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Posterior intercostal artery tortuosity and collateral branch points: a cadaveric study

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Publications report observing tortuosity in the posterior intercostal arteries of elderly patients. Studies also describe the size and course of the collateral intercostal arteries. This information is clinically significant when performing thoracentesis and video-assisted thorascopic surgery. To the best of our knowledge, no studies have examined arterial tortuosity or described collateral artery origins relative to bony landmarks. The purpose of this study was to define a safe surgical zone for thoracic access using palpable external bony landmarks. A total of 348 intercostal spaces (3rd–8th) of 29 male and female embalmed cadavers were dissected from the vertebral body to the mid-axillary line to observe the posterior intercostal artery and its collateral branch. The origins of the collateral intercostal arteries relative to the midline of thoracic spinous processes were measured. Mild to moderate tortuosity (arterial curves covering 25–50% of the intercostal space) was observed in at least one posterior intercostal artery in the majority of cadavers. The origins of the collateral intercostal arteries were variable relative to the midline. Additional collateral intercostal arteries distal to the primary collateral branch were observed, most commonly in the 5th intercostal space, which is used in video-assisted thorascopic surgery and thoracentesis. Tortuosity is common in the 3rd to the 8th posterior intercostal arteries, especially in individuals over the age of 60 years. Given the findings of this study, we recommend that any procedure involving placement of a surgical instrument into these intercostal spaces does so at least 120 mm lateral to the midline of the spinous processes. We also recommend pre-procedure ultrasound (intercostal scan) of the posterior and collateral intercostal arteries when performing non-emergent thoracentesis and video-assisted thorascopic surgery, particularly in patients over 60 years of age. (Folia Morphol 2012; 71, 4: 245–251)

Key words: thoroscopy, thoracic surgery

INTRODUCTION

Thoracentesis and thoroscopy are well-established procedures currently in widespread use, and while haemothorax is a rare complication, it is serious when it occurs. The major cause of haemothorax in thoracentesis is laceration of the posterior intercostal artery (ICA) or its collateral branches [8, 10]. Reports of ICA laceration and subsequent haemothorax have existed in the literature since 1970 [4], but at present there is no comprehensive description of the posterior intercostal and collateral vascular anatomy [3]. Another procedure gaining prevalence in clinical use for resection of lung tumours is video-assisted thoracic surgery (VATS). Haemorrhaging secondary to trocar penetration of the chest wall is one of the most common complications associated

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with VATS, and it may be severe [6–8]. One specific patient population at increased risk for haemothorax secondary to chest wall penetration are the elderly, as their posterior intercostal and collateral arteries are known to become more tortuous with advancing age, thereby decreasing the safe access area within the intercostal space (ICS) [1, 10].

The current recommended approach to the thoracic cavity in thoracentesis is 5–10 cm lateral to the spine in the 3rd–8th ICSs [9]. In VATS, access to the thoracic cavity is achieved with trocars at three sites: 1) in the 7th or 8th ICS between the mid-axillary and posterior axillary line, 2) in the 5th ICS at the anterior axillary line, and 3) in the 5th ICS 2 to 3 cm medial to the scapula [5]. It was the objective of this study to find the mean distance from palpable bony landmarks, the spinous processes of T3–T8, to the branch points of the collateral branch of the posterior ICA, the branch point of additional collateral branches of the posterior ICA, and points of maximum tortuosity within the ICS of T3–T8. This information will hopefully define a surgical safe-zone for thoracic access using external landmarks that may be palpated intraoperatively, thereby decreasing the incidence of haemothorax in thoracentesis and VATS procedures.

MATERIAL AND METHODS

Twenty-nine embalmed human cadavers (16 male/13 female) were selected for the study. The average age of the specimens was 71 years, with 23 specimens greater than the age of 60 and 6 less than the age of 60. The 3rd to the 8th ICS of each cadaver was dissected bilaterally, giving a total of 348 dissected ICSs. The dissection involved removing the anterior thoracic wall to the mid-axillary line bilaterally and removing the thoracic viscera, as well as the parietal pleurae and innermost intercostal muscles. To expose the posterior ICA and their collateral branches, the intercostal nerves were carefully retracted and removed. Care was also taken not to disturb the fat surrounding the underlying vessels or alter their course through the ICS.

Posterior intercostal artery mean outside diameter

The outside diameter of the posterior ICA was measured at the costal angle in the 3rd–8th ICSs bilaterally using a flexible fiberglass ruler. The diameters were averaged for each individual ICS bilaterally.

Posterior intercostal artery collateral branch

With respect to the collateral branch of the posterior ICA the following measurements and observations were made: 1) With the cadaver prone, the distance from the midline of the spinous processes to the point where the collateral branch originates/ /branches from the posterior ICA was measured; 2) Also with the cadaver prone, the distance from the midline to the point where the collateral branch reaches the superior edge of the rib below the respective ICS was measured; 3) The incidence that the posterior ICA produces an additional collateral branch was tabulated; 4) Again with the cadaver prone, the distance from the midline of the spinous processes to the origin/branch point of the additional collateral branch was measured. We defined an additional collateral branch of the posterior ICA as those arteries observed originating from the posterior ICA and descending to the superior margin of the rib below, and having the same outside diameter as the more medial and typical collateral branch.

With the cadaver supine, white-headed marking pins 1 mm in diameter were placed at the points of collateral posterior ICA origin/branch points. Red-headed marking pins 1 mm in diameter were placed at the point where the collateral posterior ICA reached the superior margin of the inferior rib of the respective ICS (Fig. 1). White-headed marking pins 1 mm in diameter were also placed at the origin/branch points of any additional collateral arteries (Fig. 2).

Posterior intercostal artery tortuosity

With respect to the tortuosity of the posterior ICA the following measurements and observations were made: 1) The vertical distance of tortuosity occupying the ICS as well as the vertical distance of the entire ICS was measured so the percentage of tortuosity occupying the ICS could be calculated; 2) With the cadaver prone, the distance from the midline to the site of maximum tortuosity of the posterior ICA was measured; 3) The incidence that the tortuosity of the posterior ICA occupied more than 30% of the ICS was tabulated as this represents exposure and therefore vulnerability of the artery in the ICS; 4) The incidence that posterior intercostal arterial tortuosity was present in a cadaver over the age of 60 was tabulated. We defined maximum tortuosity as the point at which the posterior ICA deviated farthest inferiorly into the ICS from its typical course in the costal groove.

Yellow-headed marking pins 1 mm in diameter were placed at the point of maximum arterial tortuosity to mark the inferior margin of the superior rib and the superior margin of the inferior rib. Measurements were then taken in millime-

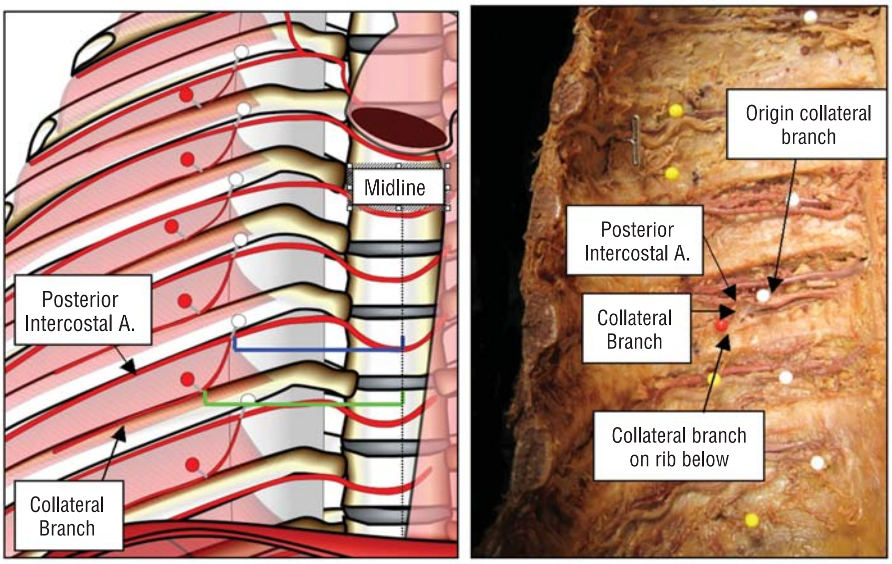

Figure 1. Measurements for the collateral branch of the posterior intercostal artery. Distance was measured from the midline to the white pin, representing the distance from the midline to the origin/branch point of the collateral branch from the posterior intercostal artery. Distance was measured from the midline to the red pin, representing the distance from the midline to the point where the collateral branch reaches its destination on the superior edge of the rib inferior to each respective intercostal space.

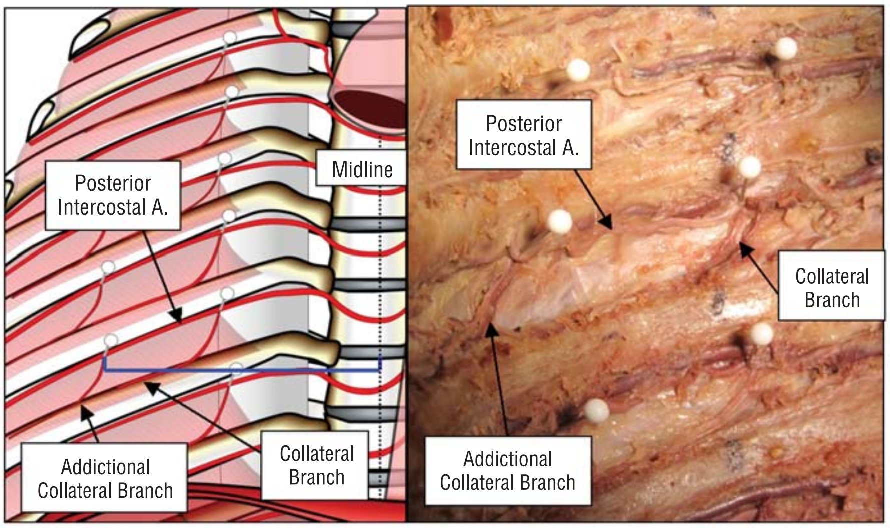

Figure 2. Identification and measurement of additional collateral branches from the posterior intercostal arteries. White-headed pins represent the origin/branch point of the collateral branches of posterior intercostal arteries as well as any additional collateral branches from the posterior intercostal arteries. Distance was measured from the midline to the more lateral white pin, representing the distance from the midline to the origin/branch point of the additional collateral branch from the posterior intercostal artery.

tres to calculate the percentage of the ICS traversed by the tortuous artery below the costal groove (Fig. 3).

Measurements from the midline

The trapezius, latissimus dorsi, and rhomboid muscles were removed to reduce the muscle tissue thickness through which the marking pins would pass. The aim was to minimise the deflection of the marking pins passing in an anterior to posterior direction through the erector spinae and intercostal muscles. With the cadaver prone, a goniometer was fixed with pins such that the vertical leg was midline on the spinous processes of T3–T8 and the horizontal leg extended laterally at 90°. A calliper was then held parallel to the horizontal leg of the goniometer, in simultaneous contact with the marking pin, the posterior surface of the erector spinae or intercostal muscles, and

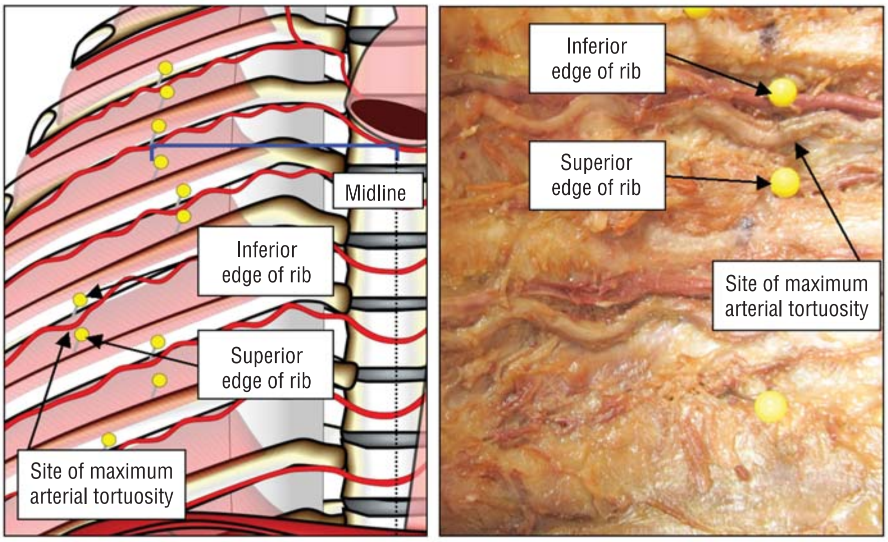

Figure 3. Identification of the point along the posterior intercostal artery where the vessel is most tortuous. Pins were placed to mark the inferior edge of the superior rib and the superior edge of the inferior rib at the site where the artery was measured to be the most tortuous. The amount that the tortuosity occupied the intercostal space as well as the whole intercostal space was measured so the percentage that the tortuosity occupied the intercostal space could be calculated. The distance from the midline to the site of maximum tortuosity was also measured.

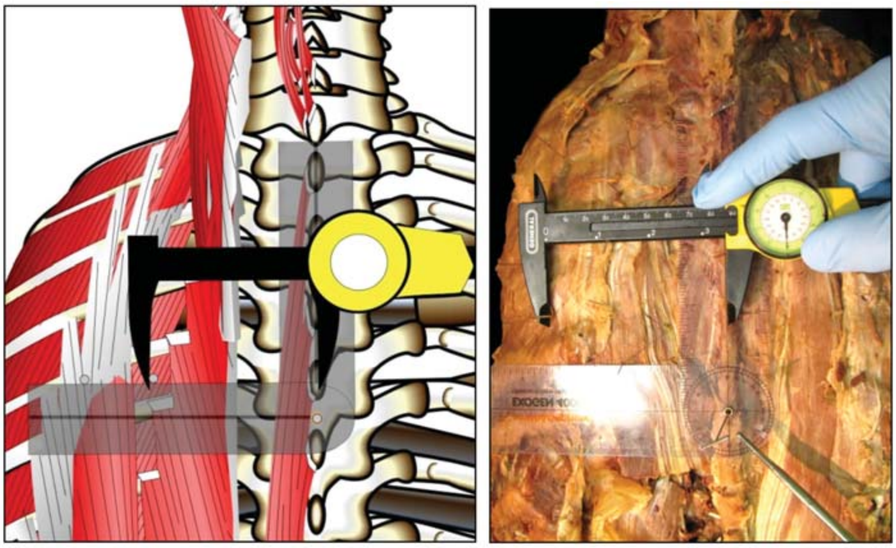

Figure 4. Measurements were made from the midline 90° to the each marker using a goniometer to ensure the measurements were made 90° from the midline, as well as a caliper to measure the distance.

the midline of the spinous processes. Measurements were taken in this manner of the distances from the midline to 1) the branch points of the collateral branch of the posterior ICA, 2) the point where the collateral branch reached the superior edge of the inferior rib in the respective ICS, 3) the branch point of any additional collateral branches of the posterior ICA, and 4) points where posterior intercostal arterial tortuosity reached its maximum in the ICS (Fig. 4).

RESULTS

Posterior intercostal artery mean outside diameter

The average outside diameter of the posterior ICA for the 3rd–8th right and left ICS is listed in Table 1.

Posterior intercostal artery collateral branch

Collateral branches of the posterior ICA were observed in 97.1% (338/348) of specimens. The average

Table 1. The mean outside diameter (and range) of the posterior intercostal artery at the costal angle for intercostal spaces (ICS) 3–8 on the right and left side (n = 348)

ICS	Left [mm]	Right [mm]
3	1.2 (1–2)	1.1 (0.5–1.5)
4	1.6 (1–2.5)	1.4 (1–1.5)
5	1.6 (1–2.5)	1.5 (1–2)
6	1.7 (1–2.5)	1.6 (1–2)
7	2.0 (1–3)	1.8 (1–2.5)
8	2.2 (1.5–3)	2.2 (1–3)

Table 2. The average distance (and range) from the midline to the origin/branch point of the collateral branch from the posterior intercostal artery (n = 338)

Intercostal space	Left [mm]	Right [mm]
3	43.1 (24–89)	42.6 (24–82)
4	45.9 (26–73)	50.0 (30–84)
5	51.0 (34–73)	55.2 (36–80)
6	52.7 (34–85)	53.6 (25–77)
7	50.0 (31–68)	53.0 (26–97)
8	50.6 (28–98)	47.9 (34–67)

distance and range from the midline to the origin/branch point of the collateral branch from the posterior ICA for the 3rd–8th right and left ICS is listed in Table 2.

Collateral branches of the posterior ICA were observed intact traversing the ICS and reaching the superior edge of the rib below in 95.1% (331/348) of specimens. The average distance and range from the midline to the point where the collateral branch reached the superior edge of the rib inferior to its respective ICS for the 3rd–8th right and left ICS is listed in Table 3.

An additional collateral branch lateral to the primary collateral branch of the posterior ICA was observed in 82.8% (24/29) of cadavers. This variation was most commonly observed in the 5th ICS with 30.1% (31/103) of 5th ICSs displaying this variation. The average distance from the midline to the origin/branch point of the additional collateral branch from the posterior ICA for the 3rd–8th right and left ICS is listed in Table 4.

Table 3. The average distance (and range) from the midline to the point where the collateral branch of the posterior intercostal artery reached the superior edge of the rib inferior to its respective intercostal space (ICS) (n = 331)

ICS	Left [mm]	Right [mm]
3	57.88 (32–99)	55.5 (31–85)
4	59.4 (40–96)	61.5 (38–88)
5	63.2 (47–86)	67.2 (41–87)
6	65 9 (47–96)	66.3 (36–88)
7	65.9 (45–79)	68.5 (31–105)
8	66.0 (40–108)	65.5 (47-–81)

Posterior intercostal artery tortuosity

Tortuosity of the posterior ICA that occupied more than 30% of the ICS was observed in 86.2% (25/29) of cadavers. Tortuosity of the posterior ICA that occupied more than 30% of the ICS was observed in 96% (22/23) of cadavers over the age of 60. Tortuosity of the posterior ICA that occupied more than 30% of the ICS was observed in 67% (4/6) of cadavers under the age of 60. The average percentage of the ICS occupied by the maximum posterior ICA tortuosity, i.e. the location where the tortuous artery dips inferiorly into the ICS for 3rd–8th right and left ICS, is listed in Table 5. The average distance and range from the midline to the point of maximum posterior intercostal arterial tortuosity, i.e. the location where the

Table 4. The average distance (and range) from the midline to the origin/branch point of the additional collateral branches of the posterior intercostal artery

Intercostal space	Incidence	Left [mm]	Right [mm]
3	7/58	83.5 (52–96) (4/29)	89.7 (78–11) (3/29)
4	22/58	94.1 (64–122) (10/29)	100.9 (80–124) (12/29)
5	31/58	91.7 (64–122) (17/29)	108.1 (79–148) (14/29)
6	25/58	118 (84–152) (9/29)	112.9 (66–143) (16/29)
7	15/58	105 (92–143) (7/29)	115.8 (97–142) (8/29)
8	5/58	87 (1/29)	112 (96–139) (4/29)

Table 5. The average percentage of the intercostal space (ICS) occupied by the tortuous posterior intercostal artery at the site of maximum tortuosity

ICS	Left	Right
3	32%	33%
4	38%	40%
5	31%	38%
6	37%	35%
7	34%	39%
8	31%	35%

tortuous artery dips inferiorly into the ICS for the 3rd–8th right and left ICS, is listed in Table 6.

DISCUSSION

Thomsen et al. [9] recommended a needle insertion point 5–10 cm lateral to the spine for thoracentesis. Da Rocha et al. [3] recommended that the 6th, 7th, or 8th ICS and a more lateral approach were preferable. ACS Surgery, Principles and Practice [5] recommend three access sites for scope and instruments in VATS: 1) scope: 7th or 8th ICS, between the posterior and mid-axillary lines, 2) instrument 1: 5th ICS, on the anterior axillary line, and 3) instrument 2: 5th ICS, 2–3 cm medial to the scapula.

In the current study, we sought to describe the posterior ICA anatomy in terms of collateral branch point position, the presence of multiple collateral branch points, and arterial tortuosity. Our goal was to define a surgical safe-zone for preventing haemorrhage during thoracentesis and VATS, which involves penetrating the chest wall with instruments 5–12 mm in diameter. The results for the 6th, 7th, and 8th ICS in terms of mean collateral posterior ICA branch point and inferolateral distance travelled (Tables 2, 3) are compelling, both for thoracentesis and VATS. The mean distances reported in our study place the collateral posterior ICA coursing inferolaterally in the following positions relative to the midline: ICS 6 = 51 → 66 mm (left), 54 → 67 mm (right); ICS 7 = 50 → 56 mm (left), 53 → 68 mm (right), ICS 8 = 51 → 66 mm (left), 48 → 66 mm (right) (Fig. 5). The collateral branch of the posterior ICA, which, based on our findings, exists in this area, is vulnerable to laceration if any of the 3 thoracentesis approaches described above are utilised. In terms of VATS, the distances for the 7th and 8th ICSs reported above also place the collateral branch of the posterior ICA in a vulnerable area if the scope is positioned as described above. Also important for VATS are the collateral branch point findings for ICS 5. We observed the collateral branch of the posterior ICA coursing inferolaterally in ICS 5 = 51 → 63 mm (left), 55 → 67 mm (right). This location renders the artery vulnerable to laceration by the insertion of instrument 2 at the position described above.

To the best of our knowledge our observation of multiple collateral posterior ICA fills a void in the literature and has multiple clinical applications given the common practice of inserting instruments into the ICS. The majority of individuals examined (83%) possessed an additional collateral branch of the posterior ICA, with mean distances from the midline as follows: ICS 7 = = 105 mm (left), 116 mm (right) and ICS 8 = = 87 mm (left), 117 mm (right) (Fig. 5). These results are particularly relevant to VATS as the arteries observed in the 7th and 8th ICSs were between the posterior and mid-axillary line, the area recommended by Flores et al. [5] for insertion of the scope. It is also notable that the additional collateral branch of the posterior ICA occurred most commonly in the 5th ICS; however, further analysis is warranted to determine the significance of this result and its implications in VATS, thoracentesis, and other procedures.

Table 6. The average distance (and range) from the midline to the point of maximum arterial tortuosity of the posterior intercostal artery

Intercostal space	Incidence	Left [mm]	Right [mm]
3	9/58	81.4 (62–109) (5/29)	60.8 (47–70) (4/29)
4	23/58	87.7 (64–118) (11/29)	78.2 (60–101) (12/29)
5	22/58	90.5 (67–135) (8/29)	84.6 (47–133) (14/29)
6	30/58	94.6 (62–146) (15/29)	86.3 (59–119) (15/29)
7	29/58	92.4 (67–127) (19/29)	91.1 (61–129) (10/29)
8	31/58	95.7 (73–127) (15/29)	83.9 (69–116) (16/29)

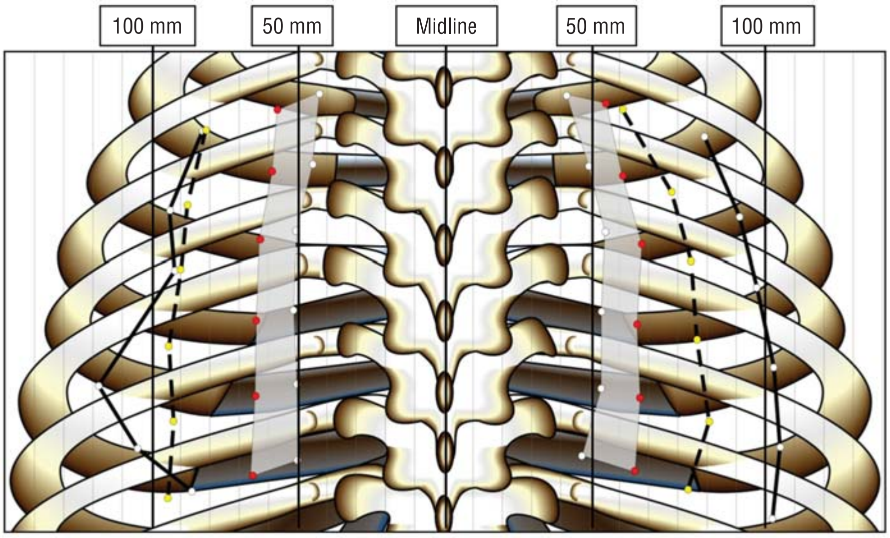

Figure 5. The figure illustrates the regions of intercostal spaces 3–8 relative to the posterior thoracic wall where there is an increased chance of lacerating the posterior intercostal artery or one of its collateral branches. The greyed-out box represents the average distance from the midline where the collateral branch originates from the posterior intercostal artery to where it reaches its position on the superior edge of the rib inferior to each intercostal space. The dashed line represents the average distance from midline to where the posterior intercostal artery becomes most tortuous. The solid line represents the average distance from the midline to where additional collateral branches originate from the posterior intercostal artery.

The tortuosity phenomenon is reported to be present in elderly individuals [2], but to our knowledge, the overall incidence is unknown. For distances from the midline to the point of maximum posterior ICA tortuosity, the current study observed: ICS 6 = 92 mm (left), 80 mm (right); ICS 7 = = 92 mm (left), 93 mm (right); and ICS 8 = = 96 mm (left), 84 mm (right). These positions of maximum posterior artery tortuosity increase the likelihood of laceration in both the thoracentesis technique described above and VATS scope placement.

The findings of this study provide areas where thoracic access in thoracentesis and VATS may be accomplished with decreased probability of injuring the posterior ICA and its collateral branches in ICS 3–8. Given that the 5th ICS had the highest number of additional collateral arteries traversing the ICS, perhaps the 4th or 7th ICS would make better choices for thoroscopic procedures. Furthermore, given the findings of the current study, it is recommended that any procedure that involves placement of a surgical instrument into the ICS take place at least 120 mm lateral to the midline. Finally, given that 96% of cadavers over the age of 60 possessed tortuosity of the posterior ICA that blocked over 30% of the ICS, it is recommended that pre-procedure ultrasound (intercostal scan) of the posterior and collateral ICA is performed for non-emergent thoracentesis and VATS for that patient population.

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