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Surgical decision making based on the on-track/off-track concept for anterior shoulder instability: a case-control study

Taku Hatta, MD, PhD, Nobuyuki Yamamoto, MD, PhD, Kiyotsugu Shinagawa, MD, Jun Kawakami, MD, PhD, Eiji Itoi, MD, PhD *

Department of Orthopaedic Surgery, Tohoku University School of Medicine, Sendai, Japan

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Background: The purpose of this study was to assess the clinical outcomes of patients with anterior shoulder instability who underwent surgical treatment according to the on-track/off-track concept.
Methods: We retrospectively analyzed patients who underwent surgical treatment according to the glenoid track concept with a minimum of 2 years' follow-up. By use of preoperative 3-dimensional computed tomography images, surgical options were selected: arthroscopic Bankart repair (ABR) for patients with on-track lesions and the Latarjet procedure or ABR with the remplissage procedure for patients with off-track lesions. The recurrence rate was assessed at 2-year follow-up after surgery.
Results: Among 92 patients enrolled in this study, 81 had on-track lesions and underwent ABR. Of the 11 patients with off-track lesions, 1 underwent ABR with the remplissage procedure and 10 underwent the Latarjet procedure. Recurrences occurred in 4 patients treated by ABR (5%), whereas no recurrences were observed in off-track cases treated by the remplissage or Latarjet procedure.
Conclusion: Clinical application of the on-track/off-track concept for determining surgical options in preoperative planning seems to be useful to prevent recurrent instability after surgery.

Anterior shoulder dislocation commonly results in recurrent shoulder instability, especially in a young population. In the literature, recurrent instability occurred in 50%-96% of patients younger than 20 years who had primary dislocation and 40%-74% of those aged 20-40 years; this may require surgical treatment because of limited shoulder function and decreased quality of life.[22,24,26]

Various surgical techniques have been advocated including open or arthroscopic stabilization of detached Bankart lesions, augmentation with the remplissage procedure, or bone grafting for the glenoid defect such as the Latarjet procedure. Of these options, arthroscopic Bankart repair (ABR) with suture anchor fixation has recently been gaining acceptance as the primary option.[12,13,20] On the other hand, some patients such as young collision or contact athletes have been recognized to have an increased risk of recurrent instability after ABR alone.[5,17] In addition, the extent of the bony defect both in the anterior glenoid rim and in the humeral head has recently been focused on regarding stability or instability in shoulders treated by ABR.[7,27] A large Hill-Sachs lesion may have a potential risk to engage with the anterior rim of the glenoid, which causes instability. Thus, the glenoid track concept has been developed to stratify the anatomic interaction between the Hill-Sachs lesion and glenoid bone loss to determine the treatment of choice for individuals with various defect patterns.[29] If the Hill-Sachs lesion occurs within the glenoid track, there seems to be no risk of engagement (called an "on-track" lesion); therefore, soft-tissue stabilization such as ABR could be selected. If the Hill-Sachs lesion extends medially beyond the medial border of the glenoid track, it may have a risk of postoperative instability after ABR (called an "off-track" lesion); therefore, treatment of the bony defect needs to be considered as well as ABR. Several studies have followed up patients treated by ABR alone and analyzed the outcomes based on the Hill-Sachs lesion being on track or off track.[14,25] These studies showed that patients with off-track lesions had a significantly higher rate of recurrence after ABR alone. However, there have been no studies to demonstrate the clinical outcomes after treatment based on the on-track/off-track concept. In advance of our first study describing the glenoid track concept in 2007, we have adopted this concept clinically and measured the glenoid

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* Corresponding author: Eiji Itoi, MD, PhD, Department of Orthopaedic Surgery, Tohoku University School of Medicine, 1-1, Seiryo-machi, Aoba-ku, Sendai, 980-8574, Japan.
E-mail address: itoi-eiji@med.tohoku.ac.jp (E. Itoi).

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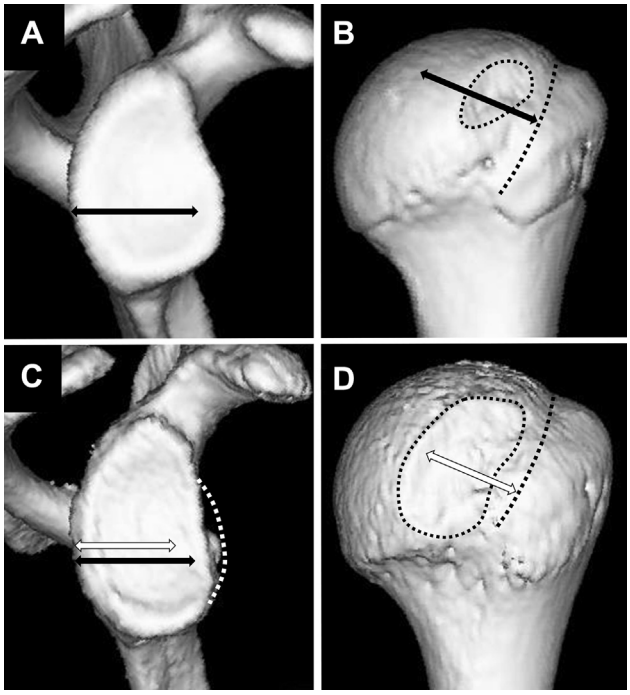

Figure 1 Computed tomography images of patients with on-track (**A, B**) and off-track (**C, D**) Hill-Sachs lesions. The *black arrows* represent the glenoid track width in patients without glenoid defects, which corresponds to 83% of the transverse glenoid width. For patients with glenoid defects, the glenoid track width (*white arrows*) is obtained by subtracting the glenoid defect width from the value for the *black arrows*.

track for surgical decision making since 2006.[29] Our hypothesis was that clinical application of the on-track/off-track concept could improve the outcomes of patients who underwent surgical treatment of anterior shoulder instability. Therefore, the purpose of this study was to assess the clinical outcomes of patients with anterior shoulder instability who had been surgically treated based on this concept.

Materials and methods

We retrospectively analyzed a database including all patients who underwent surgery for recurrent shoulder instability in our institute between 2006 and 2015. The inclusion criteria were patients surgically treated for recurrent shoulder instability, in whom the surgical procedure was determined based on the glenoid track concept described herein with a minimum of 2 years' follow-up or until recurrent instability occurred postoperatively. Patients who had epilepsy or multidirectional instability and those with any previous surgery on either side of the shoulder were excluded.

Strategy of surgical treatment

We assessed the bony lesions in all patients using 3-dimensional computed tomography images of bilateral shoulders taken preoperatively. The surgical method for each patient was selected according to the glenoid track measurement, which stratified Hill-Sachs lesions into on-track or off-track lesions. In detail, the transverse glenoid widths of bilateral shoulders (involved [W_i] and uninvolved [W_u]) were measured, and the extent of the bony defect of the glenoid in the involved shoulder was obtained as $W_u - W_i$. As the distance between the medial margin of the glenoid track and the medial margin of the rotator cuff footprint was equivalent to 83% of the intact glenoid width,[19,29] the distance, in millimeters, was determined as the glenoid track width for each individual as follows: $W_u \times 0.83 - (W_u - W_i)$.

As described in previous studies,[7,11] patients with on-track lesions were all treated by ABR alone whereas patients with off-track lesions were treated either by ABR with remplissage or by the Latarjet procedure. On the basis of a biomechanical study,[28] those with a glenoid defect, defined as $(W_u - W_i)/W_u$, greater than 25% were treated by the Latarjet procedure and those with a glenoid defect of less than 25% were treated by either the Latarjet procedure or ABR with remplissage at the surgeons' discretion (Fig. 1).

Surgical techniques

All surgical procedures were performed by 2 surgeons (E.I. and N.Y.) with high expertise in treating shoulder instability and more than 20 years of practice. Patients were in the beach-chair position under general anesthesia. ABR was performed with posterior, anterosuperior, and anterior portals. The anterior capsule and labrum were mobilized, and 3 or 4 anchors were placed along the glenoid rim. For cases with the remplissage procedure, an additional posterior portal was created to place 2 suture anchors in the Hill-Sachs lesion. Sutures were penetrated through the infraspinatus tendon before ABR and tied to attach the tendon onto the Hill-Sachs lesion after completion of ABR. The Latarjet procedure was performed through a deltopectoral approach. After splitting of the subscapularis muscle and capsule, the coracoid bone was secured on the anterior neck of the glenoid using 2 cannulated screws.

Assessment

Recurrent dislocation or instability was assessed during a 2-year follow-up after surgery by 1 of 3 surgeons (E.I., T.H., or N.Y.). If a patient had a recurrence, when and how the recurrence had occurred were recorded.

Statistical analyses

Statistical analyses were performed using JMP Pro software (version 10.0; SAS Institute, Cary, NC, USA). The Wilcoxon rank sum test was used to evaluate the significance of differences between patients with on-track lesions and off-track lesions for continuous variables, and the Pearson χ^2 test or Fisher exact test was used to evaluate categorical variables. Statistical significance was set at $P < .05$.

Results

The database included 94 patients who underwent surgical treatment with 2-year follow-up. Of these patients, 2 did not meet the inclusion criteria (1 had epilepsy and 1 had multidirectional instability); therefore, we analyzed the remaining 92 patients who had been treated surgically based on the on-track/off-track concept. These included 66 male and 26 female patients. All patients had documented traumatic, recurrent anterior dislocation of the shoulder before the surgical procedure. The mean age at surgery was 29 years (range, 17-66 years). On-track lesions were diagnosed in 81 patients, whereas off-track lesions were diagnosed in 11 patients. The mean values of the width of the glenoid track from the rotator cuff insertion on the humerus and the glenoid defect ($W_u - W_i$) were calculated to be 20.2 mm and 9.0 mm, respectively, for patients with on-track lesions and 17.7 mm and 18.5 mm, respectively, for patients with off-track lesions ($P = .01$ and $P = .01$, respectively) (Table I).

Table I
Patients' demographic characteristics

	On-track lesions	Off-track lesions	*P* value
No. of patients	81	11	
Male/female, n	57/24	8/3	.87
Age at surgery, mean (range), yr	27 (17-66)	36 (17-55)	.07
Width of glenoid track, mean (SD), mm	20.2 (2.8)	17.7 (2.6)	.01*
Glenoid defect (involved − uninvolved), mean (SD), mm	9.0 (6.5)	18.5 (9.8)	.01*

SD, standard deviation.
* Statistically significant.

Table II
Treatment options and postoperative recurrence

	On-track lesions (n = 81)	Off-track lesions (n = 11)
Surgical options, n		
ABR	81	
ABR with remplissage procedure		1
Latarjet procedure		10
Recurrence, n	4	0

ABR, arthroscopic Bankart repair.

All patients with on-track lesions underwent ABR. Among the 11 patients with off-track lesions, 1 patient with a mild glenoid defect of 1.7 mm underwent ABR with the remplissage procedure and the remaining 10 patients underwent the Latarjet procedure. During the 24-month follow-up period, 4 patients treated by ABR had recurrences (5%). The recurrences occurred between 11 and 22 months after surgery. All 4 patients underwent recurrences during sports activities (with a fall on the ground in 2 patients and a collision in 2 patients). No off-track lesions resulted in recurrence (Table II).

Discussion

This study demonstrated the clinical outcomes of patients treated by surgery based on the on-track/off-track concept. In this study, the overall recurrence rate was 4.3% at 24-month follow-up. Reported recurrence rates after ABR ranged from 4% to 29%.[2,6,16] Adding remplissage to ABR could be a useful option to prevent instability due to large Hill-Sachs lesions. The recurrence rate after ABR with remplissage has been reported to be less than 5%,[8,27] whereas the decrease in the range of shoulder motion needs to be taken into consideration.[15,18] A bone block procedure such as the Latarjet procedure is another option to decrease the recurrence rate, with a reported rate of 2.7% over a 5-year follow-up period for the Latarjet procedure.[23] Despite the satisfactory long-term outcomes, a potential risk to cause osteoarthritic changes is likely to occur after bone block procedures.[10]

The concept of the glenoid track was developed to evaluate bony lesions on the glenoid and humeral head together.[29] The initial study of the glenoid track was performed in cadaveric shoulders, and the following magnetic resonance imaging study of live shoulders showed that the glenoid track could be equivalent to approximately 83% of the width of the intact glenoid from the rotator cuff insertion.[19] Di Giacomo et al[7] were the first authors to coin the terms “on-track Hill-Sachs lesion” and “off-track Hill-Sachs lesion.” Biomechanical studies using the glenoid track model have supported its clinical role to determine the presence of either an on-track or off-track Hill-Sachs lesion for the assessment of the presence or absence of instability after repair of a detached capsulolabral lesion.[3,9]

Recently, clinical studies have verified the clinical importance of identifying the off-track lesion in determining the indication for ABR. Locher et al[14] retrospectively analyzed 100 patients who were treated by ABR. They found that revision surgery was required in 5 of 88 patients (6%) with on-track lesions versus 4 patients (33%) with off-track lesions. The odds ratio of off-track lesions compared with on-track lesions was 8.3 for recurrence after ABR. Shaha et al[25] evaluated the glenoid track for 57 patients who underwent ABR. After a mean of 4 years' follow-up, 4 of 49 patients with on-track lesions versus 6 of 8 patients with off-track lesions had recurrent instability. Shaha et al also assessed the positive predictive value for recurrence and found that the positive predictive value of using an off-track lesion to predict postsurgical failure was significantly higher than the value using a glenoid bone defect of greater than 20% (75% vs 44%). These studies strongly support that the off-track concept be used before surgery to estimate the risk of recurrence after ABR. With the recognition of the risk, it was notable that our study had no cases of recurrence in patients with off-track lesions by selecting augmentation with the remplissage procedure or glenoid bone grafting on preoperative assessment. Our results likely support clinical application of the glenoid track concept to determine the surgical options for patients during preoperative planning.

Regarding postoperative recurrence, the most common cause remains controversial. In addition to the suggestion that bone loss could be the predominant reason for failure, a systematic review indicated recurrent traumatic episodes to be the primary reason for failed ABR.[1] In contrast, a subsequent systematic review investigated outcomes after a bone grafting technique and found that collision athletes had no increased risk of recurrence compared with noncollision athletes.[21] In our study, all recurrent cases underwent ABR and had traumatic episodes, such as a collision or fall during sports activities. Therefore, surgical options for high-risk patients should be carefully considered.

There are several limitations in our study. First, this was a retrospective study. Various biases could not be excluded. In particular, we should note that this study included nonblinded assessments at 2-year follow-up. Second, this study did not focus on the patients' quality of life, especially their sports and activity levels, because we could not obtain sufficient data for other measurements from all patients. In addition, we analyzed the recurrence rate during 2-year follow-up. Although a number of studies have described clinical outcomes at 2 years after surgery, further data with a longer follow-up would be useful to clarify the validity of the treatment based on the on-track/off-track concept. Finally, in this study, we did not analyze additional risk factors for recurrence, such as patient age, sports level, and presence of hyperlaxity.[4] Further studies would be desirable to compare the relationship between these factors and the on-track/off-track concept.

Conclusion

The overall recurrence rate in patients who were treated with surgical options based on the on-track/off-track concept was 4.3% at 2-year follow-up. These results seem to indicate the validity of the on-track/off-track concept in surgical decision making to prevent recurrent instability after surgery.

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