

Capsulolabral augmentation by blood injection increases the intrinsic stability provided by the glenoid

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ABSTRACT

Purpose. To test the hypothesis that the intrinsic stability of the cadaveric glenoid can be augmented by the injection of blood into the labrum.

Methods. The intrinsic stability of 10 fresh frozen cadaveric glenoids was assessed by measuring the balance stability angle. Pretreatment values of 8 directions in each glenoid were obtained. The labrum was then injected with blood freshly drawn from a volunteer. After the injected blood clotted, measurements of the balance stability angle of the 8 directions were again obtained.

Results. The mean pre-injection balance stability angle for 7 of the 8 directions were significantly increased by the injection of blood: anterosuperior, from 25 to 35 degrees ($p<0.005$); anterior, from 27 to 34 degrees ($p<0.01$); anteroinferior, from 36 to 39 degrees ($p<0.005$); inferior, from 38 to 41 degrees ($p<0.02$);

posteroinferior, from 35 to 42 degrees ($p<0.01$); posterior, from 27 to 35 degrees ($p<0.0005$); and posterosuperior, from 26 to 29 degrees ($p<0.005$). Cross-sections of injected labra demonstrated a firm clot within the labrum with substantial increases in thickness.

Conclusion. The intrinsic stability of cadaveric glenoids can be significantly augmented by the injection of blood into the labrum. It is possible that blood injection may be a useful primary or adjunct procedure in the open or arthroscopic management of glenohumeral instability.

Key words: blood; joint capsule; joint instability; ligaments; rotator cuff

INTRODUCTION

The glenoid concavity is provided by the shape of

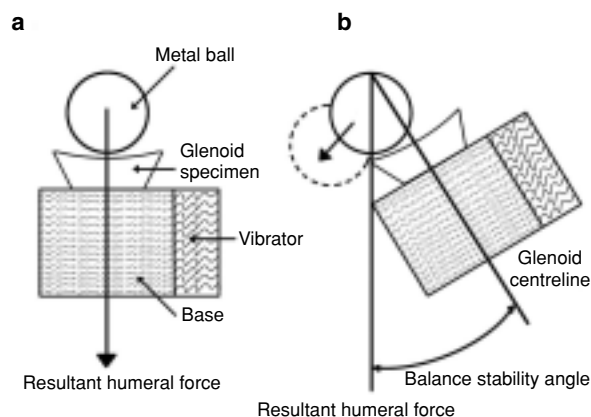


Figure 1 (a) Diagram of the tipper apparatus used to measure the balance stability angle of the cadaveric glenoid. The glenoid is mounted onto a base (square metal frame) with its centreline (a line perpendicular to the articular surface at its centre) oriented vertically. A 2-cm metal ball is placed onto the glenoid. A battery-operated vibrator is attached to the base, with low-amplitude vibrations applied to minimise the effects of friction when the metal ball translates on the glenoid surface. The base can be rotated in any direction, which allows the balance stability angle to be measured in any direction of tipping. In this situation before any tipping is done, the direction of the resultant humeral force (provided by the metal ball) is co-linear with the glenoid centreline. (b) The balance stability angle is the maximal angle at which the glenoid can be tilted before the metal ball slips over the glenoid lip. The apparatus is tipped slowly and progressively until the metal ball slips over the edge of the glenoid. The angle at which this occurs is measured as the balance stability angle.

the glenoid bone and the increased thickness of the articular cartilage at the periphery of the glenoid fossa and the glenoid labrum.^{1,2} This glenoid concavity confers intrinsic stability to the glenoid.³⁻⁵ The important contribution of the glenoid labrum to this concavity has been well documented in recent years. Howell and Galinat³ noted a 50% increase in the glenoid depth with an intact labrum. Lippitt et al.⁵ showed that by excising the glenoid labrum, the stability ratio,⁶ an index of glenohumeral stability, decreased by 20%. Lazarus et al.⁴ demonstrated that an induced chondral-labral defect reduced the glenoid concavity by approximately 80% and the stability ratio by approximately 65%. Conditions affecting the glenoid labrum have also been shown to result in clinical shoulder instability.⁷⁻¹¹

The importance of restoration of the glenoid concavity, including labral reconstruction, to achieve shoulder stabilisation is well recognised. The Bankart-type reconstruction is a well-established

surgical procedure for the treatment of traumatic instability.¹²⁻¹⁴ Capsulolabral augmentation, in which the capsule is plicated to the labrum to augment it, has been shown to be effective in the treatment of posteroinferior instability.¹⁵ Glenoid osteoplasty has been shown to effectively restore the glenoid concavity and improve shoulder stability, both in the cadaveric model¹⁶ as well as in patients with posterior instability.¹⁷

In this study, we explored the possibility of blood injection as a means of augmenting the labrum's contribution to the glenoid concavity. Tissue augmentation by injection of materials has become a well-established procedure in the fields of dermatologic and cosmetic surgery.¹⁸⁻²¹ It has also been advocated, in view of its minimal invasiveness and morbidity, as a primary treatment for velopharyngeal incompetence²² and dysphonia.²³ Materials used for injection have included bovine collagen, homologous collagen, hyaluronic acid gel, and autologous fat. The use of autologous blood to augment atrophic acne scars has also been reported to be effective and has been postulated to have a long-lasting effect by inducing collagen formation in the resulting haematoma.²⁴

In this study, we applied the concept of tissue augmentation by injection to the glenoid labrum. By injecting blood into the glenoid labrum, we tested if the resulting labral augmentation would increase the contribution of the labrum to glenohumeral stability.

MATERIALS AND METHODS

The contribution of the glenoid concavity to glenohumeral stability can be measured in terms of the balance stability angle. The balance stability angle in a given direction is the maximal angle the net humeral joint reaction force can make with the glenoid centreline before dislocation occurs. In our study, we employed a previously validated method of measuring the balance stability angle using an apparatus that progressively tips the glenoid until a ball rolls over the glenoid lip (Fig. 1).²⁵

The glenoids of 10 fresh frozen cadavers, with a mean age of 62 years (range, 31-79 years), together with an attached adjacent capsule, were sectioned at the level of the scapular neck. They were then secured onto square metal frames using plaster of Paris with the glenoid surface placed horizontally (Fig. 2). The potted glenoids were then placed onto the tipping apparatus for measurement of the balance stability



Figure 2 The cadaveric glenoid mounted onto a square metal frame and secured with plaster of Paris.

angles. The glenoid was secured in the testing frame with its centreline pointing vertically upward. A metal ball, measuring 2 cm in diameter, was placed into the glenoid fossa which was slowly and progressively tipped in the desired direction until the metal ball rolled off the glenoid. This angle was then recorded as the balance stability angle. The balance stability angle of each glenoid specimen was measured in each of 8 directions, at 45-degree intervals to one another. Three readings were taken for each direction and the mean value was recorded as the balance stability angle of the glenoid in that direction. Blood was then withdrawn from the cubital fossa of a volunteer using a 21-gauge needle and was then immediately injected into the glenoid labrum at 8 sites corresponding to the directions of tipping. This was done using a 25½-gauge needle introduced tangentially to the glenoid labrum with 1.0 to 1.5 cc of blood injected into each of the 8 sites. The glenoid specimen remained mounted on the testing frame during the injection process to assure that the position and orientation were not altered. The inferior half of the labrum was consistently fibrotic and not capable of receiving the full volume of the blood injection. Thus, the capsule immediately adjacent to the labrum was included in the injection in these locations. Ten minutes were allowed for the injected blood to clot after which the measurement of balance stability angles were repeated for all 8 directions.

The pre- and post-injection balance stability angles were then compared using the paired *t*-test. Two additional glenoid specimens were used to demonstrate infiltration of the injected material into the labrum using Indian ink for one specimen and blood from a volunteer for the other.

Table
Pre- and post-injection balance stability angles

	Mean pre-injection angles (SD)*	Mean post-injection angles (SD)	p value
Superior	34° (7°)	36° (5°)	NS†
Anterosuperior	25° (5°)	35° (9°)	<0.005
Anterior	27° (6°)	34° (7°)	<0.01
Anteroinferior	36° (7°)	39° (6°)	<0.005
Inferior	38° (5°)	41° (4°)	<0.02
Posteroinferior	35° (4°)	42° (5°)	<0.01
Posterior	27° (7°)	35° (9°)	<0.0005
Posterosuperior	26° (7°)	29° (6°)	<0.05

* SD standard deviation

† NS not significant

RESULTS

Gross anatomy

Of the 10 cadaveric glenoids, 4 had an intact labrum, 3 had a sublabral recess, 2 had a type II superior labral, anterior to posterior lesion, and one had a thin, detached posterior labrum. In all 10 specimens, the inferior half of the glenoid labrum was noted to be morphologically different from the superior half, with the inferior half being fibrotic and closely adhered to the adjacent articular cartilage, whereas the superior half more meniscal-looking and more loosely attached. The fibrotic characteristic of the inferior half made it somewhat less receptive to injection in these specimens. The biceps tendon in all 10 specimens was continuous with the superoposterior labrum so that blood injected into this portion of the labrum was noted to streak up into the biceps tendon.

Cross-sections

Comparison of the cross-sections of pre- and post-injected labrums demonstrated a substantial augmentation of the labrum. The specimen injected with Indian ink showed diffuse infiltration of the ink. The other with blood injected showed a firm clot within the labrum.

Balance stability angle

Table 1 compares the pre-injection balance stability angles and the post-injection balance stability angles. Except for the superior direction, all other 7 directions showed a significant increase in the balance stability

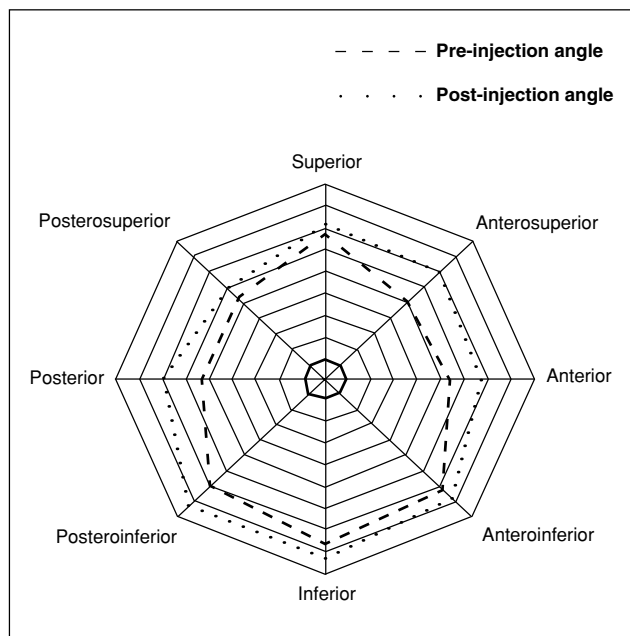


Figure 3 The augmentation effect on the balance stability angle by blood injection.

angle after injection of blood into the labrum. The largest increases were noted in the anterosuperior, anterior, posteroinferior, and posterior directions (Fig. 3).

DISCUSSION

The humeral head normally remains centred in the glenoid except at the extremes of shoulder motion.^{26,27} The compression of the humeral head into the glenoid concavity is an important contributor to this centering.⁵ The glenoid labrum is an important contributor to the glenoid concavity and thus to the stabilising effect of the glenoid fossa.²⁸ Repair of the glenoid lip for traumatic instability¹²⁻¹⁴ and augmentation of the glenoid lip for atraumatic instability^{15,17,27} have proved effective in restoring the glenoid's contribution to stability.

Tissue augmentation with injectable materials has been well documented in other applications, including injections to the face,^{18,20,21} vocal cords,²³ and soft palate.²² Injected materials have included collagen,^{20,21,23} autologous fat,²² hyaluronic acid

gel,¹⁹ and blood.²⁴ Chesney et al.²⁹ have demonstrated the presence of fibrocytes in peripheral blood which are important for the production of type I collagen at the site of tissue injury. Whether peripheral blood injected into the labrum would result in the durable formation of collagen is yet to be determined.

To our knowledge this is the first investigation exploring the potential application of labral injection to increase the contribution of the glenoid concavity to shoulder stability. We chose blood as the injectable substance in our study because in the clinical setting autologous blood is easily accessible, of no cost to the patient, and does not pose problems with regard to disease transmission or other adverse effects. In our study, blood injection into the glenoid increased the stability provided by the glenoid. We discovered that the more fibrotic nature of the inferior glenoid necessitated the injection of the immediately adjacent capsule. The injection of the perilabral capsule led to a significant increment in balance stability angle similar to that from injecting the labrum itself.

This study must be viewed in the light of several limitations. In this cadaver model, we could not investigate the longevity of or the biological response to the injection of blood. The cadavers were several decades older than typical patients with glenohumeral instability. We did not evaluate the effect of labrum injection in a model that included muscle forces and ligaments, but rather focused our efforts on the contribution of the glenoid concavity as reflected by the balance stability angle. We did not investigate the effectiveness of labral augmentation with different humeral loads—it is possible that the compliance of the injected labrum would have less effect with greater loads. We did not compare different injected materials or the possibility of concentrating certain blood fractions. Finally, we did not explore the routes by which injection might be applied in open or arthroscopic surgery. Additional research is required to address these issues.

CONCLUSION

This investigation demonstrates the potential for increasing the contribution of the glenoid labrum to stability by the injection of autologous blood. It is possible that blood injection may be a useful primary or adjunctive procedure in the open and arthroscopic management of glenohumeral instability.

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