board-certified hand surgery fellowship-trained orthopaedic surgeons prospectively collected data for six consecutive months on all patients undergoing outpatient upper extremity surgery. Data included patient demographics, surgical details, anesthesia type, and opioid prescription and consumption patterns. Linear regression was used for statistical analysis.

Results
A total of 1,466 patients with an average age of 55 years (range 5-93) were included. On average, surgeons prescribed 25 pills (range 0-110), while patients consumed 8.1 pills (range 0-90), resulting in a utilization rate of 32%. Only 6% of patients received disposal information. Soft tissue procedures required less opioids (5.1 pills for 2.2 days) compared to fractures (12.2 pills for 4.1 days) or joint procedures (14.6 pills for 5.0 days) \( (P < 0.01) \). Both hand and wrist surgeries utilized an average of 7.6 pills, compared to 10.6 pills for forearm/elbow surgeries, and 22 pills for arm/shoulder surgeries \( (P < 0.01) \). Patients undergoing surgery with only local anesthesia consumed the least opioids (4.5 pills for 2 days), compared to patients anesthetized with sedation (5.7 pills for 2.6 days), general (12.2 pills for 4.0 days), and regional (15 pills for 4.8 days) \( (P < 0.01) \). Based on morphine equivalents, procedure type, anatomical location, and
anesthesia type significantly influenced the amount of opioid used ($P < 0.001$). In contrast, age and insurance, was found to not statistically affect opioid consumption.

Summary Points

- To the best of our knowledge this is the largest prospective evaluation of opioid consumption to date and we found that patients in our series are being over-prescribed pain medications post-operatively for hand & upper extremity surgery.
- Patients only utilized 32% of their prescribed pain medication, thereby leaving 68% of unused prescribed narcotics available for potential diversion.
- Very few patients (6%) received safe disposal information for excess pain medication by their prescriber, surgical facility, or pharmacy.
- Surgeons should consider prescribing less pain medications on average and base it upon the procedure type, anatomic location, and mode of anesthesia.
Paper 74: Wrist Arthroplasty: A Complicated Matter

Clinical Paper Session 14: Arthroplasty - Saturday, September 12, 3:35 - 3:42 PM

Evaluation/Diagnosis, Treatment, Patient Education, Prognosis/Outcomes, Hand and Wrist
Level 3 Evidence

Patrick M. Kane, MD
Michael Gaspar, MD
Jesse Lou, BA
Sidney Jacoby, MD

Hypothesis
Despite continued advances in implant design for partial and total wrist arthroplasty, these surgeries present a high incidence of complications, many of which require revision surgery with the potential of a complicated post-operative course. We hypothesize that the incidence of complication is higher than the current reported literature. Follow up duration averaged 2.6 years with longest being 12.4 years.

Methods
A retrospective review of 105 wrist surgeries in 100 patients who underwent surgery with prosthetic replacement of the distal radius, the proximal carpus or both at a single institution (2005-2014) was performed. Patient factors including age, sex, BMI, handedness, underlying disease and previous injury were recorded. Outcomes were focused particularly on post-operative complications and need for revision surgery.

Results
Fourty-seven total wrist arthroplasties (TWA), 52 distal radius hemi-arthroplasties (DRH), and 6 proximal carpal hemiarthroplasties (CH) were performed. Majority (61.7%) of TWA were performed for Rheumatoid Arthritis (RA) or other inflammatory arthropathies, whereas degenerative or post-traumatic arthritis represented the underlying condition for majority of both the DRH (76.9%), and CH (66.7%) groups. Overall complication rate was 50.1% (53/105). Post-operative contracture accounted for the largest number of complications needing additional surgery (20%) though the incidence was much higher in DRH than in TWA (42.3 vs. 16.7%). Component failure composed 15% of all complications, with TWA having the highest incidence across the groups with 24%. Superficial infections occurred at 7.1 and 7.6% in TWA and DRH, respectively. One superficial infection resulted in wound dehiscence that was operatively debrided and closed. All other superficial infections resolved with a short course of oral antibiotics. Deep infections occurred in 4.7 and 3.8% of TWA and DRH, respectively. They were associated with a high number of medical co-morbidities and multiple prior surgeries. All
deep infections required removal of hardware, antibiotic spacer placement, and a prolonged course of IV antibiotics prior to a definitive operation.

Summary Points
- Though total and partial wrist arthroplasty can provide significant pain relief for the arthritic wrist, there remains a significant potential for complications and need for further surgery.
- Patients should be counseled on the potential risks and post-operative course.
- It should be noted that the likelihood of failure of wrist arthroplasty tends to increase as time from surgery increases.
- Certain patients should be screened with great caution, particularly those with multiple medical co-morbidities, and those pre-disposed to wound issues such as those with low BMI, or poor skin quality.

Hypothesis
There is a paucity of literature evaluating periprosthetic fractures in total wrist arthroplasty. The purpose of this study was to assess the factors that contributed to an increased risk for fracture and the long-term outcomes after fracture stabilization.

Methods
At a single institution over a 40-year period from 1974-2013, 425 total wrist arthroplasties were performed, with a minimum of 2-year follow-up for inclusion into this study. Demographics included age (57 years), BMI (27), and female (72%). The mean OR time was 185 minutes, while the mean tourniquet time was 135 minutes. The primary diagnosis for the TWA included 22 (5%) osteoarthritis (OA), 375 (88%) inflammatory arthritis, and 28 (7%) post-traumatic arthritis. The implants breakdown was: Remotions (n=31), Biax (n=159), Volz (n=33), Meuli (n=138), Universal (n=7), and Swanson (n=57). 357 (84%) were cemented, while 36 (8%) required bone graft.

Results
Intraoperative periprosthetic fractures occurred in 9 (2%) wrists. The distal metacarpals where fractured in 5, while the distal radius was fractured in 4. Univariate regression analysis demonstrated that increasing age ($P = 0.007$), Biax implants ($P = 0.07$), and osteoarthritis ($P = 0.07$) in increased fracture risk, as summarized in Table 1. At a mean follow-up of 12 years (2-22), 1 (8%) patient who had an intraoperative fracture suffered a postoperative fracture, compared to 12 (3%) patients without intraoperative fractures ($P = 0.27$). ($P = 0.27$). One patient who had an intraoperative fracture underwent revision surgery for pain and limited motion. No other patients suffered any complications. The 5 and 10 year survival after intraoperative fracture was 88%, 88%, compared to 84% and 74% without a fracture ($P = 0.39$).

There were 13 patients who suffered postoperative fractures overall. The 5, 10, and 20 year survival free of postoperative fracture was 99%, 96%, and 94%, respectively. The implant breakdown for these fractures was Swanson (n=5), Volz (n=0), Meuli (n=4), Biax (n=3), Remotion
(n=1), Universal (n=0). The risk of postoperative fracture was increased by increasing age ($P = 0.07$), while patients with Swanson ($P = 0.02$) and Volz ($P = 0.14$) implants had lower rates of fracture.

Summary Points
- Intraoperative fractures occur in approximately 2% of total wrist arthroplasties. When properly stabilized, these do not affect long-term outcomes.
- The implant design is an important factor in the risk of intraoperative and postoperative fractures.
Paper 76: Cementless or Cemented Fixation in Proximal Interphalangeal Joint Surface Replacement Arthroplasty?

Clinical Paper Session 14: Arthroplasty - Saturday, September 12, 3:49 - 3:56 PM

Treatment, Prognosis/Outcomes, Hand and Wrist
Level 1 Evidence

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Hypothesis
A surface replacement (SR) proximal interphalangeal (PIP) joint arthroplasty is a motion and stability preserving reconstructive surgical option for the painful osteoarthritic PIP joint, but the optimal fixation method is debated(1,2,3,4,5). We compared cementless with cemented fixation of SR PIP joint arthroplasty, and hypothesized better implant stability and less bone stress shielding with cementless fixation.

Methods
In a prospective, parallel-group, randomized patient-blinded clinical trial, we included 30 hands in 30 patients (7 M) at a mean age of 56 years (34-69) with osteoarthritis in one of the 4 ulnar fingers. Cemented (n=15) or cementless (n=15) fixation of SR PIP joint arthroplasty (PIP-SRA, SBI) was used. Dorsal Chamay approach was used. Tantalum beads were inserted in the bone and mounted on the components for marker-based radiostereometry (RSA). Patients were followed 6 times during 2 years. Outcome was evaluated by 1) implant migration (RSA), 2) periprosthetic bone mineral density (BMD) changes, and 3) clinical assessment of pain (VAS), ROM, PVA, grip/pinch strength, and complications.

Results
At 1 and 2 years, cementless fixation of the proximal component resulted in less rotation about the long-axis of the prosthesis (P 0.08). At 2 years, 5/13 patients with cemented and 1/13 patients with cementless fixation reported pain during motion (VAS>4) (P = 0.16). ROM was similar between groups at 2 years with mean 61° active flexion, mean -6° active extension, and mean 4cm PVA. Only the cementless group improved grip and pinch strength significantly at 2
years follow-up. We saw one early wound infection, 7 patients (3 C and 4 CL) with swan neck deformity, and 2 patients (1 in each group) were amputated because of poor function.

Summary Points

- Cementless fixation was superior for the proximal component with better rotation stability.
- Cementless fixation seems to have a more physiological bone stress-shielding with regain of periprosthetic BMD at 2 years.
- Grip and pinch strength increased only in the cementless group, and there was a tendency towards less pain at 2 years follow-up for cementless fixation.

Hypothesis
Metacarpophalangeal (MCP) arthroplasty has shown promise in treating inflammatory arthritis, however, there is a lack of studies comparing different implant designs and their effect on function. The purpose of this study was to assess the outcomes of MCP joint arthroplasty in inflammatory arthritis, with a comparison of the 3 most common types of implants.

Methods
Utilizing a single institution’s joint registry, we examined 583 MCP arthroplasties performed in 142 patients with inflammatory arthritis from 1998 to 2012. The mean age at surgery was 61 years and a BMI of 25.63% involving the dominant extremity. 86% were females, 11% smokers, and 12% had diabetes mellitus (DM). Implant types included pyrocarbon (n=155), silicone (n=366), and SRA (n=61). Patient characteristics comparisons, with the exception of age, did not differ significantly between implants. For pyrocarbon, SRA, and silicone groups age averaged (53, 54, 65), females (81%, 89%, 88%), smokers (12%, 0%, 11%), and DM (12%, 3%, 11%).

Results
There were 38 revision surgeries performed at a mean 2 years postoperatively. The 2, 5 and 10 year survival rates were 98%, 95%, and 87%, respectively. The 5-year survival rates for the pyrocarbon, SRA, and silicone implants were 91%, 84%, and 99%, respectively (Figure 1, silicone (blue), pyrocarbon (red), and SRA (green)). Patients receiving a SRA (HR 3.42, $P < 0.001$) and pyrocarbon (HR 2.60, $P = 0.005$) had an increased risk of revision arthroplasty compared to silicone implants. Intraoperative fractures and use of cement also increased implant failure risk (Table 1). There were 15 intraoperative complications involving a periprosthetic fracture, while postoperative complications included 19 dislocations, 2 heterotopic ossifications, 4 postoperative fractures and 9 infections. Pyrocarbon implants were associated with an increased
rate of dislocation ($P < 0.001$) and HO ($P = 0.02$). In those unrevised patients, at a mean 5 years (2-10) follow-up, preoperative to postoperative pain levels significantly improved ($P < 0.01$). In unrevised implants, there was no significant change in total arc of motion, grip or pinch strength when compared to preoperative values. SRA implants were associated with a increased total arc of motion (51°) compared to pyrocarbon (42°) and silicone (44°) ($P = 0.005$).

Summary Points
- MCP arthroplasty for inflammatory arthritis can be a successful motion sparing procedure with reasonable medium term survival and low complications.
- Silicone prosthesis was associated with a higher survival rate than pyrocarbon or SRA.
- Patients experience predictable pain relief and maintenance of their motion.
Hypothesis
The objective of this study was to examine a large prospective group of patients who underwent PIP arthroplasty utilizing a pyrocarbon prosthesis, attempting to identify those factors that have a significant influence on the outcomes.

Methods
An analysis of 254 consecutive MCP arthroplasties in 110 patients was prospectively collected using an institution’s total joints registry over a 14 year time period from 1998 to 2012. Demographics included average age of 56 years, BMI 29.8 kg/m2, 65% females, 13% smokers, 11% with diabetes mellitus (DM), 4% laborers, and with 60% involving the dominant extremity. Diagnoses included inflammatory arthritis (n=164), post-traumatic arthritis (n=37), and osteoarthritis (n=53). Of the 164 fingers with inflammatory arthritis, 51 required prednisone and 93 required methotrexate perioperatively. 32 implants were augmented with bone graft.

Results
Of the 253 arthroplasties performed over the 14-year time-period (224 primaries, 30 revisions), 26 (10%) patients underwent revision surgery. Revision surgeries were performed for dislocations (n=8), recurrent ulnar deviation or subluxation (n=5), pain with limited motion (n=12), and proximal component loosening (n=1). The 2, 5 and 10-year survival rates were 96%, 89%, and 77%, respectively. The risk for revision surgery was increased in smokers ($P < 0.05$) and those with inflammatory arthritis requiring either prednisone or methotrexate ($P < 0.02$). Breaking down by indication, the 5-year survival for inflammatory arthritis (90%) (blue), osteoarthritis (85%) (red), and post-traumatic arthritis (85%) (red) were not significantly
different. Intraoperative fractures and smokers also had an increased risk for revision surgery (Table 1). Sixteen operations were complicated by intraoperative fractures. Postoperative complications included infections (n=3), postoperative fractures (n=4), heterotopic ossification (n=5), and PIP dislocations (n=13). Female patients, those with a history of a MCP dislocation, and patients requiring methotrexate for their inflammatory arthritis had higher rates of dislocations ($P < 0.04$). In those patients who did not undergo revision surgery, at a mean follow-up of 4.8 years, patients had significant improvements in their preoperative to postoperative pain levels ($P < 0.01$), as well as MCP arc of motion from $38^\circ$ to $45^\circ$ ($P = 0.002$), as well as improvements in their pinch strengths ($P < 0.001$).

Summary Points
- MCP arthroplasty using a pyrocarbon implant demonstrates nearly a 90% 5-year survival rate with a relatively low rate of complications.
- Smokers and patients requiring methotrexate and prednisone had a higher revision surgery risk, while females and prior dislocations increased the rate of dislocations.
- Overall, patients experienced predictable pain relief and improvements in their range of motion and pinch strength.

Paper 78_Image01
Paper 78_Image02

Clinical Paper Session 15: Pediatrics - Saturday, September 12, 3:35 - 3:42 PM

Prognosis/Outcomes, Congenital and Pediatric Problems, Diseases and Disorders
Level 2 Evidence

Grant M. Kleiber, MD
Rajiv P. Parikh, MD

Hypothesis
Syndactyly has been linked with a constellation of other congenital conditions. However, our understanding of these associations is limited by small sample size and single center retrospective data. We hypothesize that a comparison of complex syndactyly and simple syndactyly patients across a large multi-center database will demonstrate significant syndromic associations with complex syndactyly.

Methods
The American College of Surgeons National Surgical Quality Improvement Program Pediatric (NSQIP Peds) is a quality improvement database that prospectively collects data on demographics, comorbidities, risk factors, and 30-day postoperative outcomes nationally across 56 institutions. Patients less than 18 years old who underwent syndactyly reconstruction were identified from the NSQIP Peds 2012 and 2013 databases. Two cohorts were compared: patients with simple syndactyly (CPT codes 26560 and 26561) and patients with complex syndactyly (CPT code 26562). Additional congenital anomalies were categorized by ICD-9 codes. Patient characteristics, intraoperative details, and 30-day postoperative outcomes were analyzed using chi-squared and Wilcoxon rank-sum tests.

Results
528 patients were identified: 418 (79%) with simple syndactyly and 110 (21%) with complex syndactyly. Average age at surgery for simple syndactyly was 2.8 years compared to 1.8 years for complex syndactyly. Concomitant congenital anomalies were present in 59% (n = 309) of all patients, 58% of patients with simple syndactyly, and 60% of patients with complex syndactyly. Common associated non-limb congenital anomalies included malformations of the skull and facial bones (4.2%), atrial septal defect (3.6%), cleft lip and palate (3.4%), Apert syndrome (2.8%), and Down syndrome (2.3%). Additional congenital limb anomalies occurred in 14% of patients, with Poland syndrome (2.5%), polydactyly of the hand (2.5%), cleft hand (2.1%), club foot (1.3%), and brachydactyly (1.1%) being most common. Certain congenital anomalies were significantly
more likely to occur in association with complex syndactyly, including Apert syndrome ($P < 0.001$), Down syndrome ($P = 0.001$), polydactyly ($P = 0.003$), and plagiocephaly ($P = 0.05$). Average operative time was significantly longer ($P < 0.001$) in complex syndactyly (176 minutes) vs. simple syndactyly (123 minutes). Complex syndactyly reconstruction also resulted in a longer hospital stay ($P < 0.001$). However, when comparing overall 30-day postoperative complications, there was no statistically significant difference between the cohorts.

Summary Points
- There is a significant association between complex syndactyly and certain congenital anomalies, including Apert syndrome and Down syndrome.
- The incidence of concomitant congenital anomalies in patients with syndactyly may be higher than previously recognized.
- Complex syndactyly reconstruction requires longer operative times and hospital stays compared to simple syndactyly; however, there is no difference in 30-day postoperative complications.
Hypothesis
This pilot study was performed to describe changes in arterial flow in neurovascula
rily intact Gartland III pediatric supracondylar humerus fractures (SCHFx) using Duplex ultrasonography. We hypothesized that these patients would have arterial flow comparable to the uninjured side.

Methods
This is an IRB-approved prospective study from October 2012 through August 2013 of eleven Gartland type III SCHFx that had no cortical continuity but did have a palpable radial pulse and normal neurologic exam. Duplex ultrasonography was performed on injured and uninjured arms, both pre-operatively and post-CRPP, and interpreted by a board-certified pediatric radiologist. Ultrasound wrist/brachial indexes (WBI) were calculated using the higher value of the radial/brachial or the ulnar/brachial index.

Results
Only 2 patients (Patients #1 and #2) had normal Duplexes with flow comparable in the brachial, radial, and ulnar arteries of the affected arm, compared to the unaffected arm, both pre-operatively and post-pinning.

Pre-operatively, 6 patients (Patients #3-8) had stenosis of the affected brachial artery at the level of the fracture site (22-60% narrowing) with elevated peripheral systolic velocity (PSV) (1.52-2.98 times higher) when compared to the brachial artery proximal to the fracture. The brachial artery in these patients demonstrated monophasic/biphasic flow, but flow of the radial and ulnar arteries was preserved. Of these 6 patients, 2 had decreased WBI in the affected arm compared to the unaffected arm, 3 had minimally lower WBI, and 1 had higher WBI. Postoperatively, for these 6 patients, 1 patient had no change in Duplex post-CRPP, 1 patient had improved artery
narrowing but continued elevated PSV, 1 had both improved artery narrowing and PSV, and 3 did not have a post-CRPP Duplex performed.

Patient #9 had brachial artery narrowing with decreased PSV in the distal arm and markedly decreased WBI compared to the unaffected arm. Post-CRPP, there was improved brachial artery narrowing but with elevated PSV and minimally improved flow to the wrist.

Patient #10 had brachial artery narrowing but normal PSV and intact ultrasound wrist/brachial index, without much change post-CRPP.

Patient #11 had a pink pulseless hand after anesthesia induction. Duplex revealed narrowed brachial artery with decreased PSV of brachial, radial, and ulnar arteries and decreased ultrasound WBI with no significant improvement post-CRPP.

Summary Points
- Type III SCHFx patients with a normal neurovascular exam may have abnormal Duplex ultrasonography with brachial artery stenosis and elevated PSV pre-operatively although distal flow remains comparable to the contralateral side.
- This study establishes a baseline of pathologic changes in the Duplex examination.
Paper 81: When Does Pediatric Trigger Thumb Start and End?

Clinical Paper Session 15: Pediatrics - Saturday, September 12, 3:49 - 3:56 PM

Prognosis/Outcomes, Congenital and Pediatric Problems
Level 2 Evidence

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Seung Hwan Rhee, MD
Young Ho Lee, MD
Goo Hyun Baek, MD

Hypothesis
Pediatric trigger thumb is a condition with flexion deformity of the interphalangeal joint in children. It rarely presents at birth and usually develops spontaneously during childhood. And we can also expect spontaneous resolution without any treatments such as splinting, exercise and surgery. The objectives of this study were to investigate the ages at the time of disease development and resolution, and to suggest a guideline of the conservative treatment.

Methods
We prospectively followed up 359 thumbs of 283 patients without any treatments such as splinting, exercise and surgery. The dates of the initial visits ranged from January 1999 to October 2012. The average duration of follow-up was 52.7 (range, 24-180) months. We measured the degree of the flexion deformity of the thumb interphalangeal joint at every six-month follow-up visit. We defined the resolution of the disease as having occurred when the flexion deformity of the interphalangeal joint became 0° with the wrist and the metacarpophalangeal joint of the thumb in neutral position.

Results
Among the unilateral cases, the average age of the symptom development was 23.9 months, that of the initial visit was 28.1 months, and that at the time of resolution was 63.6 months. Among the bilateral cases, the average age at the time of the symptom development was 26.5 months, that of the first visit was 31.9 months, and that at the time of resolution was 65.8 months. The duration of the disease showed negative correlation with the age at the time of symptom development in both groups. The resolution rates were 62% in unilateral cases and 61% in bilateral cases. However, those were increased to 84% in unilateral cases and 82% in bilateral cases among the patients with more than five year follow-up. Among the patients with more than seven year follow-up, those were 90% in unilateral cases and 89% in bilateral cases.
Summary
Pediatric trigger thumb most commonly occurs around the age of the two years and resolves between the age of the five and six years. If it develops at the younger age, it may take more time until the resolution of the disease. Pediatric trigger thumb seems to be a developmental disease and the developmental mismatch between the A1 pulley and the flexor pollicis longus tendon can be one of the possible causes.

Paper 82: Outcome of Repaired Digital Nerve Injuries in Children – Influence of Age in a Retrospective Long Term Follow Up

Clinical Paper Session 15: Pediatrics - Saturday, September 12, 3:56 - 4:03 PM

Prognosis/Outcomes, Congenital and Pediatric Problems, Nerve
Level 3 Evidence

Hans-Eric Rosberg, MD, PhD
Derya B. Hazer, MD
Lars B. Dahlin, MD

Hypothesis
Do children with a repaired digital nerve injury regain normal sensation and hand function and does age correlate with outcome?

Methods
Eighty-two children, aged 1-16 years at the time of injury, were treated for a digital nerve injury between 2002-2009 at our department. All children were invited for a follow up, including clinical evaluation (Semmes-Weinstein monofilaments, grip strength, VAS for function and cosmetic) and questionnaires (QuickDASH, CISS). Thirty-eight children (46%) accepted and outcome was evaluated at a median of 40 months (range 12-131 months) after the injury. The study population was divided into two groups – a young group (n=18) with age 0-10 years and an older group (n=20) with age 11-16 years.

Results
Most children were boys, who were injured at home and by a cut. The level of digital nerve injury was in 20/38 (53%) patients distal to the PIP-joint and the remaining patients had an injury between the PIP-joint and the distal volar crease. The index finger was the most frequently injured finger. The median Hand Injury Severity Score (HISS) was 37 (8-137). All patients regained normal sensation based on monofilament test with limited affected hand function, although some cold sensitivity remained. We found no significant difference between younger and older children concerning HISS, Cold Sensitivity Severity Scale (CISS), QuickDASH, VAS or grip power. No correlation between age and perception of touch (i.e. monofilament test) was found.

Summary Points
- Children (0-16 years) have an excellent recovery after a digital nerve injury and repair.
- Age of the children did not affect outcome.
- The majority of children have some degree of cold sensitivity.
No major hand disability was found irrespective of age.

Paper 83: Flexor Carpi Ulnaris Myotendinous Lengthening Improves Function in Children with Spastic Hemiplegic Cerebral Palsy

Clinical Paper Session 15: Pediatrics - Saturday, September 12, 4:03 - 4:10 PM

Treatment, Hand and Wrist, Congenital and Pediatric Problems
Level 3 Evidence

Matthew B. Burn, MD
Gloria R. Gogola, MD

Hypothesis
Children with spastic hemiplegic cerebral palsy with dynamic wrist flexion position during tasks, but with volitional wrist extension in isolation are often treated with Botox, which may limit muscle strength and growth. As the dynamic limitations in wrist movement are due to both abnormal myofascial loads as well as to abnormal patterns of muscle activation, we hypothesize that reducing the non-neural component via myotendinous lengthening of the flexor carpi ulnaris can reduce wrist impairment while maintaining muscle strength.

Methods
We performed a respective cohort study of forty children with spastic hemiplegic cerebral palsy (mean age 10.7 years, range 4.3-to-17 years old; 24 boys, 16 girls; MACS 1-4), with dynamic wrist flexion contractures who had FCU fractional lengthening as part of their single event multi-level surgery. We analyzed each child’s SHUEE (Shriners Hospital for Children Upper Extremity Evaluation) for overall scores and wrist sub-scores, wrist active range of motion, Pediatric Outcomes Data Collection Instrument (PODCI) scores, wrist flexion and extension strength, grip and pinch strength, and gross motor dexterity (box & blocks test). These measurements were obtained pre-operatively and at 1 year post-operatively. Statistical analysis was completed using data analysis tool sets, such as two-tailed t-tests, in Microsoft Excel.

Results
At 1 year, there were significant improvements (P 0.05) was observed in the PODCI comfort/pain subsection, SHUEE grasp and release score, wrist flexion strength, or pinch strength.

Summary
In children with spastic hemiplegic cerebral palsy with volitional wrist extension and dynamic wrist flexion contractures that impair function, FCU fractional lengthening can:

• Improve spontaneous use
• Improve dynamic wrist posture
• Improve grip strength
• Improve dexterity
• Preserve wrist flexion strength