Introduction
Excessive bone loss has been identified as the most frequent cause of failed arthroscopic shoulder stabilization. Bipolar glenoid and humeral bone loss have a cumulative impact on shoulder rotation, and these defects may engage in functional positions depending on their size and location, resulting in failure of stabilization.

The glenoid track model, allows engagement to be predicted preoperatively; however, the required glenoid and humeral defect measurements must be performed with 3DCT. This approach may not be feasible in many centers, and thus predicting engagement of bipolar bone defects, in order to plan the appropriate shoulder stabilization procedure, remains a clinical challenge in the setting of glenoid track method.

The purpose of this study was to develop a simplified method for predicting engagement in the pre-operative setting. We evaluated two approaches to predict engagement:
1) CT scanning the shoulder positioned in 90° of abduction and external rotation (ABER), and
2) 2D measurement of the glenoid defect width and a novel Hill-Sachs defect parameter, the intact anterior articular angle (IAAA), using conventional CT multi-plane reformats.

We hypothesize that these two approaches would permit accurate prediction of engagement in comparison to the glenoid track method.

Methods
45 bipolar defect combinations were produced in 12 cadaveric shoulders. A Hill-Sachs defect between 20% and 35% of the articular surface was created for each shoulder through an open posterior approach, using a protocol developed by Betti et al. The shoulders were initially imaged with an intact glenoid, and re-imaged with progressively larger glenoid defects created arthroscopically in increments of 2 mm. Cone beam CT scans were obtained with the shoulder specimens in neutral, and the ABER position.

The ABER scans were assessed for engagement on the axial sequence. The shoulder was classified as engaging on the ABER scan, if a portion of the Hill-Sachs lesion lay anterior to the intact or osteotomized anterior glenoid on any slice (Figure 2).

The Intact Anterior Articular Angle (IAAA) was defined as the angle between the anterior margin of the humeral head articular surface and medial margin of the Hill-Sachs lesion (Figure 3). This was measured on the axial slice equidistant from the inferior and superior articular margin, with the shoulder in neutral. A binary logistic regression was used to predict engagement of bipolar bone defects, in order to plan the appropriate shoulder stabilization procedure, using conventional CT multi-plane reformats.

We hypothesize that these two approaches would permit accurate prediction of engagement in comparison to the glenoid track method.

Results & Discussion
The ABER scan classified engagement correctly in accordance with the glenoid track model in 43 of 45 defect combinations (96%). The sensitivity and specificity for detecting engagement were 92% and 100% respectively, 95% CI [90-96] and [97-100]. Perfect inter-rater agreement was found for assessing the engagement on the ABER scan, Kappa = 1 (p = 0.001).

The IAAA regression model was fitted, with classification accuracy of 87% and an apparent statistic of 0.84, 95% CI [0.83 – 0.96]. Nonparametric bootstrap reampling confirmed model optimism was minimal (0.033), and yielded an adjusted statistic of 0.92 supporting the model’s internal validity and predictive ability. At the 50% probability level, the sensitivity and specificity for predicting engagement were 94% and 81%, 95% CI [89-97] and [74-88]. Inter-rater agreement was good ICC(1,1) = 0.73 (p = 0.002) for measurement of IAAA.

Given that the majority of cases of traumatic anterior shoulder instability can be successfully managed with soft tissue stabilisation alone, it is clinically useful for the IAAA approach to identify the defect ranges that can be tolerated while engagement remains unlikely.

Inter-rater reliability was assessed by two authors independently for agreement of classification on engagement on the ABER scan, and for agreement of IAAA.

Conclusions
Bipolar lesions at risk for engagement can be identified using an ABER CT at 90° of shoulder abduction and 90° of external rotation, by performing 2D measurements of IAAA and glenoid defect width on conventional axial and sagittal oblique CT multi-plane reformats. ABER CT interpretation and IAAA measurements can be performed by specialized software tools and are reproducible between observers. Our study demonstrates these methods could be effective clinical tools and warrant clinical validation.

References

Table 1: Engagement thresholds for IAAA approach (5% level)

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<thead>
<tr>
<th>Clearance Percent</th>
<th>IAAA (°)</th>
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<tbody>
<tr>
<td>0</td>
<td>119</td>
</tr>
<tr>
<td>10</td>
<td>154</td>
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<td>20</td>
<td>140</td>
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Fig. 1 - Glenoid Track: 3DCT measurements for assessing engagement using the glenoid track method.

Fig. 2 - ABER Approach: a) Engaging shoulder, in the setting of a 38% Hill-Sachs defect and an intact glenoid. b) Non-engaging shoulder, in the setting of a 23% Hill-Sachs and a 5 mm glenoid defect. c) ABER results plotted with reference glenoid track engagement threshold, demonstrating excellent agreement.

Fig. 3 - IAAA Approach: a) Measurement of glenoid defect width (AB) using Baudi’s 2D PICO method. b) Measurement of the intact anterior articular angle (IAAA) at the 5%, 10%, and 95% probability levels (P) for engagement. Data points are plotted as classified by the glenoid track model.