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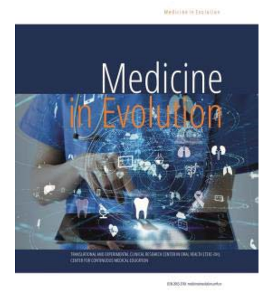
The Internal Thoracic Artery: An Anatomical Narrative Review



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Abstract

The internal thoracic artery (ITA) is a paired vessel originating from the first part of the subclavian artery, descending along the inner thoracic wall in close relation to the sternum. Owing to its reliable caliber, predictable course, and favorable long-term patency, the ITA plays a critical role in both clinical anatomy and surgical practice, particularly in coronary artery bypass grafting. This review synthesizes current anatomical knowledge of the ITA, emphasizing its origin, course, branching patterns, and collateral circulation. Variations in its trajectory, branching morphology, and termination are examined in detail, along with rare anomalies such as duplication and complete absence. Surgical relevance is addressed, with a focus on harvesting techniques, the impact of competitive flow, and strategies to manage side branches. Nomenclature is briefly discussed, noting the adoption of "internal thoracic artery" as the primary term. By integrating findings from cadaveric, radiological, and surgical studies, this review highlights the anatomical variability of the ITA and its implications for thoracic, cardiovascular, and reconstructive procedures. Understanding these variations is essential for optimizing surgical outcomes and reducing perioperative complications.

Keywords: internal thoracic artery, anatomical variations, coronary artery bypass grafting, surgical anatomy

INTRODUCTION

The internal thoracic artery (ITA), also known as the internal mammary artery, represents a paired artery situated on the anterior wall of the thoracic cavity, coursing along the lateral side of the sternum [1] (Figure 1). It supplies not only the chest wall, but also the breasts, mediastinum, pericardium, and thymus [1]. The ITA has been intensively studied due to its indispensable surgical application in coronary bypass surgery with ITA grafts, and it's currently referred to as the optimum conduit for coronary artery bypass grafting, based on its long-term results [2-7]. Clinical aspects should also be brought to attention, as the ITA adjusts its lumen's dimensions in post-ductal coarctation of the aorta, resulting in the dilatation of the artery due to the increased pressure proximal to the narrowing [8, 9]. Therefore, the objective of this review is to provide a comprehensive synthesis of the anatomical variations, clinical significance, and surgical applications of the ITA.

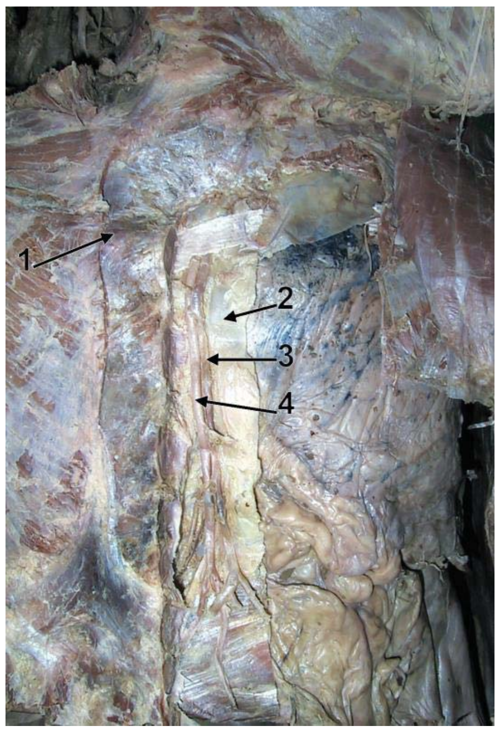

Figure 1. Original dissection of the left internal thoracic vessels. Human adult cadaver, anterior view. 1. sternal angle; 2. left anterior costomediastinal pleural recess; 3. left internal thoracic vein; 4. left internal thoracic artery.

Nomenclature

The term "internal thoracic artery" has been preferred in this study, instead of the former term "internal mammary artery", as it is considered in the literature to be more appropriate because it provides a precise, identifying topography of the vessel [10-12]. In the second edition of the Terminologia Anatomica, the former was designated as the primary term, while the latter was listed as its English synonym [13]. The term "mammary" has been largely abandoned, as it misleadingly implies a predominant vascular supply to the mammary gland. In contrast, the artery's primary distribution includes the anterior thoracic wall, sternum, and diaphragm [1]. In addition to "internal thoracic artery," other alternative denominations have been historically used, such as Vineberg artery, referring to its role in Vineberg's pioneering indirect myocardial revascularization procedure [14], and the sternal or parasternal artery, emphasizing its course parallel to the sternum [15]. However, the modern consensus favors ITA for its anatomically precise and descriptive value, aligning with current international anatomical terminology.

ORIGIN OF THE INTERNAL THORACIC ARTERY

The subclavian artery (SA) is a large-diameter blood vessel that supplies the upper limb, parts of the neck, and the head. The anatomical rapport with the anterior interscalene muscle, which passes anteriorly, divides the SA into three topographic parts: prescalene, scalene, and postscalene parts of the SA. While the 2nd and 3rd regions of the SA are, hypothetically, alike, the 1st region varies on each side [16]. The ITA commonly arises from the first portion of the SA [16-19]. However, it is subject to abundant anatomical variations. The left ITA (LITA) was reported to originate from the first part of the SA (92%), the second part (7%), and also the third part (1%), directly from the SA in 70% of the cases. In comparison, the remaining 30% was seen to derive from a common trunk with other arteries, such as suprascapular, transverse cervical, ascending cervical, inferior thyroid, and thyrocervical trunk [11, 19, 20]. Calafiore et al. [21] reported a higher incidence (36.33%, 109 out of 300 cases) of ITA origin conjoint with other branches of the SA. A 3rd region origin of the right ITA (RITA) is considered “abnormal” or “unusual” [22], as it has been seldom detected among studies, with a frequency rate of 0.83% [23], 0.78% [17], and 0.5% [24]. Bilateral 3rd part origin of the ITA was observed, on one occasion, in a 25-year-old female cadaver, during routine dissection [25]. Such an anatomical variant, however, is exceptional, as the literature lacks information regarding its frequency.

The ITA emergence from the axillary artery was first described in 1844 by Quain et al. [16]. They also reported the highest incidence of 3rd portion origin ITA at 2%. Anomalous origins have been previously reported. A LITA deriving directly from the aortic arch, with no anatomical correlation to the SA [26], was revealed via cardiac CT angiography in a 67-year-old subject. At the same time, an additional case showed a LITA emerging from the lateral junction of the left SA and the aorta [27]. Another LITA was seen arising from an aberrant left vertebral artery, which originated directly from the aorta, distal to the left subclavian artery [28]. These findings highlight the remarkable diversity in ITA origin and reinforce the importance of detailed preoperative vascular assessment. Even rare variants may carry significant surgical and interventional implications, particularly in cardiothoracic and vascular procedures, where unanticipated arterial patterns can complicate access, alter graft planning, and increase the risk of iatrogenic injury if not correctly identified in advance.

BRANCHES OF THE INTERNAL THORACIC ARTERY

The ITA gives rise to three main groups of branches according to their anatomical origin [1]. The anterior branches include the anterior intercostal arteries, perforating branches, and medial mammary arteries, which primarily supply the anterior thoracic wall and breast. The posterior branches consist of the mediastinal, thymic, pericardiacophrenic, sternal, bronchial, and tracheal branches, providing vascularization to deeper thoracic structures, including the mediastinum, thymus, pericardium, sternum, bronchi, and trachea. Finally, the terminal branches represent the artery’s distal bifurcation, continuing to supply the anterior abdominal wall and diaphragm [1, 19, 29-32]. The ITA can also be classified by its supplied territories into sternal, intercostal, and perforating branches, which respectively provide the sternum, intercostal spaces, and overlying soft tissues, including the mammary glands [1, 33]. It bifurcates anywhere between the fifth rib (around the third rib in fetuses [34]) and the seventh intercostal space [19] into the superior epigastric and the musculophrenic arteries.

The superior epigastric artery (SEA) supplies the anterior abdominal wall, the upper rectus abdominis muscle [35], and has been widely studied for the use of the SEA perforator flap in plastic reconstruction of the anterior abdominal/chest wall [36, 37]. The musculophrenic artery provides oxygenated blood to the diaphragm, the lower pericardium, and the lower intercostal spaces [1]. Less frequently, there were reported cases illustrating trifurcation of the ITA, with a 3rd ramus supplying the inferior aspect of the xiphoid cartilage, being termed as the xiphoid branch [30, 31], or even the diaphragmatic branch [19].

Appreciating the branching complexity of the ITA reveals its dual nature of structural consistency and subtle variation, with implications that extend beyond textbook anatomy. Rare branches, such as xiphoid or diaphragmatic rami, though infrequently encountered, may become critical in specific surgical contexts, offering alternative vascular supply or introducing unexpected anatomical challenges. A thorough understanding of these patterns is therefore essential for maximizing surgical precision and minimizing intraoperative risks.

DUPLICATION AND PARTIAL DUPLICATION OF THE INTERNAL THORACIC ARTERY

A LITA originating from the 3rd part of the SA was reported to bifurcate promptly after emergence [38]. Thus, two separate branches, lateral and medial, were observed descending through the thoracic cavity. The lateral one became the musculophrenic artery, whereas the medial ramus turned into the superior epigastric artery. Both vessels had a reduced diameter (less than 1.5 mm), compared to the usual diameter of an ITA (generally 2.5 mm) [39, 40]. Such thin ITAs may, therefore, represent a risk and instead an inadequate option for performing coronary artery bypass grafting (CABG). Out of 240 examined ITAs, only two were seen bifurcating, which is less than 1%; however, no additional data were reported [41]. Another case [42] presented a RITA dividing into two branches at the level of the 2nd intercostal space, with a stepladder pattern of anastomosis existing between the two. Each ramus provided additional arterial branches and ceased as the two common terminal branches of the ITA: the medial one continued as the SEA, while the lateral one as the musculophrenic artery. A case of bilateral, partially duplicated IMAs, at the level of the 1st and 2nd costal cartilage, was previously reported [43]. Even though incompletely duplicated arteries represent an interesting anatomical feature, here, the term “partially” is used without coherence. A misjudgment may be the cause of describing the same case, both as “duplication” and “partially duplicated”. No distinction was made between the two terms, which leads to further confusion, as the case cannot be adequately categorized.

These anatomical reports emphasize both the exceptional rarity and the potential surgical implications of bifurcating or duplicated ITAs. Variants with reduced caliber, early branching, or unclear morphological classification may compromise their viability as grafts in CABG and complicate reconstructive planning. Furthermore, the inconsistent use of terms such as “duplication” and “partial duplication” without precise anatomical distinction highlights a gap in the literature, pointing to the need for a standardized nomenclature to improve clarity and comparability in future studies.

MORPHOTOPOGRAPHIC CHARACTERISTICS OF THE INTERNAL THORACIC ARTERY

Following its emergence from the inferior aspect of the subclavian artery, ITA travels posterior to the brachiocephalic vein [1, 44]. It then adopts a descending course, on the anterior wall of the rib cage, deep to the first six anterior costal cartilages, parallel to the sternum, at a mean ITA-to-sternum distance of almost 15 mm [43, 45-47]. ITA gradually decreases in size as it traverses the thoracic cavity, without any significant dimension adjustment between left and right vessels [43, 46, 47]. Its average length is about 20 cm, and bifurcation at the sixth intercostal space occurs in over 90% of cases [19].

The diameter of the ITA has significant clinical significance. It is essential in the CABG and free tissue transfer for breast reconstructive surgery, as the artery should be of sufficient caliber and readily accessible for anastomoses [43]. Many values have been reported in the literature, as follows: Delmotra et al. [20] reported a mean of 2.6 mm on the left and 2.8 mm on the right, with a maximum observed value of 4.0 mm. Karaman et al. [43] observed the diameter in two specific points, at the origin and the level of the tracheal bifurcation. The difference between the measurements was roughly 0.2 mm for each side, sizing 2.56 at the origin and approximately. 2.30 at the second position. No significant disparity was found between the right and left sides, or between genders. Hefel et al. [45] communicated smaller values, with a maximum of approximately 2.5 mm, and mean values ranging from 1.76 to 2 mm.

Histologically, the ITA is a small to medium-sized elastic artery, particularly in its proximal segment. It shows high resistance to atherosclerosis, even in older individuals. Age-related elastotic degeneration may occur, but it is often compensated for by remodeling with new smooth muscle-like cells, thereby preserving elasticity and functionality [48].

Only two studies in the literature have reported cases of a completely absent ITA. Nizanowski et al. [49] grouped both abnormal and absent ITAs, reporting a combined frequency of 11.4%. However, the actual absence of the vessel remains uncertain, as abnormal ITAs appear to be reported more frequently than complete absence [11, 23]. In another investigation, the absence of the ITA was documented in only 2 out of 400 examined cases, corresponding to a prevalence of 0.28% [17].

The morphological and histological profile of the internal thoracic artery illustrates its exceptional reliability as a vascular conduit, with consistent dimensions and remarkable resistance to atherosclerosis, which supports its widespread surgical use. While variations in caliber are generally minimal and clinically insignificant, the rare occurrence of hypoplasia or complete absence, although scarcely reported, highlights the importance of thorough preoperative assessment to anticipate and mitigate potential intraoperative challenges.

The main reported anatomical variations of the ITA are highlighted in Table 1, including their prevalence, defining features, and potential clinical relevance.

Table 1. Summary of reported variations of the internal thoracic artery: prevalence, description, and clinical implications

Variation type	Description	Reported prevalence	Potential clinical impact	References
LITA origin from 1st, 2nd, or 3rd part of SA	LITA originates from the 1st part, 2nd part, or 3rd part of the subclavian artery; 30% arise from a common trunk with other arteries.	92% (1st part), 7% (2nd part), 1% (3rd part), 30% from common trunk	May alter surgical strategy in CABG or upper thoracic procedures due to atypical origin.	[11, 16-20]
Higher incidence of common trunk origin	LITA's origin is concurrent with other SA branches.	36.33%	It could complicate graft harvesting by limiting the mobilization of the artery.	[21]
RITA originates from the 3rd part of SA	Considered abnormal or unusual.	0.83%, 0.78%, 0.5%	Rare trajectory may pose challenges in exposure and grafting.	[17, 22-24]
Bilateral 3rd part origin of ITA	Bilateral emergence from the 3rd part of the SA in a cadaver.	Single reported case	Extremely uncommon; may require an altered intraoperative identification strategy.	[25]
LITA originates from the axillary artery	Reported since 1844; rare origin.	Up to 2%	Atypical course can affect surgical approach and conduit selection.	[16]

LITA originates from the aortic arch or an aberrant vertebral artery	Origin directly from the aortic arch or an aberrant vertebral artery.	Case reports only	Significant deviation from normal anatomy may mislead imaging interpretation or operative navigation.	[26-28]
Bifurcating ITA after origin	Early bifurcation into musculophrenic and superior epigastric arteries; reduced diameter (<1.5 mm).	<1% (2/240 cases)	Reduced caliber can render an artery unsuitable for CABG.	[38-41]
Bifurcation at the 2nd intercostal space with stepladder anastomosis	Two rami with additional branches, ending as the SEA and musculophrenic arteries.	Single reported case	An unusual branching pattern may complicate dissection and vascular anastomosis.	[42]
Bilateral partially duplicated ITAs	Described at 1st and 2nd costal cartilage; unclear distinction between complete and partial duplication.	Single reported case	Terminology inconsistency could hinder anatomical classification and surgical planning.	[43]
Absent ITA	Complete absence of vessel documented.	0.28% (2/400 cases)	Absence eliminates ITA as a graft option, requiring an alternative conduit.	[17]
Combined abnormal and absent ITAs	Grouped prevalence including abnormal courses and absence.	11.4%	Variable anatomy may necessitate preoperative imaging to prevent intraoperative surprises.	[49]

CLINICAL AND SURGICAL CONSIDERATIONS

The ITA reveals several clinically significant anatomical variations that can influence its use in surgery, particularly in CABG and thoracic procedures. One of the more striking reports describes bilateral aberrant branches of the ITA, where accessory branches descended laterally and gave off additional intercostal branches. This rare variation highlights how unexpected arterial courses may complicate procedures such as CABG, thoracocentesis, and breast reconstruction, underscoring the need for preoperative vascular assessment [50]. From a surgical planning perspective, such aberrant branching patterns may necessitate modifications in the harvesting technique, including more proximal dissection or selective ligation of accessory branches to preserve optimal graft flow. Furthermore, their presence may explain some cases of early graft failure that remain otherwise unexplained despite technically adequate anastomoses.

Similarly, accessory ITAs have been documented in cadaveric studies, occurring in about 4–20% of cases [51]. These arteries, which can be nearly as large as the primary ITA trunk, run along the anterolateral thoracic wall and may contribute to the "steal phenomenon," where competitive flow between grafted and accessory vessels compromises bypass outcomes [51]. The steal phenomenon is likely underdiagnosed in clinical practice, as subtle competitive flow may manifest only as late-onset angina or decreased functional capacity, rather than overt perioperative ischemia. This emphasizes the importance of integrating detailed vascular mapping into routine pre-CABG imaging, even in patients without apparent anatomical risk factors.

Another well-documented variant is the lateral costal branch, present in 15–30% of individuals, which runs parallel to the ITA and communicates with anterior and posterior intercostal arteries [52, 53]. Its identification is essential because a well-developed lateral costal artery may divert blood flow away from coronary targets following CABG, as shown in clinical cases where coil embolization was required to resolve post-operative angina [52, 53]. Given the relatively high prevalence of this branch, preoperative detection should be considered a standard practice in centers performing high volumes of CABG, particularly in patients with diffuse coronary artery disease.

Uncommon origin and duplication patterns have also been observed. For instance, a rare case of the ITA arising from the thyrocervical trunk instead of the subclavian artery was reported, which alters its proximal course and may increase the risk of vascular injury during neck procedures [54]. Routine preoperative angiographic evaluation of the ITA in patients undergoing CABG is necessary, especially those with prior mediastinal irradiation, subclavian atherosclerosis, or previous cardiac surgery [55]. The broader implementation of preoperative angiography could prevent unanticipated intraoperative difficulties, thereby reducing operative time and morbidity.

Competitive flow between the grafted ITA and its side branches compromises myocardial perfusion, sometimes necessitating corrective procedures like coil embolization [52, 53]. Unusual origins, such as ITAs arising from the thyrocervical trunk, or rare duplications of the ITA, further complicate surgical harvesting by altering expected anatomical landmarks, increasing the risk of intraoperative injury, and potentially reducing the usable graft length [38, 54]. These variations also affect sternal and chest wall perfusion, which is critical for preventing wound complications after median sternotomy in high-risk patients [51]. For these reasons, preoperative vascular mapping using angiography or duplex ultrasonography is strongly recommended to identify and assess ITA variants before surgery, allowing surgeons to optimize operative planning and reduce the risk of adverse outcomes [55]. A multidisciplinary preoperative review involving cardiac surgeons, radiologists, and anesthesiologists is advisable whenever a significant anatomical variation is detected.

The ITA poses a significant bleeding risk in cases of blunt or penetrating chest trauma, primarily when associated with sternal or rib fractures, as the vessel courses adjacent to the sternum [56]. Such injuries may lead to massive hemothorax, anterior mediastinal hematoma, or even pseudoaneurysm formation, all of which may precipitate hypovolemic or even obstructive shock due to expanding retrosternal blood collections [56]. Given the vessel's proximity to the sternum, even low-velocity trauma can result in life-threatening hemorrhage, warranting a lower threshold for advanced imaging in patients with equivocal findings but high clinical suspicion.

In hemodynamically stable patients, transcatheter arterial embolization is increasingly the first-line, minimally invasive treatment, showing success rates of around 92%, compared to about 66% for open surgery [57]. Embolization has effectively treated active ITA bleeding and pseudoaneurysms, including in type 1 neurofibromatosis patients with spontaneous rupture, with favorable outcomes and minimal morbidity [58]. However, the decision between embolization and open repair should not rely solely on hemodynamic status, but also on anticipated concomitant injuries and the availability of interventional radiology resources, which may vary significantly between institutions.

When patients present with hemodynamic instability, persistent massive hemothorax, or rapidly expanding mediastinal hematoma, emergency surgical thoracotomy may be warranted to achieve direct control of bleeding and decompress the mediastinum [59]. Early recognition and prompt, multidisciplinary intervention, typically involving imaging, interventional radiology, and trauma surgery, are critical for survival in these potentially life-threatening scenarios. The key determinant of survival in such cases is the speed and coordination of the multidisciplinary response, minimizing the interval between diagnosis and definitive intervention.

For bypass surgeons, the significant ITA variants are those that reduce conduit reliability or harvestability, including atypical origins (second/third subclavian segment, axillary, or aortic), early bifurcation that shortens the usable length, and small-caliber or hypoplastic limbs that limit flow. Practically, these issues surface as longer dissection time, greater risk of pedicle injury, and, most importantly, lower confidence in long-term patency if the lumen is <~1.5 mm. Specialists still lean too heavily on "expected" anatomy; a fast, pre-op mapping protocol (CTA or duplex when CTA is contraindicated) should be routine whenever there's prior neck/chest surgery, radiation, or discrepant pulses. In borderline cases, a low threshold to switch the target strategy (e.g., radial for non-LAD targets) rather than forcing a marginal LITA should be preferred. Guideline-level evidence continues to support the use of LITA as a cornerstone of surgical revascularization, underscoring the value of confirming anatomy before committing to surgery [60].

In plastic and reconstructive surgery, clinically relevant variations are often encountered in the terminal branches of the ITA. Shifts in dominance between the superior epigastric and musculophrenic arteries, early bifurcation, and variability of internal mammary perforators (IMAPs) may directly influence flap design and outcomes. Relying solely on Doppler examination can be insufficient, particularly in irradiated fields. CT angiography provides superior information on vessel caliber, intramuscular course, and perforator location, thereby reducing intraoperative uncertainty and ischemia time. Rare findings, such as trifurcation or accessory xiphoid and diaphragmatic branches, may also be advantageous if preoperatively identified, offering additional options for safe flap inset or secondary venous outflow [61].

From a radiological perspective, ITA variations are of most significant consequence when they are overlooked in preoperative imaging. Non-first-segment origins, high or low bifurcation levels, duplications, or unusual distances from the sternum can be critical for surgical planning. A recurring limitation is the tendency to report such anomalies simply as "aberrant" without detail. A structured radiological report should provide precise origin, vessel diameter at multiple levels, relation to the sternum, bifurcation level, and the presence of unusual branches or duplications. Multidetector CT angiography has demonstrated the ability to reliably characterize these features, and its systematic use would improve communication between radiologists and surgeons [43].

In trauma surgery, variations in the ITA may complicate the recognition and management of bleeding. Injuries to the artery may present with subtle signs, such as mediastinal hematoma or a modest hemothorax, which can delay diagnosis. Variations in the vessel's course, such as early bifurcation or a more lateral trajectory, can displace bleeding away from its expected location and hinder surgical control. In such cases, targeted CT angiography is essential when sternal fractures or unexplained blood loss are present. When feasible, endovascular embolization has been shown to provide rapid and effective control of hemorrhage with less physiological burden compared to open exploration. This supports an endovascular-first strategy for anatomically suitable and hemodynamically stable patients [56].

FUTURE DIRECTIONS

While the ITA has been well studied, there are still significant gaps that future research should address. One of the main challenges is the lack of a clear and consistent language when describing its variations. Terms like "duplication," "partial duplication," or "aberrant origin" are often used interchangeably, which creates confusion and makes it difficult to compare studies. Establishing a standardized system of classification would bring much-needed clarity and allow researchers and surgeons to speak the same "anatomical language."

Another promising direction is the use of modern imaging. Techniques such as CT angiography, cone-beam CT, and 3D reconstruction now enable the visualization of even subtle vascular differences before surgery. Applying these tools more widely could help surgeons identify unusual branching patterns or hypoplastic vessels in advance, leading to safer operations and better patient outcomes. At the same time, such imaging can complement cadaveric research by providing a more dynamic, clinically relevant perspective.

Ultimately, further prospective studies are necessary to investigate the actual impact of these anatomical variations on surgical outcomes. While many descriptions of ITA variants exist, there is still little evidence connecting them to long-term outcomes in coronary bypass surgery or reconstructive procedures. By linking anatomical findings with clinical data, future research could provide practical guidelines that help surgeons select the most suitable conduit or approach for each patient. Extensive, collaborative studies that bring together anatomists, radiologists, and surgeons will be especially valuable in this regard.

Taken together, these findings show that variations of the internal thoracic artery, though often rare, carry distinct implications across multiple specialties. Whether influencing graft reliability in cardiac surgery, flap planning in reconstruction, diagnostic accuracy in radiology, or hemorrhage control in trauma, their recognition remains crucial. A more systematic approach, through standardized terminology, consistent preoperative imaging, and stronger collaboration between specialties, would ensure that anatomical diversity is translated into safer and more effective patient care.

CONCLUSIONS

In conclusion, the ITA remains a vital structure in cardiovascular and thoracic surgery, valued for its high patency rates in coronary bypass grafting and its predictable course along the anterior aspect of the thoracic wall. Detailed knowledge of its anatomical variations, branching patterns, and hemodynamic adaptations is crucial for precise surgical planning and minimizing intraoperative risks. This review contributes to the literature by integrating anatomical, clinical, and surgical perspectives into a comprehensive synthesis, supported by original dissection material. It thereby offers both an updated reference for current practice and a visual contribution that enhances anatomical understanding. Importantly, by highlighting clinically significant variations across different specialties, the review also underscores the need for standardized nomenclature and broader use of modern imaging to improve preoperative planning and patient outcomes.

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Conflicts of Interest

The authors declare no conflict of interest.

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