

COA Paper Session 14: Upper Extremity 2 and Critical Issues in Orthopaedics •

Moderators Louis U. Bigliani, NY, President of the American Orthopaedic Association, and E. Anthony Rankin, DC, President of the American Academy of Orthopaedic Surgeons

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Effect of Coronal Shear Fractures of the Distal Humerus on Elbow Kinematics and Stability

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Purpose: Coronal shear fractures of the humerus include the Kocher-Lorenz fracture, an osteochondral fracture of the capitellar articular surface, the Hahn-Steinthal fracture, a substantial shear fragment, extension into the trochlea, and complete involvement of the capitellum and trochlea. If the fracture proves irreparable, it is not known what the impact of fragment excision would have on the biomechanics of the elbow. The purpose of this study was to examine the effect of the sequential loss of the capitellum and trochlea on the kinematics and stability of the elbow. **Method:** Eight fresh-frozen cadaveric arms were mounted in an upper extremity joint testing system, with cables attaching the tendons of the major muscles to motors and pneumatic actuators. Electromagnetic receivers attached to the radius and ulna enabled quantification of the kinematics of both bones with respect to the humerus. The distal humeral articular surface was sequentially excised to replicate clinically relevant coronal shear fractures while leaving the collateral ligaments intact. Active flexion in both the vertical and valgus-loaded positions, and passive rotation in the vertical position was conducted for each excision. **Results:** Excision of the capitellum had no effect on ulnohumeral stability or kinematics in both the vertical or valgus positions ($p=1.0$). Excision of the entire capitellum and trochlea led to significant valgus instability with the arm in the valgus position ($p=0.01$), while excision of the lateral trochlea led to increased valgus instability with pronated flexion in the valgus position ($p=0.049$). Progressive loss of the articular surface led to posterior, inferior, and medial displacement of the radial head with respect to the capitellum and increased external rotation of the ulna with respect to the humerus in the vertical position ($p<0.05$). **Conclusion:** Excision of the capitellum did not result in valgus or rotational instability, while excision of the trochlea resulted in multiplanar instability. The radial head displaced medially because it is constrained to the ulna by the annular ligament, and the ulna pivoted into valgus and external rotation on the residual trochlea and medial collateral ligament. In patients with coronal shear fractures, the trochlea must be reconstructed to prevent instability and the potential for secondary degenerative change.

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The Effect of the Posterior Bundle of the Medial Collateral Ligament on Elbow Stability

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Purpose: The role of the posterior bundle of the medial collateral ligament (PMCL) in stability of the elbow remains poorly defined. The purpose of this study was to determine the effect of sectioning the PMCL on the stability of the elbow. **Method:** Varus and valgus gravity-loaded passive elbow motion and simulated active vertical elbow motion were performed on 11 cadaveric arms. An in-vitro elbow motion simulator, utilizing computer-controlled pneumatic actuators and servo-motors sutured to tendons, was used to simulate active elbow flexion. Varus/valgus angle and internal/external rotation of the ulna with respect to the humerus were recorded using an electromagnetic tracking system. Testing was performed on the intact elbow and following sectioning of the PMCL. **Results:** With active flexion in the vertical position the varus/valgus kinematics were unchanged after PMCL sectioning ($p=0.08$). However, with the forearm in pronation, there was a significant increase in internal rotation after PMCL sectioning compared to the intact elbow ($p<0.05$) which was most evident at 0° and 120° degrees of flexion ($p<0.05$). This rotational difference was not statistically significant with the forearm in supination ($p=0.07$). During supinated passive flexion in the varus position, PMCL sectioning resulted in increased varus angulation at all flexion angles ($p<0.05$). In pronation varus angulation was only increased at 120° of flexion ($p<0.05$). However, internal rotation was increased at flexion angles of 30° to 120° ($p<0.05$). In supination, sectioning the PMCL had no significant effect on maximum varus-valgus laxity or maximum internal rotation ($p=0.1$). However, in pronation, the maximum varus-valgus laxity increased by 3.5° (30%) and maximum internal rotation increased by 1.0° (29%) ($p<0.05$). **Conclusion:** These results indicate that isolated sectioning of the PMCL causes a small increase in varus angulation and internal rotation during both passive varus and active vertical flexion. This study suggests that isolated sectioning of the PMCL may not be completely benign and may contribute to varus and rotation instability of the elbow. In patients with insufficiency of the PMCL appropriate rehabilitation protocols (avoiding forearm pronation and shoulder abduction) should be followed when other injuries permit.

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Contribution of the Olecranon to Elbow Stability: An In-vitro Biomechanical Study

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Purpose: The purpose of this study was to determine the effect of serial olecranon resections on elbow stability. **Method:** Eight fresh, previously

frozen cadaveric arms underwent CT scanning. The specimens were mounted in an in-vitro motion simulator, and kinematic data was obtained using an electromagnetic tracking system. Simulated active and passive flexion was produced with servo-motors and pneumatic pistons attached to specific muscles. Flexion was studied in the dependent, horizontal, varus, and valgus positions. Custom computer navigation software was utilized to guide serial resection of the olecranon in 12.5% increments. A triceps advancement repair was performed following each resection. **Results:** Serial olecranon resections resulted in a significant increase in valgus-varus (V-V) laxity for both passive ($p < 0.001$) and active ($p = 0.04$) flexion. For passive motion this increase reached statistical significance following the 12.5% resection. This corresponded to an increase in V-V laxity of 1.4 ± 0.10 and a total laxity of 7.5 ± 1.00 . For active flexion this increase reached significance following the 62.5% resection. This corresponded to an increase in V-V laxity of 5.6 ± 1.10 and a total laxity of 11.2 ± 1.5 . There was no significant effect of sequential olecranon excision on elbow kinematics or stability with the elbow in the vertical or horizontal positions. The elbows became grossly unstable after resection of greater than 75% of the olecranon. **Conclusion:** A progressive increase in the varus-valgus laxity of the elbow was seen with sequential excision of the olecranon. Laxity of the elbow was increased with excision of 75% of the olecranon, likely due to the loss of the bony congruity and attachment site of the posterior band of the medial collateral ligament. Gross instability resulted when 87.5% or greater was removed, likely due to damage to the anterior band of the medial collateral ligament as it inserts on the sublime tubercle of the ulna. Rehabilitation of the elbow with the arm in the dependant position should be considered following excision of the olecranon; varus and valgus orientations should be avoided. The contribution of the olecranon to elbow stability may be even more important in patients with associated ligament injuries or fractures of the elbow.

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Proximal Ulnar Anatomy: Importance of the Dorsal Angulation *PUDA*

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Purpose: Recognition of the proximal ulna dorsal angulation (PUDA) is important for anatomic reduction of proximal ulnar fractures or osteotomies, especially when using newer straight precontoured proximal ulnar plates. The purpose of this study was to characterize the PUDA in 50 patients with bilateral elbow radiographs. **Method:** Bilateral elbow radiographs (100 radiographs) were magnified four times using commercial software. The PUDA was measured from the intersection of lines tangent to the subcutaneous border of the olecranon and the proximal ulnar shaft. The olecranon tip-to-apex distance of the PUDA was also measured. Three orthopaedic surgeons independently examined the radiographs and intra/inter-observer reliability was calculated using Intra-Class-Correlation (ICC). **Results:** A PUDA was present in 96% of radiographs. The average PUDA was 5.7° (range, 0° to 14°). The Pearson Correlation coefficient for a

side-to-side comparison was 0.86($p < 0.001$). The average tip-to-apex distance was 47 mm (34 mm-78mm). No correlation was identified with sex or age. Intra-observer reliability was excellent for the PUDA (ICC 0.892 and 0.863) and good for tip-to-apex distance (ICC 0.762 and 0.827). Inter-observer reliability was good for PUDA (ICC 0.784 and 0.925) and for tip-to-apex distance (ICC 0.711 and 0.769). **Conclusion:** A mean proximal ulna dorsal angulation of 5.7° is present in 96% of patients at an average of 47 mm distal to the olecranon tip. Measurement of the PUDA has good/excellent inter/intra-observer reliability. Recognition of the PUDA may be helpful in anatomic plating of the ulna. Contralateral PUDA measurements are useful for surgical planning in cases with comminution or distorted anatomy.

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Long Term Outcome Following Elbow Resection Arthroplasty

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Purpose: Resection elbow arthroplasty is a salvage procedure typically considered as a last resort when other reconstructive options have failed. It was the intent of this study to evaluate the long-term outcome of patients following resection elbow arthroplasty. **Method:** Fifty-four elbow resections performed between 1975 and 2005 were retrospectively reviewed. Pre and post-operative elbow function was evaluated with the Mayo Elbow Performance Score (MEPS) and additional follow-up data was compiled using the Disability of Shoulder and Hand (DASH) score. All patients in this study had a resection following a failed total elbow arthroplasty (TEA). Nineteen patients had died at time of follow-up, and 5 patients were lost to follow-up, leaving 30 of the surviving 34 patients (88%) available for long-term evaluation. **Results:** The main indication for resection in this study was infection (50 of 54 elbows). The average MEPS prior to resection was 36. The long-term results in 30 patients at an average of 11 yrs (range 2.7-28 yrs) demonstrated an average MEPS score of 60, and a DASH score of 71. Complications were common including persistent infection requiring reoperation (44%), intra-operative fracture (32%), transient (11%) or permanent (5.5%) nerve damage, and one case of vascular injury requiring amputation. Achieving a stable resected elbow correlated strongly with a good long-term MEPS score ($r=0.75$). **Conclusion:** This study emphasizes the difficulty in treating patients with a failed total elbow arthroplasty. Resection arthroplasty is a salvage procedure indicated primarily for persistently infected TEA and results in satisfactory outcomes in this population.

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Clinical Characteristics of Spontaneous Osteonecrosis of the Knee, and Results of a Proposed Treatment Algorithm

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Purpose: Spontaneous osteonecrosis of the knee is a potentially greatly debilitating condition. While success has been reported with non-operative treatment of this disorder in its earliest stages, knee arthroplasty is the only viable modality if allowed to progress to condylar collapse. The purpose of this report is to review the etiologic and pathophysiologic principles of spontaneous osteonecrosis of the knee, to present our experience with joint-preserving surgical treatment of this condition, and finally to introduce a treatment algorithm developed based on this knowledge. **Method:** Seventeen patients with a clinical and/or radiographic a diagnosis of spontaneous osteonecrosis of the knee, and exclusion of secondary osteonecrosis, who failed non-operative modalities were treated with joint-preserving surgery at a single center between January 2000 and December 2006. Treatment modalities included arthroscopy, and either percutaneous core decompression and/or osteochondral autograft transfer. Three knees were lost to follow-up, leaving 14 knees with a mean follow-up of 37 months (range, 11 to 84 months). **Results:** Twelve of 14 knees (86%) had knee joint survival with a mean Knee Society Score of 80 points (range, 45 to 100 points) at final follow-up. One patient was treated with serial core decompression followed by osteochondral transfer, and was included in both groups. Six of 7 patients (86%) treated with core decompression alone had a successful clinical outcome, as did 7 of 8 patients (87%) treated with osteochondral autograft transfers. Two patients (14%) progressed to condylar collapse, and were treated with total knee arthroplasty with successful results. **Conclusion:** Based on these results, we propose a treatment algorithm that begins with non-operative treatment, followed by joint-preserving surgery consisting of arthroscopy, core decompression, and/or osteochondral autograft transfer. Although our sample size is small, the results suggest that this proposed treatment algorithm can successfully postpone the need for knee arthroplasty in selected patients with pre-collapse spontaneous osteonecrosis of the knee.

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An Economic Analysis of Liquid Waste Disposal in the Operating Room: Flushing Money Down the Toilet

Sean Haslam, Queen's University; **Daniel P. Borschneck**, Queen's University

Purpose: The purpose of this study was two-fold. First, we wanted to compare the cost of liquid waste disposal from the operating rooms (ORs) via a 3rd party medical waste company, with utilization of the sewer system at Kingston General Hospital. Secondly, we sought to assess national trends in liquid waste disposal, in order to make a national recommendation for liquid waste disposal from the OR. **Method:** The hospital cost for OR liquid waste disposal at Kingston General Hospital was calculated by weighing the liquid waste from 871 surgical cases over a 5-week period in

2008. The materials, manpower and weight of the waste were used to calculate the costs for the two methods of liquid waste disposal. Seventy teaching hospitals across Canada were surveyed to determine their practice of liquid waste disposal in the OR. **Results:** The raw cost per kg of liquid waste disposal using a medical waste company was found to be 57.126 % greater than utilizing the sewer system. Using the sewer system resulted in a total cost reduction of 40% compared with using a medical waste company. Sixty-three out of seventy teaching hospitals across the nation (90%) were found to utilize medical waste companies, while seven out of seventy hospitals (10%) utilized the sewer system to dispose of liquid waste. **Conclusion:** The sewer system is an under-utilized yet safe, legal, and cost effective way to dispose of liquid waste from the OR. Using the sewer system to dispose of liquid waste would save the Canadian health care system millions of dollars compared with disposal via medical waste companies.

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Intra-operative Hip and Knee Arthroplasty Implant Waste: A Potential Target for Cost Containment Efforts

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Purpose: Many strategies have been reported for decreasing the cost of orthopaedic procedures, including negotiating lower prices with manufacturers and using lower-cost generic implants, but prosthetic waste has not been investigated. The purpose of this study was to characterize the present and potential future cost of intra-operative waste of hip and knee implants. **Method:** A regional prospective assessment of implant waste was performed from January 2007 to June 2008, evaluating the incidence and reasons for component waste, the cost of the wasted implants, and where the cost was absorbed (hospital or manufacturer). Using published data on nationwide arthroplasty volumes, the results were extrapolated to the whole of the United States. Finally, based on peer-reviewed estimates of nationwide arthroplasty volumes for the next 20 years, a projection was made about the future cost burden of implant waste. **Results:** Implant waste occurred in 79 of 3443 recorded procedures (2%), with the surgeon bearing primary responsibility in 73% of occurrences. The annualized waste cost was \$109,295.35, with 67% absorbed by the hospital. When extrapolated to the whole of the United States, the annual cost to hospitals of hip and knee prosthetic waste is \$36,019,000, and is estimated to rise to \$112,033,000 in current dollars by the year 2030. **Conclusion:** This study discovered a notable incidence of intra-operative hip and knee implant waste, with the majority of cases attributed to the surgeon, and representing an important additional cost burden on hospitals. With arthroplasty rates projected to increase markedly over the next twenty years, this waste represents a

potentially noteworthy target for educational programs and other cost containment measures in orthopaedic surgery.

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The 80 Hour Work Week: Impact on Resident Surgical Exposure and National In-training Exam Scores

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Purpose: The current study examines the impact of the 80-hour work week on the number of surgical cases performed by PGY2 – PGY5 Orthopedic residents. We also evaluated Orthopaedic In-training Exam (OITE) scores during the same time period. **Method:** Data were collected from the ACGME national database for 3 academic years prior to and 5 years after July 1, 2003. CPT surgical procedure codes logged by all residents three years prior to and five years following implementation of the 80-hour work week were compared. The average raw OITE scores for each class obtained during the same time period were also evaluated. Data were reported as the mean \pm standard deviation (SD) and group means were compared using independent t-tests. **Results:** No statistical difference was noted in the number of surgical procedure codes logged prior to or after institution of the 80-hour week during any single year of training. However, an increase in the number of CPT codes logged in the PGY-3 year after 2003 did approach significance (457.7 vs. 551.9, $p=0.057$). There was a statistically significant increase in total number of cases performed (464.4 vs. 515.5 $p=0.048$). No statistically significant difference was noted in the raw OITE scores before or after work hour restrictions for our residents or nationally. **Conclusion:** We found no statistical difference for each residency class in the average number of cases performed or OITE scores. We also found no statistical difference in the national OITE scores. Our data suggest that the impact of the 80 hour work has not had a detrimental effect in these two resident training measurements.

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The Canadian Orthopaedic Medicolegal Climate: Global Warming or Isolated Cooling?

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Purpose: Litigation continues to be a concern in orthopaedic surgery despite suggestions on how to contain liability. The purpose of this study was to characterize orthopaedic litigation in Canada from 1997-2006. **Method:** This study reviewed all closed claims reported to the Canadian Medical Protective Association (CMPA) for 1997-2006 in which orthopaedic surgeons were named. There were 11,983 closed legal actions involving CMPA members (> 73,000 physicians), and 1,353 involved orthopaedic surgeons. A careful review of closed legal actions is a recognized tool for risk identification, assessment and management. The CMPA identifies any critical incidents

within the closed legal files. A critical incident is defined as any omission or commission in the evaluation or management which led to the problem(s) that triggered the legal action. Each closed legal action can have more than one critical incident. **Results:** Performance, diagnostic and communication issues were the most frequently identified problems. These three areas account for 55% of the critical incidents identified. Performance related issues accounted for 395 critical incidents (29%). Diagnostic issues, including deficient histories and general evaluations, were identified in 281 cases (21%). Communication-related critical incidents included those concerning informed consent. The lack of informed consent was a common allegation, proven in 71 cases. In 439 cases (32%) there was no identifiable critical incident for the orthopaedic surgeon involved. Seventy-eight per cent of patients experienced minor or no disability and 22% experienced major disability or death. Events related to tibia trauma and knee arthroscopy formed the two major categories of claims. Patient care areas of high risk include the operating room and outpatient clinic. Overall, 31% of legal actions against orthopaedic surgeons had outcomes in favour of the plaintiffs, compared with 33% of all CMPA members' claims. **Conclusion:** Although the likelihood for an orthopaedic surgeon to be sued in Canada has decreased over the last 10 years, the percentage of legal cases resolved in favour of plaintiffs has remained stable. Performance-related deficiencies, delays in diagnosis, and failures in communication represent areas of high medico-legal risk. Suggestions for risk management are provided to further decrease adverse events and the medico-legal risks for Canadian orthopaedic surgeons.