Survey of anatomical characteristics of the internal thoracic artery branches through multidetector row computed tomography

Nguyen Anh Tu[1]*, Vu Quang Vinh[2] and Tran Van Anh[2]

[1]Military Hospital 103,
[2]Le Huu Trac National Burn Hospital

Summary

Objective: To describe the anatomical features of the perforating branches of the internal thoracic artery through Multidetector row computed tomography. *Subjects and method:* A cross-sectional and prospective descriptive study on 100 healthy individuals whose perforating branches of the internal thoracic artery from intercostal space I to intercostal space VI were examined at the Department of Diagnostic Imaging, Military Hospital 103, from January 2023 to December 2024. *Result:* Distance from the point of skin penetration to the sternal edge on the same side as the penetrating branch of the internal thoracic artery: The average distances between the right and left first intercostal space are 0.42 ± 0.16cm and 0.42 ± 0.18cm, respectively; between the right and left second intercostal space are 0.76 ± 0.37cm and 0.74 ± 0.38cm, respectively; between the right and left third intercostal space are 0.68 ± 0.39cm and 0.75 ± 0.39cm, respectively; between the right and left fourth intercostal space are 0.95 ± 0.62cm and 1.13 ± 0.6cm, respectively; and between the right and left fifth intercostal space are 2.12 ± 1.49cm and 2.42 ± 1.31cm, respectively. Length of the perforating branch of the internal thoracic artery to the point of skin penetration: The average length of the perforating branch of the internal thoracic artery to the point of skin penetration at the right and left intercostal space I is: 7.86 ± 2.47 and 7.94 ± 2.55cm; at the right and left intercostal space II is: 10.08 ± 3.07 and 10.07 ± 2.94cm; at the right and left intercostal space III is: 8.8 ± 2.82 and 9.8 ± 3.13cm; at the right and left intercostal space IV is: 8.38 ± 2.56 and 8.24 ± 2.1cm; at the right and left intercostal space V is: 7.19 ± 1.52 and 7.26 ± 1.82cm. Distance from origin to lateral sternal edge: The average distance from origin to lateral sternal edge at the right and left intercostal space I is: 0.43 ± 0.21 and 0.42 ± 0.19cm; at the right and left intercostal space II is: 0.63 ± 0.4 and 0.75 ± 0.45cm; at the right and left intercostal space III is: 0.54 ± 0.52 and 0.89 ± 0.81cm; at the right and left intercostal space IV is: 0.43 ± 0.21 and 1.07 ± 0.97cm; at the right and left intercostal space V is: 1.34 ± 1.11 and 1.81 ± 2.06cm. Diameter of the perforating branches of the internal thoracic artery: The average diameter of the perforating branches of the internal thoracic artery in the first intercostal space on the right and left is: 1.43 ± 1.22 and 1.56 ± 1.44mm; in the second intercostal space on the right and left is: 1.44 ± 1.59 and 1.83 ± 1.62mm; in the third intercostal space on the right and left is: 1.27±1.12 and 2.19 ± 1.29mm; in the fourth intercostal space on the right and left is: 1.17 ± 0.84 and 1.03 ± 0.57mm; in the fifth intercostal space on the right and left is: 0.89 ± 0.68 and 0.52 ± 0.8mm. Origin diameter of the perforating branches of the internal thoracic artery: The average origin diameter of the perforating branches of the internal thoracic artery in the first intercostal space on the right and left is: 1.98 ± 1.78 and 2 ± 1.64mm; in the second intercostal space on the right and left is: 1.67 ± 1.59 and 1.72 ± 1.63mm; in the third intercostal space on the right and left is: 1.45 ± 1.49 and 1.56 ± 1.45; in the fourth intercostal space on the right and left is: 0.73 ± 1.39 and 1.45 ± 1.4 mm; in the fifth intercostal space on the right and left is: 0.59 ± 1.26 and 0.84 ± 1.4 mm. *Conclusion:* Number of perforating branches in rib spaces, distance from the point of

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***Correspondence to**: drnguyenanhtu@gmail.com - Military Hospital 103*

skin penetration to the sternal edge on the same side as the penetrating branch of the internal thoracic artery, length of the perforating branch of the internal thoracic artery to the point of skin penetration, distance from origin to lateral sternal edge, diameter of the perforating branches of the internal thoracic artery, origin diameters of the perforating branches of the internal thoracic artery vary depending on their location.

Keywords: Branches, The internal thoracic artery, Multidetector row computed tomography.

I. BACKGROUND

Imaging techniques have revolutionized the surveying of small blood vessels and perforating branches before surgery. With the combination of imaging techniques for vascular mapping, we can not only locate dominant perforating branches but also obtain information about the vascular system and flap donor area thanks to the anatomical images provided by these methods. The imaging technique used is multidetector row computed tomography (MDCT) [1,2].

Through the anatomical images provided by this method, we can know the number of perforating branches, their location, their course in the muscle, and their distribution in the subcutaneous tissue. Their sensitivity and specificity are 100% at the time of locating the dominant perforating branch, and these techniques are also reproducible (image reconstruction). In addition, the increased spatial resolution of MDCT allows for the observation of images in multiple planes with high accuracy and 3D image reconstruction, creating three-dimensional images of the perforating branches. Another advantage is that these imaging techniques also provide anatomical images of the scanned area. This is particularly useful in patients who have undergone previous surgery because it helps identify any changes that may occur in the blood-supplied area and surrounding tissue. These techniques have also helped reduce surgical time and reduce complications [1,2,3,4].

In Vietnam, research on the occipitocervical-thoracic flap in chin and neck reconstruction has only achieved initial results. The application of multi-detector computed tomography to reconstruct perforating branches helps surgeons determine the anatomical vascular map of the patient before surgery, shortening time and improving surgical efficiency. Therefore, we conducted this study with the aim of characterizing the anatomical features of the perforating branches of the internal thoracic artery through MDCT imaging, hoping to contribute to the information base for optimizing clinical decisions.

II. SUBJECT AND METHOD

100 healthy individuals underwent examination of the perforating branches of the internal thoracic artery from intercostal space I to intercostal space VI at the Diagnostic Imaging Department of Military Hospital 103 from January 2023 to December 2024.

Patient selection criteria:

Healthy individuals

Exclusion criteria:

Patients who did not consent to participate in the study.

A prospective, cross-sectional descriptive study.

Research Variables:

Age, gender.

Location and number of perforating branches of the internal thoracic artery on the chest wall.

Distance from the point of skin penetration to the ipsilateral sternal edge of the perforating branch of the internal thoracic artery.

Length from origin to point of skin penetration of the perforating branch of the internal thoracic artery.

Diameter of the perforating branch of the internal thoracic artery.

Origin diameter of the perforating branch of the internal thoracic artery.

Data processing: SPSS 26.0 medical statistical software.

III. RESULT

Characteristics of the study subjects: Our study surveyed 100 healthy individuals, including 67 males and 33 females, with average ages of 59.16 and 57.06, respectively.

Table 1. Location and number of perforating branches of the internal thoracic artery at the intercostal spaces

Position	Right	Left	Total
Rib space I	93	96	189
Rib space II	93	93	186
Rib space III	91	89	180
Rib space IV	28	27	55
Rib space V	11	6	17
Rib space VI	0	0	0
Total	627		

Comment: On MDCT images, the perforating internal thoracic artery branches most frequently appear at Rib space I to Rib space III (respectively: 189, 186, 180).

Table 2. Distance from the point of skin penetration to the sternal edge on the same side as the penetrating branch of the internal thoracic artery

Position	Right	Left	p
Rib space I	0,42 ± 0,16	0,42 ± 0,18	0,77
Rib space II	0,76 ± 0,37	0,74 ± 0,38	0,86
Rib space III	0,68 ± 0,39	0,75 ± 0,39	0,14
Rib space IV	0,95 ± 0,62	1,13 ± 0,6	0,85
Rib space V	2,12 ± 1,49	2,42 ± 1,31	0,61

Comment: There was no difference in distance to the sternal edge on the same side between the right and left rib space.

Table 3. The average length from origin to the point of skin penetration

Position	Right	Left	p
Rib space I	7,86 ± 2,47	7,94 ± 2,55	0,66
Rib space II	10,08 ± 3,07	10,07 ± 2,94	0,95
Rib space III	8,8 ± 2,82	9,8 ± 3,13	0,1
Rib space IV	8,38 ± 2,56	8,24 ± 2,1	0,63
Rib space V	7,19 ± 1,52	7,26 ± 1,82	0,52

Comment: The average length from origin to the point of skin penetration of the perforating branch of the internal thoracic artery is greatest in the branch at approximately Rib space II. This distance does not differ between the right and left sides.

Table 4. Distance from origin to lateral edge of sternum

Position	Right	Left
Rib space I	0.43 ± 0.21	0.42 ± 0.19
Rib space II	0.63 ± 0.4	0.75 ± 0.45
Rib space III	0.54 ± 0.52	0.89 ± 0.81
Rib space IV	0.43 ±0.21	1.07 ± 0.97
Rib space V	1.34 ± 1.11	1.81 ± 2.06

Comment: The average distances from origin to the sternal edge on the same side for Rib space I to Rib space V are: 0.39 ± 0.47; 0.48 ± 0.45; 0.78 ± 0.68; 0.59 ± 0.1; and 0.3 ± 0.3, respectively.

Table 5. Diameter of the perforating branches and origin of the perforating branches of the internal thoracic artery

Position	Internal Thoracic Artery Perforating Branch			Origin of the Internal Thoracic Artery Perforating Branch		
	Minimum	Maximum	Medium	Minimum	Maximum	Medium
Rib space I right	0.83	2.05	1.43 ± 1.22	0.79	2.78	1.98 ± 1.78
Rib space I left	0.81	2.37	1.56 ± 1.44	0.87	2.87	2 ± 1.64
Rib space II right	0.95	2.38	1.44 ± 1.59	0.87	2.55	1.67 ± 1.59
Rib space II left	0.91	2.74	1.83 ± 1.62	0.79	2.51	1.72 ± 1.63
Rib space III right	0.51	1.78	1.27 ± 1.12	0.75	2.20	1.45 ± 1.49
Rib space III left	0.51	2.76	2.19 ± 1.29	0.86	2.42	1.56 ± 1.45
Rib space IV right	0.31	1.47	1.17 ± 0.84	1.06	1.79	0.73 ± 1.39
Rib space IV left	0.32	1.35	1.03 ± 0.57	0.69	2.14	1.45 ± 1.4
Rib space V right	0.3	1.2	0.89 ± 0.68	1.03	1.62	0.59 ± 1.26
Rib space V left	0.38	0.9	0.52 ± 0.8	0.85	1.69	0.84 ± 1.4

Comment: The average diameter of the perforating branch is largest in Rib space III on the right and smallest in Rib space VI on the left. The origin diameter of the internal thoracic artery perforating branch is largest in Rib space I on the left and smallest in Rib space VI on the right.

IV. DISCUSSION

In the study of the perforating branches of the internal thoracic artery on MDCT imaging, to date only Kimiko Nakatani, Ko Okumura and colleagues have described the anatomical characteristics of the perforating branches of the internal thoracic artery. However, these authors also applied the perforating branches of the internal thoracic artery in breast reconstruction in female patients, and did not apply the ultra-thin occipitocervical-thoracic flap for chin-neck reconstruction [5], [6].

Location and number of perforating branches of the internal thoracic artery in Rib spaces

In our study, in Rib spaces from I to VI, only a maximum of 1 perforating branch appeared. This result is similar to Nakatani's result with 25 cases showing 1 branch and 2 cases showing 2 branches; Okumura only showed a few cases with 2 branches (8 images/131 images) and no cases with more than 3 branches [5], [6]. This result is similar to the result of Jonas Brandt (2025) [7] when the rate of perforating arterial branches was 99% of patients with an average number of 3.35 ± 1.30 per patient.

Perforating branch rate at Rib spaces: In our study, perforating branches frequently appeared at Rib spaces I, II and III (the number detected was 189, 186, 180 respectively out of a total of 627), the detection rate of perforating branches at Rib spaces IV and V was low (rates of 55/627 and 17/627 respectively), and no branches were detected at Rib space VI. The results were also similar to the studies of Okumura (49/121 at Rib space I, 52/121 at Rib space 2 and 23/121 at Rib space III, 6/121 at Rib space IV and 1/121 at Rib space V), Nakatani (5/47 at Rib space I, 27/47 at Rib space II, 6/47 at Rib space III and IV, 2/47 at Rib space V) [5] [6]. The authors also did not detect any perforating branches at Rib space VI. However, this result is different from studies on cadaver anatomy and CT or MRI scans:

Table 4.1: Summary of reports on the location of perforating branches of the internal thoracic artery [8, 9, 10, 11, 12, 5, 13, 14, 15, 6]

Position	1ICS	2ICS	3ICS	4ICS
Palmer and Taylor(1986), anatomical (n=40)	23%	57%	10%	10%
Munhoz et al (2004), anatomical (n=22)	5%	63%	27%	5%
Munhoz et al (2004), clinical (n = 29)		69%	17%	4%
Rosson et al (2005), anatomical (arterial) (n = 20)	10%	50%	25%	10%
Saint-Cyr et al (2007), clinical (n = 27)		41%	53%	6%
Kimiko Nakatani et al (2008), MDCT (n = 38)	10,4%	56,3%	14,6%	12,5%
Paes et al(2011), anatomical (n = 27)	6%	83%	11%	0%
Schellekens et al (2011), anatomical (n = 27)	15%	67%	19%	
Halim and Alwi (2013), clinical (n = 30)	3%	63%	22%	12%
Schellekens et al (2013), CT,MRI (n = 72)	42%	43%	8%	8%
Ko Okumura et al (2016), MDCT (n = 70)	37,4%	39,7%	17,6%	5,3%

The results in the table above show that in autopsy studies, the location of perforating branches is quite consistent, showing that the most perforating branches are located in the Rib space II. However, with perforating branches from Rib space I, the results are different. One study reported that perforating branches from Rib space I are rare [9], while another study said that the second most common branch is the one originating from Rib space I [8].

According to Nakatani's report (2008), using MDCT, most perforating branches appear in the Rib space II (56.3%), while other Rib spaces only account for a few tens of percent. According to Kim et al.'s report 2012 [16], with the study of the perforating branch of the internal thoracic artery using CTA imaging, the results showed that 46% had a perforating branch in the Rib space II area, 33% in the Rib space I area, and 20% in the Rib space III area. Kim's results are quite similar to our study. However, Kim used the CTA vascular survey method and mainly the correlations of the perforating branch with the deep inferior epigastric artery perforating branch.

Distance from the skin penetration point to the sternal edge on the same side of the internal thoracic artery perforating branch:

In our study, the average distance from the skin penetration point to the sternal edge on the same side of the internal thoracic artery perforating branch was calculated in Rib space intervals and divided equally on both sides. The results are shown in Table 2.

Our results are equivalent to the results of Manfred Schmidt et al. (2008) [17], in anatomical studies on cadavers with the result that the average position of the skin penetration point to the sternal edge is within 1cm of the sternal border on the same side. Or the results of Joshua A. Gillis et al. (2011) [18] in a study analyzing three-dimensional images of the internal thoracic artery flap on cadavers, with the result that the distance from the sternal edge to the skin penetration point of the internal thoracic artery perforating branch.

Length of the perforating branch of the internal thoracic artery to the point of skin penetration:

In our study, the length of the perforating branches, calculated according to each Rib space with the corresponding side, yielded the results shown in Table 3.

Our results are similar to those of Melad Naim Kelada et al [19] in their anatomical report on perforating flaps of the internal thoracic artery on

cadavers. Similarly, the results of M. Schmidt are also similar in an anatomical study report on the perforating branch of the internal thoracic artery on fresh cadavers [17].

Distance from origin to lateral sternal edge:

Our research results on the distance from origin (the point of separation of the perforating branch of the internal thoracic artery) to the lateral sternal edge on the same side are:

The average Rib space I distance on the right and left sides is: 0.43 ± 0.21 and 0.42 ± 0.19cm.

The average distance of Rib space II on the right and left sides is: 0.63 ± 0.4cm and 0.75 ± 0.45cm, respectively.

The average distance of Rib space III on the right and left sides is: 0.54 ± 0.52cm and 0.89 ± 0.81cm, respectively.

+ The average distance of Rib space IV on the right and left sides is: 0.43±0.21 cm and 1.07±0.97 cm, respectively.

The average distance of Rib space V on the right and left sides is: 1.34 ± 1.11cm and 1.81 ± 2.06cm, respectively.

Diameter of the perforating branch of the internal thoracic artery:

Our research results on the diameter of the perforating branch of the internal thoracic artery on both sides are shown in Table 5.

These results are similar to M. Schmidt et al [17], Kelada et al. [19] and are nearly equivalent to other studies on the perforating branch of the internal thoracic artery such as In-Soo Baek et al [20], Rosson et al [10], Kim et al [16], Kou et al [21], Gillis et al 18.

Origin diameter of the perforating branch of the internal thoracic artery:

On MDCT images, we measured the origin diameter of the perforating branch of the internal thoracic artery at each corresponding Rib space on both sides, with the results obtained in Table 5.

Our results are similar to those of Komemushi et al [22] in their study of the perforating branch of the internal thoracic artery using MDCT, although Komemushi's study mainly compared and analyzed the perforating branch of the internal thoracic artery and the deep inferior epigastric artery in cases of breast reconstruction surgery.

V. CONCLUSION

Through a study of 100 healthy individuals whose perforating branches of the internal thoracic artery from Rib space I to Rib space VI were examined as a basis for designing a cervicothoracic flap at the Department of Diagnostic Imaging - Military Hospital 103, from January 2023 to December 2024, we draw the following conclusions:

Number of perforating branches in Rib spaces: Rib spaces I to VI each showed a maximum of only one perforating branch.

Proportion of perforating branches in Rib spaces: Perforating branches most frequently appeared in Rib spaces I, II, and III (the number detected was 189, 186, and 180 respectively out of a total of 627).

Distance from the point of skin penetration to the sternal edge on the same side as the penetrating branch of the internal thoracic artery:

The average distance of Rib space I on the right and left sides is: 0.42 ± 0.16cm and 0.42 ± 0.18cm, respectively.

The average distance of Rib space II on the right and left sides is: 0.76 ± 0.37cm and 0.74 ± 0.38cm, respectively.

The average distance of Rib space III on the right and left sides is: 0.68 ± 0.39cm and 0.75 ± 0.39cm, respectively.

The average distance of Rib space IV on the right and left sides is: 0.95 ± 0.62cm and 1.13 ± 0.6cm, respectively.

The average distance of Rib space V on the right and left sides is 2.12 ± 1.49cm and 2.42 ± 1.31cm, respectively.

Length of the perforating branch of the internal thoracic artery to the point of skin penetration:

The average length of the perforating branch of the internal thoracic artery to the point of skin penetration of Rib space I on the right and left sides is 7.86 ± 2.47cm and 7.94 ± 2.55cm.

The average length of the perforating branch of the internal thoracic artery to the point of skin

penetration of Rib space II on the right and left sides is 10.08 ± 3.07cm and 10.07 ± 2.94cm.

The average length of the perforating branch of the internal thoracic artery to the point of skin penetration of Rib space III on the right and left sides is 8.8 ± 2.82cm and 9.8 ± 3.13cm.

The average length of the perforating branch of the internal thoracic artery to the point of skin penetration (Rib space IV) on the right and left sides is: 8.38 ± 2.56 and 8.24 ± 2.1cm, respectively.

The average length of the perforating branch of the internal thoracic artery to the point of skin penetration (Rib space V) on the right and left sides is: 7.19 ± 1.52 and 7.26 ± 1.82cm, respectively.

Distance from origin to lateral sternal edge:

The average distance from origin to lateral sternal edge (Rib space I) on the right and left sides is: 0.43 ± 0.21 and 0.42 ± 0.19cm, respectively.

The average distance from origin to lateral sternal edge (Rib space II) on the right and left sides is: 0.63 ± 0.4 and 0.75 ± 0.45cm, respectively.

The average distance from origin to the lateral edge of the sternum (Rib space III) on the right and left sides is: 0.54 ± 0.52 and 0.89 ± 0.81cm, respectively.

The average distance from origin to the lateral edge of the sternum (Rib space IV) on the right and left sides is: 0.43 ± 0.21 and 1.07 ± 0.97cm, respectively.

The average distance from origin to the lateral edge of the sternum (Rib space V) on the right and left sides is: 1.34 ± 1.11 and 1.81 ± 2.06cm, respectively.

Diameter of the perforating branches of the internal thoracic artery:

The average diameter of the perforating branches of the internal thoracic artery (Rib space I) on the right and left sides is: 1.43 ± 1.22 and 1.56 ± 1.44 mm, respectively.

The average diameter of the perforating thoracic artery branches in Rib space II on the right and left sides is: 1.44 ± 1.59 and 1.83 ± 1.62mm, respectively.

The average diameter of the perforating thoracic artery branches in Rib space III on the right and left sides is: 1.27 ± 1.12 and 2.19 ± 1.29mm, respectively.

The average diameter of the perforating thoracic artery branches in Rib space IV on the right and left sides is: 1.17 ± 0.84 and 1.03 ± 0.57mm, respectively.

The average diameter of the perforating thoracic artery branches in Rib space V on the right and left sides is: 0.89 ± 0.68 and 0.52 ± 0.8mm, respectively.

Origin diameters of the perforating branches of the internal thoracic artery:

Average origin diameters of the perforating branches of the internal thoracic artery (Rib space I) on the right and left sides are: 1.98 ± 1.78 and 2 ± 1.64mm, respectively.

Average origin diameters of the perforating branches of the internal thoracic artery (Rib space II) on the right and left sides are: 1.67 ± 1.59 and 1.72 ± 1.63mm, respectively.

Average origin diameters of the perforating branches of the internal thoracic artery (Rib space III) on the right and left sides are: 1.45 ± 1.49 and 1.56 ± 1.45mm, respectively.

Average origin diameters of the perforating branches of the internal thoracic artery (Rib space IV) on the right and left sides are: 0.73 ± 1.39 and 1.45 ± 1.4 mm, respectively.

Average origin diameters of the perforating thoracic artery in Rib space V on the right and left sides is: 0.59 ± 1.26 and 0.84 ± 1.4mm, respectively.

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