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The Addition of Remplissage to Arthroscopic Bankart Repair and Effect on Recurrent Instability in Shoulders With Critical Humeral Bone Loss

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Background: Recent literature has shown that inferior Hill-Sachs extension for on-track shoulders is predictive of recurrent instability after arthroscopic Bankart repair alone. Specifically, there is a high risk for recurrent instability when the lesion extends below the humeral equator on sagittal magnetic resonance imaging. This worrisome inferior extension has been termed ''critical humeral bone loss (CHBL).'' Remplissage has yet to be explored as a potential useful augmentation in patients with CHBL.

Hypothesis: The addition of remplissage would decrease recurrence rates for Hill-Sachs lesions with inferior extension or CHBL compared with arthroscopic Bankart repair alone in patients with on-track Hill-Sachs lesions.

Study Design: Case series; Level of evidence, 4

Methods: Retrospective analysis was performed on the records of patients who underwent primary arthroscopic Bankart repair with or without the addition of remplissage from 2007 to 2021. Off-track shoulders, revision stabilization, glenoid bone loss (GBL) >20%, and those with follow-up <2 years or incomplete medical data were excluded. The primary outcome was recurrent instability, defined as either postoperative dislocation or subluxation. The Hill-Sachs position was measured relative to the humeral axis on sagittal magnetic resonance imaging as previously described. Univariate and multivariate logistic regression analyses were implemented to determine the protective effect of remplissage.

Results: A total of 219 patients were included for analysis with a mean age of 21.1 years (range, 12.9-40.5 years) and mean follow-up of 7.0 years (range, 2-14.4 years); 44 patients (20%) underwent remplissage in addition to arthroscopic Bankart. In multivariate analysis, remplissage significantly reduced the risk of recurrent instability (OR, 0.06; *P* = .002) and CHBL was a significant predictor of recurrent instability (OR, 3.0; *P* = .029) while adjusting for age, multiple preoperative dislocations, contact athlete status, and percent GBL. When stratified by CHBL, remplissage remained protective (OR, 0.013; *P* = .007) against recurrent instability.

Conclusion: The addition of a remplissage for CHBL in patients with subcritical GBL and on-track Hill-Sachs lesions reduces the risk of recurrent instability in patients undergoing arthroscopic Bankart repair.

Keywords: shoulder; instability; remplissage; Hill-Sachs; Bankart; glenoid track

Anterior glenohumeral instability events are common injuries in young and athletic patients, including those participating in contact or collision sports (such as football and hockey) and members of the active military population.[1,16,28,32] These injuries are of particular concern because of the high prevalence among athletes, substantial time missed from competition during the postoperative rehabilitation process, and high risk of recurrence associated with continued play.[10] Despite advancement in surgical techniques and implementation of specific criteria-based return-to-play protocols, recurrent instability rates after primary arthroscopic Bankart repair remain high, with rates of up to 30% reported.[14] A growing amount of literature has identified several risk factors for failure of primary arthroscopic Bankart repair, including younger age, participation in high-risk sports, presence of critical glenoid bone loss (GBL), and presence of bipolar bone loss, including off-track, near-track, and peripheral track lesions.[9,24,37,38] While identification of these risk factors has advanced our management strategies for anterior glenohumeral instability, high recurrence rates demonstrate that further research is clearly required to better understand the indications for isolated primary arthroscopic Bankart repair.

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Humeral bone loss remains an underappreciated component of the bipolar bone loss concept that helps guide management of anterior glenohumeral instability.[2] The role of GBL continues to dominate decision-making when treating anterior glenohumeral instability, with several different methods of quantification described, critical and subcritical GBL values defined, and surgical techniques for treatment of this spectrum of bone loss well illustrated.[8,20,26,36] Humeral bone loss, however, remains relatively poorly understood.[15,18] The presence of a Hill-Sachs lesion has been shown to be an independent risk factor for the recurrence of anterior glenohumeral instability, and surgical techniques have been described to address this pathology, including remplissage and bone grafting procedures, in an attempt to prevent engagement of this lesion on the glenoid during abduction and external rotation and normalize glenohumeral tracking.[6,8,39] While the concepts of the glenoid track and Hill-Sachs interval (HSI; defined as the distance from the medial edge of the Hill-Sachs lesion to the rotator cuff insertion) have greatly advanced our management strategies for anterior glenohumeral instability, they only allow evaluation of the Hill-Sachs lesion in the medial-lateral dimension, failing to take into account the 3-dimensional nature of the lesion.[2,21] Furthermore, the optimal treatment for patients with on-track Hill-Sachs lesions and subcritical GBL remains unclear.

There is concern that patients with inferior extension of the Hill-Sachs defect in the craniocaudal dimension could represent an additional high-risk population, as these more inferior lesions could engage at lower levels of abduction, including standard motions associated with activities of daily living.[8] In a recent retrospective analysis of >170 patients with on-track Hill-Sachs lesions undergoing primary arthroscopic Bankart repair, Cong et al[8] found that the presence of inferior extension of the Hill-Sachs lesion >90° on the sagittal T2-weighted magnetic resonance imaging (MRI) sequence was an independent predictor for recurrent instability, effectively defining critical humeral bone loss (CHBL) in the vertical dimension. This study adds to recent literature by identifying an additional high-risk population with on-track Hill-Sachs lesions who remain at an elevated risk of failure with arthroscopic Bankart repair alone.[3,4,8,24] The effect of remplissage in reducing recurrent instability rates in patients with CHBL has yet to be explored.

The purpose of this study was to determine the protective value of remplissage in reducing recurrent instability rates in patients with CHBL, defined as inferior extension of the Hill-Sachs lesion >90° in the sagittal plane, and on-track Hill-Sachs lesions. We hypothesized that the addition of remplissage would significantly decrease the recurrence rates for patients with CHBL when compared with arthroscopic Bankart repair alone.

METHODS

We performed a retrospective cohort study with institutional review board approval (STUDY2003006) evaluating the records of consecutive patients at a single institution with on-track Hill-Sachs lesions who underwent primary arthroscopic Bankart repair with or without the addition of remplissage from 2007 to 2021 by 5 fellowship-trained academic sports medicine surgeons. The remplissage surgical technique was uniform across included surgeons, capturing the posterior capsule via 2 suture anchors and a double-pulley method that pulled the posterior capsule in to fill the Hill-Sachs lesion, a technique demonstrated by Nazzal et al.[27] Inclusion criteria included patients with diagnosed anterior labral tear on MRI classified as on-track as defined by Yamamoto et al[36] undergoing primary arthroscopic Bankart repair with or without the addition of remplissage. Patients with age >40 years, off-track shoulders, revision stabilization, GBL >20%, <3 suture anchors, multidirectional instability, follow-up <2 years, or incomplete medical data were excluded. Patient demographics and preoperative characteristics were collected, including contact athlete status and number of preoperative dislocations. The primary outcome was recurrent instability, defined as either recurrent dislocation or subluxation noted during patient follow-up. Subluxation was defined as a patient-reported sensation of shoulder instability or apprehension, and dislocation was defined as instability requiring manual reduction.

We utilized the measurement method devised by Cong et al[8] to evaluate the angular craniocaudal characteristics on the preoperative sagittal MRI sequences. Measurements were performed on the sagittal cut with the largest craniocaudal diameter Hill-Sachs lesion. The Hill-Sachs position was measured by the upper edge angle and lower edge angle (LEA) of the Hill-Sachs lesion relative to the humeral axis on sagittal MRI.[8] The sagittal midpoint angle was defined as the midpoint between the upper edge angle and LEA of the Hill-Sachs lesion. The critical threshold defined by Cong et al[8] was utilized, defined as an LEA of 90° (with 0° at the 12-o'clock position).

Known preoperative risk factors for recurrent instability were collected, including age, sex, contact athlete participation, and number of preoperative dislocations.[3] Additional risk factors were measured and calculated, including GBL, HSI, and distance to dislocation (DTD).

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GBL percentage was measured with the perfect circle method on T2-weighted sagittal MRI sequences.[23] The HSI was measured as the distance from the medial-most aspect of the Hill-Sachs lesion and the infraspinatus tendon insertion site. The glenoid track (GT) was calculated based on the work of Yamamoto et al[36] with the formula $GT = 0.83 \times D - d$, where D is the diameter of the glenoid best-fit circle and d is the width of anterior GBL. The GT and HSI were then used to calculate DTD as $DTD = GT - HSI$. Negative DTDs were considered off-track lesions and thus excluded, while positive DTDs were considered on-track.

Univariate and multivariate logistic regression analyses were implemented to determine risk factors for recurrent instability as well as to assess the protective effect of remplissage. Multivariate logistic regression was selected to adjust for known risk factors for recurrent instability as well as for expected differences between groups.

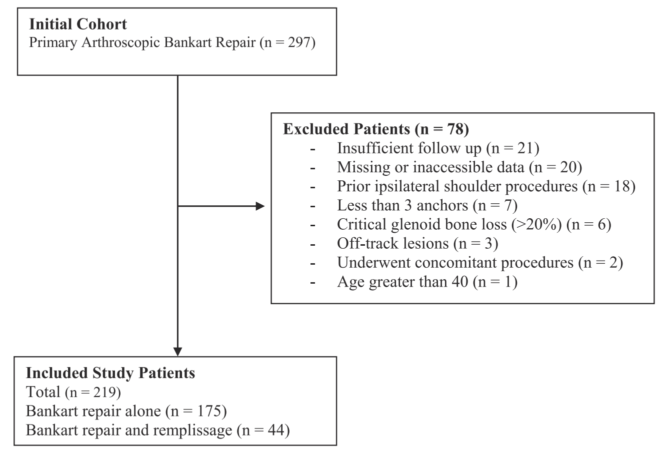

Figure 1. Flow diagram showing application of exclusion criteria to the initial cohort.

RESULTS

In total, 297 patients were identified on the initial search; 21 were excluded for insufficient follow-up, 20 for missing or inaccessible data, 18 for previous ipsilateral shoulder procedures, 7 for having <3 anchors, 6 for critical GBL (>20% GBL), 3 for off-track lesions, and 2 for concomitant procedures during primary stabilization, and 1 was excluded for age >40 years. After applying inclusion and exclusion criteria, 219 were included in the final analysis. They had a mean age of 21.1 years (range, 13-40 years) and a mean follow-up of 7.0 years (range, 2-14.4 years), and 44 patients (20%) underwent remplissage in addition to arthroscopic Bankart (Figure 1).

Regarding patient characteristics (Table 1), those who underwent remplissage were a mean of 2.8 years older and less likely to be a contact athlete; however, they had a mean 2% higher GBL, 8.9-mm difference in DTD, and a higher rate of critical humeral head bone loss. When stratifying characteristics based on CHBL (Table 2), those with CHBL were 2.5 years older with less DTD (5.8 mm) and a higher rate of (39%) remplissage.

Overall, 43 patients (19.6%) experienced recurrent instability, with 32 (74.4%) experiencing dislocation and 11 (25.6%) experiencing subluxation. Of those patients who underwent remplissage, 2 (4.5%) experienced recurrent instability compared with 41 (23.4%) among the nonremplissage group (P = .003). When stratified by critical humeral head bone loss, 30 patients (19.4%) without critical humeral head bone loss experienced recurrent instability compared with 13 (20.3%) with critical humeral head bone loss (P = .854).

Analysis with univariate logistic regression (Table 3) found that decreasing age, multiple preoperative dislocations, contact athlete participation, increasing percent GBL, decreasing DTD, increasing HSI, and Bankart repair alone were predictive of recurrent instability. In univariate analysis, sex and CHBL were not significantly predictive.

After multivariate analysis (Table 4), remplissage significantly reduced the risk of recurrent instability (OR, 0.06; P = .002), with Bankart repair alone having 16.2 times the odds of failure compared with Bankart with remplissage. When adjusting for other known risk factors, that is, age, multiple preoperative dislocations, contact athlete status, and percent GBL, CHBL was a significant predictor of recurrent instability (OR, 3.0; P = .029). When stratified by CHBL, remplissage remained protective (OR, 0.013; P = .007) against recurrent instability.

Multivariate logistic regression models were visually represented with heat maps (Figure 2) showing the risk of recurrent instability based on LEA of the humeral-sided bone loss against GBL (note the change risk range of 50% between panels A and B). Figure 2A visualizes the remplissage subgroup of this study and visualizes the sharp reduction in recurrent instability as compared with Figure 2B of the Bankart-alone subgroup. In both figures, the red box highlights patients with >10% GBL and CHBL as the highest risk cohort for recurrent instability.

DISCUSSION

The results of this study demonstrate that the addition of remplissage to primary arthroscopic Bankart repair in patients with on-track Hill-Sachs lesions, but critical inferior extension of the lesion >90°, significantly reduces the risk of recurrent instability. This study adds to the existing literature that has previously worked to identify CHBL in the vertical dimension by demonstrating that remplissage can effectively mitigate the elevated risk of instability in this unique population.[8] In addition, remplissage does not just reduce the risk of recurrent instability driven by Hill-Sachs location but also reduces the risk associated with GBL and recurrent instability as a whole. Providers should consider utilizing remplissage not only based on GBL but also for individuals with a Hill-Sachs LEA >90°.

The concern with inferior extension of the Hill-Sachs lesions is based on its anatomic relationship with the glenoid at various positions of shoulder abduction and rotation. For example, many activities of daily living are

TABLE 1
Patient Characteristics by Treatment (Bankart vs Bankart With Remplissage)[a]

	Remplissage (n = 44; 20.1%)	Nonremplissage (n = 175; 79.9%)	*P* Value
Age, y	23.3 ± 6.6	20.5 ± 6.0	**.002**
Male sex	32 (73)	131 (75)	.772
Contact athlete (yes)	22 (50)	126 (72)	**.004**
Multiple dislocations (yes)	35 (80)	114 (65)	.073
% bone loss	5.23 ± 5.7	3.2 ± 5.3	**.006**
Hill-Sachs interval, mm	14.7 ± 3.5	5.8 ± 4.9	**<.001**
Distance to dislocation, mm	7.4 ± 4.4	16.3 ± 5.6	**<.001**
Critical humeral head bone loss	25 (57)	39 (22)	**<.001**

[a]Values are given as mean ± SD or n (%). Bold *P* values indicate statistical significance.

TABLE 2
Patient Characteristics by Critical Humeral Head Bone Loss (Lower Edge Angle, >90°)[a]

	Critical Humeral Head Bone Loss (n = 64; 29%)	Subcritical Humeral Head Bone Loss (n = 155; 71%)	*P* Value
Age, y	22.8 ± 6.6	20.3 ± 5.9	**.005**
Male sex	46 (72)	117 (75)	.611
Contact athlete	38 (59)	110 (71)	.055
Multiple dislocations (yes)	46 (72)	103 (66)	.524
% bone loss	3.9 ± 5.2	3.5 ± 5.5	.424
Hill-Sachs interval, mm	11.1 ± 4.5	6.1 ± 5.8	**<.001**
Distance to dislocation, mm	10.4 ± 5.3	16.2 ± 6.1	**<.001**
Remplissage	25 (39)	19 (12)	**<.001**

[a]Values are given as mean ± SD or n (%). Bold *P* values indicate statistical significance.

TABLE 3
Univariate Logistic Regression for Predictors of Recurrent Instability[a]

	OR	95% CI	*P* Value
Age	0.85	0.77-0.94	**.001**
Patient sex			
Male	1	Reference	Reference
Female	1.00	0.47-2.15	.999
Preoperative dislocations			
First-time dislocation	1	Reference	Reference
Multiple preoperative dislocations	2.38	1.04-5.45	**.04**
Sport type			
Noncontact	1	Reference	Reference
Contact	2.65	1.11-6.34	**.028**
% glenoid bone loss	1.13	1.07-1.20	**<.001**
Distance to dislocation, mm			
Entire cohort	0.98	0.93-1.04	.514
Bankart-alone subgroup	0.92	0.86-0.98	**.009**
Hill-Sachs interval			
Entire cohort	1.00	0.95-1.06	.950
Bankart-alone subgroup	1.08	1.01-1.17	**.029**
Critical humeral bone loss (LEA, >90)			
Entire cohort	1.06	0.51-2.20	.871
Bankart-alone subgroup	1.64	0.74-3.63	.22
Bankart alone	6.43	1.49-27.69	**.013**

[a]Note that the percent glenoid bone loss is treated as a continuous variable and the odds ratio relates to a 1% increase in glenoid bone loss. Bold *P* values indicate statistical significance. LEA, lower edge angle.

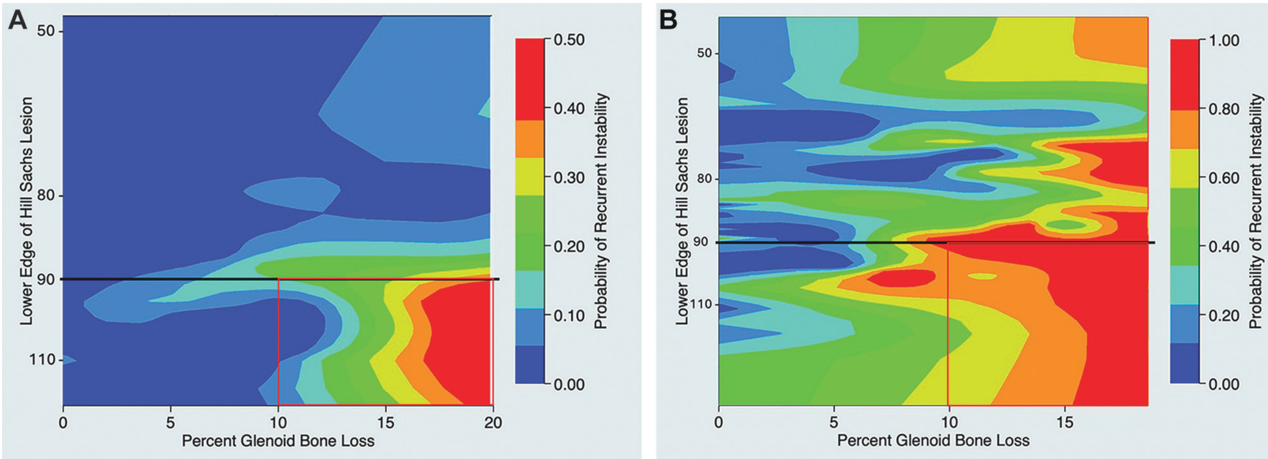

Figure 2. Heat map of probability of recurrent instability in (A) remplissage cohort and (B) Bankart-alone cohort. Critical humeral bone loss is shown below the black line, and highest risk cohort for recurrent instability is outlined by the red box.

TABLE 4
Multivariate Logistic Regression for Predictors of Recurrent Instability[a]

	OR	95% CI	*P* Value
Age	0.82	0.72-0.93	**.002**
Multiple dislocations (yes)	3.2	1.27-8.08	**.013**
Contact athlete (yes)	0.92	0.32-2.65	.884
% glenoid bone loss	1.2	1.09-1.25	**<.001**
Critical humeral bone loss (LEA, >90)	3.0	1.12-7.87	**.029**
Bankart alone	16.2	2.89-91.10	**.002**

[a]The inverse odds ratio of Bankart alone (adding remplissage) is 0.06. Note that the percent glenoid bone loss is treated as a continuous variable and the odds ratio relates to a 1% increase in glenoid bone loss. Bold *P* values indicate statistical significance. LEA, lower edge angle.

performed with the shoulder in relative adduction, including feeding and grooming activities, many career-related functions, and many nonthrowing sports and activities. Therefore, from a mechanical perspective, more inferior extension of the Hill-Sachs lesion may result in engagement with the glenoid at lower angles of shoulder abduction when compared with more superior lesions, which often require greater levels of shoulder abduction before engagement. However, studies have not yet directly quantified the relationship between arm position and inferior Hill-Sachs extension, and future study is required.[8]

Recurrent anterior glenohumeral instability after primary Bankart repair has been shown to result in significantly worse clinical outcomes, with recent literature citing higher rates of postoperative stiffness and chronic pain in addition to lower patient-reported outcomes, higher rates of future glenohumeral arthritic changes, and lower outcomes after revision stabilization procedures.[11,13,22,31] Remplissage, which secures the infraspinatus tendon and/or associated joint capsule into the Hill-Sachs defect, creates an extra-articular defect with the goal of preventing further bipolar defect engagement. Recent literature suggests that this technique has been effective in reducing recurrent instability rates in various settings, including those with off-track and on-track lesions, with reported recurrence rates as low as 5%.[25,29] However, remplissage is not without risk, as it requires increased surgical time and has been associated with an increased risk of postoperative stiffness in some studies, specifically external rotation with the shoulder in 90° of abduction.[12,17] Therefore, as the exact surgical indications for remplissage are not clear, identifying high-risk populations who truly benefit from remplissage is necessary. This study suggests that remplissage should be considered when inferior Hill-Sachs extension is identified preoperatively.

While previous researchers have worked to understand the effect of the Hill-Sachs lesion on recurrent instability, the majority of studies have evaluated the lesion in 2 dimensions (medial-lateral or cranial-caudal extent), and our understanding of the Hill-Sachs lesion as a 3-dimensional lesion remains poorly understood. To date, studies evaluating the Hill-Sachs lesion as a 3-dimensional concept have demonstrated that larger and more medially located lesions result in a higher risk of recurrent instability.[7,19,30] Furthermore, the relationship between bipolar bone loss and soft tissue constraints adds further complexity to this concept, as contributors such as capsular volume, glenoid version, labral volume, and muscular imbalance all likely play a role in recurrent instability risk after a primary anterior glenohumeral instability event.[33-35] While the current study adds to the existing body of literature, it is still limited by a 2-dimensional assessment of bipolar bone loss and is one factor in the global assessment of instability. The development of a risk assessment score that provides a comprehensive analysis of the many anatomic and patient-specific risk factors for recurrent instability and further work to understand the dynamic 3-dimensional relationship of the Hill-Sachs lesion are required.

Limitations

This study has several limitations. First, these data represent a cohort of patients from a single academic institution in the United States and may not represent patient populations in other practice settings or geographic locations. Second, other than rates of recurrent instability, additional outcome measures, including range of motion, especially external rotation, and patient-reported outcomes, were not evaluated in the present study. Third, while this study shows that remplissage is effective in reducing recurrence rates in patients with CHBL, it does not compare humeral bone loss as an equal contributor to recurrent anterior instability as GBL, and further study is required to develop a scoring system that provides a comprehensive analysis of the 3-dimensional nature of bipolar bone loss and its effect on recurrent instability. Finally, additional contributors to recurrent instability risk, including capsuloligamentous laxity, labral volume, and glenoid retroversion or concavity, were not included in this study analysis and may affect final independent risk factor assessments. The utilization of multivariate analysis was deemed the most effective methodology for adjusting for confounders, while other methods, such as matching, have been utilized in the literature. This inherently results in loss of data secondary to a subset of data being utilized. Thus, logistic regression applied to the entire study cohort was deemed the most effective method to control for confounding and maximize the data available.[5]

It is unclear why contact sports participation did not reach statistical significance in our multivariate analysis, although univariate logistic regression did identify this as a risk factor, as expected. The overall cohort was very active, with two-thirds identified as contact athletes, and it is also possible that multivariate analyses do not always reflect the true complexity of individual risk profiles. The higher rate of contact athletes in the nonremplissage group as compared with the remplissage group was temporal in nature and likely a result of changing techniques and indications. The increasing popularity of remplissage as well as having a better understanding of known risk factors, such as contact athlete status through the study time period, was observed, with higher rates of remplissage for contact athletes in surgeries performed later in the study group.

Finally, given the temporal nature of this study cohort, the known risk factors and popularity of remplissage changed during the study period; we view this as a both a strength and a limitation as it allowed us to include patients who underwent Bankart repair alone who, by our current indications, would have undergone remplissage. Currently, our primary indication for remplissage is in patients with off-track or engaging Hill-Sachs lesions with subcritical (<20%) GBL or patients with on-track Hill-Sachs lesions with risk factors for recurrence, such as contact athletes, near-track lesions, hyperlaxity, multiple preoperative dislocations, and age <25 years.[25]

CONCLUSION

The addition of a remplissage to arthroscopic Bankart repair reduces recurrent instability risk in patients with CHBL and on-track Hill-Sachs lesions. Remplissage should be strongly considered on an individual case basis, with the benefits of increased stability weighed against the potential risks of postoperative stiffness. Future research should focus on the 3-dimensional nature of the Hill-Sachs lesion, and the creation of a risk assessment tool that provides a comprehensive analysis of individual risk profiles to best guide surgical management.

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