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Comparative Study between Computed Tomography Angiography and Doppler Ultrasound in Reduction Mammoplasty

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Abstract

Background: Breast hypertrophy is a challenging condition as it is associated with increased body burden and chest oppression. The most devastating complication of breast reduction which is post-operative necrosis of the nipple-areola complex (NAC).

Objective: This prospective case series study was to investigate the vascular supply to the NAC and to compare between Doppler ultrasound and computed tomography angiography for surgical planning of breast pedicle in reduction mammoplasty.

Patients and Methods: The study was conducted on a total of 17 cases scheduled for reduction mammaplasty in The Plastic Surgery Department at Mansoura University. Preoperative CT angiography, Doppler ultrasound, and intraoperative Doppler ultrasound were used to conduct our study. Radiologists and plastic surgeons work together to conduct a presurgical plan according to the 3D scan and accompanying measurement parameters. Consequent follow-up happened immediately after surgery, up to 6 months, assessing necrosis rates and adverse events of the NAC.

Results: Based on CTA, in right side, we could detect most dominant Inferior perforators in 58.8%, Superiomedial perforator in 41.2%, Superior perforator in 11.8%. In left side, Inferior perforators in 41.2%, Superiomedial perforator in 35.3%, Superior perforator in 17.6%.

Based on Doppler ultrasound, in right breast we could detect most audible inferior equal to superiomedial perforators in 41.2%.

It does not necessitate that the most audible perforator by doppler or the most dominant one by CTA to be selected to survive NAC.

Conclusions: Doppler ultrasound is a valuable method to help in pedicle selection in reduction mammoplasty which has matching results with CT angiography in 75% of examined right breasts and 87.5% in left ones.

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Key Words: *Breast reduction – Blood supply of breast – CT angiography – Doppler Ultrasound – NAC.*

Ethical Committee: Approval was obtained from the Institutional Research Board, Faculty of Medicine, Mansoura University (MS.23.07.2494).

Disclosure: No conflict of interest.

Introduction

Breast hypertrophy is characterized by excessive growth of glandular, adipose, and connective tissues in breast. It is a frequent disease among females of various ages and has been demonstrated to be associated with several physical troubles, such as back pain, costochondritis, fungal infection, and psychiatric stress. In addition, breast hypertrophy is believed to be associated with many adverse events, such as chest oppression, and ultimately leads to cardiac and pulmonary consequences **[1,2,3]**.

Surgeons frequently use unilateral volume **[4]** to classify breast sizes, with normal being between 250 and 350ml, excessive being between 350 and 1000ml, and breast hypertrophy occurring for volumes extending beyond one thousand milliliters **[3]**.

Based on strategies for plastic surgeons, macromastia is described as an extensive amount of breast tissue of more than 1 and less than two kilogram per breast. A resection weight of more than 2.0kg is indicative of gigantomastia **[5]**. Necrosis of NAC has been considered a well-known adverse event of surgery as it could affect the vascular supply throughout dissection and incorrect pedicle selection.

Various surgical approaches emerged to decrease this adverse event; on the other hand, they still require prolonged dissection time throughout operation, and some of them affect the breast ducts, which doesn't suit young females **[6]**. To evade the

risk of NAC necrosis, precise presurgical mapping of the dominant arterial supply to NAC is important for optimum choice of vascular pedicle such as NAC, which is preserved throughout surgery, with safe excision of the remaining breast tissue to get the required size and volume, confirming continuous vascular supply to NAC [7].

Various radiological approaches were, as a result, recommended to define the main arterial supply to NAC prior to surgery to enhance pedicle selection and reduce the risk of NAC necrosis [8].

To the best of our knowledge, Doppler which is a safe, rapid, and cheap method. Versus multislice CT (MSCT) angiography, a method utilized to image various arteries, such as the central and peripheral arteries, with precise outcomes utilizing visually appealing 3D reconstructions, has gained much more popularity among surgeons owing to its similarity to the anatomical image [9].

The aim of our study was to investigate the vascular supply to the NAC and to compare between Doppler us and CTA for surgical planning of breast pedicle in reduction mammoplasty.

Patients and Methods

The current study was a prospective study carried out on a total of 17 cases suffering from breast hypertrophy and scheduled to do reduction mammoplasty at The Plastic Surgery Department of Mansoura University. The required sample size was calculated using the IBM[a] SPSS[a] Sample Power[a] version 3.0.1 (IBM[a] Corp., Armonk, NY, USA). A previous study conducted by Zakhary et al. (2022) reported that the incidence of decreased NAC sensation bilaterally was 16.6% in the cases underwent multislice CT angiography to delineate the dominant arterial supply of nipple-areola complex (Zakhary et al., 2022). Thus, it was estimated that a minimal sample size of 15 patients is required to achieve a power of 80% to detect expected difference within 20% range in the incidence of decreased NAC sensation, at a significance level of 0.05. For considering of dropout, the sample size will be increased by 10%, so the final included number will be 17 cases.

They were referred for presurgical delineation of a dominant arterial supply of NAC for both breasts using HUNTLEIGH Doppler ultrasound 9mgh and GE 128 MSCT angiography, revevo, Japanese medical device. Written informed consent was obtained from all cases contributing to the study after explaining the advantages and disadvantages of the technique, and approval was obtained from the Institutional Research Board, Faculty of Medicine, Mansoura University (MS.23.07.2494).

Doppler ultrasound:

- On cases in Supine position, using a handled Doppler 9mhz starting around the NAC to detect possible perforators and follow them towards sternum medially, supra mammary crease and clavicle superiorly, inframammary fold inferiorly, anterior axillary line laterally.
- The audible triphasic perforators with high amplitude waves over the Doppler screen were marked over the breast (Fig. 1) to be compared with CTA results.

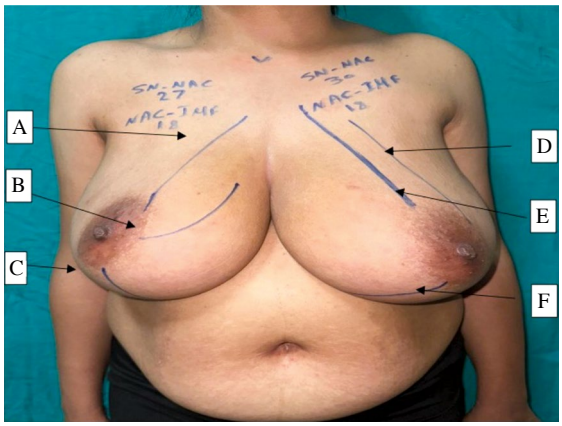

Fig. (1): Female patient aged 29 years old showing perforators of both breasts.

A: 1 Superiomedial perforators supplying NAC at 2 o'clock.
B: Medial perforator supplying NAC at 3 o'clock
C: Inferior perforator supplying NAC at 6 o'clock.
D: Left breast showing superior perforators supplying NAC at 12 o'clock
E: Superiomedial perforator supplying NAC at 10 o'clock.
F: Inferior perforator supplying NAC at 7 o'clock.
SN-NAC distance: Right side 27, left side 30.
NAC-IMF distance: Right side 18, left side 18.

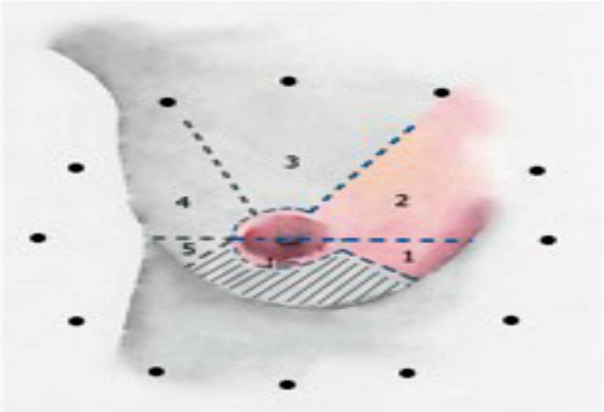

Fig. (2): Pedicles distribution.

1- Medial pedicle distribution.
2- Superiomedial pedicle distribution.
3- Superior pedicle distribution.
4- Lateral pedicle distribution.
5- Lateral pedicle distribution.
6- Inferior pedicle distribution.

Example of CTA (Fig. 3).

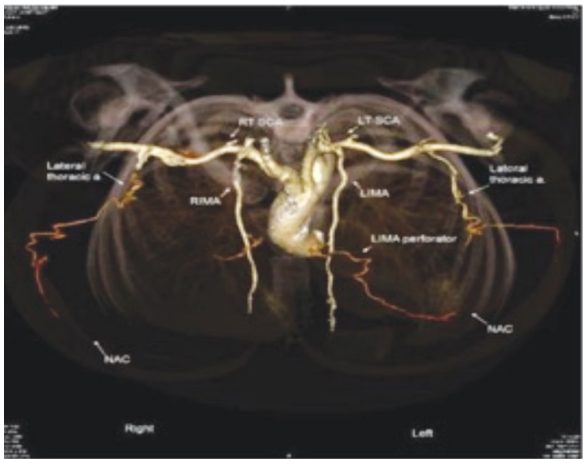

Fig. (3): CTA of the breast.

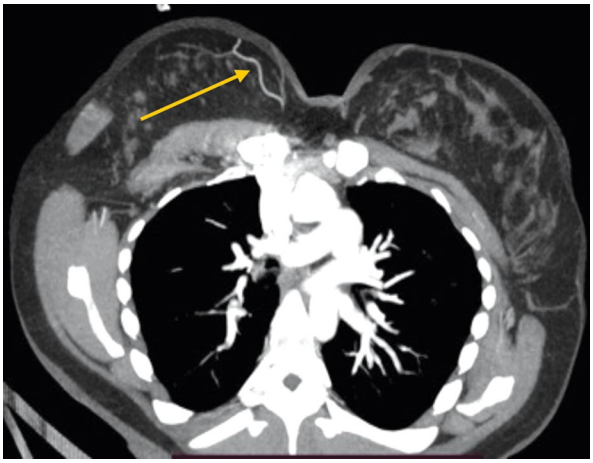

Fig. (4): Axial post contrast image of both breasts revealed, superior medial perforator of left breast, diameter is about 2.2mm (yellow arrow).

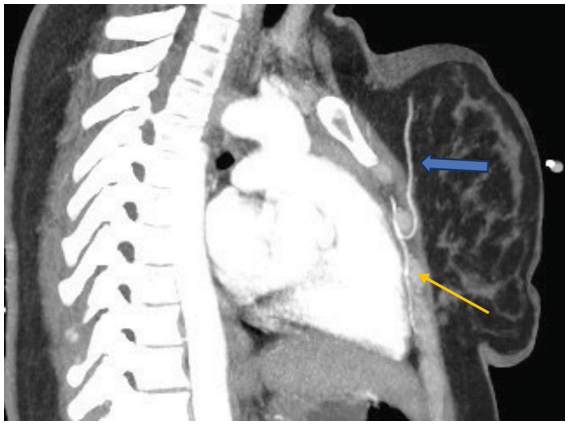

Fig. (5): Sagittal Reconstructed post contrast image of left breast revealed, superior medial perforator of left breast opposite to 2nd intercostal space from IMA, diameter is about 2.2mm (blue arrow: Superior medial perforator, yellow arrow: IMA).

• Doppler us is used intraoperatively to confirm our selection and presence of the perforator (Fig. 6).

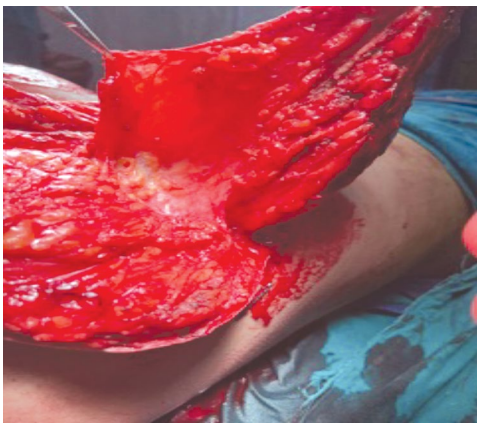

Fig. (6): Female aged 18 years old showing targeted inferior perforator confirmed by intraoperative Doppler.

Presurgical preparation:

A new renal function test was done in all cases to confirm the suitability for IV contrast injection. Pregnant females were excluded, and any preceding allergic conditions to IV contrast media underwent prophylactic medication with steroids. Entire cases were instructed to wear a gown and to remove metallic objects to evade any unwanted streak errors. Essentially, cases with huge breasts that extend beyond the CT view had to wear a soft bra in order to centralize breast tissue to the gantry.

Presurgical planning:

The distribution and position of selected perforator of NAC were marked in standing position. The patient's breast meridians were then measured, along with the distances from the sternal notch to the nipple, the midsternal line to the nipple, and the nipple on the surface of the body.

Statistical analysis and data interpretation:

Data analysis was performed by SPSS software, version 25 (SPSS Inc., PASW statistics for windows version 25. Chicago: SPSS Inc.). Significance of the obtained results was judged at the (≤0.05) level.

- Chi-Square, Fisher exact test were used to compare qualitative data between groups as appropriate.
- Student *t*-test was used to compare 2 independent groups for normally distributed data.

Kappa agreement was used for the assessment of agreement between categorical variables. No agreement could be obtained when the Kappa value is less than zero. Slight agreement could be obtained when the Kappa value is between 0.0 and 0.2. Fair

agreement could be obtained when the Kappa value is between 0.21 and 0.4. Moderate agreement could be obtained when the Kappa value is between 0.41 and 0.6. Substantial agreement could be obtained when the Kappa value is between 0.61 and 0.8. An almost perfect agreement could be obtained when the Kappa value is between 0.81 and 1.0.

Results

Seventeen females were enrolled with age range between 16 to 55 years planning to do reduction mammoplasty. Doppler Study and MSCT angiography of the two breasts were conducted to detect dominant arterial supply of NAC to aid in pedicle selection.

Table (1): Dominant arterial supply to NAC according to Doppler, CTA, pedicle used and intraoperative Doppler.

Case Number	Dominant arterial supply to NAC (Doppler)	Dominant arterial supply to NAC (CTA)	Pedicle used	Intraoperative doppler
1	Rt Inf > SM Lt Sup > SM >Inf	IMA (3rd Inf >1st SM) Lt IMA (1st Sup > 3rd SM) > LTA (Inf)	Inferior	Confirmed
2	Rt Inf > Lat > SM Lt Inf > SM > Lat > Sup	Rt IMA (4th Inf) > LTA (Lat) > IMA (3rd SM) Lt LTA (Inf) > IMA (1st SM)	Inferior	Confirmed
3	Inf > Sup = SM	Lt LTA (Inf) > IMA (4th inf , 2nd Sup) Rt LTA (Inf) > IMA(2nd SM) = AIA (Inf)	Inferior	Confirmed
4	Rt SM > Inf Lt SM	Rt IMA (2nd SM), 4th SM > AIA (Inf) Lt IMA(3rd, 4th SM) only	Superiomedial	Confirmed
5	Rt SM > Inf = Lat Lt SM > Inf > sup > Lat	IMA (2nd SM, 4th Inf)	Inferior	Confirmed
6	SM = Inf	Rt Axillary (Inf) >IMA(1st SM) = AIA Lt IMA (1st SM) > Axillary (Inf)	Superiomedial	Confirmed
7	Inf > SM	Rt Rt Axillary (Inf) > IMA (1st SM) > AIA Lt LTA (Inf) > IMA(1st SM) > AIA	Inferior	Confirmed
8	Sup = Inf = Lat	IMA (1st Sup, 4th Inf) > LTA (lat)	Inferior	Confirmed
9	Rt SM > Inf > Lat Lt Inf > SM > Sup	Rt IMA (4th Inf > 2nd SM) > LTA (lat) Lt IMA (2nd SM) > LTA (lat)	Superiomedial	Confirmed
10	SM > Sup > Inf	IMA (3rd SM, 4th Inf)	Superiomedial	Confirmed Non confirmed on left side (cut perforator during dissection)
11	Rt SM > Inf Lt SM> Sup > Inf	Rt (IMA 2nd SM, 4th Inf) Lt (IMA 2nd SM, 1st sup , 4th Inf)	Inferior	Confirmed
12	Inf > SM	Rt AIA > IMA(2nd SM) Lt AIA > IMA(3rd SM)	Inferior	Confirmed
13	Cannot be assessed	Only AIA	Amputation	No pedicle
14	Inf = SM	IMA (2nd SM, 4th Inf)	Inferior	Confirmed
15	Sup = SM > Inf	IMA (1st Sup, 3rd SM)	Superior	Confirmed
16	SM > Inf	IMA (3rd SM) > AIA (Inf)	Superiomedial	Confirmed
17	Inf > SM	Rt LTA (Inf) > IMA 2nd SM Lt IMA (4th Inf) > LTA (Lat)	Inferior	Confirmed

Rt = Right.
Sup = Superior.
IMA = Internal mammary artery.
Lt = Left.
Inf = Inferior.
AIA = Anterior intercostal artery.
SM = Superiomedial.
Lat = Lateral.
LTA = Lateral Thoracic artery.
> Means better than.

Thirty four breasts were assessed on 17 patients; Table (1) reveals comprehensive findings in the context of the dominant arterial supply of NAC in each breast and corresponding pedicle selection according to either Doppler or CTA result. Based on CTA results, the internal mammary artery (IMA) was the most common dominant arterial supply to NAC, followed by the lateral thoracic artery (14.7%), then the intercostals (11.7%) and lastly the axillary artery which was dominant in 5% of breasts. Based on CTA, in right side, we could detect most dominant Inferior perforators in 10 breasts (58.8%), Superiomedial perforator in 7 breasts (41.2%), Superior perforator in 2 breasts (11.8%). Based on CTA, in left side, we could detect most dominant Inferior perforators in 7 breasts (41.2%), Superiomedial perforator in 6 breasts (35.3%), Superior perforator in 3 breasts (17.6%). Based on Doppler ultrasound, in right breast we could detect most audible inferior equal to superiomedial perforators in 7 breasts (41.2%), Superior in 2 breasts (11.8%), Lateral in 1 breast (5.8%), No audible perforators in 1 breast (5.8%). Based on Doppler ultrasound, in left breast we could detect most audible inferior perforators in 7 breasts (41.2%), superiomedial perforators in 6 breasts (35.3%), Superior in 3 breasts (17.6%), Lateral in one breast (5.8%), No audible perforators in 1 breast (5.8%).

Table (2) Dominant arterial supply to NAC according to CTA.

Dominant Artery	Number of breast	%
IMA	23	67.7
LTA	5	14.7
Thoracoacromial	0	0
Anterior interosseous	4	11.7
Axillary	2	5
No dominant supply	0	0

Table (3): Agreement between Doppler and CTA findings of dominant perforators among studied cases at right breast.

Right side	Doppler		CTA		Confirmed intraoperative doppler	N=17	%
	N=17	%	N=17	%			
Can't be assessed	1	5.9	0.0	0	No	1	5.9
Superior	2	11.8	2	11.8			
Superomedial	7	41.2	5	29.4	Yes	16	94.1
Inferior	7	41.2	10	58.8			
Kappa agreement	0.584						
Standard Error	0.18						
95% Confidence Interval	0.231-0.937						
Percent of agreement	75.0%						

• Kappa between 0.41 and 0.60: Moderate agreement.

Table (4): Agreement between Doppler and CTA findings of dominant perforators among studied cases at left breast.

Left side	Doppler		CTA		Confirmed intraoperative doppler	N=17	%
	N=17	%	N=17	%			
Can't be assessed	1	5.9	0		No	2	11.8
Superior	3	17.6	3	17.6			
Superomedial	6	35.3	8	47.1	Yes	15	88.2
Inferior	7	41.2	6	35.3			
Kappa agreement	0.805						
Standard Error	0.129						
95% Confidence Interval	0.551-1.0						
Percent of agreement	87.5%						

• Kappa between 0.81 and 1.00: Almost perfect agreement.

Follow-up of cases throughout the early post-surgical period demonstrated partial NAC necrosis in one patient left breast. NAC sensation was preserved in all cases. (5%) of cases showed disruption of the wound.

(A): Before.

(B): After 6 months.

Fig. (7): A pre and post photos of a case underwent reduction mammoplasty.

Discussion

Breast hypertrophy could badly interfere with physical and mental health among females. Reduction mammoplasty techniques became numerous to treat such condition. On the other hand, every reduction mammoplasty approach has its benefits and drawbacks with necrosis of NAC being the main adverse event secondary to poorly vascularized pedicle **[10]**.

Conventionally identified safer and more familiar approaches which include inferior pedicle and free nipple grafting (FNG) in huge reductions have become well approved approaches to reduce the risk of nipple loss. On the other hand, NAC necrosis was still recorded even with those approaches. In addition, loss of NAC sensation is a common adverse event in those underwent FNG an approach which affects breast ducts too **[8,11]**.

Various radiological approaches were, as a result, recommended to define the dominant arterial supply to NAC prior to surgery to enhance pedicle selection and reduce the risk of NAC necrosis **[12]**. For example, radiological approaches comprise hand-held Doppler rapid, easy, but operator-dependent and don't offer an obvious angiographic roadmap to surgeons. The anatomic variation of vasculature of breast represents a problem during assessment that could make investigator miss important perforators especially in Obese patients. Some patients may feel shy if assessment consumes time. It couldn't detect depth of perforators that varies in planes, and from a patient to another. It needs frequent changing of breast position to detect the perforator. On the other hand, it has been a valuable method for us in our study that helped us predict presence and absence of perforators. Being a non-invasive vascular radiological approach, MSCT has been broadly utilized to image various body vasculatures owing to its broad availability, rapid acquisition time, and various reconstruction approaches that simulate angiography images with which surgeons' are familiar **[13]**. The current study used those radiological approaches to delineate dominant arterial supply to NAC to enhance pedicle selection aiming to improve patient's result. It is of great importance to delineate the whole course of the dominant arterial supply. On the other hand, some cases particularly the young cases with dense glandular tissue could affect the tracing of those arteries until NAC secondary to the increase in breast density.

It is unpractical and expensive to get a CTA for every patient, and there is a lot of operator dependency in using Doppler ultrasound. The more time spent with Doppler, the more perforators to be found. Our study showed that we could depend on Doppler ultrasound which has a satisfactory percentage of matching with CTA but the angiography is still more accurate.

This study displayed that IMA was the most common dominant arterial supply to NAC (67.7%) followed by lateral thoracic artery (14.7%), then intercostals (11.7%) and lastly axillary artery 5% of breasts. These results are similar to Stirling et al. **[14]** and Zakhary et al. **[15]** who demonstrated that IMA perforators are the main supply to NAC in (87.5%) followed by LTA dominance in (16.6%) with the remaining NAC being supplied mainly by anterior intercostal arteries (4.1%) and thoracoacromial artery (TTA) (4.1%). In this study TAA couldn't be de-

tected as a dominant supply. It is found that there is a change in main arterial supply between right and left breast of the same subject in 5 patients (29.4%) of our cases.

There was also variation in the vascular supply of NAC. Van Deventer showed an uneven pattern of blood supply to the breasts in another anatomical research **[16]**, with variations between the right and left breasts in the same subject. The same as li et al. **[17]** who found 70% of patients had identical arterial supply to both breasts. This is similar to Elmelegy et al. **[18]** who found difference between right and left breasts in perforators supplying NAC in 20% of cases. So it isn't possible for surgeon to predict the blood supply of the breast. It is important for surgeons to have a guide for predicting the blood supply which is facilitated by Doppler ultrasound and solved by CT angiography. In this study, surgeons used Inferior pedicle approach in 20 breasts (58.8%), Superiomedial pedicle in 10 breasts (29.4%), Superior pedicle in two breasts (5%). Amputation in 2 breasts (5%). The current study demonstrated that a single case developed partial NAC necrosis following reduction mammaplasty due to injury of a perforator during dissection. In some cases, there is more than one dominant perforator which has nearly equal diameters and entering NAC and could be detected by Doppler or CTA, in some cases with huge breasts; we preferred inferior pedicle technique despite the superiomedial perforator was more dominant. As regard CTA results, perforators with a diameter more than 2mm are significant and dependable. Internal mammary artery in known to give perforators to the NAC, different studies discussed this point to know which perforators mostly supply NAC, in our study 2nd and 4th perforators in 23.5% of breasts, only 1st perforator in (14.7%), 1st and 3rd in (11.76%) which are the same as 3rd and 4th, the same as 2nd perforator only in 11.76% of breasts. 3rd perforator only in (8%), 1st and 4thperforators in (5%), and the least is 4th perforator only the same as 1st, 2nd and 4th perforators in (2.9%) of breasts.

Some authors consider CTA as an over examinations in case of breast reduction. Preoperative Fluorescence Imaging (Indocyanine Green Imaging System) could be a possible alternative. Indocyanine green perfusion imaging has been shown to decrease ischemia in mastectomy skin flaps. A well-vascularized skin flap able to tolerate full expansion is mandatory in immediate breast reconstruction. Better and more consistent blood vessel preservation and flap perfusion could be done through identification of the perforating subcutaneous vessels to the skin **[19]**.

The main limitation of the present study was the high cost of CTA, availability of contrast material and technique of imaging which need experienced technician and radiologist. Handled Doppler is difficult in obese patients, some patients feel shy during assessment, time consuming and it is investigator dependent and do not provide clear angiographic roadmap to surgeons. It cannot detect depths or diameter of the perforators. The anatomic variation of vasculature of breast represents a problem during assessment that could make investigator miss an important perforators and make it difficult to get the artery of origin being of complex unpredicted roadmap. Finding a doppler signal does not necessarily identify where the vessel is coming from. However, it has been a valuable method for us in our study that helped us predict presence and absence of perforators despite it has a very reliable results.

Conclusions:

Presurgical planning of reduction mammoplasty using Doppler ultrasound and MSCT angiography has nearly matching results and could delineate arterial supply of NAC and enhance pedicle selection.

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