Pre-operative imaging of the supraclavicular artery island flap plays a vital role in the flap design

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To the Editor: With great interest, we read the article by Zhou *et al*[1] entitled "Application of bilateral supraclavicular artery island flaps in the repair of hypopharyngeal and cervical skin defects: a case report." The authors explored the potential of bilateral supraclavicular artery island (SAI) flaps for reconstructing through-and-through defects between the hypopharyngeal mucosa and the neck skin resulting from salvage surgery for recurrent laryngeal cancer. Although we congratulate the authors on their successful surgical results, we think they should present more details about the surgical method, especially regarding the pre-operative imaging of the SAI flap, which was of crucial importance to the success of the surgery. We would like to take the opportunity to offer some comments and further expand on the topic by presenting our current work involving the SAI flap.

In the last decade, the SAI flap has gained popularity in head and neck reconstruction in selected patients and defects because of advances in anatomical studies and refinements in SAI flap surgical techniques. In a review article, Trautman *et al*[2] summarized the outcomes of 528 SAI flaps reported between 2012 and 2017 and concluded that the SAI flap is suitable for a wide variety of oral cavity, pharyngeal, skull base, and cutaneous defects. However, the widespread utilization of the SAI flap remains a controversial issue due to reliability concerns. Among the 528 SAI flaps, minor complications occurred in 130 of 528 (24.6%) cases, of which partial flap loss/distal flap necrosis was the most common. As such, the distal region of the SAI flap is the Achilles' heel of the SAI flap.

The reasons for distal flap necrosis are manifold and not yet entirely understood. One possible reason may be that the caliber of the supraclavicular artery exhibits considerable anatomical variation among individuals. Tayfur *et al*[3] found that the diameter of the supraclavicular artery at the origin ranges from 0.5 to 1.9 mm. When the arterial diameter is small, the perfusion in the SAI flap may diminish dramatically from the pedicle to the distal region. As a result, the distal region of the SAI flap is vulnerable to ischemic conditions due to inadequate blood perfusion. Chan *et al*[4] performed three- and four-dimensional computed tomographic angiography (CTA) studies of the SAI flap in ten fresh cadavers. They found that the supraclavicular artery perfuses only 50% of the whole skin paddle in one flap because the pedicle artery was much smaller than the other flap pedicles (0.7 mm). However, no *in vivo* findings have been reported to confirm that smaller-caliber supraclavicular arteries are associated with partial flap necrosis. For this reason, it is necessary to measure the diameter of the supraclavicular artery before harvesting the SAI flap.

Another reason for distal flap necrosis is excessive flap length. Zhou *et al*[1] described the skeletonized vascular pedicle and reported the dimensions of the skin paddles, but they did not describe the harvesting techniques, length of the vascular pedicles, or length of the SAI flap; it may have been inconvenient for them to share their experience in their case report. A widely accepted practice is that the pedicle vessels need not be skeletonized to shorten the operative time and prevent kinking or compression of the pedicle. Additionally, the length of the SAI flap should be measured from its pivot point to the distal tip of the flap, which should be presented in the article because it is an important influencing factor for complications. Chan *et al*[4] found that the distal region of the SAI flap is dependent on the interperforator flow from direct linking vessels and recurrent flow through the subdermal plexus. They were optimistic that the margins of the flap could likely be extended to beyond that of the deltoid muscle.

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This means that the length of the SAI flap could extend far beyond the territory of the supraclavicular artery. However, these findings were not completely confirmed in clinical practice. The length of the SAI flap could extend beyond the territory of the supraclavicular artery, but not excessively far. Excessive length of the SAI flap is not recommended due to distal flap necrosis. To date, there is no consensus about the clear definition of "excessive flap length." It ranges from 22 to 24 cm, based on the different clinical studies. Anatomical studies have shown that the total length of the supraclavicular artery varies from 48 to 92 mm.[3] Therefore, further analysis is necessary to determine whether there is a link between the length of the supraclavicular artery and length of the SAI flap.

Pre-operative assessment of the angiosome of the SAI flap is the cornerstone of SAI flap design. A variety of methods have been used for the pre-operative assessment of the SAI flap. The most commonly used method is the handheld Doppler (HHD) method. It is non-invasive, the least expensive, and the easiest to use the devices available. Additionally, the depth of the supraclavicular artery is usually within the penetration depth of the commonly used HHD probe. As a result, mapping of the SAI flap using an HHD probe before flap harvest has been advocated extensively. Granzow *et al*[5] found that the SAI flap remains viable to the point that is at least 5 cm beyond the most distal point at which the Doppler signal can be detected after flap elevation. Although further large-scale studies are needed to confirm these findings, the findings showed that assessment of the vascular territory of the supraclavicular artery could contribute to preventing distal necrosis. Nevertheless, the main disadvantage of the HHD method is that it cannot be used to accurately estimate the vascular territory of the supraclavicular artery and is likely to produce false-positive and false-negative results. CTA can provide images with accurate visual details of the caliber of the supraclavicular artery. Nevertheless, CTA cannot reveal the localization of the entire course of the supraclavicular artery and is often used when surgeons need to determine whether the pedicle is present or has previously been injured. Indocyanine green fluorescence (ICG) angiography has been successfully applied for immediate assessment of microcirculation perfusion in a variety of reconstructive procedures, including free flap and pedicle flap surgeries. Theoretically, ICG angiography using the available imaging systems such as the SPY-Elite Intra-operative Perfusion Assessment System can be helpful to ensure adequate vascularity before and after insetting of the SAI flap, especially in cases requiring the SAI flap to be longer than 22 cm. However, studies with large sample sizes are needed to estimate the value of ICG angiography in preventing minor and major complications after reconstruction of head and neck defects with the SAI flap.

Color Doppler ultrasonography (CDU) relies on the same working principle as that of the HHD method. However, CDU is capable of providing static information about the anatomy of the blood vessels and quantitatively assessing

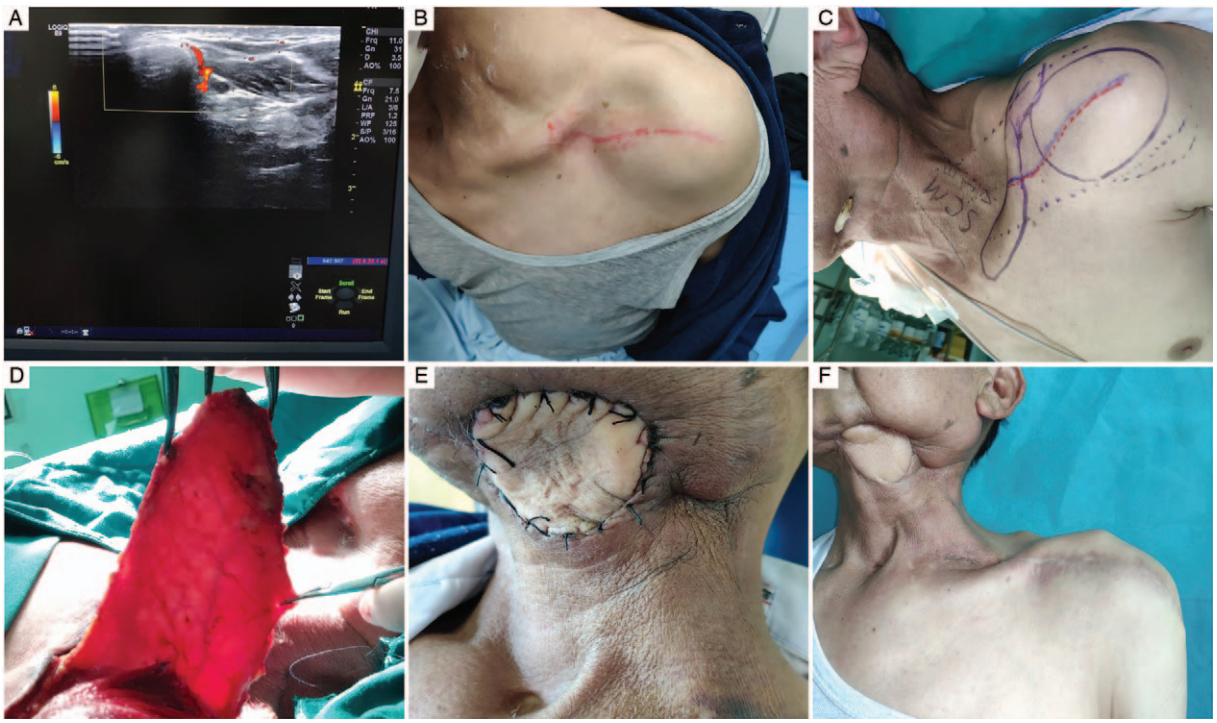

Figure 1: A male with mandible osteoradionecrosis and a soft tissue defect overlying the necrosis after level I–III neck dissection followed by radiotherapy underwent debridement and reconstruction with SAI flap. (A) A GE LOGIQ E9 ultrasonic device with an 8 to 12 MHz linear probe was used in the investigation. In this case, The supraclavicular artery was identified while crossing the junction of the middle and lateral thirds of the clavicle. The length of the supraclavicular artery after it passed the clavicle was 10.5 cm; the diameter of the supraclavicular artery was 1.4 mm at the origin; the peak systolic velocity was 15 cm/s; (B) The course of the supraclavicular artery was identified and marked; (C) A 7 × 21 cm SAI flap was designed according to the course of the supraclavicular artery CDU identified; (D) The course of the supraclavicular artery was confirmed by transillumination; (E) Post-operative view at 10 days; (F) Post-operative view at 6 months. "Point" (blue arrow) indicates the origin site of the supraclavicular artery in the transverse carotid artery.

hemodynamic characteristics, which may be relevant to the assessment of the angiosome of the SAI flap. In our practice, CDU is used as an effective means for pre-operative SAI flap design. The supraclavicular artery can be identified while crossing the junction of the middle and lateral thirds of the clavicle. Subsequently, the supraclavicular artery is traced proximally to its origin, where the diameter and hemodynamic characteristics of the supraclavicular artery are measured. The most distal point is traced to the point at which the CDU signal cannot be detected. If the supraclavicular artery is divided into smaller branches, all the branches are traced and marked as long as these branches can be traced and marked. The distal point of the SAI flap is determined according to the most distal point as confirmed on CDU. An edge not more than 3 cm distal to the point is marked as the distal-most end of the flap to be harvested. The SAI flap is harvested as per the surgical techniques introduced by Granzow *et al*[5] and trimmed according to the defect size. A case example is shown in Figure 1A–F. When the diameter and other characteristics of the supraclavicular artery exhibit any obvious abnormalities, such as a smaller caliber of the vessel at the origin or the length of the SAI flap not reaching the defect, an alternative flap should be prepared. Of course, it is undeniable that CDU is limited by its time-consuming scanning and high dependence on the experience and skills of ultrasound radiologists with knowledge of the SAI flap anatomy. Nevertheless, acquiring more information about the supraclavicular artery (SCA) within the SCA flap improves surgeons' confidence during their harvest. It is worthwhile exploring more reliable and informative methods to develop an in-depth understanding of the angiosome territory of the SAI flap and reduce the incidence of complications after SAI flap reconstruction of head and neck defects.

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Authors' Reply: Pre-operative imaging of the supraclavicular artery island flap plays a vital role in the flap design

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Thank you very much for reviewing the case report carefully and proposing meaningful comments on evaluating angiosome of the supraclavicular flap. In view of your opinions and based on our clinical experience, we hereby reply as follows:

1. The safe length of the vascular pedicle of the flap

   When harvesting the supraclavicular island flaps, we follow the principle that the position, size, and shape of the flap in the donor site are determined by the location, size, and shape of the defect. We take the originating site of transverse cervical artery as a "turning point" of the vascular pedicle of the flap. The length of the vascular pedicle of the supraclavicular flap was defined as the distance measured from the "turning point" to the proximal part of the defect area. Different from the supraclavicular fossa taken as the "turning point" by other reports, the starting site of transverse cervical artery was used as the "turning point" in our study. In this regard, it required the skeletonization of the cervical segment of transverse cervical artery during the harvesting of the supraclavicular island flap. The advantages are as follows: 1) Removal of the adipose connective tissue around the root of transverse cervical artery to prevent local lymph node recurrence; 2) Skeletonization of the transverse cervical artery to enlarge the range of motion of the flap, so as to facilitate the transfer and shaping of the flap in the recipient site; 3) Root of the transverse cervical artery is closer to the donor site than the supraclavicular fossa, which can realize a repair of the defect at a higher position when selecting the former one as the "turning point." On the contrary, for defects with the same height, when the "turning point" is designed at the root of transverse cervical artery, there may be a closer distance between the defect and the donor site, and hence flap pedicle of shorter length is needed for repair. In other words, the flap may be closer to the supraclavicular artery, showing a more abundant blood supply at the end of the transferred flap.
2. Approach to reduce the necrosis rate of distal flap

   As described in the letter, the distal part is vulnerable to ischemic condition due to inadequate blood perfusion and hence may result in the necrosis of the distal part of the flap. In this regard, it is of great significance to determine the range of perfusion of the supraclavicular artery in the clinical practice! In our process of operation, an anterograde dissection of the transverse cervical artery was made to locate the origin of the supraclavicular artery and determine the "point," namely, the starting point of the supraclavicular artery. After that, another anterograde dissection of the supraclavicular artery was carried out for 1–2 cm in length, and an "extension line" was made along the direction of the vessels as the long axis of the flap [Figure 1A]. The flap was then designed on this axis to ensure that the resected flap was within the perfusion range of the supraclavicular artery, which could

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