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# The glenoid track concept is insufficient to predict Bankart failures: a computed tomography scan study

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**Background:** The glenoid track concept identifies patients with "off-track" (engaging) Hill-Sachs lesions (HSLs) as poor candidates for arthroscopic Bankart repair (ABR) due to the high risk of shoulder instability recurrence.
**Purpose:** To retrospectively calculate the glenoid track index, using preoperative computed tomography (CT) scans, in a cohort of patients with failed ABR. We hypothesized that all patients with a failed ABR would have engaging ("off-track") HSLs on preoperative CT scan.
**Type of Study:** CT scan study.
**Methods:** Preoperative CT scan of 45 patients, seen in our facility for failed ABR, was used to retrospectively calculate the glenoid track index. The risk of recurrence was also calculated for each patient using Instability Severity Index Score (ISI-Score) and Glenoid Track Instability Management Score (GTIMS). There were 37 failed isolated ABRs and 8 associated HS remplissage. The mean *t* age at surgery was 24 years (range, 15-52) and instability recurred at a mean of 29 months postoperative (range, 3-167).
**Results:** Preoperative CT scan imaging identified "off-track" bony lesions in 85% of patients (38/45) and "on-track" lesions in 15% (7/45). No significant differences were noted between the 2 groups (off-track vs. on-track) regarding patient age, hyperlaxity, sports participation, size of HS lesion, or ISI-Score. The mean glenoid bone loss was 15.7% (range, 4-36%) with mean HS width was greater than 20 mm in 66% of CT scans. The preoperative ISI-Score was predictive of failures (>3 points in all patients) with no difference between on-track and off-track patients (6.3 ± 1.7 vs. 6.6 ± 1.7, $P = .453$). By contrast, the GTIMS did not predict failures as there was a significant difference between GTIMS for on-track and off-track patients (2.1 ± 1.3 vs. 6.6 ± 1.7).
**Conclusions:** The glenoid track concept *alone* is insufficient to predict Bankart failures: in the present series of failed ABR, 15% of shoulders had "on-track" (non-engaging) lesions on preoperative CT scan. In patients, with "on-track" bony lesions, the ISI-Score is a useful predictive tool to detect patients at risk of failure, while the GTIMS is not.



Glenoid and humeral bone loss are well-known risk factors for failure of arthroscopic soft tissue shoulder stabilization in patients with recurrent anterior shoulder instability. The presence of severe bone loss (on the glenoid and/or humeral side) clearly compromises the probability of success of isolated soft tissue shoulder stabilization and represents contraindications to arthroscopic Bankart repair (ABR). This observation was further refined with the concept of the "engaging" Hill-Sachs lesion (HSL), as described by Burkhart et al in 2000.[4] Specifically, engagement of the HSL on the anterior glenoid rim was identified as a risk factor for recurrent anterior shoulder instability. Engagement of the HSL usually occurs with the arm in abduction and external rotation (the cocking phase of throwing or "at-risk" position).

In 2007, Yamamoto et al introduced the "glenoid track" concept to describe the dynamic contact area of the glenoid on the humeral head in the setting of bipolar bone loss. In this model, lesions are identified as "off-track" if the contact area of the anterior glenoid rim falls within the HS.[25] Alternatively, in "on-track" lesions, the glenoid track covers the HSL with sufficient bony support and the anterior glenoid rim does not fall within HS. This concept was further developed by Di Giacomo et al in 2014, using 3-dimensional computed tomography (3D CT) to measure and quantify the glenoid

The University ICR Ethical Committee and Institutional Review Board approved this study (no. ICR-2020-SA-12-2). All patients gave their written consent.

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**Table I**
Measurements of glenoid bone loss and humeral head Hill-Sachs lesion.

| | |
|---|---|
| Circle area | The area of best-fit circle. A circle fit to the posterior and inferior edge of the glenoid. |
| Eroded area | Area of the best-fit circle that protrudes beyond the eroded anterior glenoid rim. |
| Erosion edge | The length of the edge of anterior glenoid bone loss |
| Anterior-posterior width | Measurement of anterior to posterior glenoid rim |
| d (width of the glenoid defect) | Measurement performed from anterior glenoid rim to the edge of best fit circle. This measurement describes the maximum width of anterior glenoid bone loss. |
| D | Diameter of best fit circle |
| Humeral best-fit circle area | Area of the circle fitted to the edge of humeral articular surface. |
| HSL maximum width | Maximal width of the Hill-Sachs lesion in transverse plane. |
| HSL maximum depth | Maximal depth of the Hill-Sachs lesion in transverse plane. |

*HSL*, Hill-Sachs lesion.

track.[7] Subsequently, multiple studies have shown that this concept and measurement method are useful tools for surgical decision-making.[11]

The glenoid track is a biomechanical concept that incorporates both glenoid and humeral head bone loss geometry to predict the risk of humeral head engagement and anterior shoulder instability.[25] According to this concept, patients with "on-track" (non-engaging) glenohumeral bony lesions evaluated on preoperative CT scan are appropriate candidates for ABR, with a low risk of failure.[12] Conversely, patients with "off-track" engaging HSLs are predicted to have a high risk of failure of soft tissue stabilization (ABR).[7]

The purpose of the present CT scan study was to retrospectively calculate the glenoid track index in a cohort of patients with failed Bankart repairs. We hypothesized that all patients with a failed ABR would have engaging ("off-track") HSLs on preoperative CT scan.

## Methods

We performed a CT scan study to retrospectively calculate the glenoid track in a cohort of patients with failed ABR. We excluded patients who underwent concomitant shoulder procedures such as fracture reduction and internal fixation, superior labrum from anterior to posterior tear reinsertion, or rotator cuff repair. Over a 10-year period, 45 patients treated with prior ABR were subsequently seen in our facility for recurrence of anterior instability with their preoperative CT scan images. Thirty-seven patients underwent isolated ABR and 8 had associated HS remplissage (HSR). Preoperative CT scan imaging was available for all patients and was used to retrospectively calculate the glenoid track and the presence of on-track or off-track HSLs. The mean patient age was 25.5 years (range, 20-42) at the time of the index surgical procedure. Instability recurred at a mean time of 29 months postoperatively (range, 3-167).

Pertinent patient demographic information was collected and analyzed including: number of dislocations or subluxations after failed Bankart, nature of recurrence event (traumatic or atraumatic), presence of hyperlaxity, sports participation (type, competitive level, and postoperative return), and subjective shoulder value. Based on preoperative medical history, composite instability recurrence risk was also calculated for each patient per Instability Severity Index Score (ISI-Score)[1] and Glenoid Track Instability Management Score (GTIMS), which integrates ISI-Score with on-track/off-track data.[8] Both scales were used to identify patients with a high risk of instability recurrence after ABR for whom the Latarjet procedure would be indicated.

Preoperative CT scans were analyzed with Horos Project v4.0.0 (Horos Project, Brooklyn, NY, USA) software by a single shoulder fellowship-trained surgeon per described methods. Glenoids were assessed with the use of two-dimensional CT (2D-CT) with multiplanar reconstruction, with evaluation based on 6 parameters: circle area,[17,23] eroded area,[17,23] erosion edge length,[9,10] anterior-posterior width,[9,10] width of anterior glenoid bone loss (d), and diameter of best fit circle (D).[14] The percentage of anterior glenoid bone loss was assessed using both the "Pico" method (as described by Baudi et al[2]) and the Sugaya et al method.[24] All measurements are described in Table 1 and presented in Figures 1 and 2.

$$Pico = \frac{area\ of\ defect\ (B)}{area\ of\ best\ fit\ circle\ (A)}$$

$$Sugaya\ et\ al. = \frac{bone\ defect\ width\ (d)}{diameter\ of\ best\ fit\ circle\ (D)}$$

HSLs were quantified based on 3 measurements: humeral best fit circle area,[5,19] HSL maximum width, and HSL maximum depth[13] using 2D-CT multiplanar reconstruction (Table 1 and Fig. 3).[21]

"On-track/off-track" evaluation was performed according to Di Giacomo et al with the use of 3D-CT.[7]

As there were no CT scans of contralateral (intact) glenoids, glenoid track width of affected glenoid (GTaf) was calculated as 83% of diameter of best fit circle (D)[18] minus the width of anterior glenoid bone loss (d):

$$GTaf = GTint - d$$

$$GTaf = 83\%*D - d$$

GTaf – glenoid track of affected glenoid; GTint – glenoid track of intact glenoid; D – diameter of best fit circle; d – width of anterior glenoid bone loss

On-track/off-track assessment was performed on the posterior view of the 3D humeral head. Medial margin of rotator cuff attachment (R) was determined and the line of medial margin of the glenoid track of affected glenoid (G1) was defined using the GTaf value (Fig. 4).

If the medial margin line of GTaf lies within the area of HSL, bone loss categorized as "off-track." Alternatively, if glenoid track covers HSL, bone loss categorized as "on-track."

Numeric variables are reported as mean (±standard deviation) and discrete variables as absolute and relative frequencies. Normality was assessed with the Shapiro-Wilk test. On-track and off-track groups were compared using the Student *t*-test or Mann-Whitney U test for numeric variables and Fisher's exact test for discrete variables. All tests were two-sided, with alpha set to 5%. Statistical analyses were performed using EasyMedStat (v3.5; EasyMedStat, Levallois-Perret, France).

## Results

### Computed tomography scan results

On preoperative CT scan imaging (pre-ABR), bony lesions were off-track (engaging) in 85% of patients (38/45), and on-track with non-engaging HSLs in 15% (7/45).

Average glenoid bone loss, assessed with both Pico and Sugaya et al methods, was greater in the off-track group (16.5% and 18.5%,

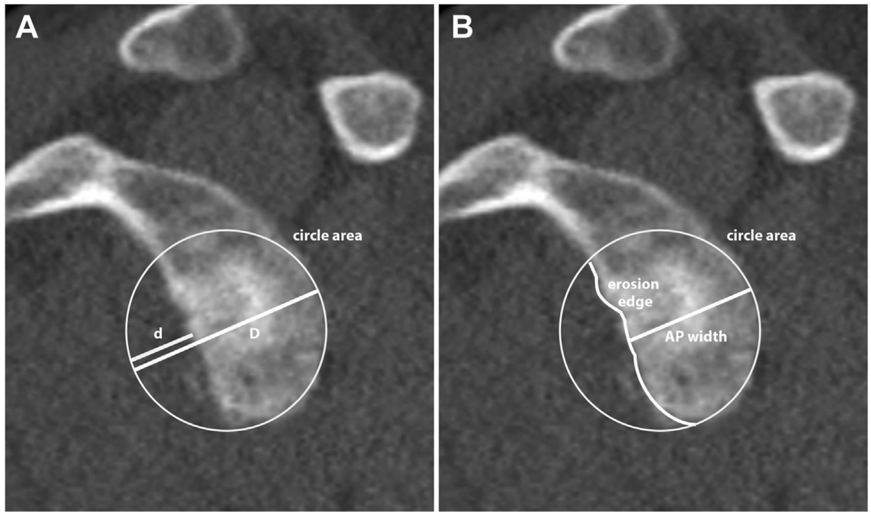


**Figure 1** Glenoid measurements: (**A**) Circle area, d-width of anterior glenoid bone loss; D-diameter of best fit circle; (**B**) Erosion edge, anterior-posterior width.

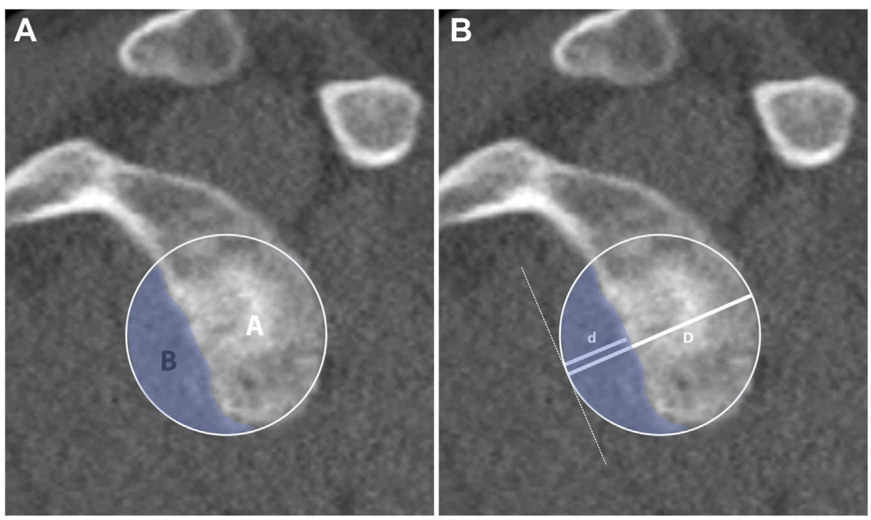


**Figure 2** Percentage evaluation of anterior glenoid bone loss with Pico method (**A**) and Sugaya et al method (**B**).

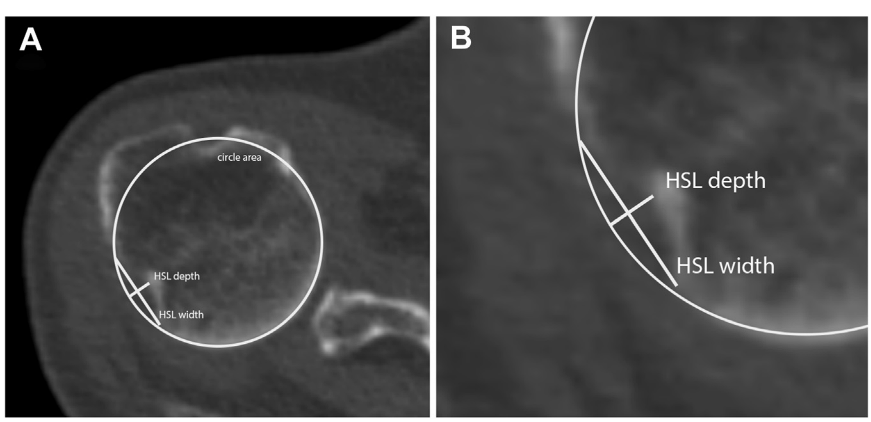


**Figure 3** Humeral head (**A**) and Hill-Sachs (**B**) measurements. *HSL*, Hill-Sachs lesion.

respectively) compared to the on-track group (10.3% and 10.7%, respectively) ($P = .049$, $P = .039$, respectively). There were no significant differences between the groups in other glenoid/humeral bone loss measurements (Table 2.)

*Clinical results*

No significant differences were observed between the 2 groups with regard to the presence of hyperlaxity, type of recurrence

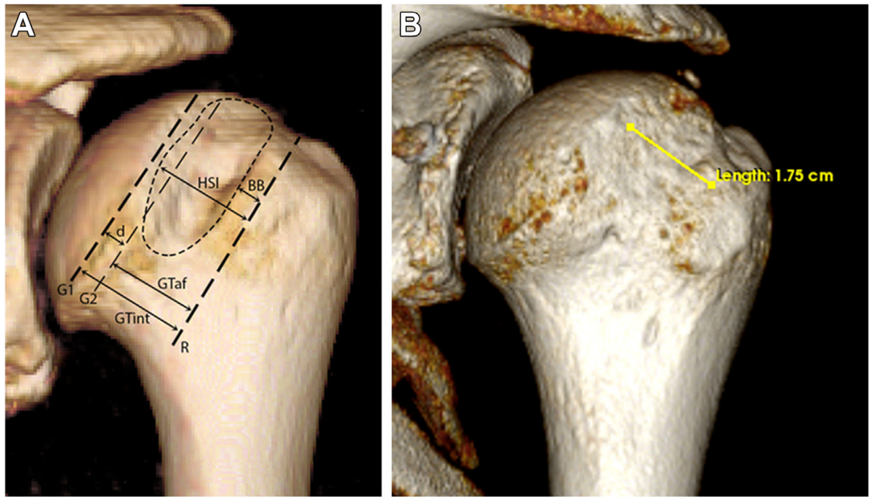


**Figure 4** On-track/off-track assessment; (**A**) Glenoid track width on 3D model (**B**); G2, medial margin of glenoid track of intact glenoid; G1, medial margin of glenoid track of affected glenoid; GTint, glenoid track width of intact glenoid; GTaf, glenoid track width of affected glenoid; R, medial margin of rotator cuff attachment; d, anterior glenoid bone loss width; *HSI*, Hill-Sachs Interval; *BB*, bone bridge.

**Table II**
Glenoid and humeral bone loss measurements in on-track and off-track groups.

| | On-track group | | | | Off-track group | | | | *P* |
|---|---|---|---|---|---|---|---|---|---|
| | Av. | SD | Min. | Max. | Av. | SD | Min. | Max. | |
| Pico method (%) | 10.33 | 3.15 | 5.00 | 15.00 | 16.50 | 7.73 | 4.00 | 36.00 | **.049** |
| Sugaya et al method (%) | 10.65 | 5.157 | 1.56 | 18.7 | 18.53 | 9.09 | 3.67 | 42.2 | **.039** |
| Circle area ($cm^2$) | 6.72 | 1.03 | 5.91 | 8.45 | 6.65 | 1.68 | 3.66 | 10.63 | .086 |
| Eroded area ($mm^2$) | 71.30 | 25.88 | 31.61 | 102.62 | 111.03 | 58.98 | 24.77 | 269.02 | .075 |
| Erosion edge (cm) | 2.48 | 0.63 | 1.587 | 3.35 | 2.51 | 0.57 | 1.54 | 4.02 | .198 |
| Anterior-posterior width (cm) | 2.65 | 0.23 | 2.23 | 2.89 | 2.36 | 0.37 | 1.63 | 3.31 | .098 |
| d (width of the glenoid defect) (cm) | 1.13 | 0.383 | 0.81 | 1.96 | 0.86 | 0.234 | 0.4 | 1.53 | .341 |
| D (cm) | 2.97 | 0.22 | 2.74 | 3.28 | 2.89 | 0.38 | 2.16 | 3.68 | .243 |
| Humeral best fit circle area ($cm^2$) | 16.89 | 2.676 | 12.16 | 20.69 | 17.97 | 3.81 | 12.03 | 27.06 | .082 |
| HSL maximum width (cm) | 1.98 | 0.85 | 0.99 | 3.76 | 2.32 | 0.41 | 1.46 | 3.23 | .072 |
| HSL maximum depth (cm) | 0.56 | 0.19 | 0.39 | 0.98 | 0.55 | 0.19 | 0.21 | 1.04 | .777 |

*HSL*, Hill-Sachs lesion; *SD*, standard deviation; *Av.*, average; *Min.*, minimal; *Max.*, maximal.
Bold indicates $P < .05$.

**Table III**
Risk factors for recurrence after Bankart repair in on-track and off-track groups expressed as: average ± standard deviation (range).

| | "On-track" group | "Off-track" group | *P* |
|---|---|---|---|
| Age | 26.2 ± 8.1 | 30.3 ± 7.7 | .251 |
| Competition level of sport activity (%) | 17% | 39% | .373 |
| Contact/overhead sport activity (%) | 83% | 53% | .373 |
| Hyperlaxity (%) | 100% | 58% | .072 |
| Traumatic recurrence (%) | 83% | 71% | 1.000 |
| ISI-Score | 6.3 ± 1.7 (range, 4-10) | 6.6 ± 1.7 (range, 4-10) | .453 |
| ISI-Score > 3 (%) | 100% | 100% | 1.000 |
| GTIM score | 2.1 ± 1.3 (range, 1-4) | 6.6 ± 1.7 (range, 4-10) | **.0001** |
| GTIM score > 3 (%) | 14% | 100% | **.0001** |
| ABR + HSR | 28% | 16% | .082 |

*ABR*, arthroscopic Bankart repair; *HSR*, Hill-Sachs remplissage; *ISI-Score*, Instability Severity Index Score; *GTIM*, Glenoid Track Instability Management.
Bold indicates $P < .05$.

(traumatic vs. atraumatic), sports participation (level or type), or subjective shoulder value.

All patients exhibited an ISI-Score greater or equal to 4. Mean ISI-Score was similarly high in both groups, 6.28 for on-track and 6.63 for off-track ($P = .45$).

In all off-track patients, GTIMS values were greater or equal to 4 (mean = 6.63; range, 4-10) but in the on-track group only one patient reached the 4-point threshold (mean = 2.1; range, 1-4). This difference between GTIMS for on-track and off-track patients was statistically significant ($P = .0001$).

All patients with an on-track lesion had additional risk factors for recurrence after Bankart repair: ISI-Score ≥ 3 (n = 7, 100%), hyperlaxity (n = 7, 100%), glenoid bone loss > 10% (n = 7, 100%), contact/overhead sport (n = 6, 83%), or age ≤ 20 years (n = 4, 57%) (Table 3).

No significant differences were observed between the groups with regard to HSR procedure (ABR + HSR) ("on-track" group: n = 2, 28%. vs. "off-track" group: n = 6, 16%; $P = .082$) (Table 3).

There were no significant differences in ISI-Score and GTIMS values between patients who underwent isolated ABR vs. ABR with HSR (ABR + HSR) in both groups ("on-track" group: ISI-Score 6.3 vs. 5.5, $P = .382$; GTIMS 2.1 vs. 1.5, $P = .065$; "off-track" group: ISI-Score 6.6 vs. 6.8, $P = .373$; GTIMS 6.6 vs. 6.8, $P = .985$) (Table 4).

## Discussion

According to the glenoid track concept, patients with non-engaging ("on-track") glenohumeral bony lesions evaluated on preoperative CT scan are appropriate candidates for ABR, with a low risk of failure.[12] Our hypothesis is not confirmed: not all patients

**Table IV**
Risk factors for recurrence in on-track and off-track groups after arthroscopic Bankart repair with (ABR + HSR) or without (ABR) Hill-Sachs remplissage.

| | "On-track" group | | | "Off-track" group | | |
|---|---|---|---|---|---|---|
| | ABR | ABR + HSR | *P* | ABR | ABR + HSR | *P* |
| ISI-Score | 6.3 ± 1.7 (range, 4-10) | 5.5 ± 0.7 (range, 5-6) | .382 | 6.6 ± 1.7 (range, 4-10) | 6.8 ± 2.3 (range, 4-10) | .373 |
| ISI-Score > 3 (%) | 100% | 100% | 1.000 | 100% | 100% | 1.000 |
| GTIM score | 2.1 ± 1.3 (range, 1-4) | 1.5 ± 0.7 (range, 1-2) | .065 | 6.6 ± 1.7 (range, 4-10) | 6.8 ± 2.3 (range, 4-10) | .985 |
| GTIM score > 3 (%) | 14% | 0% | .071 | 100% | 100% | 1.000 |

*ABR*, arthroscopic Bankart repair; *HSR*, Hill-Sachs remplissage; *ISI-Score*, Instability Severity Index Score; *GTIM*, Glenoid Track Instability Management.

with a failed ABR would have engaging ("off-track") HSLs on preoperative CT scan.

The main finding of the present study is that the glenoid track concept *alone* is useful but not sufficient to predict Bankart failures. In theory, based on the glenoid track concept, a soft tissue procedure (ie, Bankart repair) should be successful to stabilize the shoulders in patients with "on-track" (non-engaging) bony lesions. However, retrospectively reviewing the preoperative CT scans of 45 patients with failed ABR, we found that 15% (7/45) had preoperative "on-track" (non-engaging) HSLs.

Our data confirm other prior reports which have also shown that the glenoid track concept, which is a *biomechanical concept*, fails to predict *clinical* recurrence of shoulder instability after ABR.[16,20] Locher et al showed that 6% of patients (5/88) with on-track lesions had instability recurrence after ABR[16]; moreover, only 4 out of 9 revised patients (44%) had an off-track HSL. Similarly, Shaha et al noted a recurrence risk of 8% for on-track patients treated with ABR.[20] Li et al demonstrate the importance not only of on-track/off-track assessment but also of considering the distance-to-dislocation between the medial margin of the HSL and the medial edge of the glenoid track. The study indicates that a "near-track" lesion with small distance-to-dislocation (<8mm) had strong predictive power of ABR failure. It shows additional risk factor of instability recurrence in cases with small and "almost off-track" bipolar bone loss.[15]

The fact that the glenoid track concept alone is insufficient to predict instability recurrence following ABR, particularly in those patients with less glenoid bone loss, is not surprising.

Multiple factors may explain the limitations of the "on-track/off-track" concept to predict Bankart failures, with or without remplissage. Firstly, the 3D measurements are made within the constraints of a 2D spatial projection. Two-dimensional evaluation has been shown to be less reliable compared to true 3D-CT measurement for both anterior glenoid bone loss[14] and HSL characterization.[21] The on-track/off-track evaluation method was not performed in 3D space but rather on a 2D view of a reconstructed model (quasi-3D-CT).[22] Secondly, the static (non-dynamic) nature of the evaluation of the glenoid path on the humeral head makes it difficult to precisely predict the multitude of forces acting across the glenohumeral joint, as well as the influence of soft tissue tension on joint *dynamic* stability. Thirdly, the binary nature of the concept (on/off) may not consider edge cases with "almost off-track" lesions. Fifteen percent of patients after failed ABR had preoperative "on-track" lesion with high risk of recurrence (ISI-Score >3). Fourthly, the glenoid track assessment does not account for soft tissue elongation, which occurs with repeated dislocations and subluxations.[3,6] Finally, the glenoid track model does not account for patient-specific clinical parameters such as age, sports participation, and hyperlaxity.[1]

Another key finding of the present study is that the ISI-Score is a useful and complementary predictive tool for detecting "on-track" patients at risk of failure with ABR. Our data show that patients with "on-track" (non-engaging) bony lesions and an ISI-Score >3 are at risk for instability recurrence and should be contraindicated for a Bankart repair. Our findings point to the importance of integrating additional clinical risk factors into a composite understanding of the recurrence risk of anterior shoulder instability following ABR. These risk factors are well-known and include patient's age (≤20 years), practice of contact/collision sport, participation in competitive sports, and shoulder hyperlaxity. These factors are all incorporated into the ISI-Score, a 10-point scoring tool developed to assist surgeons in surgical decision-making regarding the optimal treatment for recurrent anterior shoulder instability. It has been shown that an ISI-Score greater than 3 points represents a contraindication to arthroscopic shoulder stabilization, due to the high risk of failure. This is confirmed in our study where both on-track and off-track patients who failed ABR exhibited a preoperative ISI-Score >3 points. Based on this high preoperative ISI-Score, all patients in our series, including the 7 with on-track (non-engaging) HSLs, should have undergone a bone augmentation procedure (Latarjet or glenoid bone graft) rather than ABR.

Conversely, we found that the GTIMS was not useful for detecting patients at risk of failure with ABR. Our data show that the GTIMS does not enhance patient selection: based on the GTIM, 6 out of 7 patients of our series with non-engaging HSLs who had instability recurrence after ABR were supposed to have a low risk of failure with a Bankart repair. Only one patient out of 7 with "on-track" lesions reached 4 points and should have been indicated for a Latarjet procedure using this scoring system. The use of GTIMS is supposed to decrease the rate of Latarjet recommendations in comparison to ISI-Score. By doing this, the GTIMS encourages surgeons to perform a Bankart repair, while the ISI-Score shows that this procedure is at risk of failure, despite "on track" lesions.

### *Study limitations*

This CT scan study is limited by its retrospective nature and the fact that it lacked a control group. We acknowledge that analyzing a control group could complement the study; however, it is not strictly necessary to prove our hypothesis. Additionally, multiple surgeons performed the index arthroscopic Bankart procedures while a single observer performed the retrospective CT scan measurements. The number of patients in the on-track group was also small, which could decrease the power of our risk factor analysis. Our CT scan study is the first to assess the risk of instability recurrence with on-track lesions in a cohort of patients after ABR procedures, with and without HSR. Further prospective and controlled trials will be needed to confirm our findings and develop best practices for surgical decision-making.

## Conclusion

The glenoid track concept *alone* is insufficient to predict Bankart failures: in the present series of failed ABR, 15% of shoulders had "on-track" (non-engaging) lesions on preoperative CT scan. In patients with "on track" bony lesions, the ISI-Score is a useful and complementary tool to predictive failures of ABR. The results of the present study should encourage surgeons using the glenoid track concept, but in association with the ISI-Score to detect patients at risk for failure with ABR. Patients with "on-track" (non-engaging) bony lesions who have an ISI-score >3 points are at risk for failure and should be contraindicated for ABR (with or without HSR).

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