JSES International 4 (2020) 77–84

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Radiographic evaluation of the glenohumeral joint space in patients undergoing arthroscopic shoulder surgery in the beach-chair position

Mário Chaves Corrêa, MD, MSc [a,b,*], Érica Antunes Naves, MD [b], Gilvan Ferreira Vaz, MD [b], Thalles Abreu Machado, MD [b], Marco A.P. de Andrade, PhD [c]

[a] Hospital Madre Teresa, Belo Horizonte, Brazil
[b] Hospital Governador Israel Pinheiro, Instituto de Previdência do Servidores do Estado de Minas Gerais, Belo Horizonte, Brazil
[c] Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

A R T I C L E I N F O

Keywords:
Arthroscopy
joint instability
glenohumeral joint space
radiographic imaging
patient positioning
axillary spacer
longitudinal traction

Level of evidence: Basic Science Study; Surgical Technique Study Using Imaging

Background: Shoulder arthroscopy can be performed with the patient in the lateral decubitus or beach-chair position, but in both cases, glenohumeral (GH) joint spaces must be increased to improve visualization and allow access of the optical instrument. The aim of this study was to determine the effects of limb setup and longitudinal traction on the opening of the GH space with patients placed in the beach-chair (dorsal decubitus) position.
Methods: GH spaces at 3 test points corresponding to the anatomic locations of Bankart lesions were determined indirectly from radiographic images obtained from 67 patients presenting shoulder pathology with an indication for arthroscopic surgery. Measurements were made with the operative limb in neutral rotation and positioned in relation to the coronal plane in adduction, 45° of abduction, or adduction with an axillary spacer, in each case with and without longitudinal traction.
Results: GH spaces were optimized at 2 of 3 test points when the operative limb was positioned in adduction or neutral rotation and manual longitudinal traction was applied with or without a polystyrene spacer placed under the axilla, but use of the spacer was essential to maximize the GH space at all 3 locations. In contrast, 45° of abduction proved to be the least appropriate position because it afforded the smallest GH space values with or without traction.
Conclusion: Appropriate positioning of the patient on the operating table is a critical aspect of shoulder arthroscopy. Radiographic images revealed that adducted upper-limb traction with the use of an axillary spacer in patients in the beach-chair position generates a significant increase in the GH space in the lower half of the glenoid cavity, thereby facilitating visualization and access of the optical equipment to the GH compartments.

Shoulder arthroscopy is a sophisticated intervention for the diagnosis and treatment of intra- and extra-articular injuries such as capsulolabral lesions and rotator cuff lesions, respectively. The procedure can be performed with the patient in the lateral decubitus or dorsal decubitus (beach-chair) position,[8,17] but in both cases, it is necessary to increase the subacromial and glenohumeral (GH) joint spaces to improve visualization of the compartments and allow access of the optical instrument.[9,17,26]

In the original lateral decubitus position, the patient is placed on the nonoperative side and the operative limb is abducted between 30° and 70° and submitted to longitudinal traction with a weight of up to 6.5 kg.[13] In the beach-chair position, the patient is placed in the dorsal decubitus position with the head raised 60° to 70° so that the subacromial and GH spaces are increased by the weight of the limb itself, although the opening is not as wide as that obtained by traction.[29,32] The joint spaces can be increased, if necessary, by applying manual longitudinal traction to the operative limb to induce inferior subluxation of the humeral head or by exerting a perpendicular lateral force to the humerus at the proximal-medial face of the arm to laterally displace the humeral head. However, it is

This study was approved by the Committee of Ethics in Research of Universidade Federal de Minas Gerais (approval no. 462755; November 24, 2013) and was conducted according to the principles of the Declaration of Helsinki. The aims of the investigation were carefully explained to all patients, who were then invited to sign the document of written informed consent to participate in the research.

* Corresponding author: Mário Chaves Corrêa, MD, MSc, Hospital Madre Teresa, Av Raja Gabáglia 1002, Gutierrez, 30380-090 Belo Horizonte, MG, Brazil.
E-mail address: mariochavescorrea@gmail.com (M.C. Corrêa).

https://doi.org/10.1016/j.jses.2019.11.003
2468-6026/

rather difficult to maintain the limb in the same position throughout the procedure using these techniques.[31]

Mechanically or pneumatically controlled positioners or traction devices similar to those used in the lateral decubitus technique have been employed in the beach-chair position to enhance visualization and the comfort of the orthopedic surgeon, as well as to prevent fatigue of the assistant, but such strategies are not always practical.[7,15,31] Alternatively, the GH space can be opened by manipulating the optical instrument itself between the humeral head and the glenoid cavity without relying on an assistant or on mechanical devices, but such maneuvers may produce cartilage lesions and/or damage the arthroscope.[28]

In our hospital, the arthroscopic treatment of shoulder lesions is performed with the patient in the beach-chair position and the upper limb adducted with an axillary spacer. Initially, adduction of the operative limb was sustained by means of manual pressure, exerted by an assistant, on the lateral side of the elbow flexed at 90°. Currently, we prefer to apply longitudinal traction by maintaining the patient's elbow extended and the limb firmly fixed by a hand positioner attached distally to the rail on the ipsilateral side of the surgical table. The technique, which was inspired by the adduction-distraction maneuver described by O'Brien et al,[23] creates a fulcrum for the humerus, increases the GH space by horizontal lateral displacement of the humeral head, and maintains the posterior capsule under tension. In this manner, introduction of the trocar is facilitated and the risk of iatrogenic injury to the capsule, humeral head cartilage, and glenoid cavity is reduced. Approximately 100 shoulder arthroscopies have been performed successfully by one of the authors (M.C.C.) using this technique.

To our knowledge, there are no in vivo studies comparing the opening of the GH joint space in patients submitted to beach-chair shoulder arthroscopy with different upper-limb setups; hence, it was important to acquire quantitative evidence that would verify (or contradict) the positive results that we have obtained at the operating table. For this purpose, we aimed (1) to evaluate, via radiographic measurements, the opening of the GH space with the operative limb in neutral rotation and positioned in relation to the coronal plane in adduction, 45° of abduction, or adduction with an axillary spacer and (2) to determine the effect of longitudinal traction on the opening of the GH space in different upper-limb setups.

Materials and methods

All patients involved in this retrospective cross-sectional study had been submitted to shoulder arthroscopy carried out by a single surgeon (M.C.C.) between August 2013 and August 2016. The inclusion criteria were patients older than 18 years presenting shoulder pathology with an indication for arthroscopic surgery, absence of previous surgery or a history of fractures on the operative shoulder, absence of bone deformity of the humeral head and/or glenoid fossa, and absence of any degree of shoulder stiffness at the time of surgery. The aims and objectives of the study were explained to all potential participants, and 67 patients agreed to take part in the investigation by signing a document of informed consent.

For the arthroscopic procedure, the patient was submitted to general anesthesia and placed in the beach-chair position on a standard surgical table with the head raised to an angle of 50°, the lateral wall of the thorax adjacent to the operative shoulder in line with the edge of the table, the knees semi-flexed, and the head and chest held firmly. The operative shoulder was examined to confirm the absence of stiffness, and consecutive radiographic images were taken with the operative shoulder in the following positions: (1) In position 1 (POS1), the limb was placed in adduction next to the body and in neutral rotation (Fig. 1, *A*). (2) In position 1 with traction (POS1TR), manual longitudinal traction was applied to the limb placed as in POS1 and maintained by fixing the limb with a hand positioner installed distally on the ipsilateral rail of the surgical table (Fig. 1, *B*). (3) In position 2 (POS2), the limb was positioned at 45° of abduction and in neutral rotation (Fig. 1, *C*). (4) In position 2 with traction (POS2TR), manual longitudinal traction was applied to the limb placed as in POS2 and maintained by fixing the limb with the hand positioner (Fig. 1, *D*). (5) In position 3 (POS3), the limb was positioned in adduction and in neutral rotation, and a cylindrical semi-rigid polystyrene spacer (15 cm long × 9 cm diameter) was placed under the axilla (Fig. 1, *E*). (6) In position 3 with traction (POS3TR), manual longitudinal traction was applied to the limb placed as in POS3 and maintained by fixing the limb with the hand positioner (Fig. 1, *F*).

The image intensifier tube of the Ziehm Solo radiographic instrument (Ziehm Imaging, Nürnberg, Germany) was placed parallel and proximal to the surgical table to allow strict anteroposterior visualization of the GH joint (orthogonal to the joint surface of the glenoid cavity) showing the complete overlap of bone surfaces of the anterior and posterior edges of the glenoid and forming a single vertical radiopaque structure. The center of the image intensifier tube was placed 40 cm from a point previously marked on the skin of the anterior surface of the shoulder, and identical radioscopic magnifications were used in all positions studied. The 45° angles in POS2 and POS2TR were determined with the aid of a goniometer. Traction intensity was established by visual inspection of the increasing distance between the lateral acromion and the humeral head, described as the "sulcus sign" test,[1] and confirmed by palpation of the groove made in the shoulder (Fig. 2). After radiographic imaging, the image intensifier was removed, skin asepsis was performed, the operative fields were draped, and the surgical procedure was implemented.

The opening of the GH space in the various positions was determined from the radiographic images with the aid of OsiriX imaging software (32-bit open-source version; Pixmeo Sárl, Bernex, Switzerland). Two lines were traced tangential to the lateral superior and inferior cortical edges of the glenoid and crossing laterally on the humeral head at an angle of 60°. A third, vertical line parallel to the articular surface of the glenoid cavity was drawn to connect the other 2 lines at 60° angles, thereby forming an equilateral triangle. The bisector of the angle of the humeral head coincided with the 3-o'clock position of a virtual analog clock in the right shoulder or with the 9-o'clock position in the left shoulder. Furthermore, the inferior bisectors of the angle at 30° coincided with the 4:30 clock-face position in the right shoulder or with the 7:30 clock-face position in the left shoulder. The tangential line to the lower lateral cortical edge of the glenoid corresponded to the 6-o'clock position in both shoulders. The distances (in pixels) between the subchondral cortical bone surfaces of the humeral head and the glenoid cavity were measured at the locations at the 3-o'clock position (point A), 4:30 clock-face position (point B), and 6-o'clock position (point C) (Fig. 3). These 3 points are located in the anteroinferior quadrant of the glenoid cavity and correspond to the anatomic locations of the Bankart lesions that are responsible for many cases of recurrent traumatic anterior instability of the shoulder. For each set of points, the highest GH space value observed was ascribed a score of 100% and the remaining GH space values in the same set were ascribed proportional percentage scores.

To minimize bias, which could be caused by errors in assessment or evaluation by an individual researcher, GH spaces for each patient were determined independently by the orthopedic surgeon (M.C.C.) and the radiologist (E.A.N.) (1206 measurements each). Differences between the 2 sets of mean values (bias) were evaluated using paired *t* tests and the Wilcoxon signed rank test. The Bland-Altman method was applied to quantify agreement between the 2 sets of measurements by constructing limits of agreement

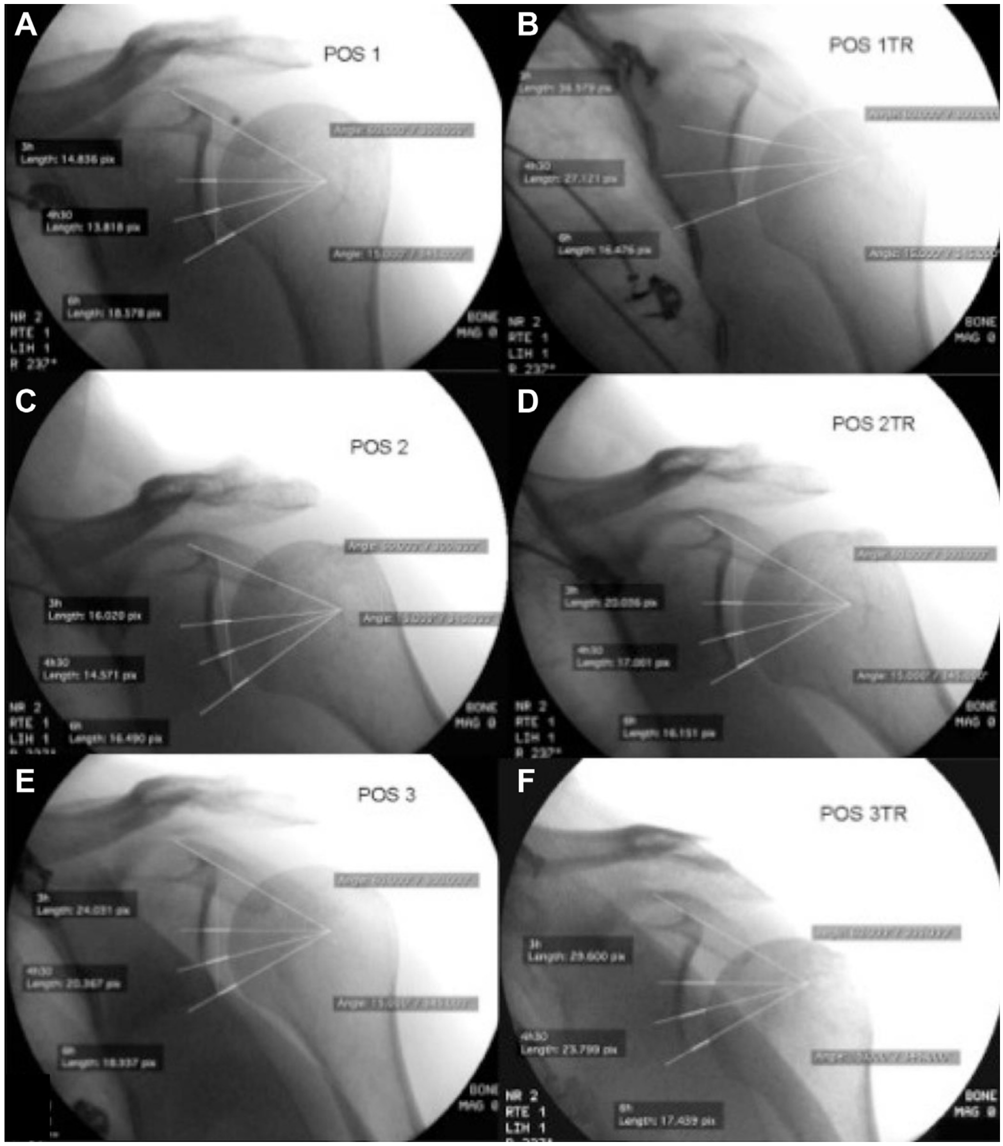

Figure 1 Positions of operating limb adopted for the purpose of radiographic imaging prior to shoulder arthroscopy in dorsal decubitus (beach-chair) position: limb positioned in adduction next to body and in neutral rotation (*POS1*) (**A**); manual longitudinal traction applied to limb placed as in POS1 and maintained by fixing limb with positioner installed distally on ipsilateral rail of surgical table (*POS 1TR*) (**B**); limb positioned at 45° of abduction and in neutral rotation (*POS2*) (**C**); manual longitudinal traction applied to limb placed as in POS2 and maintained by fixing limb with positioner (*POS 2TR*) (**D**); limb positioned in adduction and in neutral rotation with cylindrical semi-rigid polystyrene spacer (15 cm long × 9 cm diameter) placed under axilla (*POS3*) (**E**); and manual longitudinal traction applied to limb placed as in POS3 and maintained by fixing limb with positioner (*POS 3TR*) (**F**). The 45° angles in POS2 and POS2TR were determined with the aid of a goniometer.

(LoAs). Data were analyzed based on plots of pixel and percentage differences and on corresponding log-transformed plots. Measures of central tendency (mean, minimum, and maximum values) and variation or dispersion (standard deviation) were used together with 95% confidence intervals. Friedman analysis of variance and Dunn multiple-comparison tests were used to compare GH spaces at points A, B, and C when patients were placed in different positions. All data were analyzed using Prism software (GraphPad Software, La Jolla, CA, USA) with the level of significance set at 5% ($P \leq .05$).

Results

Of the 67 individuals who took part in the study, 24 were men and 43 were women; the average age of the study population was 50 years (range, 20-72 years). Participants presented the following injuries: rotator cuff lesions (n = 51), Bankart lesions (n = 14), acromioclavicular arthrosis (n = 1), and type II osteonecrosis of the humeral head (n = 1). Of the patients, 62 presented right-limb dominance whereas 5 exhibited left-limb dominance; the dominant limb was affected in 44 patients. No complications were encountered by the vast majority of patients (n = 62) after arthroscopic shoulder surgery, although in some patients (n = 5) who participated early on in the study, transient paresthesia developed in the median nerve of the hand, a condition that resolved spontaneously within a few weeks.

A statistically significant strong positive correlation ($r = 0.955$, $P < .001$; Supplementary Fig. S1) was found between the GH space values determined independently by the orthopedic surgeon and the radiologist, although the variability increased at higher GH space values. The mean difference (bias) was −17.8 pixels (0.3%) with the GH space values determined by the radiologist being, in general, slightly higher than those established by the orthopedic surgeon (Supplementary Table S1). The Bland-Altman plot of the

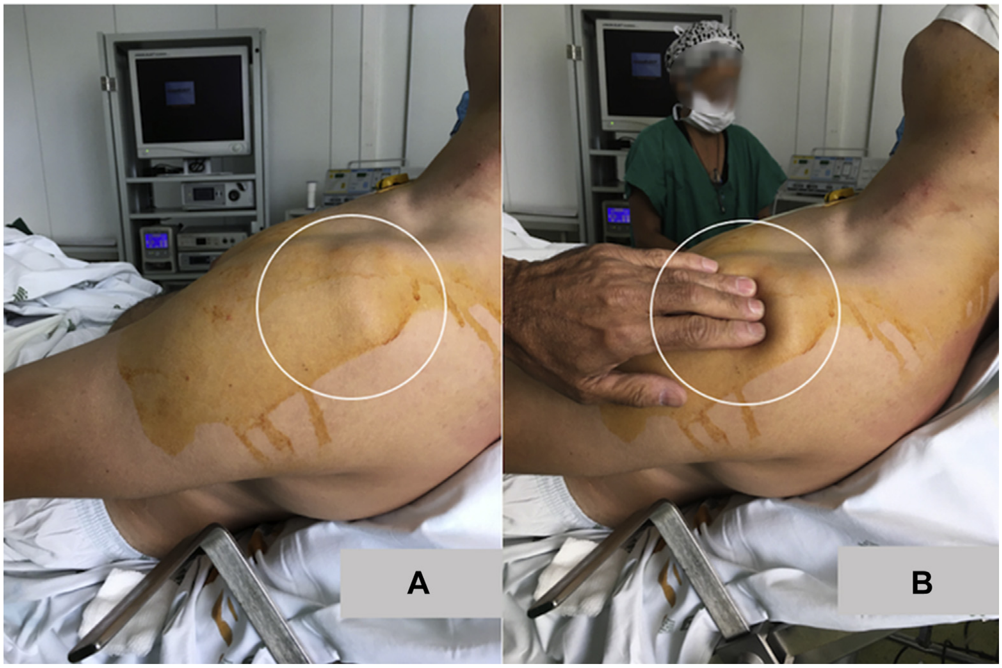

Figure 2 The intensity of traction is determined by visual inspection of the increasing distance between the lateral acromion and the humeral head (sulcus sign) (**A**) and confirmed by palpation of the groove made in the shoulder (**B**).

log-transformed data, which was applied to correct for the observed increased variability, revealed a bias of only 0.001 (Supplementary Fig. S2). The upper and lower LoA values were 33.5% and 24.5%, respectively, with 95.4% of the differences between the 2 sets of measurements falling inside the LoAs (Supplementary Table S2). Given that the bias was small and not statistically significant, the influences of the axillary spacer and longitudinal traction on the opening of the GH space in the study population were established based on the mean values of the 2 data sets. The narrow 95% confidence interval values (Table I) demonstrate that the GH space measurements could be estimated with high accuracy using this strategy.

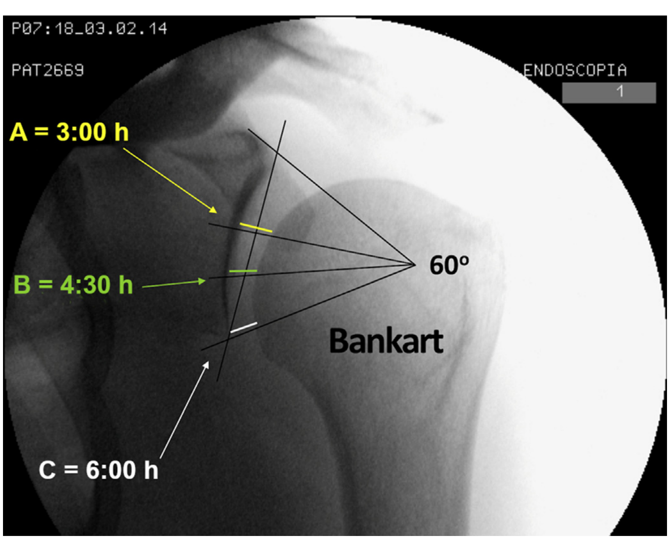

Figure 3 Measurements of glenohumeral spaces determined from radiographic images acquired from patients in beach-chair position and with 6 upper-limb setups as described in Figure 1.

Mean values of GH space at point A decreased in the following order: POS1TR > POS3TR > POS3 > POS2TR > POS1 > POS2 (Table I). Although GH spaces in POS1TR and POS3TR were statistically similar ($P > .9999$), significant differences were observed between POS1 and POS1TR ($P < .0001$) and between POS3 and POS3TR ($P = .003$) (Table II).

At point B, mean GH space values decreased in the following order: POS3TR > POS1TR > POS3 > POS2TR > POS2 > POS1 (Table I). Whereas GH spaces in POS1TR and POS3TR were statistically similar ($P = .063$), significant differences were observed between POS1 and POS1TR ($P < .0001$) and between POS3 and POS3TR ($P = .00346$) (Table II).

Mean values of GH space at point C decreased in the following order: POS3TR > POS3 > POS1 > POS2TR > POS2 > POS1TR (Table I). An interesting finding was that the mean GH space in POS3TR was significantly larger ($P < .0001$) than that in POS1TR at this point whereas no significant differences were observed between POS1 and POS1TR ($P = .1110$) and between POS3 and POS3TR ($P > .9999$) (Table II).

These results show that the submission of the surgical limb to traction in POS3TR and POS1TR (with and without an axillary spacer, respectively) optimized the GH space at points A and B whereas traction and the presence of an axillary spacer (POS3TR) were essential to maximize the GH space at point C. POS2 and POS2TR proved to be the least appropriate positions because they afforded the smallest GH space values.

Discussion

Appropriate positioning of the patient on the operating table is a critical aspect of shoulder arthroscopy. In our hospital, arthroscopic treatment of shoulder lesions is performed with the patient in the beach-chair position and the upper limb adducted with an axillary spacer and submitted to longitudinal traction. With the aim of validating the positive outcomes that we have achieved in the operating theater using this technique, we set out to determine the

Table I
Measurements of glenohumeral spaces determined from radiographic images of patients (N = 67) undergoing shoulder arthroscopy in different dorsal decubitus (beach-chair) positions

Point and position	Mean, %	95% CI, %		SD (minimum, maximum), %	P value*
		Lower limit	Upper limit		
Point A (3-o'clock position)					
POS1	47.04	43.45	50.63	14.72 (23.01, 100)	<.0001
POS1TR	92.42	89.06	95.78	13.78 (37.21, 100)	
POS2	46.69	42.92	50.46	15.46 (23.16, 100)	
POS2TR	61.55	57.28	65.82	17.50 (29.74, 99.92)	
POS3	69.92	66.58	73.27	13.73 (45.86, 97.76)	
POS3TR	87.38	84.74	90.02	10.82 (56.85, 100)	
Point B (4:30 clock-face position)					
POS1	54.14	50.5	57.77	14.89 (26.48, 94.56)	<.0001
POS1TR	83.41	79.72	87.09	15.09 (34.75, 100)	
POS2	54.27	50.63	57.91	14.94 (25.96, 100	
POS2TR	66.30	62.61	69.98	15.12 (35.47, 98.58)	
POS3	82.33	78.97	85.69	13.78 (46.67, 100)	
POS3TR	95.56	94.22	96.91	5.52 (79.44, 100)	
Point C (6-o'clock position)					
POS1	70.79	67.02	74.57	15.47 (37.40, 100)	<.0001
POS1TR	62.50	58.40	66.6	16.80 (27.80, 92.93)	
POS2	65.23	61.35	69.11	15.90 (28.74, 100)	
POS2TR	67.63	64.08	71.18	14.55 (29.49, 94.43)	
POS3	88.54	85.57	91.50	12.14 (58.65, 100)	
POS3TR	93.61	91.65	95.58	8.06 (70.77, 100)	

CI, confidence interval; *SD*, standard deviation; *POS1*, limb positioned in adduction next to body and in neutral rotation; *POS1TR*, manual longitudinal traction applied to limb placed as in POS1 and maintained by fixing limb with positioner installed distally on ipsilateral rail of surgical table; *POS2*, limb positioned at 45° of abduction and in neutral rotation; *POS2TR*, manual longitudinal traction applied to limb placed as in POS2 and maintained by fixing limb with positioner; *POS3*, limb positioned in adduction and in neutral rotation with cylindrical semi-rigid polystyrene spacer placed under axilla; *POS3TR*, manual longitudinal traction applied to limb placed as in POS3 and maintained by fixing limb with positioner.
* Level of statistical significance ($P < .05$, Friedman analysis of variance).

effects of limb setup and longitudinal traction on the opening of the GH space with patients placed in the beach-chair position. Our results showed that the opening of the GH space was maximized when the surgical limb was submitted to manual longitudinal traction when positioned in adduction and in neutral rotation with a polystyrene spacer placed under the axilla (POS3TR).

A technique that is often used in the arthroscopic treatment of recurrent anterior traumatic instability of the shoulder is the Bankart repair, which generally involves the use of suture anchors or similar devices. The procedure can be performed with the patient placed in either the lateral decubitus or beach-chair position, with techniques in both positions producing excellent clinical outcomes.[9,36] A variety of factors influence the preference for one position or the other, including the setup time in the operating theater, cost of equipment, visualization of the surgical area, and ease of performing specific procedures or unexpected conversion from arthroscopic to open surgery. Although the incidence of complications is low, each position is associated with inherent risks, such as traction nerve injuries in the lateral decubitus position and cerebral ischemia caused by hypotension induced by the raised head in the beach-chair position, and these must also be taken into consideration.[9,27,29,31,32] Ultimately, of course, the choice of technique depends primarily on the judgment of the surgeon.

Table II
Dunn multiple-comparison tests of glenohumeral spaces in different dorsal decubitus (beach-chair) positions

Position	Point A		Point B		Point C	
	Comparison	P value*	Comparison	P value	Comparison	P value*
POS1 vs. POS1TR	POS1 < POS1TR	<.0001	POS1 < POS1TR	<.0001	POS1 = POS1TR	.1110
POS1 vs. POS2	POS1 = POS2	>.9999	POS1 = POS2	>.9999	POS1 = POS2	.7868
POS1 vs. POS2TR	POS1 < POS2TR	<.0001	POS1 < POS2TR	.0003	POS1 = POS2TR	>.9999
POS1 vs. POS3	POS1 < POS3	<.0001	POS1 < POS3	<.0001	POS1 < POS3	<.0001
POS1 vs. POS3TR	POS1 < POS3TR	<.0001	POS1 < POS3TR	<.0001	POS1 < POS3TR	<.0001
POS1TR vs. POS2	POS1TR > POS2	<.0001	POS1TR > POS2	<.0001	POS1TR = POS2	>.9999
POS1TR vs. POS2TR	POS1TR > POS2TR	<.0001	POS1TR > POS2TR	.0006	POS1TR = POS2TR	.5658
POS1TR vs. POS3	POS1TR > POS3	<.0001	POS1TR = POS3	>.9999	POS1TR < POS3	<.0001
POS1TR vs. POS3TR	POS1TR = POS3TR	>.9999	POS1TR = POS3TR	.063	POS1TR < POS3TR	<.0001
POS2 vs. POS2TR	POS2 < POS2TR	<.0001	POS2 < POS2TR	.0004	POS2 = POS2TR	>.9999
POS2 vs. POS3	POS2 < POS3	<.0001	POS2 < POS3	<.0001	POS2 < POS3	<.0001
POS2 vs. POS3TR	POS2 < POS3TR	<.0001	POS2 < POS3TR	<.0001	POS2 < POS3TR	<.0001
POS2TR vs. POS3	POS2TR = POS3	>.9999	POS2TR < POS3	.0013	POS2TR < POS3	<.0001
POS2TR vs. POS3TR	POS2TR < POS3TR	<.0001	POS2TR < POS3TR	<.0001	POS2TR < POS3TR	<.0001
POS3 vs. POS3TR	POS3 < POS3TR	.003	POS3 < POS3TR	.0346	POS3 = POS3TR	>.9999

POS1, limb positioned in adduction next to body and in neutral rotation; *POS1TR*, manual longitudinal traction applied to limb placed as in POS1 and maintained by fixing limb with positioner installed distally on ipsilateral rail of surgical table; *POS2*, limb positioned at 45° of abduction and in neutral rotation; *POS2TR*, manual longitudinal traction applied to limb placed as in POS2 and maintained by fixing limb with positioner; *POS3*, limb positioned in adduction and in neutral rotation with cylindrical semi-rigid polystyrene spacer placed under axilla; *POS3TR*, manual longitudinal traction applied to limb placed as in POS3 and maintained by fixing limb with positioner.
* Level of statistical significance ($P < .05$, Dunn test).

Complete visualization of the structures of the anteroinferior region of the GH space and correct insertion of the anchors between the portals at the 3- and 6-o'clock positions—especially the most distal to include the inferior component of traumatic instability—are essential for retensioning and anatomically reinserting anteroinferior avulsions of the capsulolabral complex.[16,33] Ideally, the angle of attack for insertion of the anchors should be perpendicular to the vertical surface of the glenoid cavity,[12,18] but there are anatomic limitations to this approach. In particular, the safe area for placing 2 anterior portals required for visualization and instrumentation is located in the upper half of the GH space and is limited superiorly by the long head of the brachial biceps muscle; medially by the anterior border of the glenoid cavity; laterally by the humeral head; and inferiorly by the upper border of the intra-articular portion of the subscapularis muscle-tendon, which has a transverse or slightly oblique path close to the 3-o'clock position.[6,22] Thus, the angle of attack for insertion of the lower anchors tends to be more acute (from top to bottom) in relation to the surface of the glenoid cavity. Some researchers have reported that lateral displacement of the humeral head (in relation to the glenoid cavity) improves visualization of the anteroinferior and posteroinferior capsulolabral regions and of the inferior angle of attack for insertion of the lower anchor in patients placed in the lateral decubitus or beach-chair position. Such displacement can be achieved by manual force, static traction perpendicular to the long axis of the humerus, or introduction of a spacer in the axillary region. Others have described the use of accessory portals or special devices to facilitate the lateral displacement of the humeral head.[5,7,9,12,17,23,29]

After a meta-analysis and systematic review of the literature concerning the outcomes of arthroscopic anterior shoulder stabilization, Frank et al[9] concluded that recurrence rates were lower in patients operated on in the lateral decubitus position than in those operated on in the beach-chair position. According to Frank et al,[9] the determining factors for the success (or failure) of arthroscopic treatment were appropriate indications for treatment, adequate surgical technique, management of concomitant lesions, number of anchors introduced, amount of glenoid and humeral bone loss, age and sex of the patient, number of previous luxations, and surgical positioning, although the effects of the latter had not been previously evaluated. It is interesting to note that the lower rates of recurrence in patients in the lateral decubitus position were described in older studies in which outdated tacks were used as fixation devices, as well as in recent studies in which anchors replaced the tacks.[9]

The major difference between the 2 techniques is the systematic use of single or double static traction of the upper limb in patients assuming the lateral decubitus position. Traction increases the GH space and provides better access to the anterior, inferior, and posterior areas of the glenoid cavity. This technique facilitates the inclusion of additional posterolateral capsuloligamentous tissue for retensioning and placement of the distal anchor in a lower position and more perpendicular to the glenoid cavity, thereby creating a favorable environment for the repair. However, it is noteworthy that only 53.8% of the studies involving lateral decubitus positioning reviewed by Frank et al[9] specified that double traction was used with variable degrees of abduction, whereas the remainder did not describe the type of traction used. Furthermore, 90% of the studies involving the beach-chair position made no mention of the use of traction, although one described the use of 2 kg of traction with 20° of abduction whereas others cited cutaneous traction or application of McConnell shoulder positioner systems without specifying the use of traction or level of abduction. Frank et al[9] concluded that it would be necessary to conduct randomized clinical trials to better discern the advantages and disadvantages of each position but, until then, surgeons should choose based on their own judgment and in the best interest of the patient.

To our knowledge, there are no in vivo studies comparing the degree of intra-articular visualization or the opening of the GH space obtained in patients placed in the lateral decubitus or beach-chair position. The absence of such information is understandable because individual anatomic differences and anesthesia-induced relaxation, together with the diversity and magnitude of shoulder lesions, render the task impractical.[7] Moreover, to eliminate bias toward patients with lesions of diverse nature and magnitude, any such study would have to include healthy volunteers, but this would clearly raise questions of an ethical nature. Because of these limitations, we opted to measure the degree of opening of the GH space in the same individual, at the same time and in the same position, varying only the setup of the upper limb in the coronal plane, that is, adduction, 45° of abduction, and adduction with an axillary spacer with and without longitudinal traction. In this way, we could compare the results of the measurements obtained from 67 subjects using a consistent methodology. Moreover, the angles of the measurements were chosen to reproduce those used in the 2 basic positioning techniques and their variations, namely, POS1 and POS1TR representing the beach-chair position (with or without a positioner); POS2 and POS2TR representing the beach-chair position (with or without a positioner) and lateral decubitus position with single traction; and POS3 and POS3TR representing the beach-chair position (with or without a positioner) and lateral decubitus position with double traction.

Direct perioperative measurements of the GH space using an arthroscopic pachymeter or arthroscopic photographs are impracticable because the surgeon cannot maintain the optical instrument in a fixed position (stable depth, angle, and rotation) during changes in position of the upper limb. However, because soft tissues such as ligaments and cartilage are radio-transparent and their outline does not show up on radiographic images, the GH space can be determined indirectly using a radiographic image intensifier. By using this technique, it is possible to obtain images while maintaining strict anteroposterior incidence regardless of the position of the upper limb by simply relocating and fixing the equipment after each radiograph. It is important to note that tomographic studies on cadavers,[2,3,37] as well as magnetic resonance and radiographic investigations involving healthy young volunteers,[35] have shown that the indirect radiographic method reflects with sufficient reliability the actual anatomic situation of the GH space in the different positions of the upper limb studied. Indeed, radiographic measurements of the articular space (with or without single-plane radioscopy) have been frequently used in studies involving patients presenting minor or major degenerative joint diseases, as well as in the follow-up of arthroplasties. Moreover, single- or bi-plane fluoroscopy has often been used in joint kinematic studies and in neurosurgical, orthopedic, and vascular practice.[4,10,11,14,19-21,24,25,30,34,35] For these reasons, we consider the indirect radiographic imaging approach to be reliable and capable of accurately reproducing the anatomic features of the GH space in the different situations used in our study.

Shoulder arthroscopy requires intra-articular saline solution infusion under pressure to expand the joint and facilitate the introduction of the optical instrument through the standard posterior portal. However, infusion may not increase the GH space sufficiently, and application of additional force (manual or mechanical) may be necessary to further widen the space for visualization and manipulation. The results of our study revealed that longitudinal traction of the adducted upper limb, together with the use of an axillary polystyrene spacer, produced an effect similar to that obtained in the lateral decubitus position with the operative limb submitted to double traction. More specifically, POS3TR generated a lateral displacement of the humeral head in relation to the glenoid cavity rather than an inferior dislocation. In POS3TR, we used a standard-size semi-rigid polystyrene spacer to increase the GH space regardless of the body mass index of the patient. However, it is possible to safely increase the width of the GH space even further by using a spacer with dimensions adjusted to the biotype of the patient. Indeed, we regularly use this strategy by applying soft materials such as surgical fields or foam to better distribute the pressure and minimize the risk of compression of the neurovascular structures located deeply in the medial aspect of the arm.[5]

Complete adduction of the upper limb is essential to attaining the required biomechanical effect, and this can be achieved by means of a mechanical positioner or manually by an assistant who simultaneously exerts longitudinal traction and a force centered on the lateral epicondyle. When this technique was first applied in our hospital, some cases of transient paresthesia in the median nerve of the hand were observed, but these resolved spontaneously within a few weeks. Such complications may have been caused by bandaging the hand of the patient too tightly to the positioner (a procedure that should be avoided) and not necessarily by the axillary spacer. Moreover, the amount of traction applied to the upper limb in POS3TR was defined by the sulcus sign test, and this relies on the subjective judgment of the surgeon. Hence, it is advisable to apply traction judiciously to prevent excessive tightening and to reduce the risk of neurovascular injuries.

Our study was subject to a number of potential limitations: (1) estimates of GH spaces were based on radiographic images rather than measurements acquired in vivo, (2) within-patient rather than between-patient comparisons of GH space measurements were performed, and (3) the intensity of traction applied to the upper limb was based on the empirical sulcus sign test.

Conclusion

The complex anatomy, orientation, and biomechanics of the human shoulder render arthroscopic interventions particularly challenging and require that the senior surgeon has a sound understanding of this region. A critical aspect of the arthroscopic procedure is the proper positioning of the patient on the operating table to allow effective visualization and manipulation of the GH joint. We have used radiographic imaging in vivo for the first time to show that adducted upper-limb traction using an axillary spacer (POS3TR) in patients in the beach-chair position generates a significant increase in the GH space in the lower half of the glenoid cavity, thereby facilitating visualization and access of the optical equipment to the GH compartments.

Acknowledgments

The authors acknowledge the valuable contribution of Ms. Janaína Pereira in assisting with the statistical analysis.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jses.2019.11.003.

References

1. Bahk M, Keyurapan E, Tasaki A, Sauers EL, McFarland EG. Laxity testing of the shoulder: a review. Am J Sports Med 2007;35:131–44. https://doi.org/10.1177/0363546506294570.
2. Boileau P, Walch G. Anatomical study of the proximal humerus: surgical technique considerations and prosthetic design rationale. In: Walch G, Boileau P, editors. Shoulder arthroplasty. Berlin: Springer; 1999. p. 69–82.
3. Boileau P, Walch G. Normal and pathological anatomy of the glenoid: effects on the design, preparation, and fixation of the glenoid component. In: Walch G, Boileau P, editors. Shoulder arthroplasty. Berlin: Springer; 1999. p. 127–40.
4. Buckland-Wright C. Review of the anatomical and radiological differences between fluoroscopic and non-fluoroscopic positioning of osteoarthritic knees. Osteoarthritis Cartilage 2006;14(Suppl A):A19–31. https://doi.org/10.1016/j.joca.2003.09.012.
5. Correa MC, Gonçalves LB, Andrade RP, Carvalho LH Jr. Beach chair position with instrumental distraction for arthroscopic and open shoulder surgeries. J Shoulder Elbow Surg 2008;17:226–30. https://doi.org/10.1016/j.jse.2007.08.009.
6. Di Giacomo G, Costantini A. Arthroscopic shoulder surgery anatomy: basic to advanced portal placement. Oper Tech Sports Med 2004;12:64–74. https://doi.org/10.1053/j.otsm.2004.06.004.
7. ElMaraghy A, Pennings A, Devereaux M. Economical and efficacious beach chair traction positioning for shoulder arthroscopy. Tech Shoulder Elbow Surg 2012;13:170–6. https://doi.org/10.1097/BTE.0b013e31826db6cf.
8. Farmer KW, Wright TW. Shoulder arthroscopy: the basics. J Hand Surg Am 2015;40:817–21. https://doi.org/10.1016/j.jhsa.2015.01.002.
9. Frank RM, Saccomanno MF, McDonald LS, Moric M, Romeo AA, Provencher MT. Outcomes of arthroscopic anterior shoulder instability in the beach chair versus lateral decubitus position: a systematic review and meta-regression analysis. Arthroscopy 2014;30:1349–65. https://doi.org/10.1016/j.arthro.2014.05.008.
10. Gensburger D, Roux JP, Arlot M, Sornay-Rendu E, Ravaud P, Chapurlat R. Influence of blinding sequence of radiographs on the reproducibility and sensitivity to change of joint space width measurement in knee osteoarthritis. Arthritis Care Res 2010;62:1699–705. https://doi.org/10.1002/acr.20311.
11. Giphart JE, van der Meijden OA, Millett PJ. The effects of arm elevation on the 3-dimensional acromiohumeral distance: a biplane fluoroscopy study with normative data. J Shoulder Elbow Surg 2012;21:1593–600. https://doi.org/10.1016/j.jse.2011.11.023.
12. Jazini E, Shiu B, Robertson A, Russell JP, Iacangelo A, Henn RF, et al. A biomechanical analysis of anchor placement for Bankart repair: effect of portal placement. Orthopedics 2016;39:e323–7. https://doi.org/10.3928/01477447-20160301-04.
13. Jinnah AH, Mannava S, Plate JF, Stone AV, Freehill MT. Basic shoulder arthroscopy: lateral decubitus patient positioning. Arthrosc Tech 2016;5:e1069–75. https://doi.org/10.1016/j.eats.2016.05.010.
14. Kijima T, Matsuki K, Ochiai N, Yamaguchi T, Sasaki Y, Hashimoto E, et al. In vivo 3-dimensional analysis of scapular and glenohumeral kinematics: comparison of symptomatic or asymptomatic shoulders with rotator cuff tears and healthy shoulders. J Shoulder Elbow Surg 2015;24:1817–26. https://doi.org/10.1016/j.jse.2015.06.003.
15. Kim KC, Rhee KJ, Shin HD. Beach-chair lateral traction position using a lateral decubitus distracter in shoulder arthroscopy. Orthopedics 2007;30:1001–3. https://doi.org/10.3928/01477447-20071201-01.
16. Levy YD, Williamson M, Flores-Hernandez C, D'Lima DD, Hoenecke HR Jr. Glenoid rim anatomy: risk for glenoid vault perforation during labral repair. Orthop J Sports Med 2014;2:2325967114556257. https://doi.org/10.1177/2325967114556257.
17. Li X, Eichinger JK, Hartshorn T, Zhou H, Matzkin EG, Warner JP. A comparison of the lateral decubitus and beach-chair positions for shoulder surgery: advantages and complications. J Am Acad Orthop Surg 2015;23:18–28. https://doi.org/10.5435/JAAOS-23-01-18.
18. Lim TK, Koh KH, Lee SH, Shon MS, Bae TS, Park WH, et al. Inferior anchor cortical perforation with arthroscopic Bankart repair: a cadaveric study. Arthroscopy 2013;29:31–6. https://doi.org/10.1016/j.arthro.2012.08.013.
19. Lin DCM, Reichmann WM, Gosseck L, Losina E, Conaghan PG, Maillefert JF. Validity and responsiveness of radiographic joint space width metric measurement in hip osteoarthritis: a systematic review. Osteoarthritis Cartilage 2011;19:543–9. https://doi.org/10.1016/j.joca.2010.12.014.
20. Lollino N, Pellegrini A, Paladini P, Campi F, Porcellini G. Gleno-humeral arthritis in young patients: clinical and radiographic analysis of humerus resurfacing prosthesis and meniscus interposition. Musculoskelet Surg 2011;95(Suppl 1):S59–63. https://doi.org/10.1007/s12306-011-0122-y.
21. Millett PJ, Giphart JE, Wilson KJ, Kagnes K, Greenspoon JA. Alterations in glenohumeral kinematics in patients with rotator cuff tears measured with biplane fluoroscopy. Arthroscopy 2016;32:446–51. https://doi.org/10.1016/j.arthro.2015.08.031.
22. Ng DZ, Lau BPH, Tan BHM, Kumar VP. Single working portal technique for knotless arthroscopic Bankart repair. Arthrosc Tech 2017;6:e1989–92. https://doi.org/10.1016/j.eats.2017.07.021.
23. O'Brien SJ, Gonzalez DM, Wright JM, Fealy S. The adduction distraction maneuver. Arthroscopy 1997;13:530–2.

24. Ornetti P, Maillefert JF, Paternotte S, Dougados M, Gossec L. Influence of the experience of the reader on reliability of joint space width measurement. A cross-sectional multiple reading study in hip osteoarthritis. Joint Bone Spine 2011;78:499–505. https://doi.org/10.1016/j.jbspin.2010.10.014.
25. Osti M, Krawinkel A, Benedetto KP. Skeletal imaging following reconstruction of the posterior cruciate ligament: in vivo comparison of fluoroscopy, radiography, and computed tomography. Skeletal Radiol 2014;43:1687–95. https://doi.org/10.1007/s00256-014-1970-y.
26. Ozsoy MH, Bayramoglu A, Demiryurek D, Tuccar E, Hayran M, Dincel VE, et al. Rotator interval dimensions in different shoulder arthroscopy positions: a cadaveric study. J Shoulder Elbow Surg 2008;17:624–30. https://doi.org/10.1016/j.jse.2007.11.007.
27. Paxton ES, Backus J, Keener J, Brophy RH. Shoulder arthroscopy: basic principles of positioning, anesthesia, and portal anatomy. J Am Acad Orthop Surg 2013;21:332–42. https://doi.org/10.5435/JAAOS-21-06-332.
28. Pedowitz RA, Billi F, Kavanaugh A, Colbert A, Liu S, Savoie FH, et al. Arthroscopic surgical tools: a source of metal particles and possible joint damage. Arthroscopy 2013;29:1559–65. https://doi.org/10.1016/j.arthro.2013.05.030.
29. Peruto CM, Ciccotti MG, Cohen SB. Shoulder arthroscopy positioning: lateral decubitus versus beach chair. Arthroscopy 2009;25:891–6. https://doi.org/10.1016/j.arthro.2008.10.003.
30. Petersson CJ, Redlund-Johnell I. Joint space in normal gleno-humeral radiographs. Acta Orthop Scand 1983;54:274–6.
31. Provencher MT, McIntire ES, Gaston TM, Frank RM, Solomon DJ. Avoiding complications in shoulder arthroscopy: pearls for lateral decubitus and beach chair positioning. Tech Shoulder Elbow Surg 2010;11:1–3. https://doi.org/10.1097/BTE.0b013e3181c80acc.
32. Rains DD, Rooke GA, Wahl CJ. Pathomechanisms and complications related to patient positioning and anesthesia during shoulder arthroscopy. Arthroscopy 2011;27:532–41. https://doi.org/10.1016/j.arthro.2010.09.008.
33. Reda W, Khedr A. Using a posterolateral portal to pass and tie the suture of the inferior anchor during arthroscopic Bankart repair. Arthrosc Tech 2016;5: e1467–70. https://doi.org/10.1016/j.eats.2016.08.023.
34. Reichmann WM, Maillefert JF, Hunter DJ, Katz JN, Conaghan PG, Losina E. Responsiveness to change and reliability of measurement of radiographic joint space width in osteoarthritis of the knee: a systematic review. Osteoarthritis Cartilage 2011;19:550–6. https://doi.org/10.1016/j.joca.2011.01.023.
35. Schleich C, Bittersohl B, Antoch G, Krauspe R, Zilkens C, Kircher J. Thickness distribution of glenohumeral joint cartilage: a normal value study on asymptomatic volunteers using 3-Tesla magnetic resonance tomography. Cartilage 2017;8:105–11. https://doi.org/10.1177/1947603516651669.
36. Zhang AL, Montgomery SR, Ngo SS, Hame SL, Wang JC, Gamradt SC. Arthroscopic versus open shoulder stabilization: current practice patterns in the United States. Arthroscopy 2014;30:436–43. https://doi.org/10.1016/j.arthro.2013.12.013.
37. Zumstein V, Kraljević M, Conzen A, Hoechel S, Müller-Gerbl M. Thickness distribution of the glenohumeral joint cartilage: a quantitative study using computed tomography. Surg Radiol Anat 2014;36:327–31. https://doi.org/10.1007/s00276-013-1221-2.