

Original Article

Design of internal mammary artery perforator island pedicle flap with digital subtraction angiography for head and neck reconstruction

Xiu-Juan Kou¹, Xi-Hong Liang², Yun-Long Bai³, Fan-Qian Lu¹, Ya-Ru Feng¹, De-Min Han¹, Xiao-Hong Chen¹

Departments of ¹Otolaryngology Head and Neck Surgery, ²Radiology, Beijing Tongren Hospital, Capital Medical University, Beijing, P. R. China; ³Department of Otolaryngology Head and Neck Surgery, Fuxing Hospital, Capital Medical University, Beijing, P. R. China

Received May 30, 2016; Accepted August 3, 2016; Epub October 15, 2016; Published October 30, 2016

Abstract: Internal mammary artery perforator (IMAP) flap is the major tissue source for head and neck reconstructive surgery. However, the flap survival is still uncertain due to the anatomical variations of the IMAP. In this study, we optimized the flap design with digital subtraction angiography (DSA) and metal pins marked on the chest, and achieved a 100% survival rate. 20 patients with head and neck defect were subjected to preoperative DSA to trace the IMAP. 14 were selected to receive reconstruction surgery using IMAP flaps. Flap design and survival rate were recorded. The intro-operative examination for distribution and shape of IMAP confirmed the preoperative DSA imaging on all cases. Each flap had a suitable perforator confirmed during dissection. There was no occurrence of postoperative necrosis. All donor sites were closed primarily. IMAP flap design assisted with preoperative DSA and metal pins marked on the chest can markedly increase operation success rate.

Keywords: Internal mammary artery perforator, island pedicle flap, head and neck defect, digital subtraction angiography, reconstructive surgery

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 [1, 3]. The pectoralis major flap can be used in conjunction with a free flap for combined defects or for salvage procedures. However, it is not feasible to be used for the reconstruction of tracheo-esophageal fistula, penetrating or retropharyngeal defects; and not to be used on 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 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]. In the current work, we established a novel approach by using combination of digital subtraction angiog-

IMAP flap design with the guidance of DSA

Table 1. Patients' medical records

Case	Age	Defect and Fistula	Protopathy
1	50	Penetrating defect	Recrudescence Hypopharyngeal Cancer*
2	42	Tracheo-esophageal fistula	Recrudescence Laryngocarcinoma*
3	44	Tracheo-esophageal fistula	Total Laryngectomy
4	61	Large area of surface neck defect	Total Pharyngolaryngectomy
5	57	Esophageal stricture	Radiotherapy after Pharyngectomy
6	44	Laryngostenosis	Hypopharyngeal Cancer*
7	45	Esophageal stricture	Radiotherapy after Esophageal Trauma
8	54	Laryngostenosis	Hypopharyngeal Cancer*
9	42	Esophageal stricture	Total Laryngectomy
10	56	Esophageal stricture	Cervical Spinal Injury
11	41	Penetrating defect on anterior Neck	Recrudescence Laryngocarcinoma*
12	26	Esophagus fistula	Cervical spine fracture
13	37	Laryngostenosis	Hypopharyngeal Cancer*
14	23	Anterior defect of neck	Recurrent Mucoepidermoid carcinoma

*Pathology was squamous cell carcinoma (SCC).

raphy (DSA) [10] with metal pins marked on the chest to accurately trace the internal mammary artery, which allowed us to improve the flap design and therefore significantly improve the flap survival rate.

Material and methods

Patient selection

Adult patients of both genders with head and neck defects caused by various reasons and in need for flap reconstruction were enrolled in this study. However, patients with contraindication for DSA or surgery operation contraindication were excluded. 20 patients from department of Otolaryngology, Head and Neck Surgery in our hospital received preoperative examination of DSA for IMAP from October 2011 to October 2015. The patients voluntarily signed the informed consent form. Six cases were excluded due to the low location (the 3rd or 4th or even lower intercostal space) (4/20) or dysplasia of the dominant perforator (2/20). All the rest 14 patients were males with a mean age of 48 years (ranging from 26 to 61). Their basic information and medical records were list as follows (Table 1). The IMAP island flap was performed to repair head and neck defects or fistulas. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and Beijing Tongren Hospital, Capital Medical University guidelines on human experimentation and with

the Helsinki Declaration of 1975, as revised in 2008.

Procedures

Main defects of the 14 patients were summarized in Table 1. The distributions of the IMAPs were assessed by selective DSA and metal pins on the chest 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 (Figure 2). Then, the DSA was performed before the surgery.

DSA imaging was performed by right transfemoral approach with an angiography catheter (5FVER, Cobra and/or H1). The location, visual length and the diameter of the beginning 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.

We first determined and marked the dominant IMAPs of both sides based on DSA imaging and metal pins on the chest. The perforator of the

IMAP flap design with the guidance of DSA

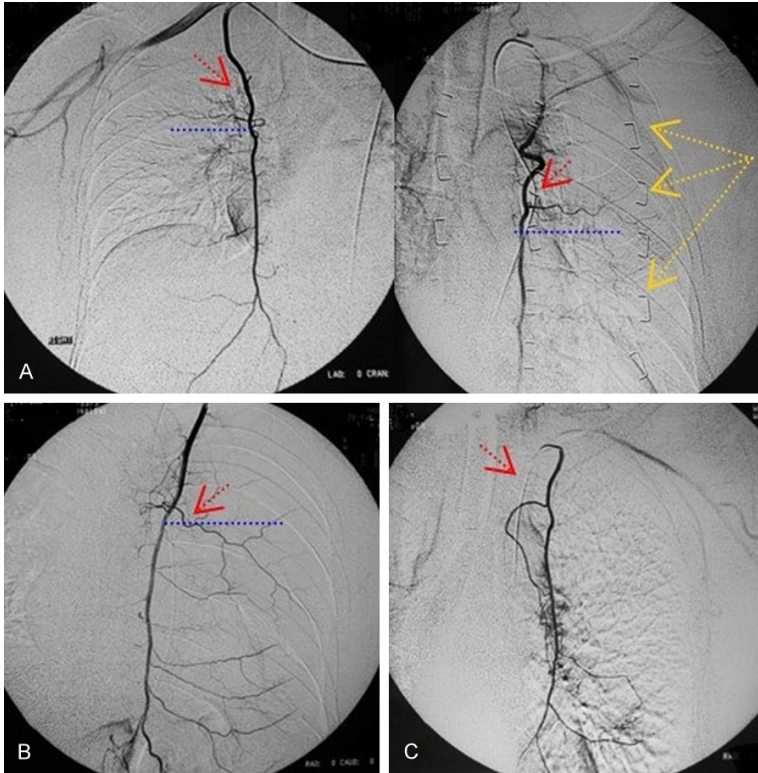


Figure 1. DSA images showing detailed course of the IMAP. According to the course of the perforator, the IMAP was separated into three categories: ascending (A), descending (B) and irregular pattern (C). The different courser types of the IMAPs were marked by the red arrows. The tracks of IMAPs were marked according to metal pins on the chest marked by yellow arrows. The dashed line of blue was horizontal line as confer. IMAP, Internal mammary artery perforator.

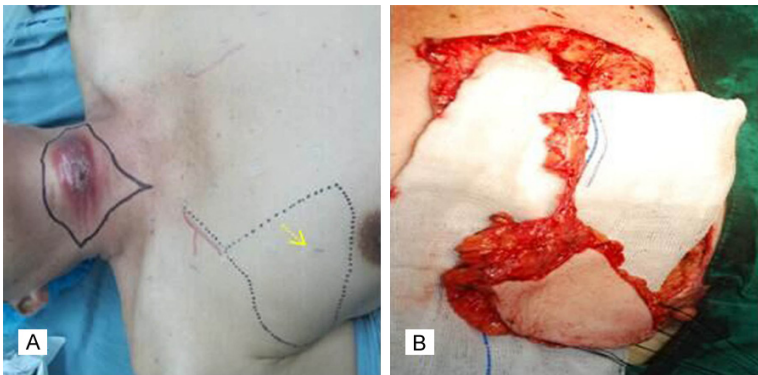


Figure 2. Case 2. A. The track of IMAPs was marked according to the DSA images and metal pins (yellow arrow) on the chest before surgery. B. The vessel pedicles island flap was harvested according to the marked track shown in the left picture. IMAP, Internal mammary artery perforator. DSA, digital subtraction angiography.

largest diameter of each side was decided as the dominant IMAPs. The dominant IMAP located on the second intercostal space and on the

same side of recipient region was preferred as the surgical island flap (**Figure 1**).

The eliminated cases were because either when the dominant perforator was located on a lower level that difficult to reach the recipient site or the vessel was visualized variable and dysplastic.

Subsequently, the flap was circumferentially incised and raised from its distal edge toward the IMAP, turning it into a true island flap. The incision was parallel to the dominate vessel from the chief trunk of the selected internal mammary artery perforator in a subfascial plane along the vessel. Then, it proceeded in the dissection of pectoralis major muscle and intercostal muscle accompanied by a retrograde fashion dissection to the pedicle origin which is generally located 1 to 2 cm lateral to the edge of the sternum to improve the arc rotation of the flap. The flap was then rotated from 90 to 180 degrees around the pivot point to reconstruct the neck defect, either through a subcutaneous tunnel or by dividing the narrow skin bridge between the donor site and the neck defect. The soft tissue defect resulting from fasciocutaneous flap resection and muscle splitting was subsequently closed by suturing the pectoral muscle to the lateral edge of the sternum primarily without the need of a skin graft and no rehabilitation.

To minimize the incidence of pneumothorax during the IMAP resection, it was considerable to dissect close to the rib and raise the carti-

IMAP flap design with the guidance of DSA

Table 2. The data of IMAP and post-operation follow up

Case	Flap Size (cm × cm)	Required Time for Obtain Flap (minute)	Length of Follow-up (month)
1	12×8	44	25
2	12×10	50	32
3	8×8	35	40
4	14×8	52	25
5	12×9	42	36
6	11×10+8×6*	67	27
7	10×8	38	25
8	10×9	41	26
9	12×8	45	24
10	12×8	38	26
11	10×9	40	32
12	8×8	36	36
13	10×8	39	28
14	4×3	35	6

*double flaps with a single perforator. IMAP, Internal mammary artery perforator.

lage up gently with a small periosteal elevator to protect the undersurface before sectioning. When necessary, the never along the perforator should be cut off to avoid the oppression on the vascular pedicel.

To minimize the incidence of pneumothorax during the IMAP resection, the dissection was as close to the rib as possible and the cartilage was raised up gently with a small periosteal elevator to protect the undersurface before sectioning. When necessary, the nerve along the perforator should be cut off to avoid the oppression on the vascular pedicel.

Results

All 20 patients were initially examined for the IMAP by DSA. After the examination of DSA, no patients suffered ischemia, vessel-block, vessel-fistula, infection or other complication caused by immobilization of the extremity. From DSA imaging and the metal pins marked on the chest, the dominant IMAP was documented to be on the second (16/20), third (3/20) and forth (1/20) intercostal space. According to the direction of IMAP stem to a horizontal line, the ascending type accounted for 3/20 of cases while the descending type for 15/20. The irregular type which make the IMAP present a wave or a large angle turn accounted for 2 of the 20

cases. As a result, the 6 patients who had dominant IMAP located on a low level (the 3rd or 4th intercostal space, 4/20) or displayed an irregular form (2/20) were excluded from the operation. The 6 patients have received the reconstruction by traditional pectoralis major myocutaneous flap to repair the defect.

During the operation, an average time of 90 minutes was needed for flap elevation with a small amount of bleeding. The intro-operative finding of IMAP flap confirmed the diagnosis of preoperative DSA imaging and metal pins mark. An average time of 43 minutes (35 to 67) was needed for flap design during the operation. All of the transfers were successful without occurrence of intraoperative flap alteration. The location and course of the IMAP separated during the operation was in line with the images by preoperative DSA (**Figure 2**). The viability of the flap was confirmed by active bleeding from the skin edge. Harvested flap size ranged from 4×3 cm² to 14×8 cm². There was no occurrence of pleura breach during dissection of the vascular pedicle.

All donor sites were closed primarily without any wound-healing problems. No donor site wound-healing complication occurred in the postoperative recovery for all the 14 patients. All the flaps displayed sufficient perfusion, excellent texture, and no postoperative necrosis (**Table 2**). All 14 patients recovered well after a mean follow-up of more than 6 months (ranging from 6 to 40 months). All the patients were satisfied with the functional and cosmetic results at both the donor and recipient sites (for examples see **Figures 3, 4**).

Discussion

The concept of perforator flap was first introduced by Koshima and Soeda in 1989. The IMAP flap is based on a single or double perforator of the internal mammary artery that is included in the pedicle for added length. Since its application on tracheostoma reconstruction reported by Yu in 2006, the IMAP flap has been shown to have many advantages for reconstruction of cutaneous, pharyngeal and tracheostomy defects [9, 10] in the head and neck. In addition, it provides thin pliable tissue suitable for cutaneous, pharyngeal and tracheostoma reconstruction, whereas the deltopectoral flap does not. However, postoperative flap necrosis

IMAP flap design with the guidance of DSA



Figure 3. Case 5. A. Intra-operative view of the donor site and IMAP flap. B. Immediate post-operative photograph of the donor and recipient site. C. Follow-up examination at 20 months showed a well-healed and showed a satisfactory donor site. IMAP, Internal mammary artery perforator.

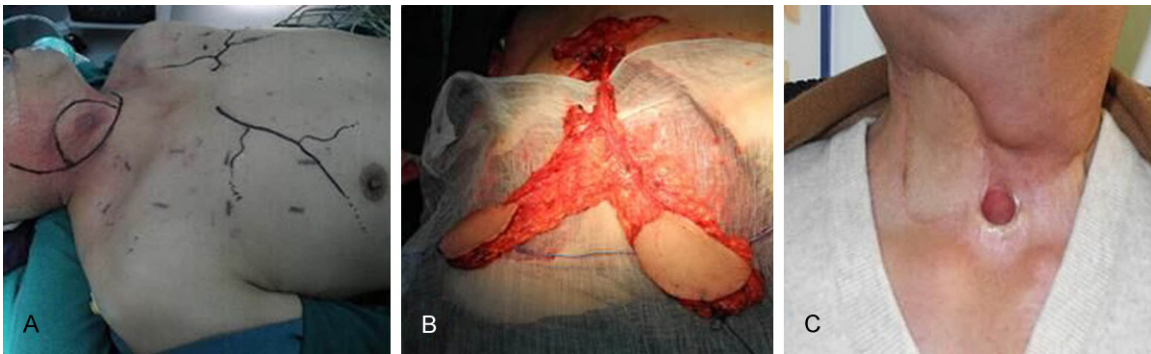


Figure 4. Case 6. A. Preoperative view of recipient site and design of the flap. B. Intra-operative view of double flaps with a single perforator after the excision. C. Follow-up examination at 24 months showed a satisfactory internal mammary artery perforator flap contour.

or intra-operative flap alteration still occurs due to the variability in the location or the uncertainty in the perfusion of the perforators [5, 10, 11]. Furthermore, individual variations in the diameter, length and course of the IMA can make an accurate flap design [12, 13] further difficult. Not only improper design and IMAP alterations can course flap necrosis, it can also considerably prolong the operation time. Therefore, we consider it is vital important to obtain an accurate trace of the IMAP prior to reconstruction surgery.

Doppler ultrasonic imaging method has been a widely used technique to locate IMAP preoperatively. However, this technique tends to be less reliable in predicting the course, size and the terminals of these vessels, and is particularly limited in patients of obese and with thick flaps [14-16]. 20 participants from our hospital were retrospectively collected in this study. The distributions of the IMAPs were assessed also by

ultrasonic examination and the imaging data were compared. Of the 20 cases, ultrasonic imaging detected IMAPs with some details only in 8 cases, while in the rest 12 cases detected was only the beginning part of the arteries (**Figure 5**). CT angiography might provide precise anatomical details, but usually fails to display smaller vessels. Moreover, CT angiography can cause severe side effects such as nephrotoxicity, allergies to contrast medium and radiation exposure [17, 18].

In contrast, DSA imaging can provide visualization of the entire vasculature tree. In our study, DSA was used to examine the distribution of the IMAP prior to the flap design and reconstruction surgery. The location and detailed branching pattern of the perforators were displayed clearly (**Figure 1**). Moreover, in combination with metal pins marked on the chest (**Figure 2**), the traces of the IMAP can be precisely located, which enables us to design a more accurate flap for the reconstruction.

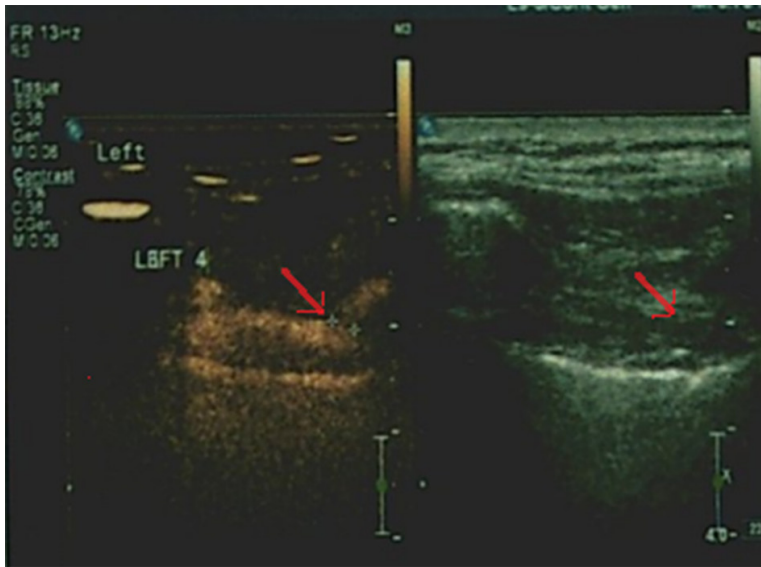


Figure 5. Ultrasound Images of IMAP. The track of starting point of IMAP was marked by the red arrows. IMAP, Internal mammary artery perforator.

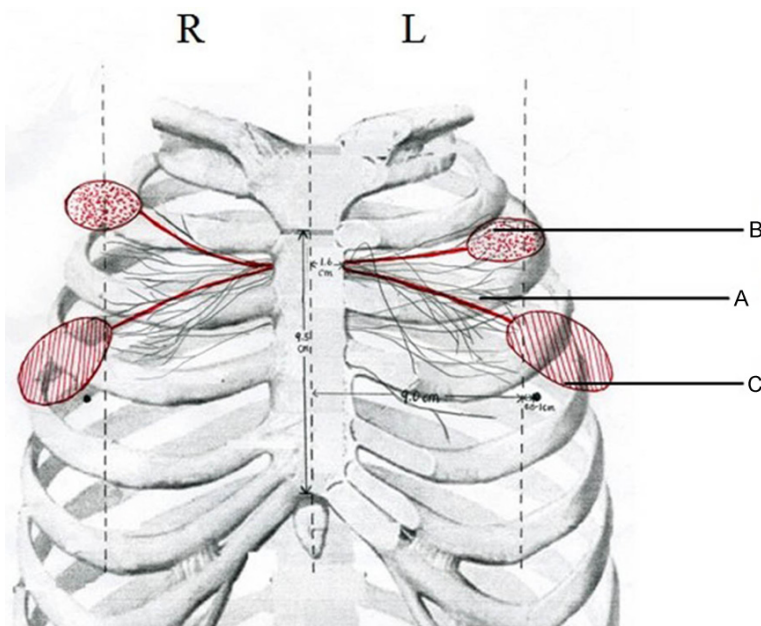


Figure 6. Drawing of the flap design. The dominant internal mammary artery perforators and the branches were delineated according to the DSA images (A). Based on the angle and contra-angle between the horizon line and DSA trace of IMAP vascular, the IMAP traces were classified into 2 patterns: the ascending (B) and descending (C) patterns respectively. The average angle was 5.2° in the ascending group and 13.4° in the descending group. DSA, digital subtraction angiography. IMAP, Internal mammary artery perforator.

Preoperative DSA imaging also guided us for the selection of the dominant IMAP. As a result, we were able to achieve a 100% success on all the operated cases and the operation duration was significantly shortened. Based on DSA

imaging, the dominant IMAPs located on the 2nd intercostal space were found on 16 cases, whereas on the 3rd and the 4th intercostal space accounted for 3 cases and 1 case, respectively. The IMAP of irregular and hypogenetic type accounted for 2 of the 20 cases. In order to minimize the risk of operation and formulate individualized treatment plan, these 6 patients were excluded. Moreover, intra-operative skin mark on the chest under the guidance of the DSA imaging provided a very clear surface projection of the dominant perforator, which, we think, dramatically enhanced the accuracy for the flap design. As a result, there was no occurrence of ischemia or necrosis in all the 14 operated patients, including the case who received the largest flap ($14 \times 8 \text{ cm}^2$) in this study. To our knowledge, this flap design method has not been reported before. We demonstrated that with the help of pre-operative imaging, IMAP flap design is optimized with more accuracy, and, therefore, a 100% success rate can be achieved.

Since the IMAP flap presents a thin and flexible skin coverage, it can also be used to repair tracheostomal and penetrating defects. With DSA imaging, the design of two or more flaps with a single vessel can be done to cover complex penetrating defects (Figure 4).

The conventional way on deltopectoral flap design is not suitable for the island flap because of the change of courses of the IMAPs. Under DSA imaging, the patterns of the IMAPs can be classified on three types according to

the direction of IMAP stem to a horizontal line: ascending type, descending type and irregular type. We found that most preponderant internal mammary artery perforators originated from the second intercostal space (14/20), and most cases presented the descending pattern (15/20), which is in accordance with our previous study on IMAP anatomy using DSA. The design of IMAP flap for head and neck reconstruction described in the current work is summarized in the figure below (**Figure 6**). It suggests that it is better to apply the flap design of descending type if no accurate preoperative examination was taken.

Conclusion

In summary, preoperative DSA and metal pin marks on the chest can provide excellent guidance for accurate individualized IMAP flap design for head and neck reconstruction. We believe this work could provide a novel approach for surgeons to improve IMAP flap design and increase success rate.

Acknowledgements

This project was supported by Beijing city health personnel "Thou" 100 level candidates project and the training project of high-level medical technical personnel in health system in Beijing City (No. 2013-03-054).

Disclosure of conflict of interest

None.

Address correspondence to: Drs. De-Min Han and Xiao-Hong Chen, Department of Otolaryngology Head and Neck Surgery, Beijing Tongren Hospital, Capital Medical University, Dongjiaominxiang Street, Dongcheng District, Beijing 100730, P. R. China. Tel: 86-10-58269107; Fax: 86-10-58265818; E-mail: 18511799145@163.com (DMH); trcxh@163.com; trcxh2015@yahoo.com (XHC)

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