# Differences in Radiomic Features of the Scapula Between a Cohort of Patients Experiencing Acromial/Scapular Fracture After Reverse Total Shoulder Arthroplasty Versus a Control Cohort

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INTRODUCTION: Incidence of acromial and scapular fractures (ASF) following reverse total shoulder arthroplasty (rTSA) has been reported at varying rates. Previous studies have sought to elucidate patient and implant-related risk factors for ASF, finding that certain demographics, diagnoses, comorbidities, and implant designs may be correlated with occurrence of ASF. The role of other patient-specific characteristics, such as scapular shape and bone quality, that may predispose certain patients to ASF remains largely unclear. Radiomics, which are objectively quantifiable features that can be extracted from 2D or 3D medical images, may provide insight into bone-related parameters and patterns that are not perceptible via visual inspection of images. First-order radiomic features are determined by performing statistical analyses on the intensity values of the pixels (for 2D) or voxels (for 3D) without regard for spatial distribution of intensities. Texture features relate to the variation of intensities while accounting for spatial distribution of those intensities. Shape features, such as volume and surface area, are related to morphology without regard for intensity values. The purpose of this pilot study was to investigate if differences in radiomic features of the scapula exist between cohorts of patients that experienced ASF following rTSA versus those that did not.

METHODS: Patients undergoing rTSA from a multi-center, IRB-approved, international database of a single shoulder arthroplasty system (Equinoxe; Exactech Inc, Gainesville, FL) with available pre-operative 3D CT scans were identified retrospectively. This database includes patient demographics, diagnoses, operative information, pre- and post-operative outcomes, as well as documentation of adverse events via standardized forms. Patients experiencing ASF were matched 1:2 with control subjects not experiencing ASF on the basis of age, gender, diagnosis, and reconstruction kernel of the CT image. Boundaries of the scapulae within the CT images were identified using a machine-learning based segmentation algorithm. Radiomic features were then extracted from the images within the region of the scapular masks using an open-source python package, pyradiomics[1]. In total, 18 first-order intensity statistical features, 14 shape features, and 75 texture features were extracted from each image. Radiomics were compared between the ASF and control cohorts using Welch's t-test for the overall cohorts regardless of CT reconstruction kernel, with significance set at $p < 0.05$. Sub-analyses were then conducted on cohorts stratified by reconstruction kernel where sufficient data was available.

RESULTS SECTION: Thirty-two patients were identified as having ASF following rTSA. The average age at surgery was 76 years, 78% were female, 53% had a diagnosis of osteoarthritis, 19% had a diagnosis of rotator cuff tear, and 47% had a diagnosis of cuff tear arthropathy. CTs were reconstructed using one of five convolution kernels including: Bone (41%), Bone Plus (38%), B60s (13%), I31s (6%), or FC30 (3%). Sixty-four control subjects were matched based on age, gender, diagnosis, and reconstruction kernel, resulting in equivalent distributions of these parameters to the ASF cohort. In comparing cohorts of ASF patients to a control group considering only images reconstructed using a Bone kernel, 15/18 first-order, 1/14 shape, and 57/75 texture features were significantly different. However, the same results were not observed when comparing ASF to control cohorts including only a Bone Plus kernel, where only 1 shape feature was significantly different, and considering all kernels simultaneously, where only 3 texture radiomic features were significantly different. Differences in several readily interpretable radiomic features between the ASF and control cohorts are shown in Table 1 for each of the kernel-agnostic, Bone Plus kernel only, and Bone kernel only analyses.

DISCUSSION: This study found several differences in radiomic features of the scapula between cohorts of patients experiencing ASF versus an age, gender, and diagnosis matched control cohort. One interesting finding was that differences elucidated between ASF and control cohorts appeared to be dependent on reconstruction kernel, where 73/107 radiomic features were significantly different when considering only a Bone kernel, but the number of differences was 1 and 3 when considering only Bone Plus and all five kernels, respectively. It should be noted that distributions of matching parameters between ASF and control cohorts (i.e. age, gender, and diagnosis) were maintained in the kernel-specific analyses. There were few differences in shape metrics, regardless of kernel inclusion, but the number of differences between cohorts in intensity-related metrics (first-order and texture) was highly variable based on kernel inclusion. This may be related to the effect of CT kernel on intensity (i.e. x-ray attenuation) measurements, illustrating that kernel should be carefully investigated and considered in future work extracting radiomics from scans with varying kernels. Limitations of this study include relatively small sample sizes as well as use of a single implant design. While inclusion of a single implant system allows for a controlled analysis, results may not be generalizable to other implant systems. Additionally, the applied statistical approach was relatively simple, where it is unknown if statistically significant differences in radiomic features using the traditional p-value cut-off are predictive of ASF.

SIGNIFICANCE/CLINICAL RELEVANCE: This pilot study investigated differences in radiomic features between ASF and control patients, and while some differences in radiomic features were identified, consideration of the CT convolution kernel was found to be of greatest importance. Future work should account for the effect of CT kernel and utilize machine-learning methods to examine feature importance relative to the prediction of ASF, which could aid in identification of patients that may have elevated risk of this complication following rTSA.

REFERENCES: [1] van Griethuysen, J. J. M., Fedorov, A., Parmar, C., Hosny, A., Aucoin, N., Narayan, V., Beets-Tan, R. G. H., Fillon-Robin, J. C., Pieper, S., Aerts, H. J. W. L. (2017). Computational Radiomics System to Decode the Radiographic Phenotype. Cancer Research, 77(21), e104–e107.
[2] https://pyradiomics.readthedocs.io/en/latest/

Table 1. Differences between ASF and control cohorts in select radiomic features of the scapula based on reconstruction kernel.

| Feature Class | Feature | All Kernels | | | Bone Plus | | | Bone | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ASF | Control | p-value | ASF | Control | p-value | ASF | Control | p-value |
| Shape | Volume ($cm^3$) | 76.0 | 76.8 | 0.852 | 79.8 | 81.9 | 0.788 | 75.1 | 74.4 | 0.901 |
| Shape | Surface Area ($cm^2$) | 443.1 | 441.5 | 0.922 | 465.9 | 454.5 | 0.728 | 430.0 | 436.9 | 0.739 |
| First-order | Mean Voxel Intensity | 435.1 | 452.5 | 0.228 | 470.3 | 457.5 | 0.612 | 393.4 | 449.5 | **0.003** |
| First-order | $90^{th}$ Percentile Voxel Intensity | 981.8 | 1037.1 | 0.074 | 1068.4 | 1076.8 | 0.860 | 886.9 | 1003.9 | **0.006** |
| Texture | Contrast* | 0.23 | 0.26 | 0.056 | 0.24 | 0.26 | 0.593 | 0.20 | 0.26 | **0.008** |
| Texture | Joint Energy** | 0.0010 | 0.0009 | 0.310 | 0.0008 | 0.0007 | 0.536 | 0.0013 | 0.0010 | **0.022** |

*Measure of spatial intensity change considering local range and rate of change of intensity levels[2]
**Measure of homogenous patterns, with higher values representing more homogeneity[2]