Inferior Craniocaudal Hill-Sachs Extension is Associated with Recurrent Instability following Primary Arthroscopic Bankart Repair

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INTRODUCTION:
The glenoid track concept for shoulder instability primarily describes the medial-lateral relationship between an engaging Hill-Sachs lesion and a Bankart defect. On-track lesions still retain risk for failure following primary arthroscopic Bankart repair of up to 30% in literature. Surgical techniques that include remplissage or open capsular shift may be useful for addressing higher risk shoulders, but to date there is no clear method for surgical stratification. While risk for recurrence can be partly explained by the distance-to-dislocation concept, the contribution of craniocaudal Hill-Sachs position in the Sagittal plane to risk of recurrence has never been clarified. This study aims to characterize the relationship between the craniocaudal extent of Hill-Sachs lesions and risk for failure following primary arthroscopic Bankart repair, with the hypothesis that caudal Hill-Sachs extension represent a higher risk lesion due to engagement at lower degrees of arm abduction.

METHODS: We performed a retrospective analysis of 176 individuals with on track lesions who underwent primary arthroscopic Bankart repair (without remplissage) between 2007 and 2019 who have minimum 2-year follow up. Patients with failure were defined as those who sustained a dislocation or subluxation after the index procedure. Craniocaudal position of the Hill-Sachs was measured referencing the mid-humeral axis on sagittal MRI, against either a Hill-Sachs bisecting line through the humeral head center (Sagittal Midpoint Angle; SMA), or by a similar line that is tangent to the inferior Hill-Sachs Edge (Lower Edge Angle; LEA); an angle of 0 is axial on the humeral head, while 90 is equatorial. We defined *a priori* three Hill-Sachs craniocaudal angular regions for semi-quantitative analyses, based on physiologic arm positions for activities of daily living: Superior (angle < 60), Mid (61-90), and Inferior (>90) (Fig 1A). Hill-Sachs regions were then correlated against failure data. Univariate and Multivariate regression was used to determine predictive values of SMA and LEA for recurrent instability.

RESULTS: Forty-two (23.9%) patients experienced failure following arthroscopic Bankart repair. Average time from surgery to recurrent instability was 1.7 years (95% Confidence Interval (CI): 1.3 – 2.1 years). Recurrently unstable patients were younger (18.0 ± 2.3 versus 21.4 ± 6.6 years, $p = 0.001$), more likely to play a contact sport (81% versus 64%, $p = 0.039$), more likely to have had multiple dislocations before surgery (79% versus 60%, $p = 0.03$), and exhibited evidence of more glenoid bone loss, compared to patients who did not experience recurrence. Both SMA >60 degrees (OR = 2.24, $p = 0.05$) and LEA >90 degrees (OR 3.29, $p = 0.022$) were found to be predictive of failure following primary arthroscopic Bankart repair, based on a multivariate analysis accounting for confounders. In comparison, percent glenoid bone loss demonstrated OR of 1.17 ($p < 0.001$). A post-hoc analysis performed using the recurrent dislocation dataset (subset of the recurrent instability cohort), demonstrated that patients with Hill-Sachs lesions with LEA greater than 90 degrees is at 4.8-fold higher odds to experience a recurrent *dislocation* after surgical correction compared to patients without a Hill-Sachs lesion or a Hill-Sachs lesion with a LEA less than 90 degrees on sagittal MRI, (OR: 4.80, $p = 0.003$). Both LEA and SMA were found to be collinear with Hill-Sachs interval, distance-to-dislocation, and craniocaudal Hill-Sachs diameter, suggesting that greater LEA and SMA are reflective of more severe Hill-Sachs lesions. Heat map analysis illustrates the bipolar nature of the anteriorly unstable shoulder, highlighting a relationship between LEA/glenoid bone loss and the likelihood of failure following primary arthroscopic repair (Fig 1B).

DISCUSSION AND CONCLUSION: Caudal extension of a Hill-Sachs lesion below the humeral head equator is highly associated with increased risk for failure following primary arthroscopic Bankart repair for on-track lesions, and is overall representative of larger, more severe Hill-Sachs lesions. Caudal extension on sagittal MRI may prove useful for surgical stratification for procedures such as remplissage or open capsular shift.

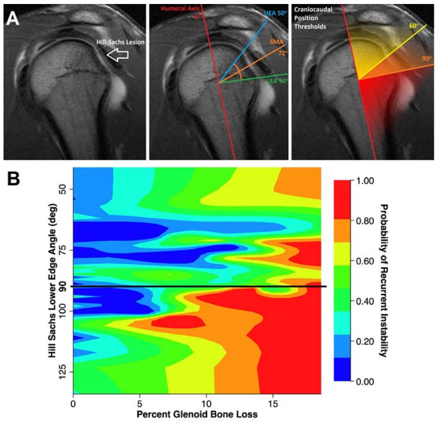

Fig 1. Hill-Sachs craniocaudal position and its contribution to the bipolar lesion of the anteriorly-unstable shoulder. **(A)** Hill-Sachs craniocaudal position; using a sagittal MRI section that captures the maximal diameter of the Hill-Sachs lesion, a humeral axis (red) is drawn through the center of the humeral head. Two lines each bisecting the circle and the upper (blue) and lower (green) limits of the Hill-Sachs lesion are drawn and angles calculated against the humeral axis, forming the Upper Edge Angle (UEA) and the Lower Edge Angle (LEA) of the lesion. The average of these two angles (Orange) comprise the Sagittal Midpoint Angle (SMA). Craniocaudal position thresholds were defined at 60 and 90 degree *a priori*. **(B)** A graphical representation of risk of recurrent instability following primary Bankart repair for on-track lesions, with a critical LEA cutoff of 90 degrees (humeral head equator) labeled by a black line, plot against glenoid bone loss. Higher percent glenoid bone loss plus an LEA below the humeral head equator represented the highest risk for recurrent instability.