Original Article

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Anatomy Section

Arterial Supply of the Breast and Nipple-areola Complex: A MRI and Cadaveric Study

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ABSTRACT

Introduction: Preservation of the Nipple-areola Complex (NAC) is currently being attempted for a better aesthetic and functional outcome, necessitating precise knowledge of its vascular supply to minimise postoperative necrosis.

Aim: To determine the source, branches, and pattern of arterial supply to breast parenchyma and the NAC using Magnetic Resonance Imaging (MRI) and cadaver.

Materials and Methods: The present retrospective observational study was conducted in the Department of Anatomy, AIIMS, New Delhi, India, from March 2015 to October 2016. Total of 50 MRI scan images of female patients who underwent breast MRI as part of their preoperative assessment were collected and retrospectively reviewed. Cadaveric dissection was performed on 11 breasts (5 left and 6 right) obtained from 10 female cadavers with no breast pathology. Radiographic and cadaveric data pertaining to the source, branches, and pattern of arterial supply to breast parenchyma and the NAC were collected. Data was studied using statistical tests like Dunn test followed by Bonferroni correction and Signed-rank test.

Results: The MRI scans revealed that most vessels bilaterally supplying the medial half of the breast originate from the Internal Mammary Artery (IMA), while those supplying the lateral half arise from the Lateral Thoracic Artery (LTA), and the branches of IMA were found to be consistently supplying the NAC. Cadaveric dissection confirmed, in all cases except one, that the principal parenchymal and NAC supply on either side arises from the IMA.

Conclusion: IMA perforators supply the NAC most consistently and the major part of the breast parenchyma, as well. MRI breast is the most precise modality currently available for the preoperative evaluation of breast vascularity during conservative mastectomies.

Keywords: Internal mammary artery, Lateral thoracic artery, Magnetic resonance imaging, Nipple-sparing mastectomy

INTRODUCTION

The breast lies in the superficial fascia of the pectoral region anterior to the pectoralis major muscle. It has an internal or secretory part, which is a modified sweat gland, while the external part is formed by the nipple-areola, which acts as a conduit for milk to reach the infant [1]. The breast has specialised milk-secreting glandular tissue to fulfill its primary function of feeding and nourishing an infant during lactation. The region of the nipple and areola together is called the NAC, and stimulation of its nerve endings enhances lactation. Thus, the NAC functionally forms a very important part of the breast [2]. The NAC is a region of particular interest due to the growing demand for relatively less disfiguring conservative mastectomies. Surgical excision of glandular breast tissue is the standard treatment for several breast pathologies, including cancer. An accurate and detailed knowledge of the blood supply in this region is essential for a favourable surgical outcome and for sparing the NAC, if free of cancer cells. However, accounts vary regarding the arterial supply in standard texts.

The human breast, including the NAC, is supplied by the branches of the axillary, internal thoracic and some intercostal arteries, medial mammary branches arising from perforating branches and anterior intercostal branches of the internal thoracic artery, lateral mammary branches from the LTA, pectoral branches of the Thoracoacromial Artery (TAA), and lateral cutaneous branches from the posterior intercostal arteries in the 2nd, 3rd and 4th intercostal spaces [3-6]. NAC tissue viability is critical for the surgeon performing nipple-areola sparing breast surgeries. The exact location and distribution of the main blood vessels supplying the NAC require clear demarcation for a better postsurgical outcome [7]. There is a chance of recurrence of a tumour in the NAC due to undetected nipple involvement [8]. Neoplastic involvement of the NAC can be predicted before surgery, and its sustained postoperative viability is likely with appropriate surgical technique [9]. Nipple Sparing Mastectomy (NSM) includes the removal of tissue located behind the NAC, putting the nipple at risk for ischaemic necrosis because it is now left dependent on dermal microvasculature [10]. Although effective local control is the primary goal of surgery for breast cancer, the long-term aesthetic outcome is also important [11]. Knowledge of the exact location of the main vessels to the NAC is important for postsurgical preservation of function and for avoiding complications. Therefore, several modalities, including Computed Tomographic Angiography (CTA) and Magnetic Resonance Imaging (MRI), have been incorporated for the preoperative evaluation of blood supply to breast parenchyma, including the NAC [12-19]. Preoperative breast MRI is an excellent diagnostic tool to characterise blood supply to the breast parenchyma and NAC. This technique can predict ischaemia and necrosis after NSM and hence can also correlate vascular findings with NSM outcomes [14]. However, the use of MRI is limited only by its cost and availability.

Most of the studies have been done on cadavers, and very few on radiographs. However, no integrated study has been undertaken so far, to the authors knowledge, for comparison and correlation. The present study was designed with the aim of studying the origin and distribution of the main vessels supplying the mammary gland and tracing the distribution pattern of specific vessels supplying the NAC, with the overall goal of assisting functional preservation during surgery by limiting postoperative complications.

MATERIALS AND METHODS

The present retrospective observational study was conducted in the Department of Anatomy, AIIMS, New Delhi, India, from March 2015 to October 2016. Institutional Ethical Committee approval was obtained (IESC/T-34/21.01.2015).

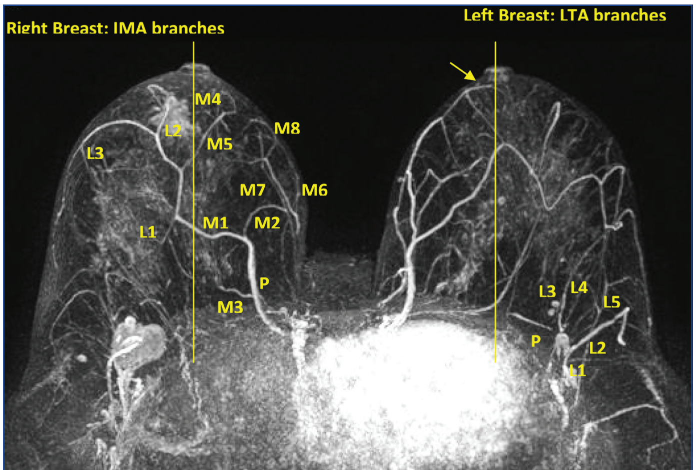
Inclusion criteria: MRIs of cases between 20 years and 80 years of age and for cadaveric study, cadavers of adult Indian females (approximate age 40-70 years) were included in the study.

Exclusion criteria: Distorted, blurred MRIs and MRIs of cases below 20 years and above 80 years, and cadavers with any breast pathology were excluded from the study.

Study Procedure

A: MRI study- The data were collected in the form of 50 breast MRIs of Indian female patients, obtained from the Department of Radiodiagnosis, AIIMS, New Delhi, India.

In each MRI, both (right and left) breasts were studied, and each breast was divided into two halves using an anteroposteriorly directed plane, perpendicular to and bisecting the nipple. The branches of the internal mammary (thoracic) artery and LTA were counted in both halves, as well as, any other vessel, if present. The parent vessel was followed to its terminal part, and no vessel was counted more than once [Table/Fig-1]. The data obtained were tabulated as Mean±Standard Deviation (SD) for three age groups, group 1: 21-40 years, group 2: 41-60 years and group 3: 61-80 years, side (left/right) and half (medial/lateral).



[Table/Fig-1]: MRI (Axial view) showing method of counting arteries supplying the breast and NAC.
IMA: Internal mammary artery; LTA: Lateral thoracic artery; P: Parent artery; M1-M8: IMA branches in the medial half of breast; L1-L3: IMA branches in the lateral half of breast; L1-L5: LTA branches in the lateral half of breast; yellow arrow: IMA branches supplying the NAC

B: Cadaveric study- Cadaveric dissection was performed on 11 female breasts {5 left and 6 right breasts, (9 unilateral and 1 bilateral dissection)} belonging to embalmed cadavers of adult Indian females (approximate age 40-70 years), with no obvious breast pathology, these being donated to the Department of Anatomy for teaching and research at AIIMS, New Delhi, India.

A midline vertical incision was made extending from the jugular notch to the xiphoid process followed by a horizontal incision extending from the acromion process to the sternoclavicular joint. The skin flap was raised by extending the first incision from the xiphoid process superolaterally and diagonally to the areola, continued surrounding the areola, and then extended to the axilla. After raising the skin flap, the breast tissue in the parasternal region was dissected. Each of the vessels found was traced to identify its course, branching pattern, and whether it reached up to the NAC. The axilla was also dissected to identify the branches of LTA, supplying the mammary gland. The data were systematically recorded, tabulated and classified into age groups, as above-mentioned in MRI study.

STATISTICAL ANALYSIS

The data acquired was statistically analysed, and correlations were studied using statistical tests: Dunn test followed by Bonferroni correction and Signed-rank test for MRI data.

RESULTS

A: MRI study- The majority of cases fell within the 41-60 years age range (54%), with 38% in the 21-40 years age group and 8% in the 61-80 years age group. Significant differences were observed for IMA only in the medial half and for LTA only in the lateral half of the right breast [Table/Fig-2].

Principal artery	Medial half/ Lateral half/ Indeterminate	Number of branches: Median value (minimum-maximum value)			p-value
		Group 1 (21-40 years)	Group 2 (41-60 years)	Group 3 (61-80 years)	
Right IMA	Medial half	6 (0-15)	9 (2-14)	3.5 (2-4)	**0.0065**
	Lateral half	1 (0-5)	1 (0-8)	0.5 (0-2)	0.4826
Right LTA	Medial half	0 (0-4)	0 (0-2)	0 (0-1)	0.8703
	Lateral half	4 (0-8)	5 (2-14)	1 (0-4)	**0.0043**
Others (right side)	Indeterminate	2.5 (2-3)	2.5 (1-4)	4 (4-4)	0.5459
Left IMA	Medial half	6 (0-11)	6 (2-11)	4 (2-6)	0.1663
	Lateral half	1 (0-5)	2 (0-10)	1 (0-4)	0.4518
Left LTA	Medial half	0 (0-1)	0 (0-1)	0 (0-0)	0.8839
	Lateral half	3 (0-8)	4 (0-10)	0 (0-7)	0.2761
Others (left-side)	Indeterminate	2 (1-5)	2 (2-7)	4 (4-4)	0.5982

[Table/Fig-2]: MRI data on branching pattern of arteries supplying breast: age-wise comparison.
Values presented as number of branches of each artery: Median value (minimum-maximum value); IMA: Internal mammary artery; LTA: Lateral thoracic artery; Dunn test with bonferroni correction; The p-value in bold font indicates statistically significant value

The number of branches supplied by IMA in the medial half and LTA in the lateral half were significantly greater in both breasts (right and left) of the 21-40 years and 41-60 years age groups. The difference was significant for LTA in the lateral half of only the right breast in the 41-60 years age group. The differences in the 61-80 years age group followed a similar pattern but were not significant, likely due to only four subjects in this age group [Table/Fig-3,4]. Some vessels were observed arising from a central position in the MR scan but could not be traced back to their parent vessel [Table/Fig-5]. IMA branches were found supplying the NAC [Table/Fig-6] in most cases on either side, with LTA branches observed in less than 20% of cases [Table/Fig-7]. The likelihood of any other vessel supplying it is minimal.

B: Cadaveric study- Among the six right breasts dissected, three had their main parenchymal and NAC supply from the IMA perforator arising from the 2nd intercostal space [Table/Fig-8], two from the 3rd space perforator [Table/Fig-9], while one was supplied by both the 2nd and 3rd space perforators. The 2nd and 4th space [Table/Fig-10] perforators were identified as the major vessels supplying parenchyma and reaching the NAC in only one left breast each, and the 3rd space perforator in two left-side breasts. One left breast among the five studied was primarily supplied by a vessel extending up to the NAC from the superior aspect of the pectoralis minor muscle, originating from TAA [Table/Fig-11]. Of all the perforators emerging from intercostal spaces to supply breast parenchyma, only one reached the NAC. The major perforator, as it emerged from its respective intercostal space, coursed towards the NAC, giving off parenchymal and cutaneous branches along the way. The NAC was observed to be supplied by perforator branches from IMA both superficially and from deeper parts in all except one of the dissected breasts studied.

DISCUSSION

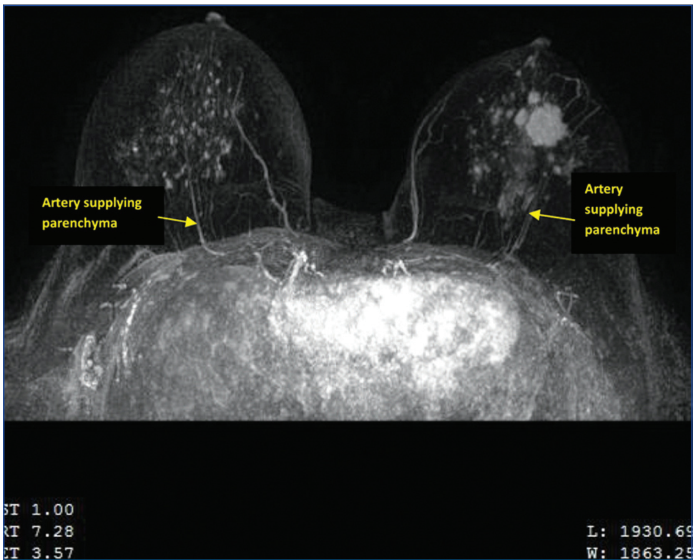
Surgical procedures on the breast often lead to vascular complications such as Nipple-areola necrosis and reduced sensation, compromising its functional capacity. Ischaemic complications can be minimised

Group	Right IMA		p-value	Right LTA		p-value	Medial half		p-value	Lateral half		p-value
	Medial half	Lateral half		Medial half	Lateral half		Right IMA	Right LTA		Right IMA	Right LTA	
Group 1	6.0 (0-15)	1.0 (0-5)	**0.0003**	0.0 (0-4)	4 (0-8)	**0.0013**	6.0 (0-15)	0.0 (0-4)	**0.0003**	1.0 (0-5)	4.0 (0-8)	0.0407
Group 2	9.0 (2-14)	1.0 (0-8)	**0.001**	0.0 (0-2)	5 (2-14)	**0.001**	9.0 (2-14)	0.0 (0-2)	**0.001**	1.0 (0-8)	5.0 (2-14)	**0.001**
Group 3 (61-80 y)	3.5 (2-4)	0.5 (0-2)	0.0679	0.0 (0-1)	1 (0-4)	0.1615	3.5 (2-4)	0.0 (0-1)	0.0656	0.5 (0-2)	1.0 (0-4)	0.5807

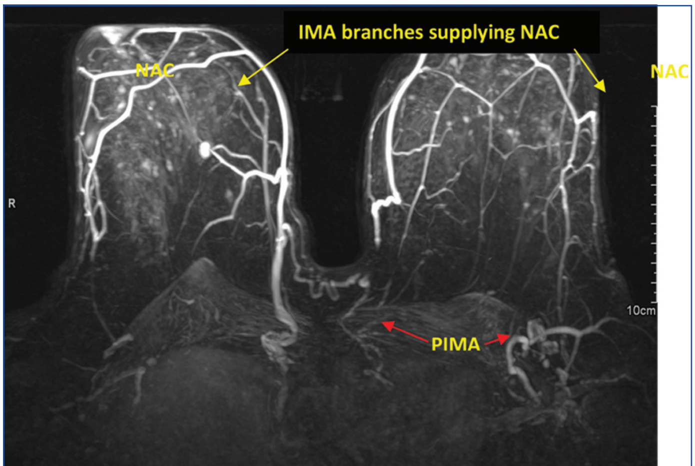
[Table/Fig-3]: Statistical analysis of MRI data on branching pattern of arteries supplying right breast: comparison of variables.
Values presented as number of branches of each artery: Median value (minimum-maximum value)
IMA: Internal mammary artery; LTA: Lateral thoracic artery; Dunn test with Bonferroni correction

Group	Left IMA		p-value	Left LTA		p-value	Medial half		p-value	Lateral half		p-value
	Medial half	Lateral half		Medial half	Lateral half		Left IMA	Left LTA		Left IMA	Left LTA	
Group 1	6.0 (0-11)	1.0 (0-5)	**0.0002**	0.0 (0-1)	3.0 (0-8)	**0.0003**	6.0 (0-11)	0.0 (0-1)	**0.0001**	1.0 (0-5)	3.0 (0-8)	**0.0293**
Group 2	6.0 (2-11)	2.0 (0-10)	**0.001**	0.0 (0-1)	4.0 (0-10)	**0.001**	6.0 (2-11)	0.0 (0-1)	**0.001**	2.0 (0-10)	4.0 (0-10)	**0.0230**
Group 3	4.0 (2-6)	1.0 (0-4)	0.0918	0.0 (0-0)	0.0 (0-7)	0.3173	4.0 (2-6)	0.0 (0-0)	0.0656	1.0 (0-4)	0.0 (0-7)	0.8527

[Table/Fig-4]: Statistical analysis of MRI data on branching pattern of arteries supplying LEFT breast: comparison of variables.
Values presented as number of branches of each artery: Median value (minimum-maximum value)
IMA: Internal mammary artery; LTA: Lateral thoracic artery; Wilcoxon signed-rank test



[Table/Fig-5]: MRI (Axial view) showing arteries supplying the breast parenchyma from a central position and distributed in both halves of the breast.
Yellow arrows: central arteries supplying the breast parenchyma



[Table/Fig-6]: MRI (Axial view) showing arterial supply of the NAC.
PIMA: Perforator branch of Internal Mammary (thoracic) artery (IMA); red arrows point towards the perforator arteries; NAC: Nipple-areola complex; yellow arrows: branches from the perforator arteries (from IMA) that supply the NAC

through accurate surgical technique combined with a better understanding of vessels supplying the breast parenchyma and NAC. The present study was designed to examine the distribution of the main vessels supplying the gland and NAC, with the overall goal of aiding functional preservation during surgery and thus limiting postoperative complications. The present analysis could assist

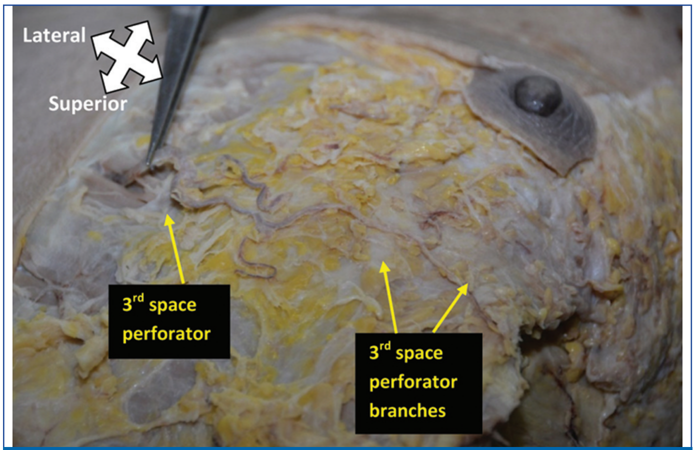
Principal artery of supply	Side	Cases with MRI finding, n (%)		
		Group 1	Group 2	Group 3
IMA	Right	8 (42.11)	16 (59.26)	1 (25)
	Left	12 (63.16)	21 (77.78)	2 (50)
LTA	Right	3 (15.79)	2 (7.41)	0
	Left	0	0	0
Both	Right	5 (26.32)	6 (22.22)	2 (50)
	Left	3 (15.79)	2 (7.41)	0
Not seen	Right	3 (15.79)	3 (11.11)	1 (25)
	Left	4 (21.05)	4 (14.81)	1 (25)
Others	Right	0	0	0
	Left	0	0	1 (25)

[Table/Fig-7]: MRI data on principal artery supplying NAC.
IMA: Internal mammary artery; LTA: Lateral thoracic artery

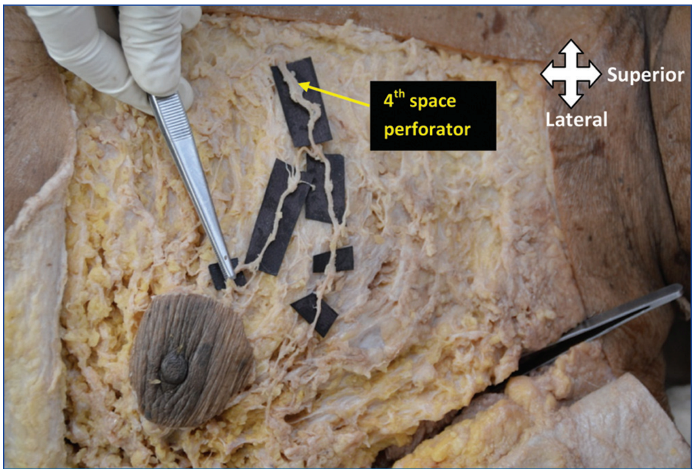
[Table/Fig-8]: Dissected right breast showing perforating branch of IMA, arising from 2nd intercostal space, supplying breast parenchyma and NAC.

surgeons in enhancing their existing surgical knowledge about breast vasculature, specifically focusing on that of NAC. The observations recorded from MR scans were largely consistent with the results seen during cadaveric dissection in the current study.

Both MRI and cadaveric breast dissection revealed that the majority of vessels supplying the medial half of both breasts arise from the IMA, while those supplying the lateral half on either side arise from the LTA. This aligns with the findings reported by several researchers in the past [20-27]. Contributions from the pectoral branch of TAA were observed in only one of the cadavers dissected; however, its minimal contributions have been reported [24]. The vascular horizontal ligamentous septum described in a study was not



[Table/Fig-9]: Dissected right breast showing perforating branch of IMA arising from 3rd intercostal space, supplying breast parenchyma and NAC.



[Table/Fig-10]: Dissected left breast showing perforating branch of IMA arising from 4th intercostal space, supplying breast parenchyma and NAC.

Side	Number of breasts dissected	Number (n) of cases with principal supply from		
		IMA perforators	LTA branches	Other arteries
Left	5	4	0	1 (TAA)
Right	6	6	0	0

[Table/Fig-11]: Cadaveric data on arteries supplying breast parenchyma and NAC.
IMA: Internal mammary artery; LTA: Lateral thoracic artery; TAA: Thoracoacromial artery

observed during cadaveric dissection in the present study [28]. MRI showed perforator branches from the IMA in both the medial and lateral halves of the breast, distributing more extensively on the medial side. The branches of LTA were predominantly found in the lateral half, with fewer branches reaching the medial half. The parenchymal branches were clearly visible in MRI, but could not be adequately traced in cadaveric dissection as some were found adherent to the fascia and were damaged, if separation was attempted. Some small cutaneous branches were stripped off as the skin flap was raised during dissection. The vascular supply of NAC was primarily found to originate from IMA perforator branches in the 2nd, 3rd and 4th intercostal spaces. These perforators were either direct branches of the IMA or its anterior intercostal branches. Contribution from the LTA was considerably less as deduced from MRI and virtually not identifiable during cadaveric breast dissection. While tracing the internal mammary perforators during dissection, they were seen to divide into a number of branches after emerging from the intercostal spaces. Most of these branches supplied the greater part of the breast parenchyma, while a few were observed traversing the subcutaneous tissue to supply the overlying skin and NAC. These results somewhat corroborate with the findings of studies conducted in the past [7,21,26,27,29,30], but do not correlate with one study [20].

Some parenchymal branches were also found to reach the NAC from the underlying deeper tissue. The branches of IMA perforators were observed to reach the NAC from both superficial and deeper parts, as seen in MRI and during cadaveric breast dissection. Therefore, the risk of complications was found to be higher if plexuses (dermal and subdermal) around the NAC were disturbed while dividing the deeper blood vessels during mastectomy [31]. The findings of the present study correlate well with a recent cadaveric study, which observed that perforator branches reach the NAC while coursing within the subcutaneous tissue and also demonstrated the utility of preserving the perforator branches in a case of NSM [32]. Preoperative evaluation of the vascular anatomy of NAC, utilising the CTA technique, also found that IMA perforators predominantly supply the NAC [13,17-19]. And large IMA perforators emerge from the first and second intercostal spaces in a majority of the study population [12].

The MR scans could also locate the arteries supplying the NAC through branches arising both in superficial and deep parts of the breast. These findings correlate well with the studies conducted in the past [14,15]. Some researchers also utilised MRI techniques to evaluate and classify NAC perfusion. They found that the superomedial source vessels predominantly supply the NAC and concluded that defining the NAC supply preoperatively may help in planning the surgical procedures, which correlates with the present study [16].

The finding of one major perforator in each breast supplying the parenchyma and then reaching to supply the NAC was consistently observed in MRI and also during cadaveric breast dissection. Hence, it becomes vital to preserve the medial side of the breast, as far as, possible. Therefore, the anatomic configuration of blood flow to the breast and NAC may be helpful in preventing postoperative ischaemia and NAC necrosis, if assessed preoperatively.

Limitation(s)

The vascular supply of the mammary gland and NAC in normal and pathological cases/specimens cannot be compared, and how the vascular supply is altered by benign and malignant pathology can also be interpreted.

CONCLUSION(S)

The IMA perforators supply the NAC most consistently and a major part of breast parenchyma as well. Preoperative assessment of blood flow to the breast and NAC, utilising MRI techniques, may prevent postoperative ischaemia and nipple necrosis, allowing modifications to the operative approach.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
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- Manual Googling: Dec 27, 2023
- iThenticate Software: Jan 01, 2024 (4%)

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- Financial or Other Competing Interests: None
- Was Ethics Committee Approval Obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

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