Special Emphasis Session: MSK Imaging Innovations

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Special Emphasis Session: ***MSK Imaging Innovations*** **Session Chair: David Cooper & Jenna Schulz**

1:30 **Sydney M Robinson** – *Western University; Master's*

"Evaluation of scaphoid kinematics using 4-dimensional computed tomography"

Background: Traumatic injury of the scapholunate ligament (SLL) can lead to long-term degenerative arthritis. Current diagnostic tools for SLL injuries are radiographs and clinical examinations, which are unable to detect subtle bony movement abnormalities nor dynamic instabilities. Four-dimensional computed tomography (4DCT) can capture abnormal bony movements and allows for quantification of carpal kinematics in real time. The purpose of this study was to use 4DCT as a method of measuring the translation of a scaphoid's centroid during radio-ulnar deviation in situ. Methods: Twelve participants with no history of wrist pain nor injury were recruited and underwent unilateral imaging of the wrist using a 4DCT scanner while performing three cycles of radio-ulnar deviation. Models of the scaphoid and radius in extreme radial and extreme ulnar deviation were made in Materialise Mimics 22.0 and registered to a neutral model using Python. Transformation matrices and a radius-based coordinate system (Matlab) were used to describe the position of the scaphoid's centroid in each kinematic frame relative to the position of the radius in the static frame. Results: The average scaphoid translation was 1.7±1.5 mm dorsal, 5.5±1.4 mm distal, and 2.3±0.9 mm lateral (6.4±1.3 mm total) and showed no statistically significant difference according to sex ($p=0.170$) nor lunate type ($p=0.961$). The scaphoid extended from extreme radial to extreme ulnar deviation, which is consistent with the literature. Significance & Impact and Future Studies: These results show that 4DCT can be used to analyze scaphoid motion in vivo in a clinical setting. This data provides a starting point for establishing normal scaphoid motion in healthy subjects, which can be used as a control for comparison with individuals with scapholunate instabilities and to advance the understanding of the complex motion of the carpals. Future studies will examine the effects of SLL injury on scaphoid centroid translation.

1:40 **Puneet K Ranota** – *Western University; Master's*

"4DCT To Examine Joint Congruency Following Wrist Fracture"

BACKGROUND: Previous studies are limited by their ability to capture dynamic data (3D reconstructions + time). Four-Dimensional Computed Tomography (4DCT) captures joint motion and measures 3D joint space. Previous studies solely focused on the distal radioulnar joint (DRUJ) space and the impact of fracture on surrounding joint mechanics has yet to be examined. OBJECTIVE: To employ 4DCT and examine joint surface area (JSA) at DRUJ and radiocarpal joints following fracture. METHODOLGY: Eleven healthy and eleven distal radius fracture participants were recruited. Patients underwent 1 "static" and 1 "kinematic" scan throughout wrist extension/flexion (GE Revolution 4DCT Scanner, 5°/sec). Semi-automated segmentation was used to create 3D reconstructions of the distal radius and carpal bones (Materialise Mimics). A surface-based registration algorithm (ICP) was used to match the kinematic bone surfaces with the static bone surfaces. A previously developed inter-bone distance algorithm was used to measure JSA at maximum extension, neutral and maximum flexion for each joint (normalized to the individual's total static JSA). Univariate and repeated measures ANOVA were conducted (statistical significance was set at $p<0.05$). RESULTS: The JSA % of the DRUJ was significantly different between healthy and fracture cohorts. The JSA % was significantly different across the range of motion (ROM) in radiocarpal joints for the healthy cohort and only in radioscaphoid joint for the fracture cohort. SIGNIFICANCE: The results showed that joint congruency was affected by health status and changed across ROM. Future work needs to examine the link between altered contact mechanics and osteoarthritis.

1:50 **Sam Papernick** – *Western University; Master's*

"Validation of 3D ultrasound for quantifying trochlear knee cartilage loss"

Introduction: Osteoarthritis (OA) is the most prevalent chronic health condition in Canada. X-ray imaging and MRI are the current standards for assessing cartilage loss. However, x-ray imaging is unable to provide soft tissue assessments, and MRI is expensive, associated with long waitlists, and is inaccessible to many patients. There is a tremendous clinical need for an objective/imaging-based point-of-care tool to assess OA status, progression, and response to treatment. We propose the use of a handheld mechanical 3D ultrasound (US) device we have developed for quantifying the volume of the femoral articular cartilage (FAC) at the patient's bedside. Objectives: We aim to validate volume measurements of the trochlear FAC using 3D US segmentations against the current standard of MRI in healthy subjects. Methods: Knee images of 25 healthy volunteers were acquired using our 3D US device with accompanying 3.0T MR images. The trochlear FAC was repeatedly manually segmented by 2 raters at 2 time points on MR and 3D US images. 3D US segmentations were registered to MRI using a semi-automated surface-based registration algorithm. Intra- and inter-rater reliabilities were assessed using intraclass correlation coefficient (ICC) values calculated from segmentation volumes. Correlations between MRI and 3D US cartilage volumes were assessed using a Spearman Rank-Order Correlation. Results: 3D US intra-rater ICC were 0.99 ($n = 5$) for both raters while inter-rater ICC was 0.95 ($n = 25$). MRI intra-rater ICC were 0.97 and 0.90 ($n = 5$) for each rater while inter-rater ICC was 0.83 ($n = 25$). Spearman correlation resulted in $\rho = 0.88$ ($p < 0.0001$, $n = 25$). Significance: We have validated a handheld 3D US acquisition device that can be used to acquire volume measurements of the trochlear FAC with higher reliability than MRI in healthy subjects. 3D US has the potential to increase the quality of lives of knee OA patients by reducing the need for MRI in OA clinical trials and future care.

2:00	**Baraa Daher** – *Western University; Master's* "Four-Dimensional Computed Tomography Scans Allow kinematic Visualization and Measurement of Scapulothoracic Joint" Background and Objective: Literature surrounding the characterization of the scapulothoracic joint is limited and controversial. One of the many challenges faced when characterizing scapulothoracic motion is the difficulty in detecting/palpating anatomical landmarks due to skin artifacts. However, these obstacles are circumvented when using a 4-dimensional computed tomography (4DCT) scanner. The objective of this study is to quantitatively evaluate scapular translation during active internal/external rotation using 4DCT scanning. Methods: A single healthy participant with no previous history of shoulder injuries was recruited and underwent dynamic 4DCT imaging of their shoulder. CT scans during motion were performed for eight seconds (producing 25 frames of images). Neutral CT frame and first and last dynamic frames were reconstructed into 3-dimensional models of the scapula and spine. Translations of the trigonum relative to the neutral position of third thoracic (T3) vertebrae and the superior angle relative to its neutral position were calculated. Results: Translation of the scapula was measured for both dynamic frames relative to the neutral frame. In the first frame, the trigonum moved 21mm laterally with respect to the T3, and the superior angle moved 19mm inferiorly with respect to its neutral position. In the last frame, the trigonum moved 19mm medially with respect to the T3, and the superior angle moved 17mm superiorly with respect to its neutral position. Significance and Impact: Preliminary results suggest that the scapula translates with respect to the spine and glides across the thorax during shoulder motion. Understanding the motion of the scapulothoracic joint will improve the engineering design of shoulder implants and surgeries approach.
2:10	**Sara Hakim** – *Western University; Master's* "Modelling Ischemia in Duchenne muscular Dystrophy" Introduction: Duchenne muscular dystrophy (DMD) is a progressive neuromuscular degenerative disorder caused by the absence of dystrophin, which results in a loss of cell membrane integrity. Necrotic fibers are often observed in groups, and it has been previously hypothesized that this may be due to a reduction in regional blood supply. The accumulation of adipose and fibrotic tissue replacing muscle fibers further exacerbate the ischemic condition. Here we aim to develop an imaging protocol to non-invasively and systemically model hemodynamic parameters in DMD. We hypothesize that CT perfusion will help model DMD disease progression by quantifying such changes in the heart, brain, and skeletal muscle. Methods: Two cohorts of DMD mice (n=6) and their respective controls were scanned using CT to collect both longitudinal and acute data at differing time points 4-5 weeks, 8-10 weeks, and 15-20 weeks. These critical periods are associated with disease progression and correspond to pre-fibrotic, fibrotic, and post fibrotic conditions respectively. Wire myography was used to study aortic vascular reactivity, and histological staining (n=3) to validate CT findings. Results: DMD mice have qualitatively shown increased levels of collagen deposition within the brain, and cardiac tissue. Furthermore, wire myography has concluded that DMD mice are less likely to mediate dilatory responses than contractile responses at the 15-20 week time point. Discussion: Currently, there is little knowledge of functional tissue perfusion parameters in DMD patients. This research will be essential in developing therapeutics to restore tissue integrity and function when the natural ability of the tissues for repair is exhausted. Further, it will serve as a non-invasive diagnostic measure to assess disease progression prior to the onset of fatal complications.
2:20	**Gregory Hong** – *Western University; PhD* "MRI Artifact Reduction Near 3D-Printed Porous Metal Scaffolds" Background: Infection is the most common reason for early revision (within 5 years of primary surgery) of both hip and knee replacements. The gold standard treatment of infection is to implant a temporary antibiotic impregnated cement spacer in a 2-stage revision. Originality, Rationale, and/or Scope: We aim to maintain the benefits of a 2-stage revision in a single surgery through a 3D printed porous metal scaffold that can be filled with antibiotics and deployed as a permanent replacement for the failed solid implant. The porosity will also reduce metal artifacts, leading directly to better monitoring of the infection. Objectives: Our objective is to characterize the signal loss and magnetic susceptibility of titanium scaffolds of varying porosities to quantify image artifact. Methodology: 5 gyroid-based scaffolds were 3D printed in titanium with nominal porosities between 60% and 90% in cylinders of 17 mm diameter and 40 mm length. The cylinders are placed in a fiducial phantom that establishes a co-registration between scan and simulation. Field maps were calculated from the difference in phase accumulation between two gradient-echo scans. The scaffold's effective susceptibility was measured by comparing the scanned field maps against simulated field maps of a cylinder assigned susceptibility values ranging from water to titanium (-9 to 182 ppm). Results: The susceptibility estimates give a highly correlated ($R2 = 0.9993$) linear relationship with a 100% porosity value of $\chi = -9.9$ ppm, comparable to the expected value of pure water ($\chi = -9.06$ ppm). Significance & Impact and/or Future Studies: We have shown that artifact size and effective susceptibility are strongly correlated with porosity. The reduced artifact around porous implants is promising for MR imaging as lowering effective densities reduces the artifact size to within millimeters of the scaffold, which may allow for quantitative imaging techniques to track antibiotic elution.
2:30	**Discussion & Session Wrap up**