Anatomic Risks of Shoulder Arthroscopy Portals: Anatomic Cadaveric Study of 12 Portals

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Purpose: The purpose of this anatomic cadaveric study was to determine with trocars in situ the relationships of 12 shoulder arthroscopic portals frequently used with the adjacent musculotendinous and neurovascular structures. **Methods:** Twelve shoulders of embalmed cadavers installed in a beach-chair position were dissected. Twelve different portals were established by using their authors' description: posterior "soft point," central posterior, anterior central, anterior inferior, anterior superior, 5 o'clock portal, Neviaser, superolateral, transrotator cuff approach, Port of Wilmington, anterolateral, and posterolateral. Six of these portals were placed on each shoulder so that each portal was studied 6 times. Dissections were conduced with trocars in situ to take into account their volume. The distance to the adjacent relevant neurovascular structures at risk (axillar and suprascapular nerves, axillar and suprascapular arteries, and cephalic vein) were measured, arm at side, by using a calliper. Musculotendinous structures crossed by portals were noticed. **Results:** The cephalic vein was injured twice by anterior portals. The 5 o'clock portal is at most risk of neurovascular injury. It is located at mean distances to the axillar artery and nerve of 13 and 15 mm, respectively. Other anterior, posterior, superior, and lateral portals are safe with mean distances higher than 20 mm. No musculotendinous rupture nor large injury occurred. **Conclusions:** The present study shows that the trocars placement of the studied portals did not create, except for the cephalic vein, any lesion of the neurovascular adjacent structures. **Clinical Relevance:** This study suggests, except for the 5 o'clock portal, the safety of the shoulder arthroscopic portals tested regarding to the neurovascular adjacent structures. **Key Words:** Shoulder—Arthroscopy—Portal—Anatomic study—Risks—Injuries.

During the development of shoulder arthroscopy, the first difficulty to resolve was the creation of portals that provide a good vision of the surgical zone but also allow the right angle of approach and the range of motion required by the surgical procedure. As noticed by Nottage,[1] the proximity of vascular and nervous structures confers a high risk level to the establishment of arthroscopic portals, especially because the surgeon does not have a direct vision of the structures located between the skin incision and the ending point in the glenohumeral joint or in the subacromial space.

The literature review reports a low prevalence of direct arterial or nervous injuries. Most of the neurologic injuries are transient neurapraxias and involve the musculocutaneous, ulnar, radial, axillary, and median nerves. The rate of neurapraxia after shoulder surgery has ranged from 0% to 30%.[2] However, the risk of permanent nerve damage after shoulder arthroscopy is low, with a prevalence of less than 0.1%.[3] Brachial-plexus traction injuries and axillary nerve damage are the most frequent lesions encountered after shoulder arthroscopy. On the other hand, a high number of venous injuries, especially the cephalic vein, were reported after establishment of ante-

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TABLE 1. *Dissections Planning*

	Posterior Portals	Anterior Portals	Superior Portals	Lateral Portals
Planning 1	Soft-point portal	Anterior central portal Five o'clock portal		Superolateral portal Port of Wilmington Lateral posterior portal
Planning 2	Posterior central portal	Anterior superior portal Anterior inferior portal	Neviaser portal	Transrotator cuff portal Lateral anterior portal

rior portals; some of those led to additional surgery.[2,4-8] However, no direct arterial injury was reported. Anatomic relationships of arthroscopic shoulder portals have often been studied. Nevertheless, these reports concerned only a few portals, and most of them were conducted by the promoter of the portal studied. Also, in these studies, distances were measured after trocars ablation without taking into account the risks related to their volume. Keeping trocars in situ may show a significant reduction of distances to the relevant anatomic structures.

The goal of our anatomic study is to determine in a beach-chair position, with arm at the side and with trocars in situ, the relationships of 12 shoulder arthroscopic portals frequently used to the adjacent relevant musclotendinous and neurovascular structures.

METHODS

Twelve embalmed cadaveric shoulder joints were dissected including 8 right and 4 left shoulders. The selected cadavers had no shoulder scares and were not known to have had a shoulder surgery. Four shoulders had a rotator cuff tear: 3 supraspinatus tendon tears and 1 associated tear of the supra- and infraspinatus tendons. Two shoulders had a long-head biceps tendon ruptured. Cadavers were installed in a beach-chair position without traction to allow the mobilization of the arm during the trocar insertion procedure. Twelve different portals were studied. Six portals were established on each shoulder. Each portal was chosen to not be in conflict with the other 5 portals (Table 1, Figs 1 and 2). Each portal was studied 6 times.

Initially, a 30° arthroscope (Richard Wolf GMBH D-75434, Knittlingen, Germany) was introduced through a posterior portal, and then the 5 other portals were established as described by their author. A 12-mm trocar was placed in each portal. This size of trocars was selected because it is the largest one available for shoulder arthroscopy and consequently the most at risk of injury.

The posterior optical portal was created through the "soft point" or was a posterior central portal. The

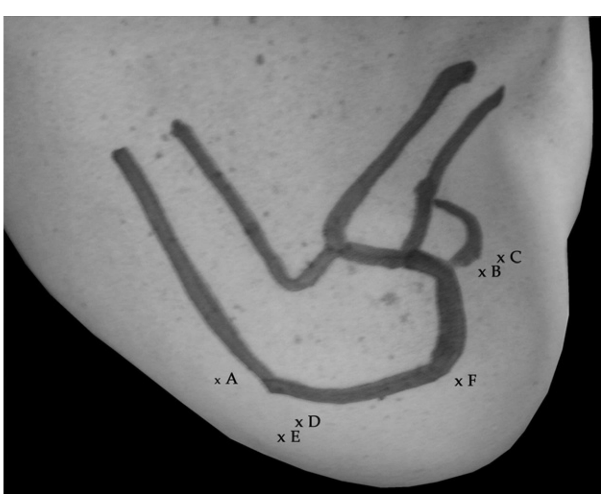

FIGURE 1. Dissection planning 1 (right shoulder from above) (A, "soft-point" portal; B, anterior central portal; C, 5 o'clock portal; D, Port of Wilmington; E, lateral posterior portal; F, superolateral portal).

FIGURE 2. Dissection planning 2 (right shoulder from above) (G, central posterior portal; H, anterior superior portal; I, anterior inferior portal; J, Neviaser portal; K, lateral anterior portal; L, transrotator cuff approach portal).

"soft-point" portal[9] was performed blindly through a point located 2 cm inferior and 2 cm medial to the posterolateral corner of the acromion by directing the arthroscope to the coracoid as described by Andrews et al.[9] Wolf[10] described a central posterior portal whose only difference with the "soft-point" portal is the skin incision located 1 to 2 cm medial and 2 to 3 cm distal to the posterolateral corner of the acromion. It corresponds to the level of the posterior joint line so it can traverse the joint parallel to the glenoid surface.

After the introduction of the arthroscope into the joint, the anterior portals were established. The Matthews' anterior central portal[11] was established in our study by using an outside-to-inside technique. The portal was marked by using a spinal needle introduced from a skin point lateral to the coracoid into the joint going through a triangle limited by the humeral head laterally, the glenoid rim medially, and the long head of the biceps tendon superiorly while remaining above the subscapularis tendon.

An anterior-inferior portal has been described by Wolf[10] to provide an increased capacity to explore the glenohumeral joint and to perform arthroscopic anterior shoulder capsulorraphy regardless of the type of fixation used. It is established in an inside-to-outside technique. With the arthroscope inserted in the central posterior portal, an intra-articular palpation of the coracoid is performed with the arthroscope, which slides off the inferior edge of the coracoid tip and then is withdrawn from its sheath to allow the Wissinger rod to pass through the capsule. A cannula is subsequently inserted over the rod, which is withdrawn, thus creating the anterior inferior portal.

The anterior superior portal, also described by Wolf,[10] is an optical portal created to allow the operative triangulation with the anterior inferior portal in the anterior aspect of the glenohumeral joint. This portal is created following an outside-to-inside technique and is located between the coracoid and the acromion. It enters the joint just anterior to the long-head biceps tendon.

Davidson and Tibone[12] described the "5 o'clock portal" to allow the approach of the glenoid rim at a right angle to the area of the capsulolabral detachment in a Bankart lesion, facilitating direct insertion of fixation devices. This portal is established by using an inside-to-outside technique once the arthroscope is placed through the posterior "soft-point" portal. The intra-articular starting point for this portal was the leading edge of the inferior glenohumeral ligament at the 5 o'clock position of the glenoid rim. The arthroscope is then replaced by a blunt-tipped Wissinger rod that is passed through the anterior capsule. The humerus is maximally adducted while establishing the portal to medialize neurovascular structures.

The Neviaser portal,[13] also called the "supraclavicular fossa portal," is a superior portal initially described as an additional inflow portal, but it can also be used during anchor placement for posterior SLAP repair. It is created in the superior soft spot surrounded by the clavicle anteriorly, the medial acromion, and the spine of the scapula posteriorly. The skin incision is located 1 cm medial to the medial border of the acromion. The portal is established in an outside-to-inside technique by advancing down the cannula at 30° laterally and slightly posteriorly into the glenohumeral joint.

Superior and lateral portals have also been studied. Laurencin et al.[14] developed a superolateral portal that permits the direct visualisation of the anterior glenoid neck. It is located far enough from the traditional Matthews anterior portal to allow operative triangulation anteriorly. It is placed at a position just lateral to the acromion on a line drawn from the acromion to the coracoid. It is created by using an outside-to-inside technique with the use of a spinal needle placed such that it enters the joint obliquely directly above the biceps tendon where it pierces the rotator interval tissue.

The Port of Wilmington[15] allows the treatment of SLAP lesions[16-18] with a large posterior component. It is established 1 cm anterior and 1 cm lateral to the posterolateral corner of the acromion and is placed to allow a 45° approach angle to the posterosuperior glenoid.

The transrotator cuff approach described by O'Brien et al.[19] allows access to posterior aspect of the superior labrum. It is placed following an outside-to-inside technique from the lateral or posterior lateral aspect of the shoulder, through the rotator cuff and onto the posterior superior aspect of the labrum. Thus, the location of this portal varies with the anatomy of the patient to provide a workable angle for the placement of anchors in the posterosuperior glenoid. In this study, the skin incision was always located 2 cm lateral and 1 cm posterior to the posterolateral corner of the acromion, and the portal was established to the aspect of the labrum located at the 11 o'clock position of the glenoid rim (for a right shoulder). Elmann[20] described the anterolateral and posterolateral portals that allow direct access to the anteroinferior surface of the acromion and can be used to perform arthroscopic acromioplasty. These portals are established blindly from a skin incision located 2 cm below the lateral edge of the acromion in the prolongation of the anterior edge of the acromion (anterolateral portal) or of its posterior edge (posterolateral portal) into the subacromial bursa. Table 3 summarizes the different portals tested.

The dissection was performed with trocars placed to take into account their volume, which reduces the distance to anatomic structures at risk. Once the portals had been established, the dissection was started by the partial detachment of 2 large anterior and posterior fasciocutaneous flaps to allow the exposure of deltoid and trapezius muscles and the identification of the cephalic vein. These muscles were then detached from their scapular and clavicular insertions to expose the rotator cuff and the axillary nerve. After that, a coracoid tip osteotomy was performed to detach the conjoint tendon. The humeral insertion of the pectoralis major tendon was then cut to allow the approach of the axillary vascular structures and the brachial plexus. The 2 last steps were the detachment of the rotator cuff from the humeral head and the acromion osteotomy to facilitate the dissection of the suprascapular artery and nerve.

Table 2 shows the anatomic structures we considered initially at risk. The anterior aspect of the shoulder includes many neurovascular structures. We only considered the vascular and nervous structures that were the nearest from the anterior portals. These neurovascular structures proved to be the same for the different anterior portals studied. There were the cephalic vein, the axillary artery (more lateral and superior than the axillary vein), and the axillary nerve at the quadrangular space (always closer to the anterior portals studied than the musculocutaneous nerve). It represents the most proximal branch of the brachial plexus. The musculotendinous structures crossed by the portals were noticed. For neurovascular structures, the distance considered was the shortest one, measured by using a calliper between these structures and the cannulas.

All the distances to anatomic structures were measured, arm at the side, by using a calliper. Each distance was measured twice by each of the 2 first authors of the present article that means that all distances were measured 4 times. We chose the calliper for its reliability. We did not find a difference superior to 2 mm between the 4 measurements of each distance considered, and we recorded as the final distance the average of those 4 measurements.

RESULTS

In the “soft point” and the central posterior portals, the mean measured distances were the same. The axillary nerve and the suprascapular artery and nerve were situated at a mean distance of 49, 27, and 29 mm from the portals, respectively. The teres minor and the infraspinatus muscles were injured once by the “soft-point” portal. The infraspinatus muscle was crossed 3 times by the central posterior portal.

For anterior portals, the nearest anatomic structure at risk was the cephalic vein whose mean measured distances to the central, inferior, and superior anterior portals were 17, 14, and 39 mm, respectively. Two dissections showed an injury of the cephalic vein (1 anterior-central portal and 1 anterior-inferior portal). For these 3 anterior portals, the axillary artery and nerve were located at a further range as follows: 33 and 31 mm, respectively, for the anterior central portal (Fig 3); 42 and 40 mm for the anterior-inferior portal; and 53 and 54 mm for the anterior-superior portal. Regarding the “5 o’clock portal,” the axillary artery is the main structure at risk and was located at a mean distance of 13 mm. The axillary nerve and the cephalic vein were located further at 15 and 17 mm away from the trocar. For each 1 of these 3 anatomic structures, 1 dissection showed a trocar at a distance shorter than 10 mm. On the other hand, no musculotendinous structures were injured except the deltoid muscle that cannot be avoided because of its superficial position.

TABLE 2. *Anatomic Structures At Risk*

	Muscles and Ligaments at Risk	Vascular Structures at Risk	Nervous Structures at Risk
Anterior portals	Subscapularis muscle Coracoacromial ligament	Axillary artery Cephalic vein	Axillary nerve
Posterior portals	Infraspinatus muscle Teres minor muscle	Suprascapular artery	Axillary nerve Suprascapular nerve
Superior portals	Supraspinatus tendon	Suprascapular artery	Suprascapular nerve
Lateral portals	Supraspinatus muscle		Axillary nerve

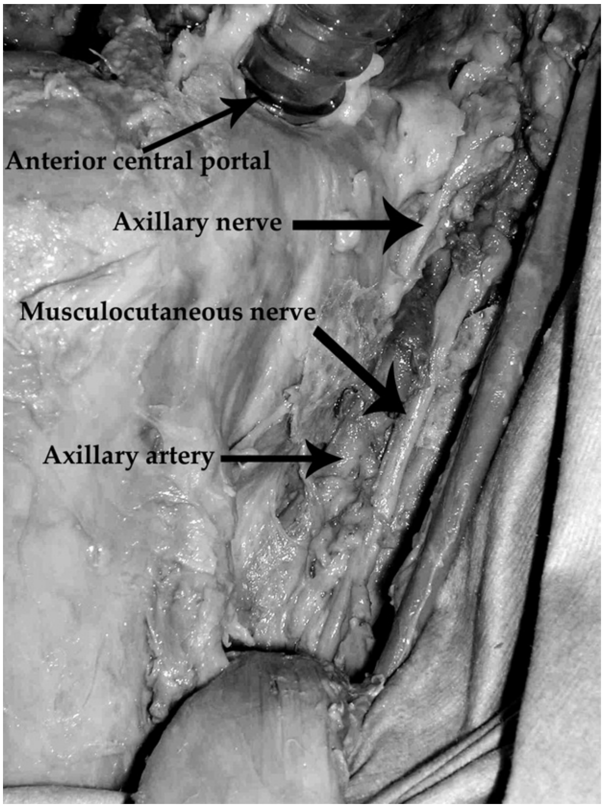

FIGURE 3. Relations between anterior central portal and anterior neurovascular structures.

The Neviaser portal was located at a mean distance of 24 mm away from the suprascapular artery and 26 mm away from the suprascapular nerve. The suprascapular tendon was never injured performing this portal.

The lateral transrotator cuff portal is the nearest lateral portal from the suprascapular nerve at a mean distance measured at 53 mm. This distance was measured at 55 mm for the Port of Wilmington, 56 mm for the lateral posterior portal, 58 mm for the superolateral portal, and 70 mm for the anterolateral portal.

The supraspinatus tendon was systematically crossed by the establishment of the Port of Wilmington and of the transrotator cuff portal, whereas the superolateral portal goes through the rotator interval and the anterolateral and posterolateral portals remain in the subacromial space. Results of dissections are reported in Table 4.

DISCUSSION

The principal finding of our study is the high proximity of the 5 o'clock portal with the axillary artery and nerve. Shoulder arthroscopic portals positioning is a key point in the good realization of surgical gestures. Portals have to allow the surgeon to see the operated zone and have to provide him the work angle and the range of motion required by the surgical procedure. The least portal malpositioning could compromise the operation success. But creation of these portals encounters constraints that are the musculotendinous and neurovascular structures that must not be injured.

Axillary and suprascapular nerves are the 2 nervous structures at most risk in the shoulder arthroscopic portals establishment; thereby, they have been the subject of many anatomic studies. In a study turning on 42 cadavers (20 men and 22 women), Nassar et al.[21] reported a significant difference with the gender regarding the distance between the acromioclavicular joint and the axillary nerve, which is, respectively, 7.90 cm (range, 7.2 to 9.1) for men and 6.37 cm (5.2 to 8.1) for women. As for Bigliani et al.,[22] he showed that the suprascapular nerve was located at a mean distance of 1.8 cm from the posterosuperior labrum and 2.5 cm from the supraglenoid tubercle.

Although known, neurovascular complications of shoulder arthroscopy are not often reported in the literature. In 2001, the prospective study directed by Buisson et al.[23] on 207 shoulder arthroscopies reported a complication rate of 22.7% (10 intraoperative and 37 postoperative), but no vascular nor neural injuries were noticed. As for Rodeo et al.,[2] in a large review, they record studies with complication rates reaching up to 30%, in most cases, regressive neurapraxias after excessive intraoperative arm traction. In a review of 1,184 shoulder arthroscopies performed by 21 expert surgeons, Small[24] did not report vascular or nervous injuries. Matthews et al.[11] described 1 case of high median nerve palsy in a 47 shoulder arthroscopies' series with anterior portals despite the use of intra-articular landmarks to establish these portals. The palsy was definitive, and the patient had subsequently required tendon transfers. Matthews et al. stressed the importance of portals' good positioning.

The aim of the present study was to perform cadaveric dissections with trocars left in place to take into account their volume that was not done in the other anatomic studies in which trocars were replaced by spinal needles or Steinman pins. Remaining trocars placed reduces automatically the range to structures at risk of a distance equal to the half of trocars' diameter, 6 mm in our study. It increases significantly the risk of injury in view of the shortest distance to a structure at risk in our study, which is 5 mm.

TABLE 3. *Description of the Portals of the Study*

Portal's Name (Portal's Author)	Starting Point	Direction
Portals Established by Using an Inside-to-Outside Technique		
Five o'clock (Davidson)	The leading edge of the inferior glenohumeral ligament at the 5 o'clock position of the glenoid rim (right shoulder)	The arthroscope placed through the posterior "soft-point" portal is withdrawn and replaced by a wissinger rod which is passed through the anterior capsule while the humerus is maximally adducted
Anterior inferior (Wolf)	The arthroscope slide off the inferior edge of the coracoid tip	The arthroscope placed through the posterior "soft point" portal is withdrawn and replaced by a wissinger rod which is passed through the anterior capsule
Portals Established by Using an Outside-to-Inside Technique		
Soft point	1.5 cm inferior and 2 cm medial to the posterolateral corner of the acromion	To the coracoid
Central posterior (Wolf)	2 cm medial and 3 cm inferior to the posterolateral corner of the acromion	To the coracoid
Anterior central (Matthews)	Skin point lateral to the coracoid	The space limited by: the humeral head laterally, the glenoid rim medially, the long head of biceps tendon superiorly, the subscapularis tendon inferiorly
Anterior superior (Wolf)	Mid-distance between the coraroid and the acromion	Enters the joint just anterior to the long head of biceps tendon
Neviaser portal	Superior "soft spot" surrounded by: the clavicle anteriorly, the medial edge of the acromion 1 cm medially, the spine of the scapula posteriorly	Down at 30° laterally and slightly posteriorly into the glenohumeral joint
Superolateral (Laurencin)	Lateral to the acromion on a line drawn from the acromion to the coracoid	Enters the joint obliquely directly above the biceps tendon where it pierces the rotator interval tissue
Port of Wilmington	1 cm anterior and 1 cm lateral to the posterolateral corner of the acromion	45° approach angle to the posterosuperior glenoid labrum
Transrotator cuff (O'Brien)	1 cm posterior and 2 cm lateral to the posterolateral corner of the acromion	To the 11 o'clock position on the glenoid labrum (right shoulder)
Anterolateral (Elmann)	2 cm below the lateral edge of the acromion in the prolongation its anterior edge	Medially to the subacromial bursa
Posterolateral (Elmann)	2 cm below the lateral edge of the acromion in the prolongation its posterior edge	Medially to the subacromial bursa

In our study, anterior portals appear to be the most at risk to injure neurovascular structures. Among those structures, the cephalic vein is the most vulnerable because it is reported 6 times at a distance less than 10 mm (25% of all anterior portals dissections). If cephalic vein injuries usually expressed as simple hematomas, Cameron[7] reports a pseudoaneurysm that appeared after a shoulder arthroscopy with cephalic vein injury practiced in a chronic hemodialyzed patient with a homolateral arteriovenous fistula.

According to us, among anterior portals studied, the "5 o'clock portal" is the only approach which should be avoided. Indeed, mean distances to the axillary nerve and artery are low, 13 and 15 mm, respectively, with, for each of these 2 anatomic structures, 2 dissections (33%) found at distance below 10 mm. This conclusion is shared by Pearsall et al.[25] who reproached the "Davidson 5 o'clock portal" established by using an inside-to-outside technique to be too close to anterior neurovascular structures and to be responsible for humeral head chondral injuries. Therefore, Pearsall advised against using the 5 o'clock portal whatever the way of its establishment. Our conclusion differs significantly from Lo et al.'s results[15] (endnote) who did not find the 5 o'clock portal to be unsafe. However, Lo et al.[15] performed their study by using an outside-to-inside technique that is a main difference because it allows this portal to be created from a more lateral point of the anterior aspect of the shoulder. In fact, in the present study using an inside-to-outside technique to create the 5 o'clock portal, the humeral head prevents the Wissinger rod from going out of the joint laterally, and it might explain why lower distances to the relevant structures were found. Lo et al. also removed trocars, and needles were left in place during the dissections that did not take into account the risk related to the trocars' volume. Finally, Lo et al. conducted their study in a lateral decubitus

Table 4. *Mean Distances, [Ranges], and (Standard Deviations) in Millimeters to the Adjacent Neurovascular Structures*

Posterior Portals	Suprascapular Artery	Axillary Nerve	Suprascapular Nerve
Soft point	27 [22-34] (6)	49 [46-58] (9)	29 [24-33] (5)
Posterior central	27 [22-30] (2)	49 [30-73] (19)	29 [25-31] (3)
Anterior Portals	**Axillary Artery**	**Cephalic Vein**	**Axillary Nerve**
Anterior superior	53 [32-67] (10)	39 [20-60] (15)	54 [44-65] (13)
Anterior inferior	42 [10-57] (13)	14 [0-30] (11)	40 [20-55] (17)
Anterior central	33 [18-50] (13)	17 [0-27] (11)	31 [23-37] (8)
Five o'clock	13 [5-20] (6)	17 [6-35] (13)	15 [6-22] (7)
Superior Portal	**Suprascapular Artery**		**Suprascapular Nerve**
Neviaser	24 [16-33] (7)		26 [18-35] (7)
Lateral Portals	**Axillary Nerve**		
Superolateral	58 [49-70] (11)		
Transrotator cuff	53 [33-64] (12)		
Port of Wilmington	55 [42-64] (9)		
Lateral anterior	70 [57-80] (11)		
Lateral posterior	56 [41-67] (13)		

position, whereas the present study examined the safety of the portal in a beach-chair position that might change the distances to the relevant structures. On the other hand, anterior portals are not found at risk for musculotendinous injuries except the 5 o'clock portal, which injured the Pectoralis major muscle twice.

Posterior portals seem to be at a lower risk than anterior portals. The nearest anatomic structure at risk is the suprascapular artery located at a mean distance of 27 mm from the "soft point" and the central posterior portals with a lower distance measured at 24 mm. On the other hand, finding the interval between the supra- and infraspinatus muscles appear to be harder because we noted 4 infraspinatus injuries and 1 teres minor injury.

The Neviaser portal does not appear to be unsafe. We do not report for this portal established in a beach-chair position any supraspinatus injury that does agree with Souryal's results[26] who believes this portal to be used safely provided the arm should be brought to a position of no more than 45° of abduction with no forward flexion during trocar introduction. The neurovascular risk of the Neviaser portal was low with mean distances to the suprascapular artery and nerve of 24 and 26 mm, respectively.

Lateral portals establishment appears safe for the axillary nerve with a range from 53 to 70 mm that is confirmed by Lo et al.'s study[15] that reported on 5 fresh cadavers dissection in whom they never measured the axillary nerve closer than 30 mm from these portals. On the other hand, in our study, the Port of Wilmington always crossed the supraspinatus tendon at the myotendinous junction, whereas for Lo it goes through the interval between supra- and infraspinatus in 4 of his 5 dissections.

Our study's main weakness is that only 12 cadavers were used, and other anatomic structures at risk may have been found with a higher number of cadavers. Another weakness is that 7 out of 12 shoulders used presented a pathology such as rotator cuff tears and long-head biceps ruptures. However, it did not matter for the placement of trocars and the measurement of distances to the structures at risk.

On the other hand, we only used the beach-chair position without arm traction to establish the portals. We chose this position because it is commonly used and because it allows arm mobilization during the trocars insertion procedure. It might have led to different results compared with previous studies that were performed in the lateral decubitus position. We also used 12-mm trocars, which are thicker than those routinely used, and it might have influenced the results in a negative way. We chose this cannulas size because it is the largest available for shoulder arthroscopy, and, consequently, it can be used for this kind of surgery.

Finally, the size of cadavers was not taken into account, which could be considered as another weakness of the study. In fact, it would be logical to find higher distances to anatomic structures at risk for the tallest cadavers.

CONCLUSIONS

The present study shows the safety of the posterior, lateral, and superior portals tested. Anterior portals are the most at risk of neurovascular injuries especially for the 5 o'clock portal that we consider unsafe because they are very close to the anterior neurovascular structures. The only relevant anatomic structure injured was the cephalic vein during anterior portals placement.

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