Original Article	**The Anatomical Basis for the Possible Internal Mammary Artery Perforators Flaps**

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ABSTRACT

Background: Conservative therapy for breast tumors respecting the patient psychology is gaining popularity; but it could be followed by deformities especially in dealing with tumors involving the medial part of the breast. The internal mammary artery perforators' flap is widely used for immediate tissue replacement following local excision of tumors in the medial part of the breast.

Material and Methods: Ten formalin preserved cadavers from the dissecting room of the Anatomy and Embryology Department, Faculty of Medicine, Alexandria University were used. the beginning of the internal mammary artery was injected with red latex, the perforators of the internal mammary artery were dissected from medial to lateral where the course, length, diameter and branching pattern of each perforator was recorded and photographed.

Results: The second internal mammary artery perforator (IMP 2) was the largest constant and the dominant perforator in 55%; it gave arterial supply to the cranial part of the breast; its mean diameter was 2.23± 0.42 mm. The fourth internal mammary artery perforator (IMP 4) was dominant in 45%; it gave arterial supply to the caudal part of the breast from the level of the third space and going down. Its mean diameter was 1.95± 0.17 mm.

Conclusion: IMPs 2, 3 and 4 could be used in breast reconstruction for the contra lateral breast. IMP 4 could be used to reconstruct the contra lateral breast especially to reconstruct defects following wide local excision in tumors involving the medial part of the contra lateral breast.

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Key Words: Breast reconstruction, dominant perforator, free flab, IMA perforators, medial breast defects and mammoplasty, pedicle flap.

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INTRODUCTION

Conservative therapy for breast cancer has become very common; but it may cause complications especially when more than 20 % of the medial part of the breast should be removed.[1]

The internal mammary artery perforators' flaps are widely used for immediate tissue replacement following local excision of tumors in the medial part of the breast.[2]

The most possible free flap transfers in breast reconstruction are internal mammary artery perforators (IMPs), thoracodorsal vessels (TDVs) and the internal mammary vessels (IMVs). Each of which has advantages and disadvantages.[3]

The easy exposure of the internal mammary artery perforators without the need for costal chondrectomy or dissection of pectoralis or intercostal muscles had made the IMP flaps superior to internal mammary artery (IMA) flaps.[4]

The use of IMP flaps spares the internal mammary artery which may be needed for possible coronary bypass surgery.[3, 4] In case of immediate tissue replacement, the use of IMPs is the best compared to IMVs or TDVs because of its easy exposure, less tissue manipulation and dissection, and less flap complications as partial or complete loss either or fat necrosis.[5]

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The most important target for breast reconstruction is to decrease donor site morbidity which could be reduced by the use of discarded tissue.[5]

Wide local excision of neoplastic tissue in one breast would be followed by asymmetry or discrepancy of both sides, which is very marked in Egyptian women and many other countries where obesity rates are high and the sizeable breast are common.[6]

IMPs flaps could be used to cover anterior neck defects and in breast reconstruction. This is now gaining popularity which requires complete accurate detailed anatomical knowledge of such vessels as regards their number, course, branching pattern, length, diameter, dominance and the possible variations of such vessels.

MATERIAL AND METHODS

Ten formalin preserved female cadavers from the dissecting room of Anatomy and Embryology Department, Faculty of Medicine, Alexandria University was used.

The cadavers' age ranged from 32 to 65 years. None of them showed scars of open heart, breast or thoracic surgery.

The thoracic cavity was opened from the lateral side using electric bone saw to facilitate cutting through the ribs; Dissection of the sterno-clavicular joint followed by separation of the clavicle from the sternum was done. The thoracic rim was released from the neck root to facilitate opening of the thoracic cavity.

The beginning of the internal mammary artery was identified, injected with ammonium hydroxide for removal of clots from the arteries followed by injection with red latex and left for a week to allow latex to settle down.

The perforators of the internal mammary artery was dissected and carefully traced from medial to lateral where, the course, length, diameter at its origin and branching pattern of each one were recorded and photographed.

Each perforator was traced till its final ramification laterally while medially it was traced till the point of perforation of the pectoralis major then dissected and followed through pectoralis major and intercostal muscles till its origin from the internal mammary artery.

The possible added length of the internal mammary artery to be used in advanced flap was measured from the origin of each perforator in the inner aspect of the opened chest wall till the first costal cartilage.

RESULTS

By dissection of twenty hemi-cadaveric specimens, the IMPs 1-5 supplied the skin of the medial side of the chest including the medial part of the breast extending to the midclavicular line.

I- Length, diameter and skin area supplied by IMP 1

Out of twenty dissected first intercostal spaces, IMP1 was absent in four cases (20%). In 16 out of twenty dissected first intercostal spaces (80%), the diameter of IMP1 ranged from 0.98 mm to 1.65 mm with an average of 1.17± 0.16 mm, its length from the point of perforation till final ramification ranged from 4.98 mm to 7.36cm. with an average of 6.22± 0.05 cm, its length from the origin till final ramification ranged 5.02 cm to 7.51 cm with an average of 6.27 ± 0.74 cm (Tables1- 3, Figures 1, 5a, b).

The total length of IMP1 plus the added length of the IMA till the first costal cartilage ranged from 5.75 cm to 8.51 cm with an average of 7.4 ± 0.8cm (Tables 4).

II- Length, diameter and skin area supplied by IMP 2

Out of twenty dissected second intercostal spaces, IMP2 was present in all cases. In 14 cadaveric specimens (70%), it was single artery and in six cases (30%) it divided into superficial and deep divisions that ran parallel to each other. (Figures 2 a, b,3a,b, 4 a,b,c, 5 a,b).

The diameter of IMP2 ranged from 1.48 mm to 2.96 mm with an average of 2.23± 0.42 mm, its length from the point of perforation till final ramification ranged from 7.22 mm to 13.08 cm. with an average of 10.66± 1.72 cm, its length

from the origin till final ramification ranged from 7.28 cm to 13.13 cm with an average of 10.71± 1.72 cm. (Tables 1, 2)

The total length of IMP2 plus the added length of the IMA till the first costal cartilage ranged from 10.99 cm to 18.33 cm with an average of 14.24 ± 1.43 cm. (Tables 4)

III-Length, diameter and skin area supplied by IMP 3

Out of twenty dissected third intercostal spaces, IMP3 was absent in two cases (10%).it was a single artery in14 cases (77.8%) and in four cases (22.2%), it divided into superficial and deep divisions that ran parallel to each other.

The diameter of IMP3 ranged from 0.88 mm to 1.8 mm with an average of 1.33± 0.24 mm, its length from the point of perforation till final ramification ranged from 6.02 cm to 10.45 cm. with an average of 8.54± 1.22 cm, its length from the origin till final ramification ranged from 6.07 cm to10.48 cm with an average of 8.59 ± 1.23 cm. (Tables 1, 2, 3, Figures 1, 2a, b).

The total length of IMP3 plus the added length of the IMA till the first costal cartilage ranged from 11.85 cm to 18.8 cm with an average of 15.09 ± 1.74 cm. (Tables 4).

VI-Length, diameter and skin area supplied by IMP 4

Out of twenty dissected fourth intercostal spaces, IMP4 was present in all cases. In 16 cadaveric specimens (80%), it was a single artery and in four specimens (20%) it divided into superficial and deep divisions that ran parallel to each other. (Figures 1, 2 a, b,4 a,b,c, 5 a,b).

The diameter of IMP4 ranged from 1.39 mm to 2.32 mm with an average of 1.95± 0.17 mm, its length from the point of perforation till final ramification ranged from 8.66 cm to 11.01 cm. with an average of 9.8 ± 0.52 cm, its length from the origin till final ramification ranged from 8.71 cm to 11.07 cm with an average of 9.85 ± 0.52 cm. (Tables 1, 2, 3).

The total length of IMP4 plus the added length of the IMA till the first costal cartilage ranged from 16.11 cm to 19.02 cm with an average of 17.41 ± 0.44 cm. (Tables 4)

V- Length, diameter and skin area supplied by IMP 5

Out of twenty dissected fifth intercostal spaces IMP5 was absent in five cases (25%). The diameter of IMP5 ranged from 0.86 mm to 1.1 mm with an average of 0.95± 0.05 mm, its length from the point of perforation till final ramification ranged from 3.98 mm to 6.44 cm. with an average of 5.34± 0.73 cm, its length from the origin till final ramification ranged from 4.03cm to 6.48 cm with an average of 5.39 ± 0.73 cm. (Tables 1, 2, 3, Figures 5a, b)

The total length of IMP5 plus the possible added length of the IMA till the first costal cartilage ranged from 13.25 cm to 16.22 cm with an average of 14.66 ± 0.55 cm. (Tables 4)

IV-Dominance and branching patterns of IMPs

In eleven out of the 20 cadaveric specimens (55%), the IMP2was the dominant perforator (has the largest diameter) and supplied the cranial part of the breast while in the remaining 9 cadaveric specimens (45%), the IMP4 was the dominant one and supplied the caudal part of the breast.

In thirteen out of hundred dissected intercostal spaces (13%), the perforator arteries had a very short stem that divided into two divisions a superficial and a deep one of which the deep branch was larger. They ran parallel to each other. With large voluminous female cadaveric breasts 2 arteries were seen in the space. This was noticed with IMP2 (6 spaces), IMP3 (3 spaces) IMP4 (4 spaces). (Figures 3, 4, 5).

The superficial division ran just under the skin and gave numerous branches to supply the skin, fat and superficial part of the breast. The deep division ran between the glandular tissue of the breast and the deep fascia giving numerous branches to supply the breast glandular tissue. (Figures 3, 4, 5).

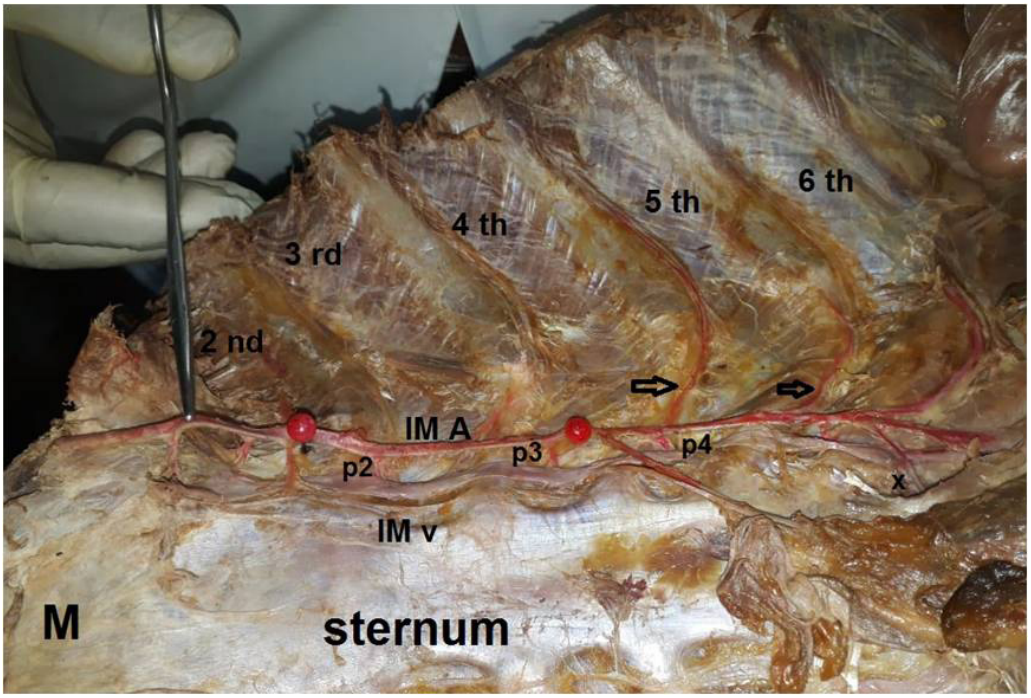

Fig. 1: A photograph of the right side of chest with the thoracic wall opened laterally showing the right internal mammary artery (IMA) and vein (IM v) and the second (P2), third (P3) and fourth perforators (p4) originating from the IMA. The fifth and sixth anterior intercostal arteries are seen originating from IMA.
2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} are the second, third, fourth, fifth and sixth intercostal spaces respectively. (Arrows)
M = manubrium. X= xiphoid branch of the IMA.

Fig. 2a: a photograph showing left breast with the left second, third and fourth internal mammary perforators (IM2, IM3 and IM4). The IM 4 divided into two branches.
C = cannula for injection of the beginning of the IMA with red latex. Right breast (rt breast)

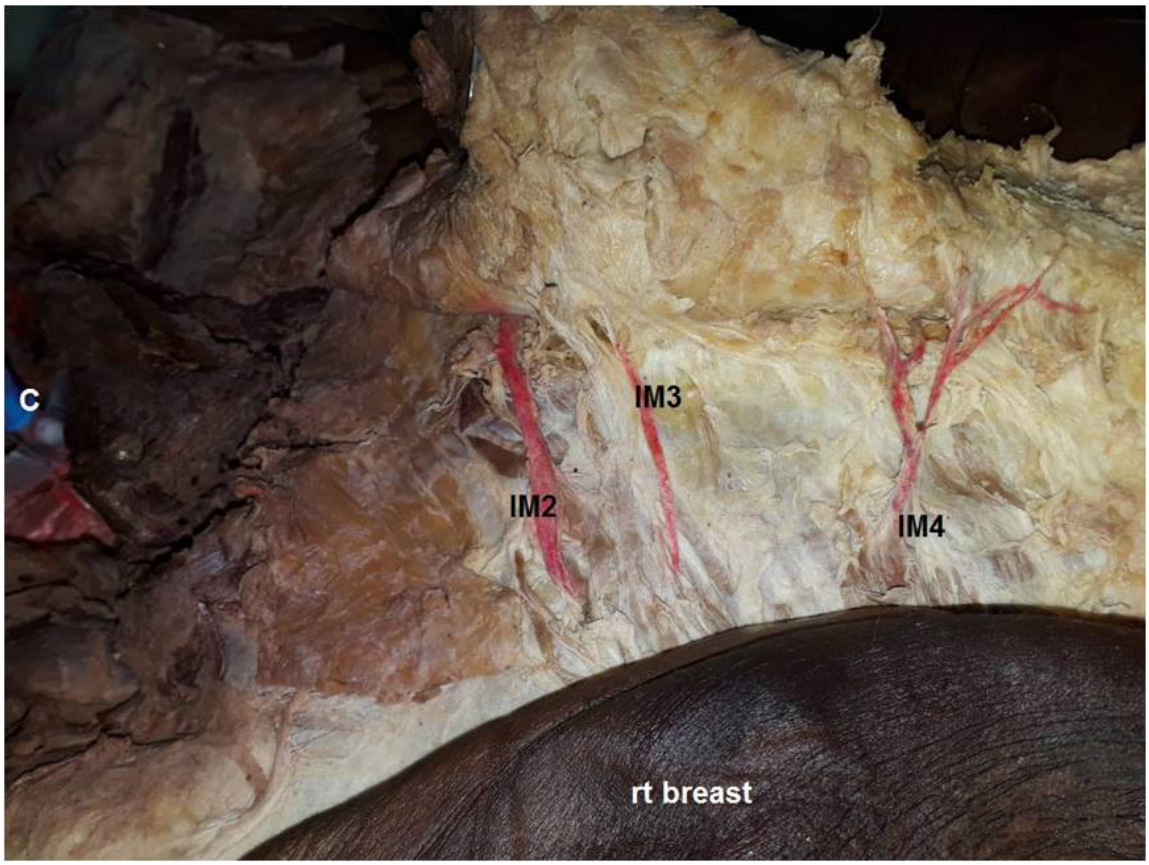

Fig. 2 b): A close up view of the previous figure.

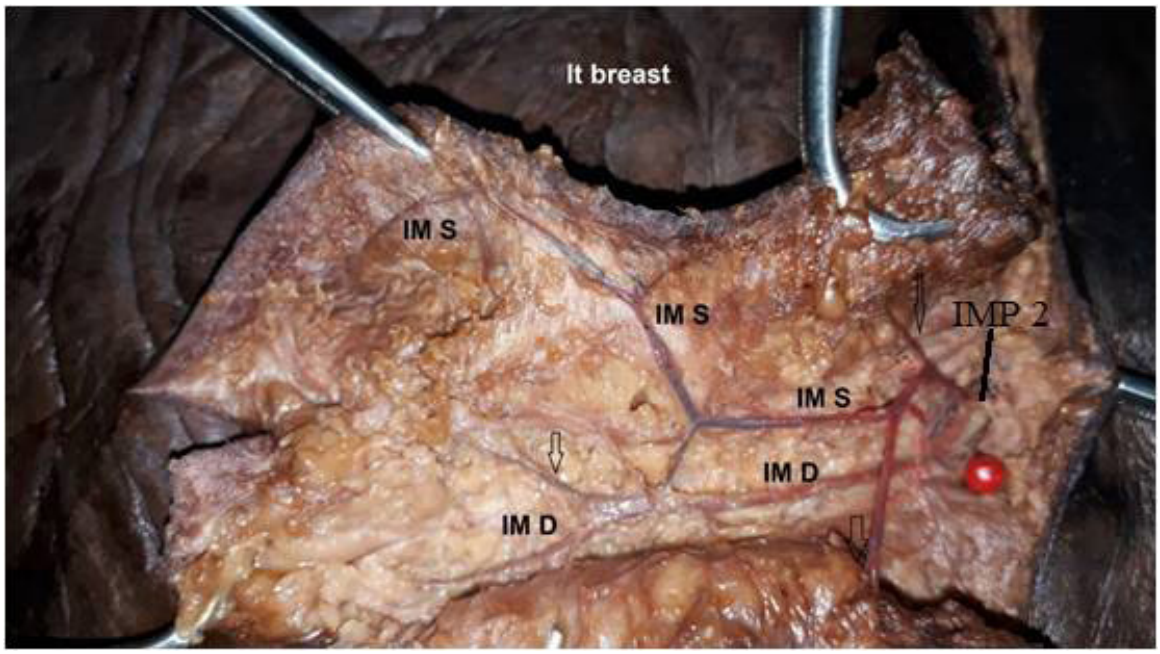

Fig 3a: A photograph of the left side of the chest showing the left second internal mammary perforator (IMP2) just after the perforation divided into superficial (IM S) and deep (IM D) divisions. The IM S runs just below the skin giving many cutaneous branches (arrows). The IMD runs deep to the glandular tissue of the breast. The red pin is inserted in the second intercostal space.

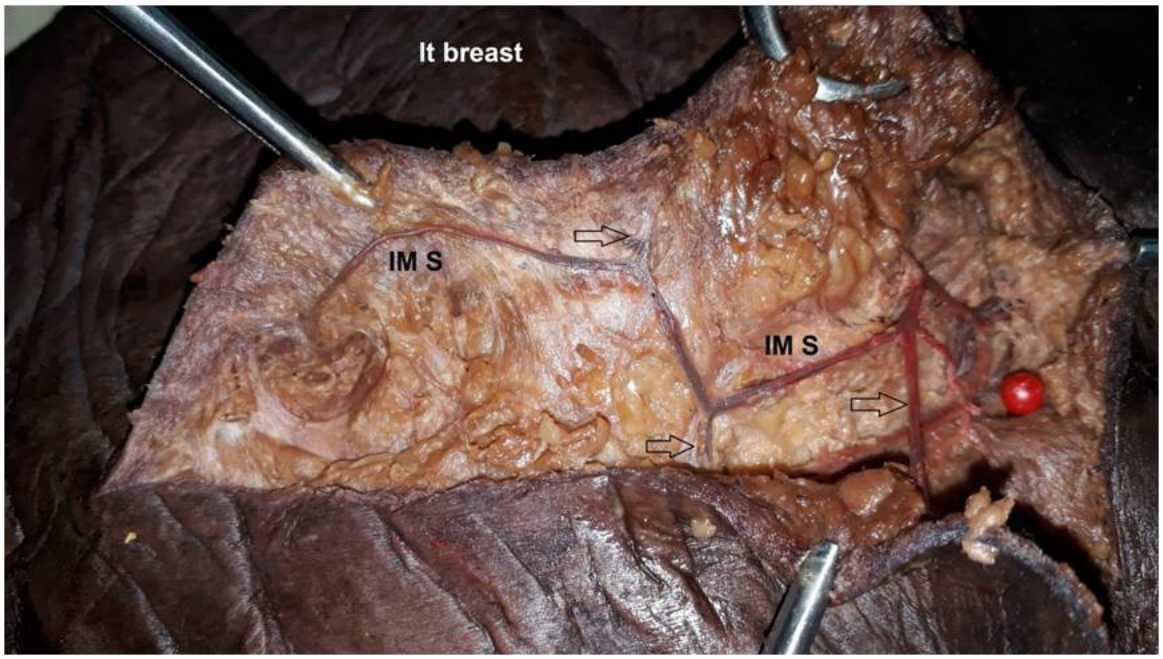

Fig. 3b: A close up view of the previous photograph showing the branches of IM S (⇨). Lt Breast: left breast.

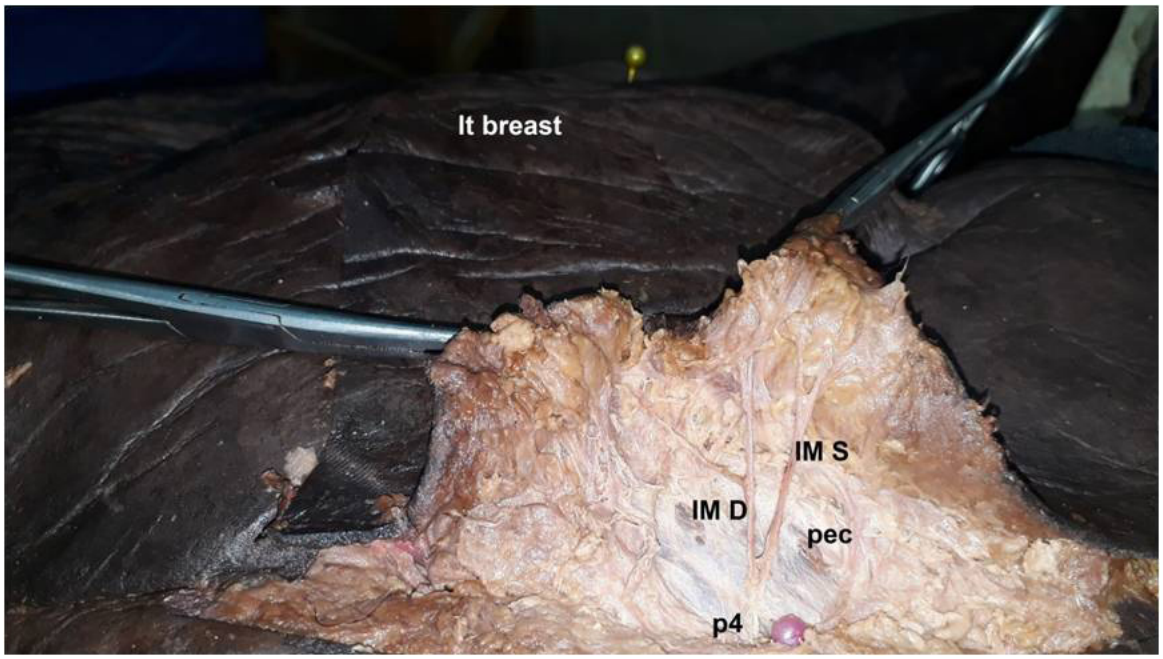

Fig. 4 a: a photograph of the left side of the chest showing the fourth internal mammary perforator (p4) is giving a superficial (IM S) and deep divisions (IM D). The yellow pin indicating the nipple of the left breast (Lt Breast) and the pin is inserted in the fourth intercostal space. Pec: pectoralis major muscle.

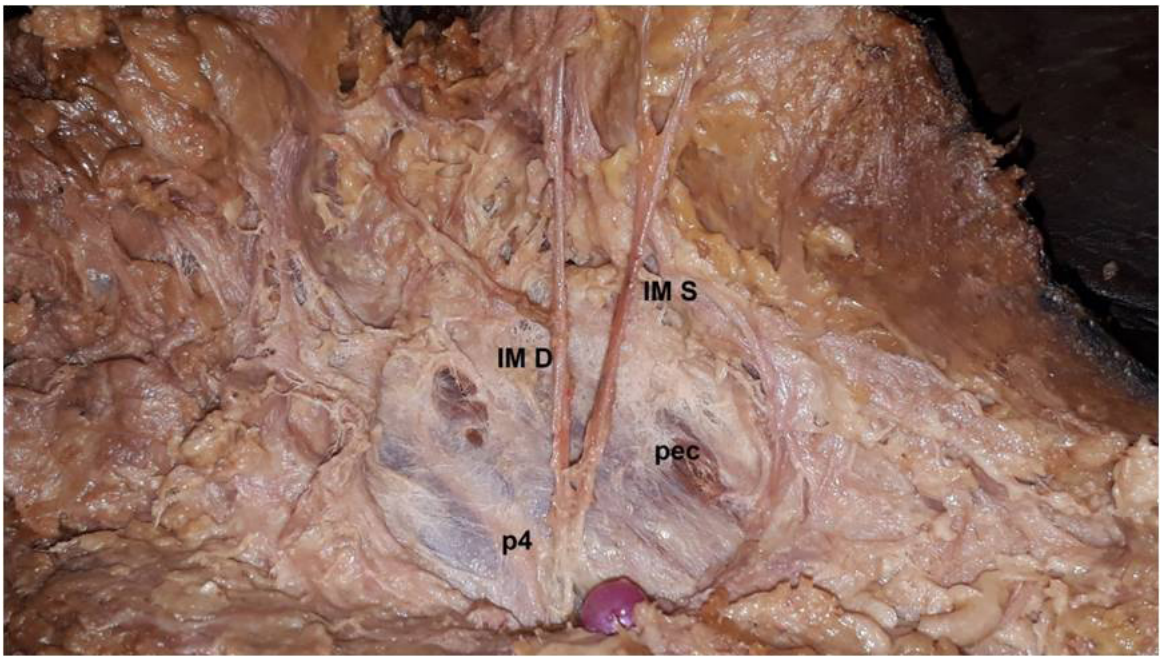

Fig. 4 b: a close up view of the previous photo.

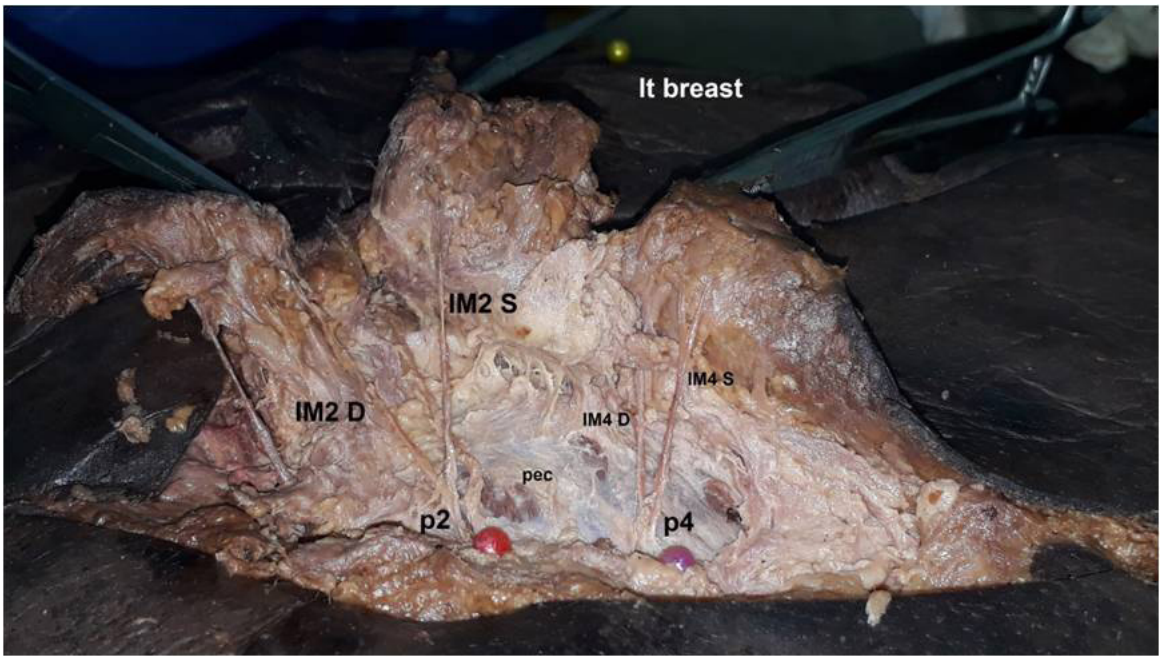

Fig. 4 c: a photograph of the previous specimen showing second (p2) and fourth (p4) internal mammary perforators each giving superficial (IM2S, IM4S) and deep (IM2 D, IM4 D) divisions, the red pin and the violet pin are inserted into the second and fourth intercostal spaces respectively and the yellow pin indicating the nipple.

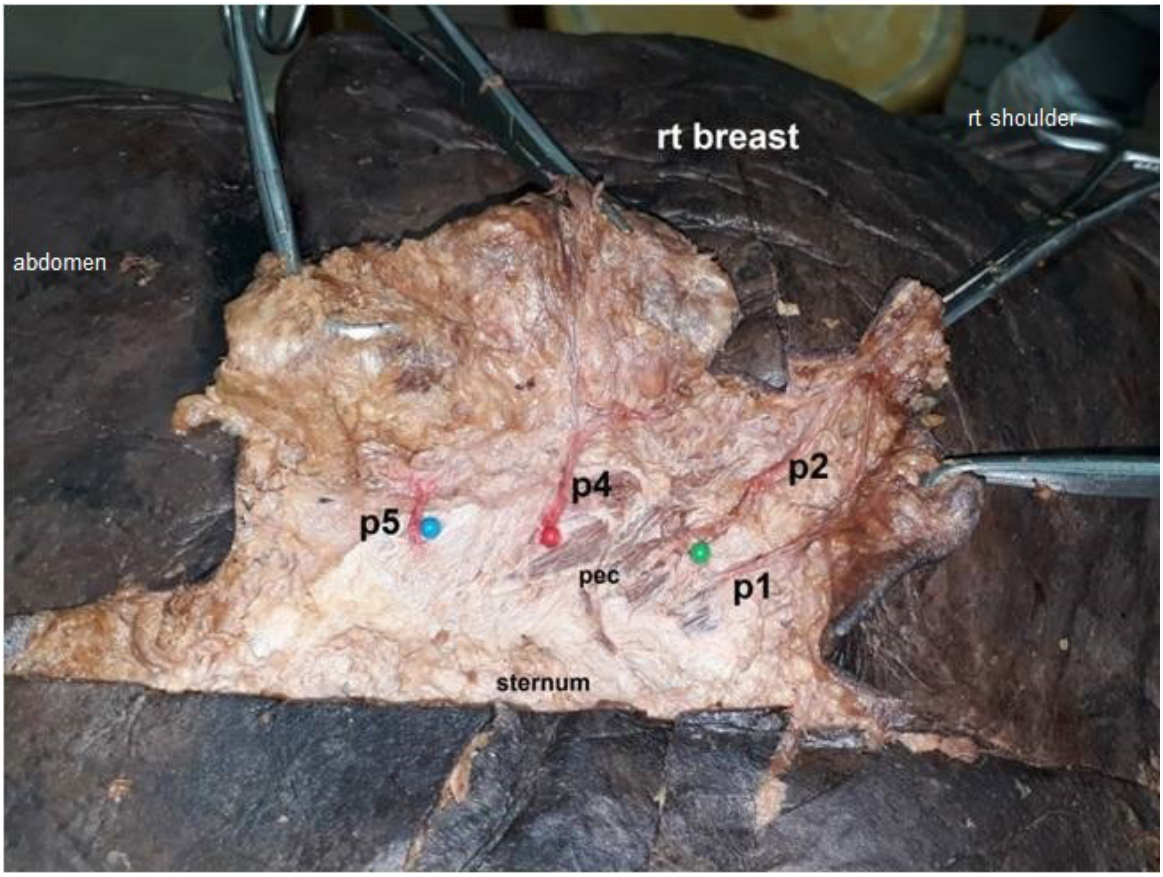

Fig. 5 a: a photograph showing the right female breast (rt breast) and the first (p1), second (p2), fourth (p4) and fifth (p5) internal mammary artery perforators. The green, red and blue pins are inserted into the second, fourth and fifth intercostal spaces respectively.
Pec= pectoralis major muscle.

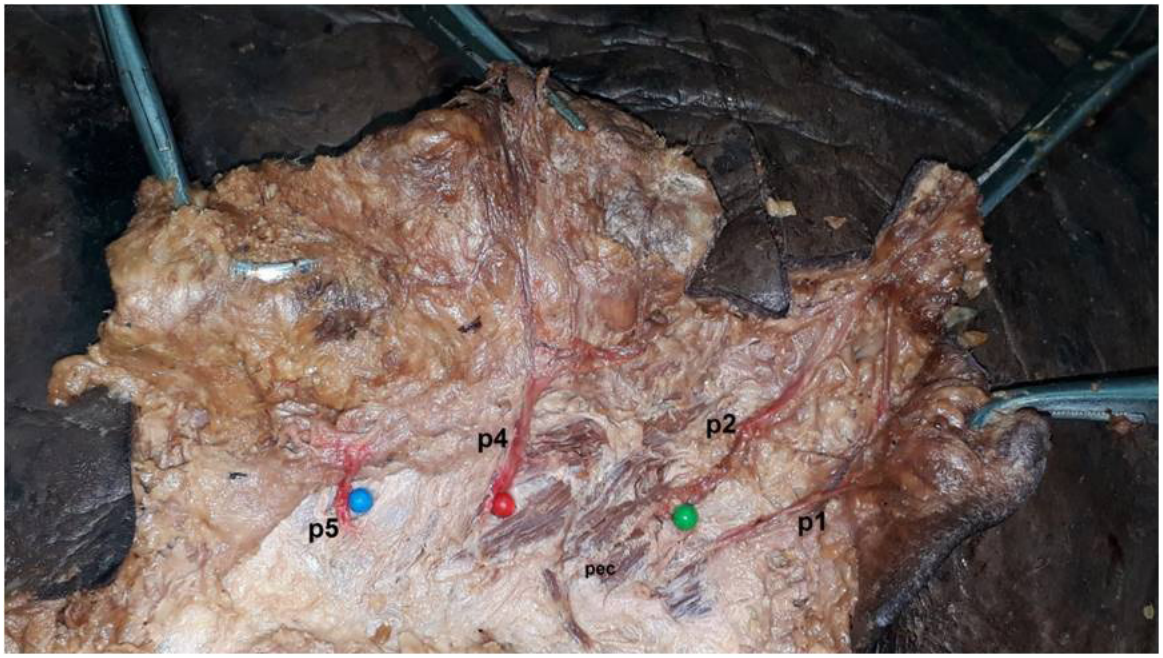

Fig. 5 b: a close up view to the previous photo.

Table 1: Diameter of internal mammary artery perforators (IMP) in mm in 20 cadaveric specimens

Perforator	range	Mean(mm)
IMP1	0.98-1.65	1.17±0.16
IMP2	1.48-2.96	2.23±0.42
IMP3	0.88-1.80	1.33±0.24
IMP4	1.39-2.32	1.95±0.17
IMP5	0.86-1.10	0.95±0.05

Table 2: Length of internal mammary artery perforators (IMP) in cm from the point of perforation till final ramification in 20 cadaveric specimens (the dissectible length).

Perforator	range	Mean(cm)
IMP1	4.98-7.36	6.22±0.05
IMP2	7.22-13.08	10.66±1.72
IMP3	6.02-10.45	8.54±1.22
IMP4	8.66-11.01	9.80±0.52
IMP5	3.98-6.44	5.34± 0.73

Table 3: Length of internal mammary artery perforators (IMP) in cm from the origin till the final ramification in 20 cadaveric specimens.

Perforator	range	Mean(cm)
IMP1	5.02-7.51	6.27± 0.74
IMP2	7.28-13.13	10.71±1.72
IMP3	6.07-10.48	8.591.23±
IMP4	8.71-11.07	9.85±0.52
IMP5	4.03-6.48	5.39± 0.73

Table 4: Length of internal mammary artery perforators (IMP) in cm plus the length of internal mammary till the first costal cartilage in 20 cadaveric specimens.

Perforator + IMA	range	Mean(cm)
IMP1+IMA	5.75-8.51	7.4±0.8
IMP2+IMA	10.99-18.33	14.24±1.43
IMP3+IMA	11.85-18.8	15.09±1.74
IMP4+IMA	16.11-19.02	17.41±0.44
IMP5+IMA	13.25-16.22	14.66±0.55

DISCUSSION

Conservative therapy for breast cancer is more psychologically accepted for the patient and has a survival rate equivalent to mastectomy but in cases of sizable tumors especially of the medial half of the breast where more than one fifth of the breast would be removed, it could be associated with deformities.[1]

The internal mammary artery perforators' flaps are popular especially for immediate tissue replacement following local excision of tumors in the medial part of the breast.[2]

Studies concerning the detailed anatomy of the internal mammary artery perforators are minimal despite the increasing importance and popularity of the internal mammary artery perforators` based flaps for both head and neck or breast reconstructive surgeries.

In the present study IMP1 has an average diameter of 1.17 ± 0.16 mm, its length was 6.27 ± 0.74 cm. it was absent in four cases (20%). It was the second smallest after IMP5 as regards length, diameter and skin area supplied.

Schellekens *et al*.[6] in their study on IMP flap for head and neck reconstruction, found that IMP1 was the least dominant one and was found in only 15%. These results match our results. But this study was directed for IMP 1, 2 and 3 that could be used mainly to reconstruct anterior neck defects and did not follow all the IMPs.

In our study, the IMP2 has an average diameter of 2.23 ± 0.42 mm, its length was 10.66 ± 1.72 cm. It was present in all specimens. It was the largest internal mammary perforator as regards length; diameter and skin area supplied. It supplied the cranial parts of the breast.

Schmidt *et al*.[7] in their cadaveric study on IMP`s stated that the second IMP supplies the area medial and cranial to the areola and was the perforator with the widest diameter and supplied the biggest area of the skin, a finding which is in agreement with the present study.

Hamdi *et al*.[8] stated that flaps depending on IMA 2 provide valuable options in breast surgery and for challenging defects on the trunk without sacrifice of the underlying muscle. This is explained anatomically by the dominance of the IMP 2 proved by the present study.

In the present study the average diameter of IMP3 was 1.33 ± 0.24 mm, its length was 8.54 ± 1.22 cm. It was not found in two cases (10%). It rated the third in order after the IMP2 and IMP4 as regards the diameter, the length and the skin area supplied.

Elzawawy *et al*.[9] in their study on the Submammary adipofascial flap based on its arterial supply noted that IMP4 was markedly large in women and that IMP3 and IMP4 can be used as a base for fascial or fasciocutaneous flaps for breast reconstruction. They did not mention any possible role for IMP2and did not follow all the IMPs as their study was conducted on the IMPs that supply the submammary adipofascial flap (SMAF).

Schellekens *et al*.[6] stated that IMP3 was second in dominance among the perforators after the IMP2. But this study was directed for head and neck surgery and focused mainly on the upper three IMPs those could be used and their length can be enhanced by costal cartilage excision and adding a part of the internal mammary artery. But the IMP4 and IMP5 could not be used to avoid disrupting the integrity of the thoracic cavity and were not included in the study.

In the present work, the average diameter of IMP4 was 1.95 ± 0.17 mm, its length was 9.8 ± 0.52 cm, and was found in all dissected cadaveric specimens. It was the second in dominance of the perforators after IMP2 and thus IMP4 can ensure a good blood supply to the caudal part of the breast.

IMP4 thus provide adequate blood supply for the caudal part of the breast and can provide a base for a flap either fascio-cutaneous or adipo-fascio-cutaneous or glandulo-fascio-cutaneous flap. Either a rotational flap or a free island flap or it can be used as a recipient vessel in free island flaps.

Flaps based on IMP4 using the caudal part of the breast will be very valuable in reconstructing defects in the medial side of the contra lateral breast especial following wide local excision of tumors in the medial side of breast; Thus reducing the size of the healthy breast and using the tissue that would be normally discarded; the tissue of the reduction mammoplasty of the healthy side.[5,7]. This has many advantages especially in obese patients where wide local excision results in obvious discrepancy in the size of both breasts.

In this group of patients using the caudal part of their healthy breast to reconstruct defect following wide local excision of cancer especially those tumors involving the medial side of the breast provide a very good solution, decrease operation time, and provide immediate breast reconstruction with minimal morbidity at the donor site thus improving patients' psychology and this matches with schoeller5technique and coincide with the opinion of Schmidt *et al*.[7]

Schellekens *et al*.[6] did not mention IMP4 in their study and the dominant perforators was the second, third or the first in this order as they studied the enhanced flap for head and neck reconstruction where IMP4 and IMP5are not suitable for advanced head and neck flap.

Schmidt *et al*.[7] noted that as regards the length and diameter of the perforators, the IMP4 ranked the fourth after IMP2, IMP3 and IMP1respectively although the differences in

the perforators measurements were minimal, a finding which is not in agreement with the present study.

In the present study the average diameter of IMP5 was 0.95 ± 0.05 mm, its length was of 5.39 ± 0.73 cm. It was absent in five cases (25%). It was the smallest perforator and ranked fifth regarding the length, diameter and the skin area supplied.

Schmidt *et al*.[7] stated that IMP5 supply the skin of the abdominal wall just below the submammary fold and it is the smallest IMP thus matching our results.

According to the present study, the main perforator supplying the caudal part of the breast inferior to the areola is IMP4 while the IMP2 is the main perforator supplying the cranial part of the breast. This findings support Morain *et al*.[10] and Würinger *et al*.[11] concept as regards the anatomy and blood supply of the breast and the presence of the horizontal septum dividing the breast in two main parts; cranial and caudal each with dependent blood supply which give a chance to deal with the caudal part of the breast as a dependent unit with separate blood supply and a clear boundaries the horizontal septum so we could mobilize it easy either for removal in reduction mammoplasty or for reconstruction of contra lateral side in split breast flap technique by Schoeller.[5]

In the present study the size of the IMPs in each single specimen was not equal usually there is one large IMP with a clear difference in diameter and length with the other IMPs. In eleven specimens (55%) IMP2 was the dominant perforator and in the remaining 9 specimens (45%) the IMP4 was dominant.

This go with the general principle of the dominance of one perforator and this possible anatomical variation on the measurements of the IMPs necessitate a preoperative imaging study either CTA (computed topography angiography), magnetic resonance angiography (MRA). Doppler or duplex study could be used to map the location, size and blood flow inside the perforators or simply the use of a hand hold Doppler to map and asses the IMPs this is of ultimate importance in planning of any reconstructive surgery involving an IMA or IMP based flap.[12,13]

In thirteen intercostal spaces (13%) the perforator arteries divided into two divisions a superficial and a deep one. Two arteries in one space some but not always was noticed in case of absence of perforator in the nearby space but most cases where with large voluminous breasts this was noticed with IMP2 (6 spaces), IMP3 (3 spaces) IMP4 (4 spaces) in female cadavers, to ensure a good share in blood supply for the requirements of the large bulk of the breast.

Schmidt[7] noted the absence of IMPs in seven out of hundred intercostal spaces, IMP5 absent in 3 spaces, IMP4 was absent in two spaces and IMP1 and IMP3 each was absent in one case. And the presence of two separate perforators in one intercostal space was found for IMP2 in two spaces and was found in one case for each IMP3 and IMP4. A finding that matches the results of the present study.

CONCLUSIONS

The IMPs 1, 2 and 3 could be used for head and neck reconstruction either simply or as advanced flap with a possible added segment from IMA itself up to the level of the first costal cartilage.

IMPs 2, 3 and 4 could be used in breast reconstruction for the contra lateral breast.

Usually there is one dominant perforator artery which is larger than the other perforators. This mostly could be IMP2 or IMP4.

IMP4could be used to reconstruct the contra lateral breast especially to reconstruct defects following wide local excision in tumors involving the medial part of the contra lateral breast.

Pre-operative radiological assessment for the perforators using either CTA or MRA or duplex study or just the use of preoperative hand hold Doppler is mandatory for mapping the perforator for good surgical planning.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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الاسس التشريحية للرقع الجراحية الممكنة لمخرزات الشريان الثدى الداخل

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جامعة الاسكندرية

ملخص البحث

المقدمة: العلاج التحفظى لاورام الثدى يزداد شيوعا حيث انه يحترم نفسية المريض , و لكنه قد يكون متبوعا بحدوث تشوهات فى شكل الثدى و ذلك خاصة فى علاج الاورام الموجودة بالجانب الانسى للثدى .

رقعة الشريان الثديى الداخلى تستخدم على نطاق واسع للتعويض الفورى للانسجة الناتج عن عمليات استئصال الاورام بالجزء الانسى للثدى و منع حدوث تشوهات بشكل الثدى.

مواد وطرق البحث: تم اجراء البحث على عشرة جثث من مشرحة قسم التشريح بكلية الطب جامعة الاسكندرية.

تم فتح القفص الصدرى و حقن بداية الشريان الثديى الداخلى بمادة اللاتكس الاحمر لاظهار الشرايين بشكل اوضح.

تم تشريح مخرزات الشريان الثدى كلا عل حدة و تتبع مسار كلا منها مبتدأ من الجانب الانسى حيث تم تسجيل و تصوير المسار , الطول , القطر و نمط التفرع لكلا منها.

النتائج: المخرز الثانى للشريان الثديى الداخلى كان المخرز السائد فى ٥٥٪ من العينات و كان المصدر الرئيسى للامداد دموى للجزء العلوى من الثدى , متوسط قطره كان ٢,٢٣ ± ٠,٤٢ مم.

المخرز الرابع للشريان الثديى الداخلى كان المخرز السائد فى ٤٥٪ من العينات و كان المصدر الرئيسى للامداد الدموى للجزء السفلى من الثدى , متوسط قطره كان ١,٩٥ ± ٠,١٧ مم.

الاستنتاج: مخرزات الشريان الثديى الداخلى الثانى و الثالث و الرابع يمكن استعمالها كأساس للرقع الجراحية لتعويض فقد الانسجة من الجزء الانسى للثدى الاخر و بخاصة فى جراحات تعويض فقد الانسجة الناتجة عن استئصال اورام الجزء الانسى من الثدي الاخر.

الكلمات الرئيسية: مخرزات الشريان الثديى الداخلى , اعادة تكوين الثدى , مخرز سائد , رقعة شريانية , تجميل الثدى و نقص الجزء الانسى للثدى.