Vulnerable Neurovasculature with a Posterior Approach to the Scapula

Coen A. Wijdicks MSc, Bryan M. Armitage MSc,
Jack Anavian MD, Lisa K. Schroder BS, MBA,
Peter A. Cole MD

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Abstract Anatomic studies have described areas where there is no direct threat of inadvertent suprascapular nerve injury; however, these studies did not describe danger zones during open reduction and internal fixation of the fractured scapula. We therefore sought to define the topographic distribution in which these vulnerable structures most commonly are found, thus establishing danger zones. Twenty-four nonpaired cadaveric specimens were dissected. The infraspinatus and teres minor musculature were elevated off the posterior scapula body to reveal critical areas where the suprascapular neurovasculature and circumflex scapular artery were vulnerable to injury. We established radial coordinates to determine this relation to osseous landmarks. The mean distance from the spinoglenoid notch to the inferior border of the danger zone was 2.4 cm (range, 1.2–3.8 cm). The mean distance from the medial extent of the scapular spine to the medial border of the danger zone was 4.3 cm (range, 3.0–6.7 cm). The entry of the ascending branch of the circumflex scapular artery was located at the lateral border 5.6 cm (range, 4.5–7.0 cm)

inferior to the spinoglenoid notch. These danger zones can aid the surgeon in determining the risk for suprascapular nerve injury, specifically with scapula fractures involving the spinoglenoid notch and/or lateral border.

Introduction

Anatomic knowledge is paramount with surgical exposure of the shoulder girdle to avoid an area that encompasses the suprascapular nerve. Surgically treated scapula fractures predominantly use a posterior surgical approach in combination with a Judet skin incision to facilitate open reduction and internal fixation [10, 12, 17, 19, 21, 25]. Using the classic Judet posterior approach [10], the infraspinatus muscle is dissected and subsequently retracted from the infraspinatus fossa while avoiding injury to the underlying suprascapular neurovascular bundle. Moreover, it is important to create a window between the infraspinatus and teres minor muscles to avoid denervation of the infraspinatus muscle [7, 20]. In addition, if it is not already thrombosed as a result of trauma, the ascending branch of the circumflex scapular artery typically is ligated intraoperatively to prevent excessive bleeding [19, 21]. Observation of the glenoid and scapula body is paramount to obtain adequate reduction and fixation of the displaced bony fragments. Numerous experimental studies have emphasized intraoperative traction and/or compression of peripheral nerves results in postoperative neurologic deficits [5, 6, 8, 13, 15, 16, 22, 23]. Excessive elevation of the infraspinatus muscle and associated violation of the suprascapular nerve reportedly are risks for iatrogenic injury [6, 7, 19, 21]. However, anatomic studies have described areas where there is no direct threat of inadvertent suprascapular nerve injury during arthroscopic Bankart

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C. A. Wijdicks, B. M. Armitage, J. Anavian,
L. K. Schroder, P. A. Cole
Department of Orthopaedic Surgery, University of Minnesota,
Minneapolis, MN, USA

P. A. Cole (✉)
Department of Orthopaedic Surgery, Regions Hospital,
640 Jackson Street, St Paul, MN 55101, USA
e-mail: peter.a.cole@healthpartners.com

and rotator cuff repair procedures [2, 24, 27]. However, these studies did not relate their findings to surgical procedures or approaches pertaining to open reduction and internal fixation of the fractured scapula.

We aimed to define the topographic distribution in which the (1) suprascapular nerve and the (2) ascending branch of the circumflex scapular artery are most commonly found; and thus (3) establish clinically relevant danger zones of these vulnerable structures as a guide to evoke caution and consideration for these important neurovascular structures during preoperative planning, and intraoperative execution of the posterior approach of the fractured scapula.

Materials and Methods

We dissected the shoulders of 24 nonpaired full-body fixed cadaveric specimens. Specimens were distributed evenly to include 12 female (six left and six right shoulders) and 12 male (six left and six right shoulders) specimens with an average age of 78 years (range, 31–100 years).

For each dissection, the cadaver was placed in a prone position. A posterior skin incision was made starting at the posterolateral acromion and then extending medially toward the medial extent of the scapular spine of the scapula at which point the incision turned caudad to follow the medial (vertebral) border inferiorly to the inferior angle. The skin and subcutaneous tissue were reflected to observe and define the borders of the trapezius muscle. The trapezius was reflected partially to expose the levator scapulae and rhomboid (major and minor) muscles. The distal attachment of the trapezius was identified and reflected from the lateral third of the clavicle, acromion, and scapular spine. The deltoid, supraspinatus, infraspinatus, teres major, and teres minor muscles subsequently were identified. The deltoid muscle was reflected to observe the infraspinatus. The infraspinatus and teres minor musculature were elevated off the posterior scapula body to reveal the suprascapular artery and nerve as they emanated from the spinoglenoid notch. The neurovascular structures were followed superiorly toward the spine of the scapula and then proximally as they traversed the transverse scapular ligament. The visible aspect of the suprascapular nerve was identified coming from its pedicle at the base of the acromion and it was dissected meticulously as it fanned out and entered the infraspinatus muscle. The plane between the infraspinatus and teres minor was dissected carefully down to the lateral scapula border to observe the ascending branch of the circumflex scapular artery and its associated bony groove (Fig. 1).

To compare scapulae of different sizes, we establish a normalized unit of measure based on the anatomy of each

Fig. 1 Anatomic posterior dissection of a right shoulder girdle shows the visible aspect of the suprascapular nerve identified coming from its pedicle at the base of the acromion as it fanned out and entered the infraspinatus muscle. A probe is seen placed underneath the ascending branch of the circumflex scapular artery.

specimen. A radial coordinate system was established by anchoring the hinged apex of a goniometer at the apex of the medial extent of the scapular spine with a Kirschner wire, whereas the lower arm of the goniometer was secured with a Kirschner wire along the medial border. The upper arm of the goniometer was mobile and used to measure the reference distance and angle at the terminal motor branches where the nerve entered the rotator cuff musculature.

We marked points onto the scapula posterior surface with a surgical pen to identify the exact location of the nerve as it traveled along the undersurface of the muscle (Fig. 2). These marks were made by carefully lowering the muscle and pedicle until it contacted the posterior surface, thus allowing careful identification with a permanent marker. Additional points were documented by marking the scapula at key bony landmarks for subsequent normalization [3]. These landmarks included the superior and inferior angles, scapular and spinoglenoid notches, medial and lateral borders, and entry of the circumflex scapular artery [26].

We quantified the scapula using radial (polar) coordinates for morphometric analysis, also known as polar coordinate measurements (Fig. 2). The anatomy of the scapula is conducive to establishing this radial coordinate system as a result of its relatively straight medial (vertebral) border and the natural pole location created by the

Fig. 2 Through a radial coordinate system, the upper arm of the goniometer was used to measure the reference distance to the point of interest and measured angle at the terminal motor branches where the nerve entered the infraspinatus musculature. A point also was noted for the location where the circumflex scapular artery crossed the lateral border.

intersection of the scapular spine with this straight border. Polar coordinates provide a two-dimensional system that can determine a relationship between a point of interest and a reference point and defines it according to an angle (pole angle, θ) and distance (r). The distance measured from a central reference point, known as the pole, was located at the medial extent of the scapular spine and was measured to the point of interest. The angle, otherwise known as the pole angle, refers to the angle required to reach the distance of the point of interest.

To normalize the radial coordinates for each specimen and for laterality, we converted the polar coordinates into a Cartesian (x and y) coordinate system through trigonometric formulae. The redefined x and y values were divided by the normalized distance specific to each individual scapula being analyzed (Fig. 3). Points were plotted and a polynomial curve was fit to the collected nerve path points using MatLab R2006b analysis software (The MathWorks Inc, Natick, MA). Discrete x values were used to calculate y values at each point along the scapula. This created a type of map that allowed for creation of a logical matrix with true values of the nerve path over a standardized scapula.

These matrices then were overlaid, thus creating an intensity map to determine the number of times a nerve ran through a specific point. A normalized scapula with pertinent bony landmarks was overlaid with the suprascapular nerve and ascending branch of the circumflex scapular artery shaded danger zones to show these distance measurements (Fig. 4). These data allowed for graphic construction of the danger zone defining the maximum area of the suprascapular nerve position frequency as it curves around the spinoglenoid notch, and before its intramuscular position in the infraspinatus muscle.

Results

The nerve coursed directly across the supraspinatus fossa around the base of the acromion in a region defined as the spinoglenoid notch. The suprascapular nerve was exposed after exiting the spinoglenoid notch and before entering the infraspinatus muscle, at which point the nerve terminated in up to three terminal motor branches. These last branches of the suprascapular nerve served as the basis for the morphometric results presented in this study because this is most relevant to the operating surgeon using a posterior approach to the shoulder. These branches then continued distally along the undersurface of the infraspinatus muscle. The circumflex scapular artery curved posteriorly around the lateral border of the scapula. It then proceeded to pass posteriorly between the subscapularis and teres major muscle. The ascending branch of the circumflex scapular artery branches off to wrap around the lateral border of the scapula, which, as stated previously, continued to anastomose with the suprascapular artery. The suprascapular neurovascular bundle was exposed in a vulnerable location along the undersurface of the infraspinatus muscle and its trunk was always adjacent to the base of the acromion as it traversed the spinoglenoid notch.

In relation to the medial border with the axis at the medial extent of the scapular spine, the danger zone occurred entirely between pole angles of 62° to 94° . All measurements of the data collected were summarized in a table format (Table 1). The pertinent mean distance, standard deviation, and range between danger zones and bony landmarks were illustrated on a normalized scapula (Fig. 5). The rounded maximal distances (Fig. 5)

Fig. 3A–C (A) A radial coordinate system was used to provide two-dimensional coordinates to determine the relationship between two points based on measured distance (r) and angle (θ) from a central point (Kirschner wire) to the point of interest. (B) Trigonometric formulae of sine and cosine allow for calculation of the radial coordinate to determine x and y values. (C) A Cartesian coordinate system obtained from the previously calculated x and y values provides for scapula standardization and frequency mapping of danger zones onto a template.

produced a triangle determined by a maximum of 7 cm down the lateral border of the scapula from the spinoglenoid notch encompassing the potential location of the circumflex artery entry and 4 cm toward the medial border from the spinoglenoid notch outlining the maximum suprascapular nerve location. The connection of the two sides creates an 8-cm line and thus completes the 4-7-8 triangle (Fig. 6).

Fig. 4A–B (A) A diagrammatic representation shows the suprascapular nerve danger zone position frequency placed over an image of a normalized scapula. (B) A diagrammatic representation shows the danger zone as represented by the mean and standard deviation of the ascending branch of the circumflex scapular artery entry point.

Discussion

Surgically treated scapula fractures predominantly use a posterior surgical approach in combination with a Judet skin incision to facilitate open reduction and internal fixation [10, 17, 19, 21, 25].

Observation of the glenoid and scapula body is paramount to obtain adequate reduction and fixation of the displaced bony fragments, and excessive elevation of the infraspinatus muscle and violation of the suprascapular neurovascular bundle have been described in surgical technique manuscripts as potential risks for iatrogenic injury [6, 7, 19, 21]. Anatomic studies have described areas where there is no direct threat of inadvertent suprascapular nerve injury; however, these studies did not relate their findings to surgical procedures or approaches pertaining to open reduction and internal fixation of the fractured scapula [2, 24, 27]. We aimed to define the topographic distribution in which the (1) suprascapular nerve and the (2) ascending branch of the circumflex scapular artery are most commonly found; and thus (3) establish clinically relevant danger zones of these vulnerable structures.

We designed our study to closely approximate the posterior approach to the scapula using cadaveric specimens. We acknowledge the use of cadaveric specimens may not fully represent the dynamic anatomic relationships in vivo as a result of the formalin fixative, and individual variations may not have been fully identified given the small number of specimens. However, we standardized our technique and consistently measured from the same location among variable types of scapulae. Moreover, with the use of fixed cadaveric specimens, some decreased mobility of structures is known to occur, although studies have described insignificant anatomic differences between embalmed and fresh-frozen specimens [4, 18]. The suprascapular artery

Table 1. Quantitative distance relationships of suprascapular nerve and circumflex scapular artery entry to scapula landmarks on the posterior view

Mean distance $\pm$ standard deviation (range)	Superior angle	Spinoglenoid notch	Suprascapular notch	Circumflex artery crossing lateral border	Inferior angle	Medial border of suprascapular nerve danger zone	Inferior border of suprascapular nerve danger zone
Superior angle	—	5.7 $\pm$ 0.7 cm (4.5–7.0 cm)	3.6 $\pm$ 0.8 cm (1.9–5.0 cm)	8.0 $\pm$ 0.7 cm (6.5–9.3 cm)	12.5 $\pm$ 1.4 cm (9.3–15.3 cm)	4.4 $\pm$ 0.9 cm (2.8–6.2 cm)	4.9 $\pm$ 0.7 cm (3.5–6.2 cm)
Spinoglenoid notch	5.7 $\pm$ 0.7 cm (4.5–7.0 cm)	—	2.2 $\pm$ 0.6 cm (1.1–3.7 cm)	5.7 $\pm$ 0.7 cm (4.5–7.0 cm)	11.2 $\pm$ 1.2 cm (9.1–13.6 cm)	2.5 $\pm$ 0.6 cm (1.3–3.8 cm)	2.4 $\pm$ 0.6 cm (1.2–3.8 cm)
Suprascapular notch	3.6 $\pm$ 0.8 cm (1.9–5.0 cm)	2.2 $\pm$ 0.6 cm (1.1–3.7 cm)	—	3.6 $\pm$ 0.8 cm (1.9–5.0 cm)	11.9 $\pm$ 1.2 cm (9.0–14.3 cm)	2.4 $\pm$ 0.8 cm (1.0–4.5 cm)	2.8 $\pm$ 0.7 cm (1.4–4.5 cm)
Circumflex artery crossing lateral border	8.0 $\pm$ 0.7 cm (6.5–9.3 cm)	5.7 $\pm$ 0.7 cm (4.5–7.0 cm)	3.6 $\pm$ 0.8 cm (1.9–5.0 cm)	—	8.0 $\pm$ 1.2 cm (5.6–9.5 cm)	3.7 $\pm$ 0.9 cm (1.9–5.1 cm)	3.2 $\pm$ 0.7 cm (1.9–4.5 cm)
Inferior angle	12.5 $\pm$ 1.4 cm (9.3–15.3 cm)	11.2 $\pm$ 1.2 cm (9.1–13.6 cm)	11.9 $\pm$ 1.2 cm (9.0–14.3 cm)	8.0 $\pm$ 1.2 cm (5.6–9.5 cm)	—	9.6 $\pm$ 1.1 cm (7.5–11.1 cm)	9.3 $\pm$ 1.2 cm (7.1–11.0 cm)
Medial border of suprascapular nerve danger zone	4.4 $\pm$ 0.9 cm (2.8–6.2 cm)	2.5 $\pm$ 0.6 cm (1.3–3.8 cm)	2.4 $\pm$ 0.8 cm (1.0–4.5 cm)	3.7 $\pm$ 0.9 cm (1.9–5.1 cm)	9.6 $\pm$ 1.1 cm (7.5–11.1 cm)	—	0.6 $\pm$ 0.7 cm (0–2.2 cm)
Inferior border of suprascapular nerve danger zone	4.9 $\pm$ 0.7 cm (3.5–6.2 cm)	2.4 $\pm$ 0.6 cm (1.2–3.8 cm)	2.8 $\pm$ 0.7 cm (1.4–4.5 cm)	3.2 $\pm$ 0.7 cm (1.9–4.5 cm)	9.3 $\pm$ 1.2 cm (7.1–11.0 cm)	0.6 $\pm$ 0.7 cm (0–2.2 cm)	—

Fig. 5 A normalized scapula with pertinent bony landmarks (black dots) was overlaid with the suprascapular nerve and ascending branch of the circumflex scapular artery shaded danger zones to show distance measurements (gray dots). **Fig. 6** The maximum area of vulnerable structures produces the 4-7-8 triangle.

contributes to a highly vascularized shoulder girdle, which assists in fracture healing. Although the suprascapular artery was not quantified, it joined the suprascapular nerve in a neurovascular bundle fashion.

The suprascapular nerve is a mixed sensory and motor peripheral nerve arising from the superior trunk of the brachial plexus (C5-C6) with a variable contribution from the fourth cervical nerve root [1, 14]. We noted the suprascapular nerve to be in a vulnerable location as it tethers against the base of the acromion through the spinoglenoid notch and before entering the innervated infraspinatus muscle. We described boundaries of the suprascapular nerve in relation to the most invariable landmark, the spinoglenoid notch, to be on average 2.5 cm to the medial border and 2.4 cm to the inferior border of the danger zone. In prior anatomic studies, authors have described areas where there is no direct threat of inadvertent suprascapular nerve injury in regard to arthroscopic Bankart and rotator cuff repair procedures [2, 24, 27]. One study detailed a safe zone for avoiding suprascapular nerve injury during open surgical procedures of the posterior shoulder [24]. This study noted the safe zone to be 2 cm medial to the superior rim of the glenoid and 1 cm medial to the posterior rim of the glenoid at the level of the spinoglenoid notch [2]. A subsequent study described a similar purpose and noted a safe zone 2.3 cm medial to the superior rim of the glenoid and 1.4 cm medial to the posterior rim of the glenoid at the level of the spinoglenoid notch [24]. Our study agrees with their frequency data around the glenoid, although we have further quantified the suprascapular nerve as it traverses distal to the spinoglenoid notch before entering the infraspinatus muscle [6, 7, 19, 21]. Furthermore, these studies did not relate their findings to surgical procedures or approaches pertaining to the open reduction and internal fixation of the fractured scapula. A scapula fracture scenario may leave the glenoid comminuted and displaced eliminating the aforementioned study reference point to determine the safe zone. Using our multiple invariable landmarks and associated danger zones will alleviate uncertainty of the actual points of interest.

We noted the ascending circumflex scapular artery as it curved around the lateral aspect of the scapula. This therefore also was defined as highly vulnerable to common fracture patterns, and also to retractors placed over the lateral border. The entry of the ascending branch of the circumflex scapular artery danger zone was located 5.6 cm inferior to the spinoglenoid notch. Technique articles advocate prompt observation and ligation of this artery in the operative scenario to prevent avoidable hemorrhage [7, 9, 19, 21]. One study noted the circumflex scapular artery to be an average of 2.8 cm inferior to the inferior glenoid margin [9]. We believe our data also agree with this previously mentioned data and also provide invariable landmarks pertinent to the posterior approach of a fractured scapula.

With modified surgical approaches to the posterior aspect of the scapula, it is paramount for the surgeon, while

Fig. 7 The relationship of the suprascapular nerve with a posterior approach to the scapula is shown. The suprascapular nerve is shown in close proximity to the retractor, drill, and instrument placement in surgical areas.

dissecting and placing traction onto the innervated muscles (Fig. 7), to be mindful of the area encompassing the suprascapular nerve and circumflex scapular artery [7, 11, 19, 21]. We have identified the anatomic landmarks of the area (danger zone) using frequency mapping of the trajectory of these structures. The 4-7-8 triangle (Fig. 6) could provide a general guideline for the orthopaedic surgeon. Familiarity with these anatomic landmarks using the 4-7-8 triangle can help the surgeon determine risk for suprascapular nerve injury and aid in the selection of surgical approach, dissection strategy, retractor placement, and degree of traction.

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