International Journal of Multiphysics
Volume 18, No. 1, 2024
ISSN: 1750-9548

Analysis of Arterial Blood Supply to the Nipple-Areola Complex, An Imaging Study.

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Abstract:

Background: The nipple–areola complex represents an important aesthetic and functional unit of the breast. Accurate knowledge of its arterial blood supply is essential during breast reduction, mastopexy, and reconstructive breast surgery to reduce the risk of ischemia and nipple–areola complex necrosis.

Methods: This observational descriptive imaging study was conducted at the Computed Tomography Unit, Badr University Hospital, Helwan University. Forty female volunteers underwent contrast-enhanced computed tomography scanning of the thorax and thoracic organs. The nipple–areola complex was identified on reconstructed images, and arteries terminating in the peri-areolar region were traced to determine their source, course, dominance, reproducibility, and mode of entry.

Results: The study included 40 female participants, with a total of 80 breasts. The mean age was 37 years, ranging from 18 to 60 years, and the mean BMI was 24, ranging from 21 to 29. The internal thoracic artery was the most common source artery for nipple–areola complex perfusion, being reproducible in 77.1% and dominant in 75% of cases. The lateral thoracic artery was reproducible in 22% and dominant in 21% of cases. A single-source arterial pattern was observed in most breasts, while dual-source supply was detected in 12.5%. The arterial supply pattern between both breasts was mostly asymmetric, with symmetry observed in 42.5% of participants.

Conclusion: The arterial blood supply to the nipple–areola complex arises mainly from the internal thoracic artery and lateral thoracic artery, with greater dominance and reproducibility of the internal thoracic artery. The frequent asymmetry between both breasts highlights the importance of individualized vascular assessment before breast surgery.

Keywords: Nipple–areola complex; Internal thoracic artery; Lateral thoracic artery; Computed tomography angiography; Breast vascularity; Breast surgery.

Introduction:

One important functional and aesthetic feature of the female breast is the nipple-areola complex. During breast reduction, mastopexy, nipple-sparing mastectomy, and reconstructive breast operations, maintaining its viability is crucial. Partial or complete ischemia consequences, such as delayed healing, sensory impairment, or nipple-areola complex necrosis, may arise from any compromise of its vascular supply. Thus, safe surgical planning and better postoperative results depend on a thorough understanding of the vascular anatomy of the breast and nipple-areola complex (1).

Numerous possible sources, such as branches of the internal thoracic artery, lateral thoracic artery, thoracoacromial artery, intercostal arteries, axillary artery, and brachial artery, have been identified as contributing to the varied vascular supply of the nipple-areola complex. The internal thoracic and lateral thoracic arteries are among the most significant contributors to nipple–areola complex perfusion, according to earlier anatomical and radiological studies, though the dominant vessel may vary between individuals and even between the two breasts of the same individual (2).

The vascular architecture of the nipple-areola complex in living subjects is increasingly being studied using computed tomographic angiography. According to Stirling et al., the internal thoracic artery's perforating branches were the most consistent and significant vascular input to the nipple-areola complex, with the lateral thoracic artery coming in second. The idea that customized vascular mapping could be helpful for breast pedicle design was further supported by **Zheng et al. (3),** who employed computed tomographic angiography to define the source arteries of the nipple–areola complex and showed notable diversity in arterial origin and symmetry.

Variations in the nipple-areola complex blood supply are still clinically significant despite the morphological and imaging investigations that are currently available, especially in breast surgeries where pedicle selection directly impacts vascular safety. With a focus on determining the major source artery, reproducibility, vascular course, entry mode, and symmetry between both breasts, the current study used contrast-enhanced computed tomography imaging to examine the arterial blood supply of the nipple-areola complex **(4).**

Patients and Methods

This observational Descriptive study was carried out after being approved by the local Ethics Committee of the Faculty of Medicine, Helwan University, Cairo, Egypt. The study was held at Computed Tomography Unit, at Badr University hospital, Helwan University. In a single center (Badr University Hospital) a total of 40 female volunteers undergone a computed topography scan after administration of an intra-venous contrast material, for thorax and thoracic organs.

Inclusion Criteria:

1. Physically developed female
2. Intravenous contrast enhancement should be in arterial phase with ROI plotted on the aortic arch to give maximal intensity of contrast in the aortic arch and its branches for better visualization of arteries of the anterior chest wall.
3. At least one breast and potential blood supply should be visible in extended fields.

Exclusion Criteria:

1. Prior breast surgery.
2. Presence of organic breast disease.
3. Renal impairment (creatinine level more than 1.5)

Before participating in the study, all volunteers provided written agreement, and all patients were assessed mostly using:

- Every participant's complete medical history was obtained, including any history of intravenous contrast hypersensitivity.
- Each patient's height and weight were assessed, and each participant's BMI was computed.
- The size of the breast cup was noted.
- A baseline renal function test was performed and documented.

Technique:

After receiving an intravenous contrast agent, 40 female volunteers had a computed topography scan for the thorax and thoracic organs. A power injection device (Ulrich, Germany) was used to infuse iopamidol (370 mgI/ml, Iopromide Injection, Bayer), a nonionic contrast medium, via a peripheral venous line. Following an injection of 60–70 ml of iopromide (Ultravist 370, 370 mg I/mL, Bayer Schering Pharma, Berlin, Germany) at a flow rate of 5 ml/s, each patient was given 20–50 ml of saline solution.

Image interpretation and data collection:

- ❖ Interpreting images and gathering data A commercial workstation that enabled data processing, interactive reconstruction, and picture archiving was used to review the images. A thoracic radiologist and a plastic surgeon reviewed every image together and reached a consensus on the results.
- ❖ The following scans were examined. The thorax's surface anatomy was exposed using a maximum intensity projection (MIP) volume rendering approach. The areola centered above the base was used to identify and display the nipple areola complex (NAC) in a plane. From the NAC, this visible plane was moved in the direction of the anterior chest wall. The source, course, and entry of arteries that ended in the peri-areolar region were traced and documented.
- ❖ Reproducible vessels were defined as any vessel in continuity with the NAC, and dominant vessels were defined as the biggest diameter vessel.
- ❖ The course was classified as either superficial (often less than 15 mm from the skin's surface) or deep (mostly more than 15 mm).
- ❖ Anastomoses and the existence of dominance or co-dominance were noted when multiple vessels supplied the NAC.
- ❖ An o'clock method was used to explain a vessel's entry into the NAC, with 12 o'clock being superior and the areola representing a clock face. 12 o'clock is better.
- ❖ Following the identification of supplying vessels in this manner, further known prospective sources were examined for potential anterograde contributions, i.e., from axillary and sub-clavian branches until termination. For data set functionality, this information was entered into Microsoft ExcelTM 2013.

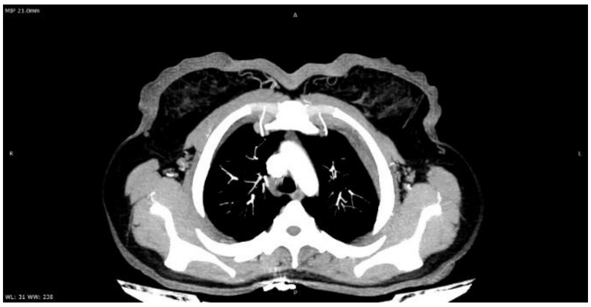

Figure (1): Symmetrical blood supply of right and left NAC (Internal Thoracic Artery).

Figure (2): Symmetrical blood supply of Right and Left NAC (Anastomosis between Internal Thoracic artery and Lateral Thoracic Artery.

Figure (3): Symmetrical blood supply of right and left NAC (Internal Thoracic Artery).

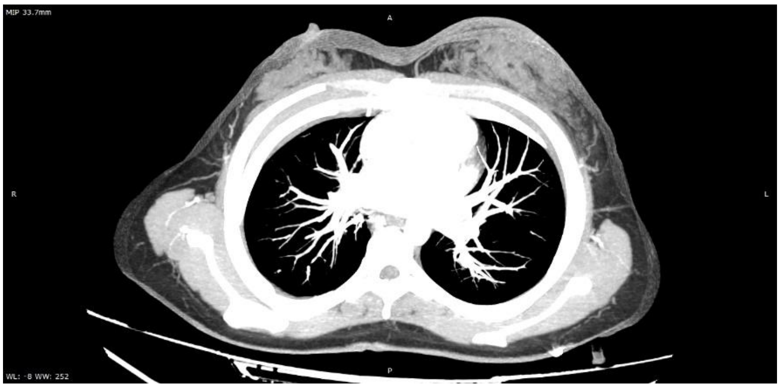

Figure (4): Asymmetrical blood supply to the Right and Left NAC (Right NAC Supplied by Lateral Thoracic Artery) (Left NAC Supplied by Anastomosis between Internal Thoracic artery and Lateral Thoracic Artery).

Figure (5): Symmetrical blood supply of right and left NAC (Lateral Thoracic Artery)

Result:

Table (1): Demographic characteristics of the study participants:

		Mean / N	Range / %
Age (Years)		37	(18-60)
BMI		24	(21-29)
Breast size (number of breasts)	Small (A/B Cup)	10	25%
	Medium (C Cup)	25	62.50%
	Large (D Cup +)	5	12.50%

Regarding the Demographic characteristics of the study participants, the mean age of the participating females was 37 years, ranging from 18 to 60 years. The mean BMI was 24, with a range of 21 to 29. The majority of the participating females (62.5%) had a medium breast size, 25% and 12.5% had a small, and a large breast size, respectively.

Table (2) Number of source arteries providing NAC perfusion in the study participants:

Source Artery	**Right Breast**	**Left Breast**	
	N (%)	N (%)	Total
Internal Thoracic Artery	26 (61.9%)	38 (92.68%)	64
Lateral Thoracic Artery	16 (38.1%)	3 (7.3%)	19
Thoracoacromial Artery	0	0	
Intercostal Artery	0	0	
Brachial Artery	0	0	
Axillary Artery	0	0	

Regarding the number of source arteries providing NAC perfusion in the right and left breasts of the participants. The internal thoracic artery is the most common source artery for NAC perfusion in both breasts, followed by the lateral thoracic artery. The left breast has a higher percentage of internal thoracic artery perfusion than the right breast (92.68% vs 61.9%). While the right breast has a higher percentage of lateral thoracic artery perfusion than the left breast (38.1% vs 7.3%). None of the participants had any other source arteries (thoraco-acromial, intercostal, brachial, or axillary) in either breast

Table (3): Percentage of dominant source arteries for NAC perfusion in the 80 breasts

Arteries	**N (%)**
Internal Thoracic Artery	60 (75%)
Lateral Thoracic Artery	17 (21.25%)
Thoracoacromial Artery	0
Intercostal Artery	0
Brachial Artery	0

Axillary Artery	0
No Visible Artery	3 (3.75%)

Regarding dominant source arteries for NAC perfusion, in 75% of the 80 studied breasts, Internal Thoracic Artery was the dominant source artery for NAC perfusion. While Lateral Thoracic Artery was the dominant source artery in 21.25% of the studies breasts. However, in 3.75% of the studied breasts, there was no visible artery.

Table (4): Pattern of source arteries for NAC perfusion:

Source arteries		**Right Breast (n=40)**	**Left Breast (n=40)**	**Total Breasts (n=80)**
		N (%)	**N (%)**	**N (%)**
Single Source Vessel	Internal Thoracic **(Type I)**	20 (50%)	33 (82.5%)	53 (66.25%)
	Lateral Thoracic **(Type II)**	10 (25%)	4 (10%)	14 (17.5%)
	Thoracoacromial	0	0	0
	Brachial	0	0	0
	Axillary	0	0	0
Dual Source Vessels (Type III)	Internal thoracic + lateral thoracic	7 (17.5%)	3 (7.5%)	10 (12.5%)
	Internal thoracic + Thoracoacromial	0	0	0
	Internal thoracic + brachial	0	0	0
No Visible Artery (Type IV)		3 (7.5%)	0	3 (3.75%)

Regarding the pattern of source arteries for NAC perfusion. Single Source pattern was noticed in most of the participants with only 12.5% showing Dual Source pattern. From a total 40 right breasts, Internal Thoracic artery was the source vessel in 50%, while Lateral Thoracic artery was the source in 25%, internal thoracic and lateral thoracic arteries were the source vessels in 17.5% and 7.5% had no visible artery. Meanwhile in the left breasts, Internal Thoracic artery was the source vessel in 82.5%, while Lateral Thoracic artery was the source in 10 % and both internal thoracic and lateral thoracic arteries were the source vessels in 7.5%.

Table (5): Arterial source and characteristics.

Source	**Characteristics**	**N (%)**
Internal Thoracic Artery	Reproducibility	64 (77.1%)
	Dominance	60 (75%)
	Superficial Course	55 (85.9%)
	Deep Course	9 (14.06 %)
	Right NAC Entry Mode (O'clock)	10

	Left NAC Entry Mode (O'clock)	2
	Anastomosis	10 (15.62%)
Lateral Thoracic Artery	Reproducibility	19 (22%)
	Dominance	17 (21%)
	Superficial Course	17 (89.47%)
	Deep Course	2 (10.52%)
	Right NAC Entry Mode (O'clock)	10
	Left NAC Entry Mode (O'clock)	3
	Anastomosis	10 (52.6%)

*Anastomosis Percentage was calculated upon Reproducibility of each Artery

*Course was Superficial if less than or equal 15 mm from skin surface, deep if more than 15 mm from skin surface.

Regarding the characteristics of the arterial source. The ITA was the most common source artery for NAC perfusion, occurring in 77.1% of the participants, followed by the LTA, occurring in 22% of the participants. The ITA was also the most dominant source artery, accounting for 75% of the total source arteries, while the LTA accounts for 21% of the total source arteries. The ITA and the LTA had different courses and entry modes in the NAC. The ITA has a superficial course in 85.9% of the cases and enters the right NAC at 10 o'clock and the left NAC at 2 o'clock. The LTA has a superficial course in 89.47% of the cases and enters the right NAC at 10 o'clock and the left NAC at 3 o'clock.

Table (6) Comparison of source artery pattern between breasts in all volunteers

Pattern	N	%
Symmetric	17	42.5%
Asymmetric	23	57.5%

Regarding the source artery pattern between breasts in all participants was mostly asymmetric with 42.5% showing symmetry.

Table (7): Source arteries of the Asymmetrical patterns (n=17)

Identification Number	**Right Breast**	**Left Breast**
1	ITA + LTA	ITA
2	ITA + LTA	ITA
3	ITA	LTA
4	LTA	ITA + LTA
5	LTA	ITA
6	LTA	ITA
7	ITA	LTA

8	No Visible Artery	ITA
9	LTA	ITA
10	LTA	ITA
11	LTA	ITA
12	LTA	ITA
13	No Visible Artery	ITA
14	ITA	LTA
15	LTA	ITA
16	LTA	ITA
17	No Visible Artery	ITA

Regarding the pattern of asymmetry with the most common asymmetrical pattern was LTA in the right breast and ITA in the left breast, which occurs in 8 out of 17 participants (47%).The second most common asymmetrical pattern was ITA in the right breast and LTA in the left breast, which occurs in 3 out of 17 participants (17.6%).The third most common asymmetrical pattern was NVA in the right breast and ITA in the left breast, which occurs in 3 out of 17 participants (17.6%).

Discussion:

The most consistent arterial contribution to the NAC was found to be perforating branches originating from the internal thoracic artery (ITA) (77.1%), followed by the lateral thoracic artery (LTA) (22%). Forty female volunteers underwent a computed topography scan for the thorax and thoracic organs following the administration of an intravenous contrast material. In 60 breasts, perforating branches of the ITA constituted the predominant supply (75%). The ITA has a superficial course in 85.9% of cases and enters the right NAC at 10 o'clock and the left NAC at 2 o'clock, whereas the LTA was prominent in 17 breasts (21%). In 89.47% of cases, the LTA has a superficial course and enters the right NAC at 10 o'clock and the left NAC at 3 o'clock. Additionally, most participants had a single source pattern of arterial supply, with only 12.5% exhibiting a dual source pattern; all participants' source artery patterns between breasts were primarily asymmetric, with 42.5% exhibiting symmetry.

As for related studies regarding out topic, **Stirling et al. (4)** Perforating branches from the internal thoracic artery (ITA) accounted for 81.8% of the most consistent arterial contribution to the NAC in a study involving 132 breasts. These branches were followed by those from the lateral thoracic artery (LTA) (23.5%) and the anterior intercostal arteries (AIA) (15.9%). The least repeatable was the superior thoracic artery (STA) (0.8%). In 96 breasts (72.7%), the predominant supply was perforating branches of the ITA. The ITA has a superficial course in 79.6% of cases and enters the right NAC at 10 o'clock and the left NAC at 2 o'clock. The LTA was dominant in 21 breasts (15.9%), while AIA and perforators were prominent in only 5 breasts (3.8%). In 90.3% of cases, the LTA has a superficial path and enters the left NAC at 3 o'clock and the right NAC at 10 o'clock.

The aforementioned findings support our conclusions about the superiority of ITA over LTA in terms of dominance and reproducibility, as well as the superficial course of both arteries. However, we disagree with AIA because we were unable to find any perforators originating from them.

Zheng et al. (3) in a study that included CTA examination of 23 female subjects, found that a total of 61 dominant blood vessels were identified. The source arteries were traced as the internal thoracic artery (ITA, 50.8%), lateral thoracic artery (LTA, 27.8%), thoraco-acromial artery (TA, 14.8%), brachial artery (BA, 3.3%), and axillary artery (AA, 3.3%), and the corresponding reproducibility of these source vessels was 31, 37, 9, 4.3, and 4.3%, in all breasts, and 52.2% of the breasts demonstrated anatomically symmetrical patterns of blood supply for the NAC, also they analyzed the patterns of the source arteries in all 46 hypertrophic breasts, and the results indicated that 26 breasts had a single NAC blood supply that originated from the ITA (14 cases, 30.4%), TA (7 cases, 15.2%), LTA (3 cases, 6.5%), BA (1 case, 2.1%), and AA (1 case, 2.1%), whereas NAC blood supplies in the other 17 breasts were derived from multiple source arteries, and each of the combinations of ITA plus LTA, ITA plus TA, ITA plus BA, and ITA plus LTA and AA was identified as the contributing source blood vessels in 14 (30.4%), 1 (2.1%), 1 (2.1%), and 1 (2.1%) breasts respectively, these results corresponds to ours regarding dominance of ITA also regarding the pattern of arterial supply being primarily from single source, but doesn't go in line with our results regarding that the majority of subjects received symmetrical blood supply in both breasts , as we came to that only 17 case (42%) received symmetrical blood supply to NAC.

Li et al. (5) In this study, 60 individuals had their arteries delivering blood to the NAC area rebuilt. Among these, 116 internal thoracic artery perforating branches (56.3%), 42 lateral thoracic artery branches (20.3%), 20 thoraco-acromial artery branches (9.7%), 16 brachial artery branches, and 12 axillary artery branches (4.9%) were rebuilt. The aforementioned results are consistent with our findings, with the exception of TA, BA, and AA, as we were unable to identify any alternative arterial origin.

Conclusion

The internal thoracic artery and lateral thoracic artery provide the majority of the arterial blood supply to the Nipple-Areola complex, with the internal thoracic artery having greater dominance and repeatability. The majority of instances have an asymmetrical pattern of arterial supply.

Conflict of Interest:

The writers affirm that they have no conflicting interests.

Financial Disclosures:

No particular grant from any governmental, private, or nonprofit funding organization was received for this study.

Availability of the data:

Upon reasonable request, the corresponding author will provide the datasets created and/or analyzed during the current work.

Authors contribution:

M. M. and B. A. were in charge of writing and publication, while A. W. and M. A. were in charge of data gathering and analysis.

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