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Original Article

A new method to locate internal mammary artery perforator: by DSA and the metal pins on the chest

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Abstract: Background: This study was aimed to investigate the distribution of Internal mammary artery perforator for flap design by digital subtraction angiography and metal pins on the chest before operation. Methods: 32 participants were randomly collected in observation. The distributions of the IMAPs were assessed by either selective DSA combining the metal pins on the chest as experimental group, or ultrasonic examination as control group before surgery and the anatomical data were recorded. 22 were assessed using DSA while 10 ultrasound. The island flap was harvested according to the marked traces. Results: All 44 sides of IMAP distributions detected by DSA were displayed clearly while 12 ultrasound imagings of 20 cases showed only the starting point of IMAP. Of the DSA imagings, the largest IMAP was documented to be in the second (36/44), third (7/44) intercostal space and 4th (1/44) intercostal space. The average length of visible IMAPs was 5.72±1.20 cm on the right side and 5.70±1.16 cm on the left side, and the average caliber was 1.37±0.23 mm and 1.35±0.22 mm respectively. The ascending, descending and irregular type of IMAP distributions respectively accounted for 3/44, 38/44 and 3/44. The mean angle between the horizontal line and IMAP stems was 5.2° and 13.4° respectively in the ascending and descending type. Conclusions: DSA combining with metal pins on the chest offers a vascular distribution of IMAP before operation and greatly improves the safety of the IMAP.

Keywords: Internal mammary artery perforator, digital subtraction angiography, ultrasound, head and neck reconstruction, anatomy, iconography

Introduction

The deltopectoral flap was once the workhorse for head and neck reconstruction in the late 1960s, followed by the pectoralis major musculocutaneous flap introduced by Ariyan in 1979 [1, 2]. Both flap designs showed certain advantages such as feasibility and reliability to harvest, and the protection of the great vessels of the neck [2, 3]. The pectoralis major flap can be used in conjunction with a free flap for combined defects or for salvage procedures. However, it is in particular not feasible to be used for the reconstruction of tracheo-esophageal fistula, penetrating defects, retropharyngeal defect, penetrating defect and the patients who have undergone radical neck dissection or adjuvant radiotherapy [3, 4]. Moreover, skin paddle reliability was even lower in female patients [5]. After head and neck reconstruction, patients often have difficulty fitting into society because of their deformity. In such cases, it is important to restore function and aesthetic appearance rather than simply covering the resultant defects. Recent studies on anatomy of internal mammary artery perforator (IMAP) and its application on breast plastic surgery [6] prompted us to improve a flap design for head and neck reconstruction. The internal mammary artery presents several advantages such as providing a thin, flexible, sizable coverage with well-vascularized and excellent color-matching skin area, which could reduce donor-site morbidity by allowing primary closure of the donor site [7]. However, inaccurate preoperative anatomic evaluation of the trace of the IMAP could result in insufficiency in blood supply for the flap. Ultrasonic examination has been the most common method to locate the internal mammary artery, however, it does not

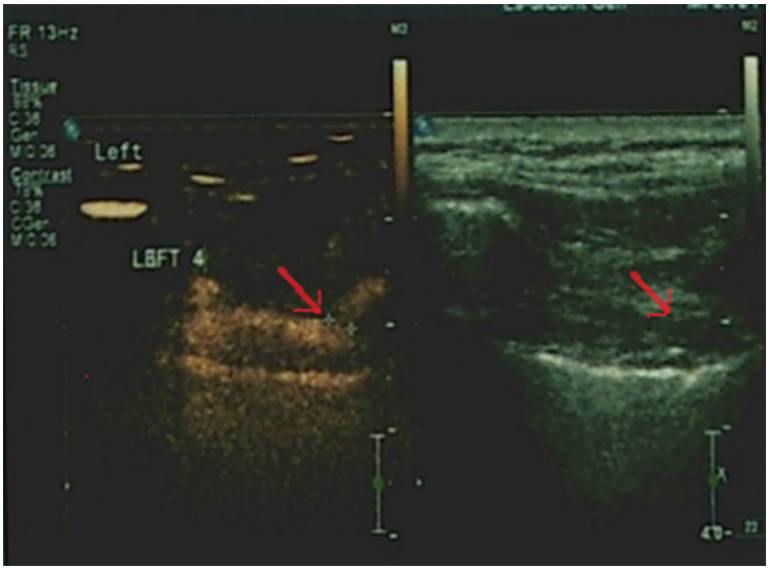

Figure 1. Ultrasound Images of IMAP. The track of starting point of IMAP were marked by the red arrows.

provide clear details of IMAP, especially on obese patients [8]. As a result, variability and diversity of IMAP could lead to postoperative flap necrosis and intra-operative flap design alteration [9].

This retrospective study was aimed to analyzing the distribution features of IMAPs on 32 patients who have used either the DSA or ultrasonic examination on chest. This is the first time to report DSA combining metal pins marked on the chest to mark the IMAP outline before operation which may have some novelty exploration on anatomy of IMAP and allow us to improve the flap design and therefore significantly improve the flap survival rate.

Patients and methods

Patients

From 2011 January to 2015 January, either digital subtraction angiography or ultrasound of IMAP was performed on 32 patients from department of Otolaryngology, Head and Neck Surgery in our hospital, Capital Medical University. Observational participants were randomly selected without gender restriction. All 32 patients were ensured to have no contraindications of both DSA and ultrasonic examination. 22 were assessed using DSA while 10 ultrasound.

Methods

The distributions of the IMAPs were assessed by either selective DSA combining the metal pins on the chest as experimental group, or ultrasonic examination as the control group before surgery and the anatomical data were recorded.

Before the DSA examination, two metal pins were marked on each rib intercostal groove from the first floor to the fifth of both left and right sides. Each pair of metal pins was placed in parallel with the lateral margin of the sternum: with one pair located 2 cm from the lateral margin of the sternum while the other one through the nipple. Then, the DSA was performed before the surgery.

The DSA images of patients were obtained by right transfemoral approach with an angiography catheter (5FVER, Cobra and/or H1). The location, visual length and the diameter of original part of IMAPs were recorded. According to the horizontal line, the IMAP would be defined as “ascending type” if the IMAP stem goes above, and “descending type” if the IMAP stem goes below, and “irregular type” if the IMAP stem has a wave pattern or a large angle turn. The IMAPs of each side were detected and marked on the basis of the DSA imaging and metal pins on the chest.

Results

Control group

10 (all female) of 32 patients were collected to measure the IMAPs using ultrasound as control group. The average age ranged from 42 to 70. Of 10 cases, 5 cases were diagnosed as laryngeal cancer, 2 cases as hypopharyngeal cancer, 2 cases as tracheo-esophageal fistula, 1 case as radix linguae goiter.

Of 20 ultrasonic images of IMAPs, only 8 cases were clearly displayed the structure of arteries, while the rest 12 cases only showed

Table 1. Location of the Largest IMAP (in which intercostal space)

		2nd	3rd	4th
Male	Left	16	2	1
	Right	17	0	0
Female	Left	1	3	0
	Right	2	2	0
Total	Left	17	5	1
	Right	19	2	0
Ratio		81.8%	15.8%	2.4%

Table 2. Diameter and Length of the Largest Perforators

		Diameter of the Largest Perforators (mm)	*Length of the Largest Perforators (cm)*
Male	Left	1.34±0.21	5.69±1.13
	Right	1.36±0.23	5.72±1.21
Female	Left	1.35±0.25	5.70±1.17
	Right	1.38±0.26	5.74±1.22
Total	Left	1.35±0.22	5.70±1.16
	Right	1.37±0.23	5.72±1.20

The mean diameter of right side IMA perforators was slightly larger than the left. The mean diameter of the females was larger than the males. In contrast, the mean length of the females' was smaller than the males'.

Table 3. Courser of the Perforators

		Ascending (*<0°)#	Descending (0°≤*)	Irregular
Male	Left	2	15	2
	Right	1	16	0
Female	Left	0	3	1
	Right	0	4	0
Total	Left	2	18	3
	Right	1	20	0
Ratio		6.8%	86.4%	6.8%

*The angulation between the internal mammary artery perforator and the horizontalline. #The contra-angle represents the courser of ascending, the positive represents the courser of descending.

the diameter of starting point of arteries (**Figure 1**).

Experimental group

IMAPs images of 44 sides on 22 patients (male 18, female 4 cases) in experimental group were collected retrospectively. The average age ranged from 22 to 81. 18 cases of the 22 patients (81.8%) were male and 4 (18.2%) were female. Of 22 cases, 8 cases were diagnosed as laryngeal cancer, 8 cases as hypopharyngeal cancer, 2 cases as tracheo-esophageal fistula, 1 case as radix linguae goiter, 1 case as tonsil cancer, 1 case as mediastina goiter and 1 case as thyroid cancer.

All the IMAPs of 22 patients were displayed clearly by DSA images. After the examination of DSA, no patients suffered ischemia, vessel-block, vessel-fistula, infection or other complication caused by immobilization of the extremity. Internal mammary artery perforators from 44 sides were harvested from 22 adult patients, including 18 males and 4 females.

Location of the prominent perforator

The largest IMAP appeared in the second intercostal space (36/44), the third (7/44) and the 4th (1/44). Interestingly, among the cases of the third intercostal space, 5 were female, 2 were male (**Table 1**).

Caliber and length of the largest perforators

The average length of the visible internal mammary artery perforators was 5.72±1.20 cm on the right side and 5.70±1.16 cm on the left side. The mean emerging diameter of largest IMAPs was 1.37±0.23 mm on the right side and 1.35±0.22 mm on the left side. The diameter of 90.9% (20/22) on the right side was larger than the left side. The average and largest dimension of IMAPs caliber for the 4 female cases was slightly larger than for the male cases (**Table 2**).

Course of the perforators

The mean angle in the ascending type and descending type was 5.2° and 13.4° respectively. There were 3/44 ascending types, 38/44 descending types for and 3/44 irregular types. Interestingly, for 3 cases out of 4 female patients' perforators both sides were the descending type (**Table 3**; **Figure 2**).

In three different patterns excluding for the irregular pattern, the IMAP flap designs were developed as below (**Figure 3**). For the irregular pattern, there was no way to design the flap accurately but the DSA that could track blood vessel contours precisely.

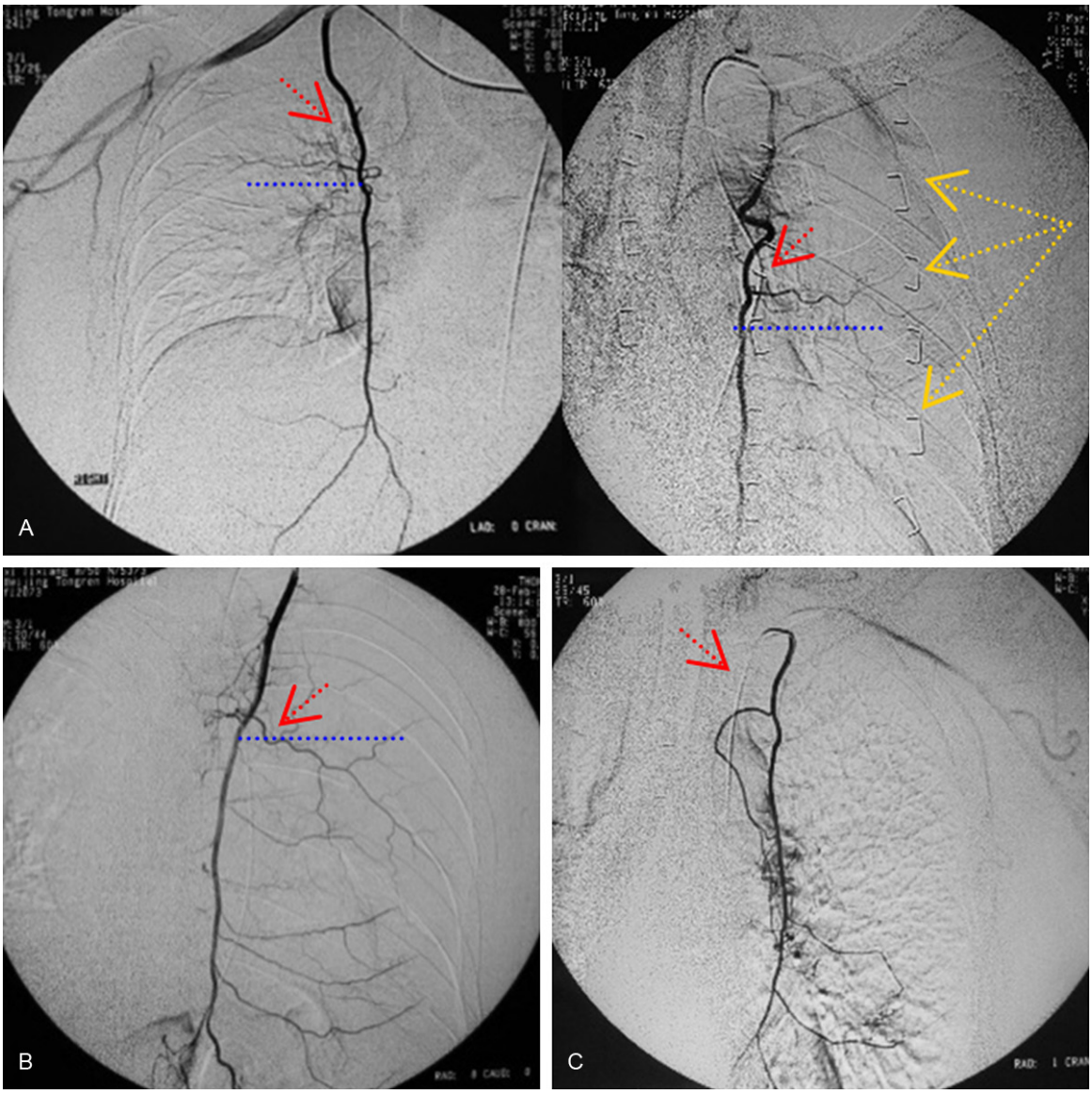

Figure 2. Course of the perforators. According to the course of the perforator, the IMAP was separated into three categories: ascending (A), descending (B) and irregular pattern (C). The different courser types of the IMAPs were marked by the red arrows. The tracks of IMAPs were marked according to metal pins on the chest marked by yellow arrows. The dashed line of blue was horizontal line as confer.

Quantity of the perforator branches

According to the quantity of IMAP branches, single branch type accounted for 5/44, two branches type accounted for 16/44, three branches type accounted for 13/44 and multi-vessel type accounts for 10/44. Besides, the IMAP of the left side was visualized with either single or two branches, In contrast, the right side mostly distributed three to four braches (**Figure 4**; **Table 4**).

In the **Figure 5**, the track of IMAPs was marked according to the DSA images and metal pins on the chest before surgery (A). The vessel pedicles island flap was harvested according to the marked track shown in the left picture (B).

Discussion

Internal mammary artery perforator flap appears to be a reliable option that provides an ideal tissue that well-vascularized, reliability, versatility, wide arc of rotation, primary closure of the donor for reconstruction of lower neck where thin, pliable tissue is needed. It provides thin pliable tissue that is suitable for cutaneous, pharyngeal and tracheostoma reconstruc-

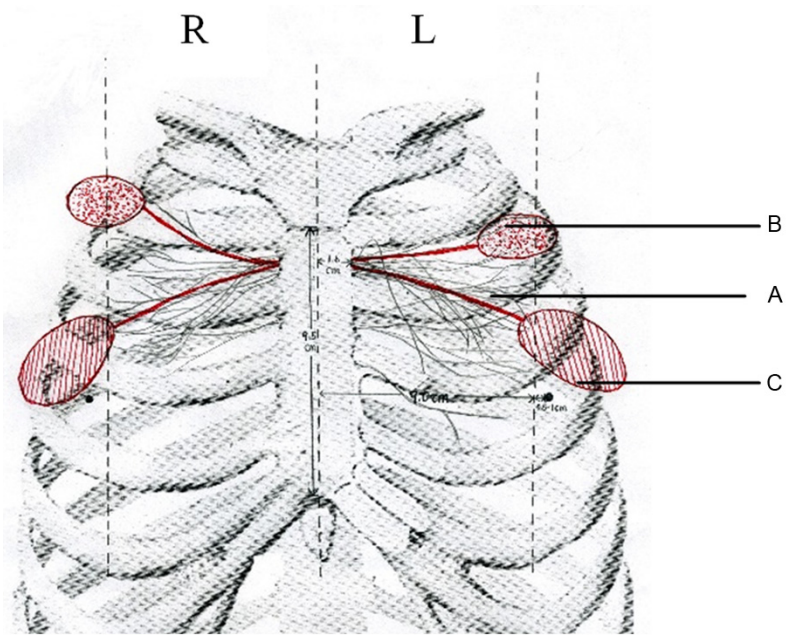

Figure 3. Flap design. All of the 44 dominant internal mammary artery perforators and the branches were delineated according to the DSA images (A). Based on the angle and contra-angle between the horizon line and DSA trace of IMAP vascular, the IMAP traces were classified into 2 patterns: the ascending (B) and descending (C) patterns respectively. The average angle was 5.2° in the ascending group and 13.4° in the descending group.

tion when compared with the deltopectoral flap. The IMAP flap has been reported on use for many surgeries, although the survival rate of island flap can notbe fully guaranteed [10, 11]. Because of the variation between individuals, the anatomy of IMAPs is so dependent on the diameter, length and course of the perforators that it is difficult to mark the course of the IMAPs [12, 13]. Doppler ultrasonicand three-dimensional reconstruction have been used to describe the internal mammary perforator arteries [14, 15]. However, Doppler tends to be less reliable in predicting the course, size and the terminal of these vessels and limited in the applicability to obese patients and thick flaps [16]. CT angiography may give more precise anatomical detail, but fail to display the tiny peripheral vessel. Moreover, the problems of nephrotoxicity, allergies to contrast medium and radiation exposure have been discussed intensively with regard to CTA imaging [17, 18]. Therefore, it is significant to obtain an accurate trace of internal mammary artery perforator using a technique of high accuracy [19, 20].

22 patients who have suffered DSA examination on internal mammary artery perforator were collected retrospectively to analyze the distribution feature of IMAP. All the IMAPs were clearly imaged by DSA with the detailed anatomic data of length, caliber, course and branches. DSA enables clear visualization of the entire vascular tree. Combining the metal pins marked on the chest, exact trace of the IMAP can be harvested and this greatly contributed to imaging guided flap design before the reconstruction. However, preoperative DSA examination is inevitably limited for its invasiveness and expensiveness. Caution also must be taken on the case of hypersensitivity to contrast media which hasn't occurred in this collective group.

In this retrospective study, 44 IMAPs of 22 cases stemed from the outside of the first segmental of the left and right subclavian artery respectively and descend along the back of upper 6 costal cartilages. Finally, the IMA was demonstrated down to the bifurcation into the superior epigastric artery and the musculophrenic branch on the level of the 6th intercostal space. The IMA distributed many perforators in each intercostal space. Of all the largest internal mammary artery perforators, 81.2% (36/44) originated from the second intercostal space, in accordance with previous cadaveric dissection or other iconographic study. As IMAP in the second intercostal space is very close to the neck area, it is a strong candidate technique for neck or esophagus reconstruction.

Comparison of the caliber on **Table 2** showed the perforating branches were not symmetrical. The data above showed that the mean diameter of the right side of IMA perforators was larger than the left which indicated that the use of right IMAP could provide a better blood supply. Also, the average number of the branches of internal mammary artery perforators varied from 3 to 4, more than 1 to 2 in the left. These results imply that when recipient site is close to the median line, the IMAPF on the right will be a better choice.

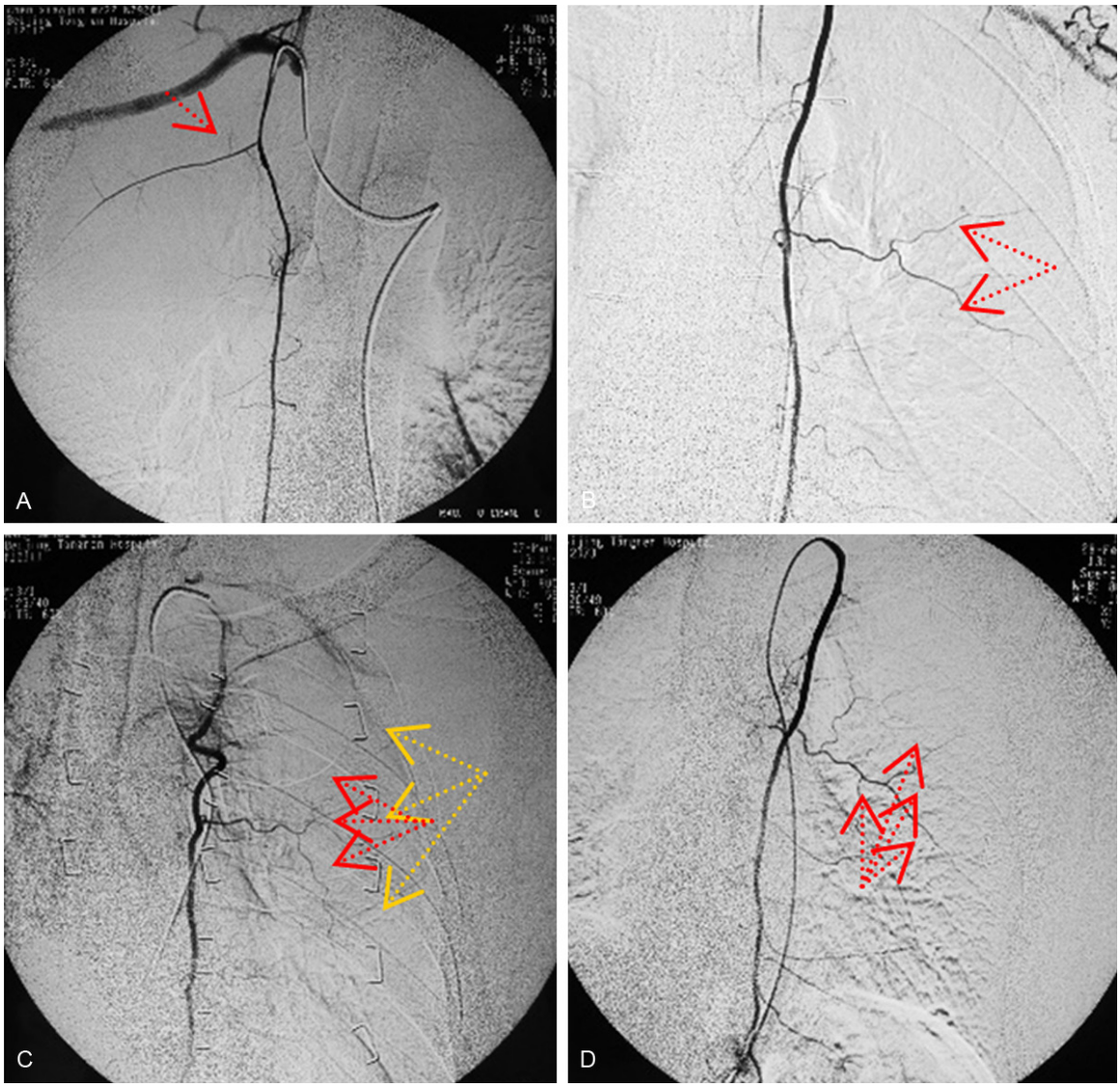

Figure 4. Quantity of the perforator branches. According to the quantity of the perforator branches, the IMAP was separated into four categories: single branch (A), two branches (B), three branches (C) and multivessel (D). The quantity of the perforator branches were marked by the red arrows. The tracks of IMAPs were marked according to metal pins on the chest marked by yellow arrows.

Table 4. Branches of the Perforator

		Single branch	Two branches	Three branches	Multi-vessel
Male	Left	3	9	3	3
	Right	2	5	6	5
Female	Left	0	1	2	1
	Right	0	1	2	1
Total	Left	3	10	5	4
	Right	2	6	8	6
Ratio		11.4%	36.4%	29.5%	22.7%

The distribution of IMAP is very important to design a flap during the surgery. According to the angle of the IMAP to the horizontal line, three patterns can be seen. Surprisingly, 86.4% (38/44) cases presented the decline pattern, while 6.8% cases presenting the rising pattern. That pattern variation should be considered when designing an IMAP flap, otherwise flap necrosis can occur if developing an ascending flap in a case with descending pattern.

In the data above, females' dominant perforators were mostly located in the third intercostal space. Besides, perforators of females were larger than the males and the IMAP course type of females appeared mostly downward. These

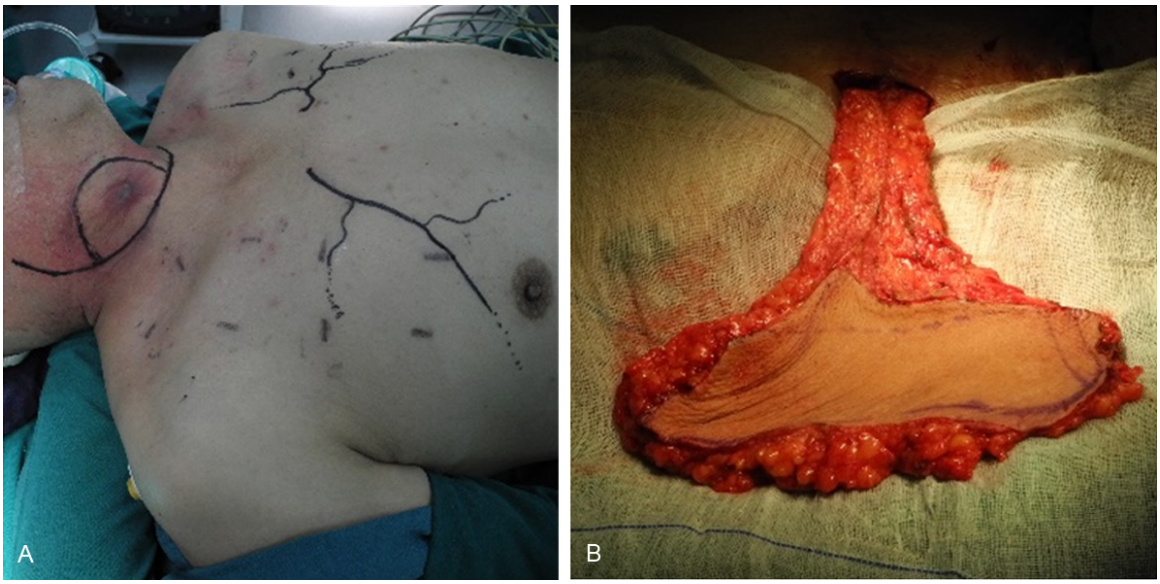

Figure 5. Preoperative marker and selected flap.

differences may be the result of the breast blood supply. So, when designing the IMAP flap for a female patient, a slightly lower location of the flap will be safer and provide a better cosmetic outcome for both donor and recipient.

In summary, preoperative DSA combining metal pins marked on the chest can provide clear guidance for IMAP island flap reconstruction and more precise and individualized flap design. We believe this work would provide a novel approach for surgeons to make an accurate flap design and increase success rate for head and neck defect reconstruction.

Conclusions

The above preliminary data has shown the anatomical variability of the internal mammary artery perforators by digital subtraction angiography. These differences include original location, the variation in the size, branches and length of the perforators, as well as the distribution angle. At the same time, with the help of the mark of the metal pins on the chest, the exact course of the IMAP can be determined and this will greatly help the surgeon to make anaccurate design and avoid accidentally injury.

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Disclosure of conflict of interest

None.

Authors' contribution

Xiao-Hong Chen made substantial contributions to conception and design. Xi-Hong Liang made contributions to acquisition of data. Xiao-Hong Chen and Xiu-Juan Kou made contributions to analysis and interpretation of data. Xiu-Juan Kou was involved in drafting the manuscript or revising it critically for important intellectual content. De-Min Han gave final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content. Xiao-Hong Chen and De-Min Han agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors read and approved the final manuscript.

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