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The clinical anatomy of the internal thoracic veins

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The branching pattern and adequacy of the internal thoracic veins (ITV) are important factors, providing useful information on the availability of vessels and their appropriateness as an option for anastomoses in plastic and reconstructive surgery. During 100 cadaveric examinations of the anterior thoracic wall it was observed that ITVs were formed by the venae commitantes of ITAs, which united to form a single vein (one for the right side and one for the left) draining into the right and left brachiocephalic veins. The tributaries of ITVs corresponded to the branches of ITA. The right internal thoracic vein bifurcated at the 2nd rib in 36% of the specimens, at the 3rd rib in 30% of the specimens, at the 4th rib in 10% of the specimens and in 24% of the specimens it remained a single vein. The left internal thoracic vein bifurcated at the 3rd rib in 52% of specimens, at the 4th rib in 20% of specimens and in 28% of the specimens it remained as a single vein. In addition, it was observed that in 78% of specimens ITVs were connected to each other by a venous arch. This arch displayed four distinct morphologies: transverse (n = 7), oblique (n = 16), U-shaped (n = 51) and double-arched (n = 4). All 78 arches were posterior to the xiphisternal joint and no artery accompanied them. In the remaining specimens, RITV and LITV exhibited a venous plexus formation.
The distance from the sternum to ITV gradually decreased as the vessel passed caudally; the diameter of the vessel similarly decreased along the vein's caudal course. The frequent appearance of two concomitant veins on both sides of the thorax may offer the opportunity to reduce venous congestion by two vein anastomoses. More detailed knowledge of the anatomy of ITV may prove useful in planning surgical procedures in the anterior thorax in order to avoid unexpected bleeding.

Key words: internal thoracic vein, free tissue transfer, venous drainage of the sternum, venous arch, xiphoid process

INTRODUCTION

Although descriptions of the right internal thoracic vein (RITV) and left internal thoracic vein (LITV) are typically very brief and lacking in detail in anatomy textbooks, these vessels have received increased attention in recent clinical literature. This stems largely from the discovery of their involvement in breast reconstruction with free flaps, free microvascular tissue transfer or reconstruction of complex thoracic wall defects [1, 7, 11, 31].

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Standard anatomy textbooks describe the internal thoracic veins (ITVs) as the principal veins on the internal surface of the thorax, accompanying the internal thoracic arteries (ITAs) [8, 21, 32]. More specifically, these veins are the venae commitantes to the inferior half of ITAs, corresponding to the superior epigastric veins that mainly receive the anterior intercostal veins [22, 36]. At the point of the manubriosternal joint RITV and LITV form a common trunk that ascends and joins the right and left brachiocephalic veins respectively [8]. According to Romanes, the number of RITVs or LITVs could vary from one to two, but these veins will typically unite at the third costal cartilage medial to ITA [27].

The ITVs represent an important and, at times, superior, alternative to other recipient vessels of the region, especially in delayed reconstruction after mastectomy [30]. The importance of such knowledge lies in the fact that the use of ITVs in breast reconstruction has numerous advantages. The ITVs are better than the thoracodorsal vessels with regard to flap positioning, as well as positioning for the vascular anastomoses. The field of dissection is not violated and there is no perivascular scarring in the delayed reconstruction scenario [7].

Although ITAs have been investigated anatomically [15, 16, 26] because of their frequent use in cardiac surgery [2, 5, 35] or for diagnosis in breast cancer lymphadenopathy [4, 9, 17, 29], detailed anatomical descriptions of ITVs are still rare [8, 21, 22, 27, 34]. Therefore the aim of this study was to investigate the surgical anatomy of RITV and LITV and provide useful data to surgeons operating in this area.

MATERIAL AND METHODS

We examined 50 adult human cadavers during the "Human Body" course at Harvard Medical School throughout the academic semesters of 2004–2005 and 50 cadavers from St George's Medical School during 2005–2006. The cadavers derived from female and male subjects (24 female and 76 male) with an age range of 55 to 86 years and a mean age of 72 years. All the cadavers were fixed in formalin-phenol-alcohol solution. The cadavers examined did not have any gross anatomical anomalies or traumatic lesions of the thoracic wall. Furthermore, no signs of surgical procedures involving the thoracic cavity (such as coronary artery bypass grafting) were observed.

In order to obtain a clear field for visualisation, the anterior thoracic walls, together with the corresponding clavicles, were removed from the cadavers. A complete dissection along the course of ITV and ITA was performed in order to observe their origin, complete distribution and termination. Regular dissection techniques were employed, but non-traditional approaches were also used, some dissections intentionally deviating from the regular designs in order to expose the hidden details and intricate relationships of the venous structures.

A preliminary examination was performed, after which images from all the dissected specimens were recorded with a Sony digital camera (model: Nikon CoolpixS5) and studied using the Lucia software 5.0 computer-assisted image analysis system (2000, edition for Windows XP) made by Nikon (Laboratory Imaging Ltd.). The digital camera was connected to an image processor (Nvidia GeForce 6800 GT) and linked to a computer. Digitised images of ITVs, together with their surrounding structures, were stored in the Lucia program (2048 × 1536 pixels) and converted to grey levels in the intensity range of 0 (darkest) to 32 bit (lightest). After applying a standard 1 mm scale to all pictures, the program was able to use this information to calculate pixel differences between two selected points, such as origin and termination of a given vein, as previously described [19]. The purpose of the software was to allow easy and accurate translation of pixel differences into metric measurements. Specifically, we measured the distance from the origin of ITVs to their termination (the xiphosternal joint to right and left brachiocephalic veins). Additionally, at the xiphosternal joint and at the third intercostal space, the vessels were transected, the lumen photographed, and the diameter (diametrically opposite endothelial surfaces) measured.

RESULTS

During 100 cadaveric examinations of the anterior thoracic wall it was observed that all the specimens possessed an ITA and an ITV. The ITVs were formed by the venae commitantes of ITAs that united to form a single vein (one for the right side and one for the left side) draining to the right and left brachiocephalic veins. The tributaries of ITVs corresponded to the branches of ITA.

The RITV bifurcated at the 2nd rib in 36% of the specimens, at the 3rd rib in 30% of the specimens, at the 4th rib in 10% of the specimens and in 24% of the specimens it remained a single vein. The LITV bifurcated at the 3rd rib in 52% of specimens, at the 4th rib in 20% of specimens and in 28% of the specimens it remained a single vein.

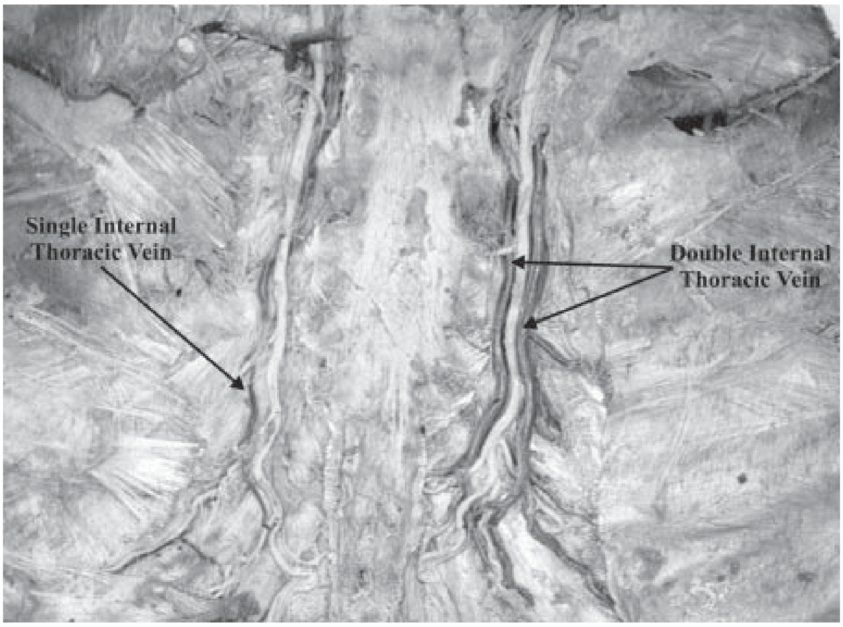

Figure 1. Right double internal thoracic veins and a left single internal thoracic vein.

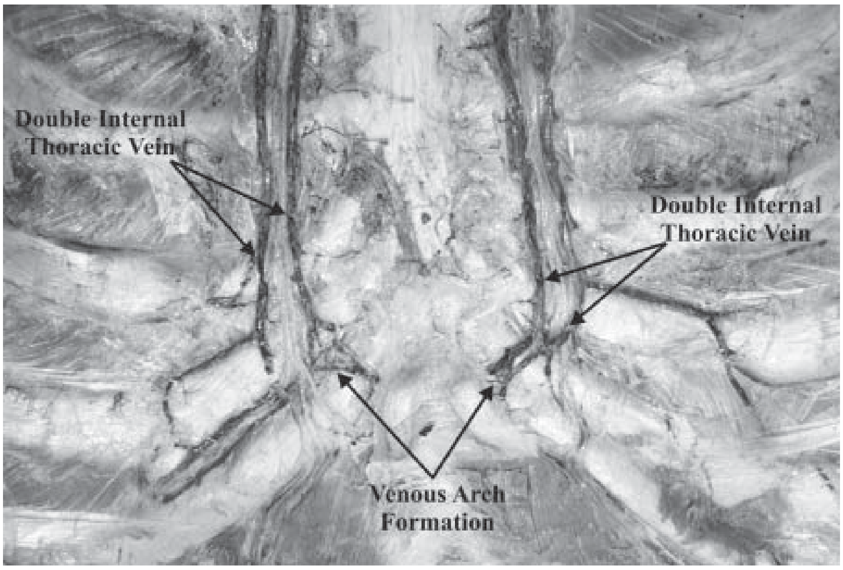

Figure 2. Right and left double internal thoracic veins forming a venous arch under the xiphoid process.

The bifurcated RITV and LITV formed by the venae commitantes showed considerable variation. In 56 (56%) specimens there were two concomitant veins on each side of the sternum. In 20% of specimens there were two concomitant veins on the right side and one concomitant vein on the left side of the sternum (Fig. 1). In 16% of specimens there were two concomitant veins on the left side and one concomitant vein on the right side of the sternum. In 8% of specimens, there was a single vein of the left and a single vein on the right side of the sternum.

It was observed that in 78% of specimens the ITVs were connected to each other by a venous arch (Fig. 2–4). This arch displayed four distinct morphologies in the study: transverse (n = 7), oblique (n = 16), U-shaped (n = 51) and double-arched (n = 4) (Fig. 5). All 78 arches were anterior to the xiphisternal joint and no artery accompanied them. In the remaining specimens RITV and LITV exhibited a venous plexus formation (Fig. 6). When the sternocostal head of the pectoralis major muscle was removed, the lateral ends of the venous arch could be seen entering

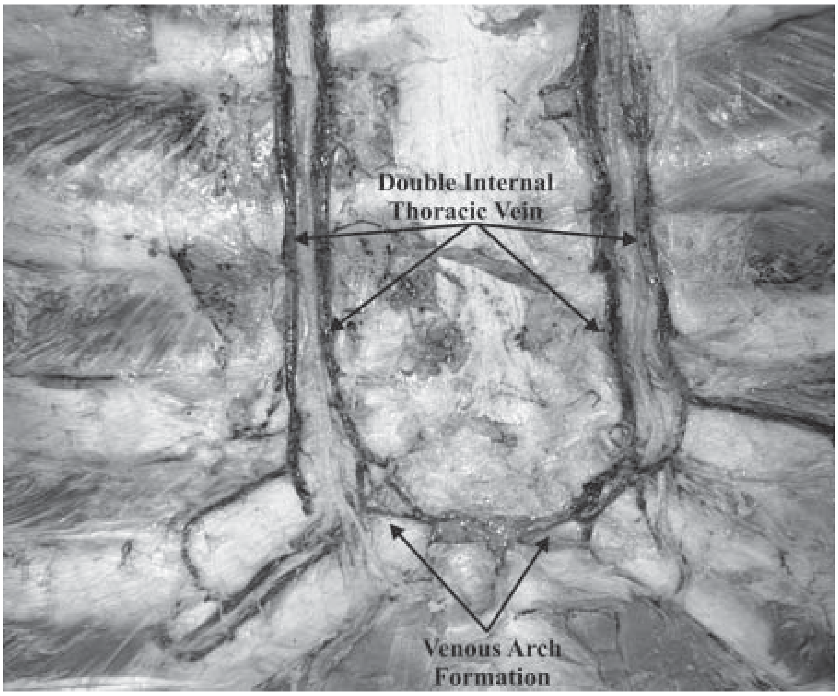

Figure 3. The xiphoid process is removed in order to expose the venous arch formed by the union of the left and right internal thoracic veins.

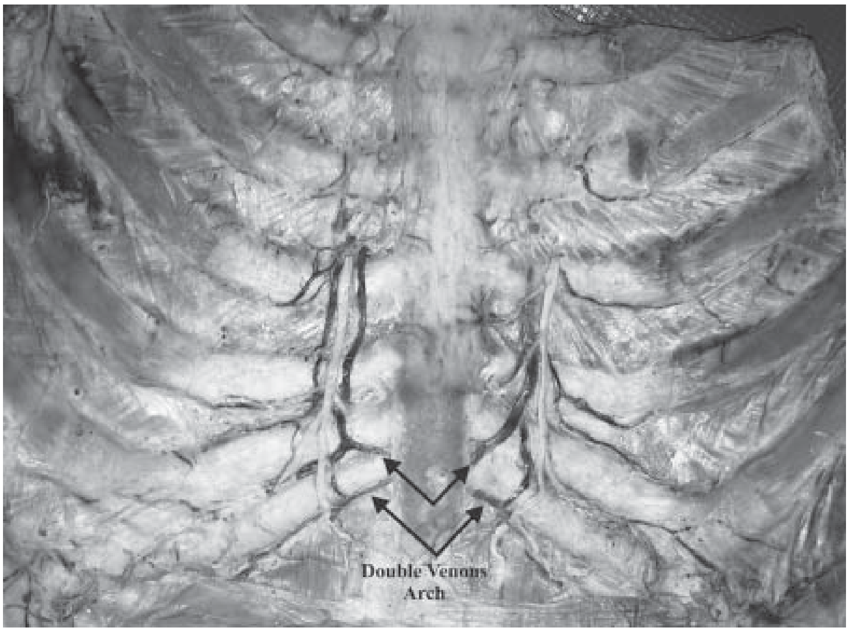

Figure 4. A double venous arch from the union of the right and left internal thoracic veins.

the thorax between the xiphoid process and the 7th costal cartilage. The length and diameter of ITVs were averaged and are shown in Table 1.

DISCUSSION

Microvascular transfers offer almost unlimited reconstructive resources in trauma or tumour surgery. However, suitable recipient vessels are a requisite for a plethora of available free flaps designed from almost every region of the body. The availability and quality of recipient vessels is of particular importance with regard to the reliability and success of reconstruction [30]. Currently veins of the axillary region, such as the thoracodorsal vein, are most widely used

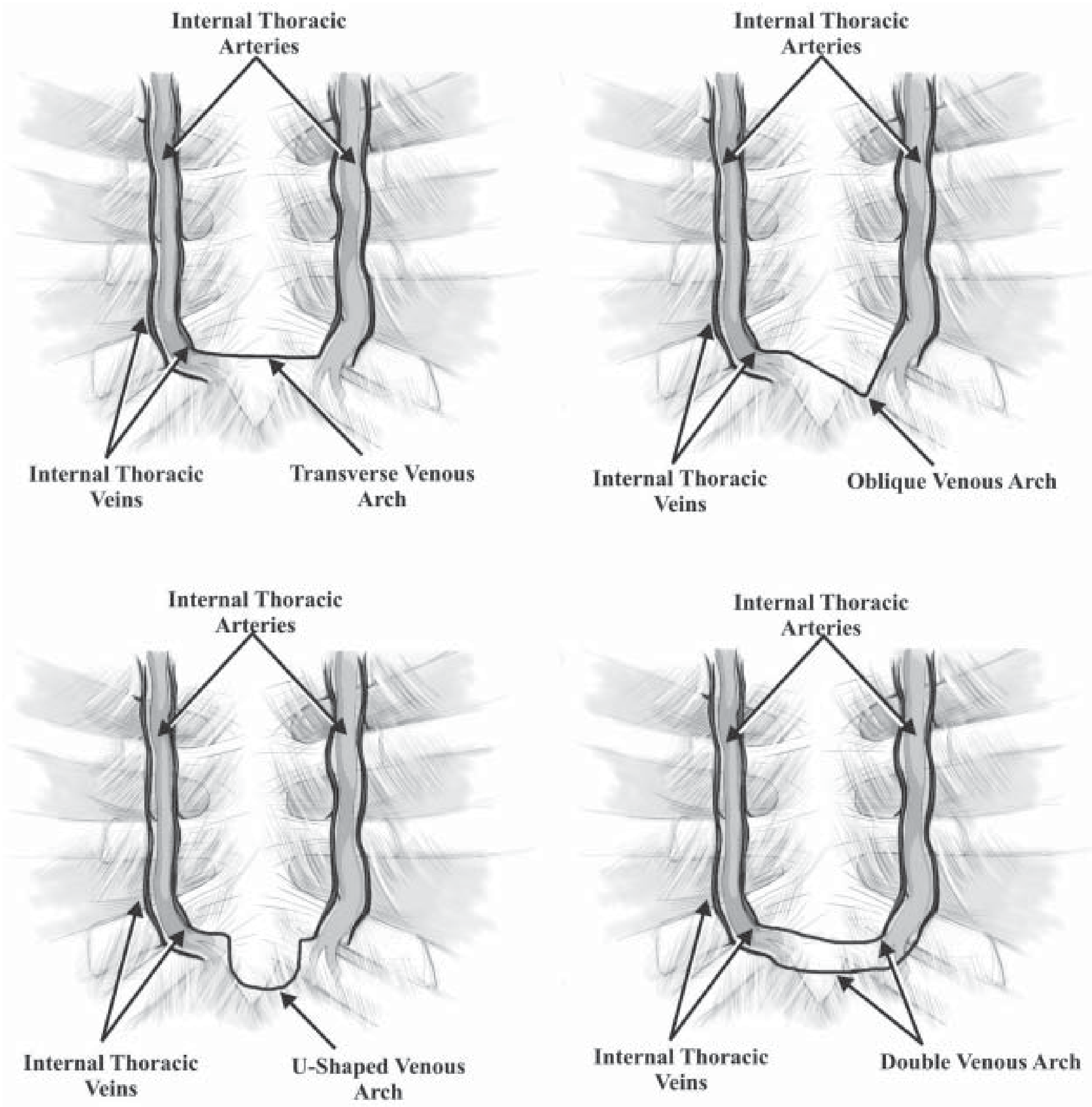

Figure 5. The different types of venous arch formed internal to the xiphisternal joint from the union of the right and left internal thoracic veins.

Table 1. The mean length and mean diameter of the internal thoracic veins (ITV)

	Right ITV	Left ITV
Length	12.9 cm	12.4 cm
Diameter at 3rd rib	2.42 mm (1.6–3.1)	2.51 mm (1.7–3.2)
Diameter at the xiphisternal joint	1.62 mm (1.1–1.9)	1.31 mm (0.8–2.0)

as recipient vessels in breast reconstruction with free flap [7, 12, 32]. However, these vessels are often damaged during radiotherapy [1, 7]. The ITVs, in contrast, are not affected by radiotherapy owing to their location and so offer a suitable alternative for reconstruction.

Clark et al. [7] investigated the size and bifurcation of ITVs in 10 specimens and found that 10% of RITVs bifurcated by the 2nd rib, 40% of RITVs bifurcated by the 3rd rib, and 50% bifurcated by the 4th rib [7]. However, the small sample size of the study meant that their results could not be considered conclusive. The present study expanded on Clark's findings that 36% of RITVs bifurcated at the 2nd rib, 34% bifurcated at the 3rd rib and 30% at the 4th rib. The ten-fold larger sample size showed that RITV bifurcation distribution is evenly split at the 2nd, 3rd and 4th ribs. Clark's study also showed that LITV

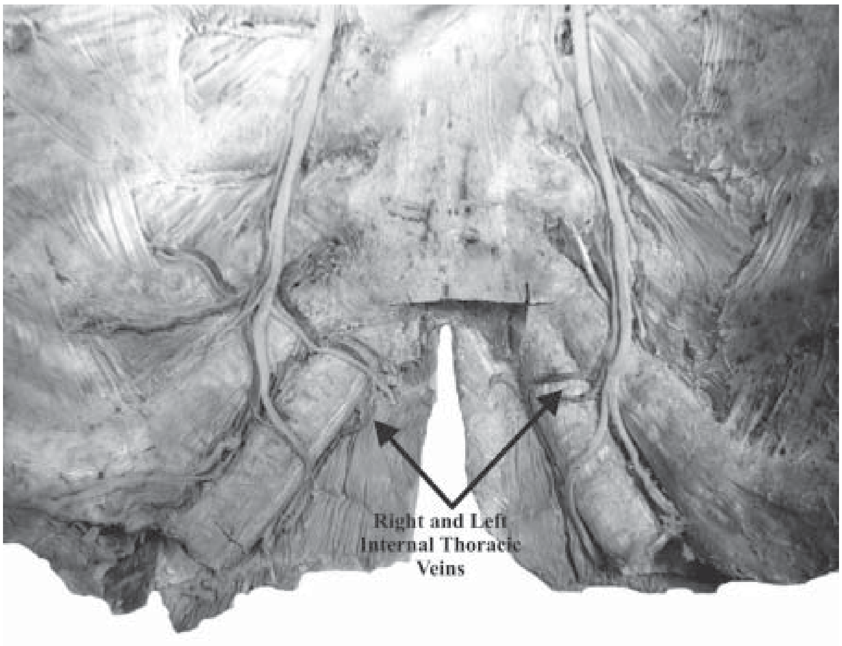

Figure 6. The xiphoid process is removed. However, the internal thoracic veins do not form a venous arch between them.

bifurcates in 20% of specimens at the 2nd rib and at the 3rd rib in 70% of specimens [7]. In contrast, the present study showed that LITV bifurcates at the 3rd rib in 73% of specimens and at the 4th rib in 26% of specimens. Bifurcation sites of ITVs are useful to surgeons, since small veins are usually inappropriate for anastomoses, while the bifurcation sites of vessels tend to be greater in diameter, making them suitable for easier anastomoses [11].

Microsurgical tissue transfer in the thoracic region, especially in breast reconstruction or tumour surgery, requires recipient vessels which are centrally located, easily accessible and large enough for sufficient anastomoses [30]. The present study showed that 61% of specimens had at least one ITV with two concomitant veins at the level of the 3rd rib and 40% of specimens had two concomitant veins on both sides. The study of ITVs by Schwabegger et al. [32] had similar results at the cranial edge of the 4th rib. They found that 83% of specimens had at least one ITV with two concomitant veins and 53% had two concomitant veins on both ITVs. The frequent appearance of two concomitant veins on both sides might offer the chance to reduce venous congestion by making two vein anastomoses [11].

The ITVs have been shown to be useful in breast reconstruction with free flaps because they are centrally located, allowing optimal flap positioning and vascular anastomoses, and are usually less affected by radiotherapy [13]. However, there are limitations to using ITVs as free flaps in breast reconstructions owing to the risk of the development of a pneumothorax [14]. On the other hand Schwabegger et al. were unable to detect any cases of pneumothorax in their studies [30, 33].

Careful investigation of presurgical patients' ITVs may lead to breast reconstruction procedures with fewer complications. Such measures have been facilitated in recent years by the use of iodine-contrasted computed tomography scans and may be revolutionised by magnetic resonance imaging of venous anatomy [6].

Catheter malposition represents the most frequent complication of central venous line insertion [23]. The complication is most likely when a subclavicular approach is used [20]. Cannulation of ITVs occurs with an incidence of greater than 2% [31]. In most cases the cannulation is asymptomatic [28, 31]. Brandi et al. described a case where the malpositioned catheter presented with symptoms similar to pulmonary embolism: thoracic pain, dyspnoea and tachycardia [3]. The anterior position of ITVs in the chest wall as compared to the subclavian vein makes the diagnosis of malpositioned catheter fairly easy by standard lateral radiographs, and many techniques have been developed to correct the problem. Lois et al. [18] described passing various wires or balloon catheters directly through the catheter lumen in an attempt to pull or push the catheter back into a central vein. Olcott et al. [24] described injecting sterile saline solution through the catheter to redirect its tip. Hartnell and Roizental [13] and Walker et al. [37] described indirect manipulation of the catheter with the use of various catheters or snare devices placed from a common femoral approach. Owens et al. [25] described an internal jugular vein approach with two glidewires attached to a shaft used to push the cannulated catheter into place.

Lastly, Gupta et al. [10] described variations in the venous arch formed by the junction of ITVs at the xiphisternal joint. Their results identified five shapes of the venous arch: inverted-U, U-shaped, oblique, V-shaped and transverse. However, Gupta et al. [10] were unable to identify a double venous arch or an absent arch as found in our study.

CONCLUSION

The anatomical clarification presented by our study, along with the further use of the technology available to surgeons, may provide useful data that may increase the success rate of breast reconstructions.

REFERENCES

1. Arnez ZM, Valdatta L, Tyler MP, Planinsek F (1995) Anatomy of the internal mammary veins and their use in free TRAM flap breast reconstruction. Br J Plast Surg, 48: 540–545.
2. Bauer EP, Bino MC, von Segesser LK, Laske A, Turina MI (1990) Internal mammary artery anomalies. Thorac Cardiovasc Surg, 38: 312–315.
3. Brandi LS, Oleggini M, Frediani M, Lachi S, Di Trani M, Ferrannini E (1988) Inadvertent catheterization of the internal thoracic vein mimicking pulmonary embolism: A case report. J Parenter Enteral Nutr, 12: 221–222.
4. Bruneton JN, Dalfin FY, Caramella E, Roux P, Hery M (1986) Value of ultrasound in localizing the internal mammary vessels. Eur J Radiol, 6: 142–144.
5. Canver CC, Ricotta JJ, Bhayana JN, Fiedler RC, Mentzer RM (1991) Use of duplex imaging to assess the suitability of the internal mammary for coronary artery surgery. J Vasc Surg, 13: 294–301.
6. Chasen MH, Charnasangavej C (1997) Venous chest anatomy: clinical implications. Eur J Radiol, 27: 2–14.
7. Clark III CP, Rohrich RJ, Copit S, Pittman CE, Robinson J (1997) An anatomic study of the internal mammary veins: clinical implications for free-tissue-transfer breast reconstruction. Plast Reconstr Surg, 99: 400–404.
8. Clemente CD (1985) Gray's anatomy of the human body. 13th Ed. Lea & Febiger, Philadelphia, PA, p. 829.
9. Glassberg RM, Sussman SK, Glickstein MF (1990) CT anatomy of the internal mammary vessels: importance in planning percutaneous transthoracic procedures. Am J Roentgenol, 155: 397–400.
10. Gupta M, Sodhi L, Sahni D (2004) A venous arch: connector of the internal thoracic veins. Clin Anat, 17: 364–365.
11. Han S, Yoon YY, Pak JM (2003) The anatomical evaluation of internal mammary vessels using songraphy and 2-dimensional computed tomography in Asians. Br J Plast Surg, 56: 684–688.
12. Harashina T, Imai T, Nakajima H, Fujino T (1980) Breast reconstruction with with microsurgical free composite tissue transplantation. Br J Plast Surg, 33: 30–37.
13. Hartnell GG, Roizental M (1995) Percutaneous transfemoral repositioning of malpositioned central venous catheters. Am J Roentgenol, 164: 1003–1006.
14. Hefel L, Schwabeggar AH, Ninkovic MM, Wechselberger G, Moriggl B, Waldenberger P, Anderl H (1995) Internal mammary vessels: anatomical and clinical considerations. Br J Plast Surg, 48: 527–532.
15. Henriquez-Pino JA, Gomes WJ, Prates JC, Buffolo E (1997) Surgical anatomy of the internal thoracic artery. Ann Thorac Surg, 64: 1041–1045.
16. de Jesus RA, Acland RD (1995) Anatomic study of the collateral blood supply of the sternum. Ann Thorac Surg, 59: 163–168.
17. Kuzo RS, Ben-Ami TE, Yousefzadeh DK, Ramirez JG (1995) Internal mammary compartment window to the mediastinum. Radiology, 195: 187–192.
18. Lois JF, Gomes AS, Pusey E (1987) Nonsurgical repositioning of central venous catheters. Radiology, 165: 329–333.
19. Loukas M, Hullett J, Wagner T (2005) The clinical anatomy of the inferior phrenic artery. Clin Anat, 18: 357–365.
20. McLure HA, Filshie J (1998) Radiological screening for Hickman catheter insertion. Anesth Analg, 86: 216–217.
21. Moore KL, Dalley II AF (2006) Clinically oriented anatomy. 5th ed. Lippincott Williams & Williams, Baltimore, MD, p. 105.
22. Morris K (1942) Human anatomy. 10th ed. The Blakiston Company, Philadelphia, PA, p. 729.
23. Oakes DD, Wilson RE (1975) Malposition of a subclavian line. JAMA, 233: 532–533.
24. Olcott EW, Gordon RL, Ring EJ (1989) The injection technique for repositioning central venous catheters: technical note. Cardiovasc Intervent Radiol, 12: 292–293.
25. Owens C, Mercurio S, Conneely M (2002) Salvage of a misplaced Hickman catheter: a new endovascular technique. J Vasc Interv Radiol, 13: 657–658.
26. Pietrasik K, Bakon L, Zdunek P, Wojda-Gradowska U, Dobosz P, Kolesnik A (1999) Clinical anatomy of internal thoracic artery branches. Clin Anat, 12: 307–314.
27. Romanes GJ (1972) Cunningham's textbook of anatomy. 11th ed. Oxford University Press, London, England, p. 907.
28. Sandroni C, Pirronti T, Tortora F, Santangelo S, Rinaldi P, Antonelli M (2003) Unusual central venous catheter malposition into the left internal mammary vein: a case report. Intensive Care Med, 29: 2338–2339.
29. Scatarige JC, Hamper UM, Sheth S, Allen III HA (1989) Parasternal sonography of the internal mammary vessels: technique, normal anatomy, and lymphadenopathy. Radiology, 172: 453–457.
30. Schwabegger, AH, Bodner G, Rieger M, Jaschke WR, Ninkovic MM (1999) Internal mammary vessels as a model for power Doppler imaging of recipient vessels in microsurgery. Plast Reconstr Surg, 104: 1656–1661.

31. Schwabegger AH, Hefel L, Ninkovic MM (1995) Internal thoracic (mammary) vessels: a reliable recipient system for free flaps in breast reconstruction. Surg Radiol Anat, 17: 203–209.
32. Schwabegger AH, Ninkovic MM, Morigl B, Waldenberger P, Brenner E, Wechselberger G, Anderl H (1997) Internal mammary veins: classification and surgical use in free-tissue transfer. J Reconstr Microsurg, 13: 17–23.
33. Shapiro MJ, Allen HM, Talpos GB (1982) Internal thoracic vein cannulation as a complication of central venous catheterization. Am Surg, 48: 408–411.
34. Skandalakis JE (2004) Skandalakis' surgical anatomy, paschalidis medical publications. Athens, Greece, p. 143.
35. Sons HJ, Marx R, Godehardt E, Losse B, Kunert J, Bircks W (1994) Duplex sonography of the internal thoracic artery: preoperative assessment. J Thorac Cardiovasc Surg, 108: 549–555.
36. Standring S (2005) Gray's anatomy. 39th ed. Hearts and great vessels. Chapter 60. Elsevier, Churchill, Livingstone; Edinburgh, p. 1027.
37. Walker TG, Geller SC, Waltman AC, Malt RA, Athanasoulis CA (1988) A simple technique for redirection of malpositioned Broviac or Hickman catheters. Surg Gynecol Obstet, 167: 246–248.