Original Article

Superior Epigastric Artery: Safety Zones for Pedicle TRAM Flap Reconstruction: A Case Series

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Abstract   Deep superior epigastric artery (DSEA) can be damaged in pedicled transverse rectus abdominis musculocutaneous (TRAM) flap reconstruction. Current descriptions of the course of the DSEA do not provide surface landmarks that would be of help to the surgeon. Surface markings of the deep inferior epigastric artery (DIEA) with description safe zones of the TRAM flap are available in the literature, but this is not the case for the DSEA. This study aimed to map surface markings for the DSEA and identify the "danger zone", which must be avoided during pedicled TRAM flap reconstruction.

Keywords: Immediate autologous flap reconstruction, Deep superior epigastric artery, Transverse rectus abdominis musculocutaneous flap.

INTRODUCTION

Deep superior epigastric artery (DSEA) can be damaged in pedicled transverse rectus abdominis musculocutaneous (TRAM) flap reconstruction. Current

descriptions of the course of the DSEA do not provide surface landmarks that would be of help to the surgeon. Surface markings of the deep inferior epigastric artery (DIEA) with description safe zones of the TRAM flap

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ANATOMY

The main arterial supply to the abdominal wall comes from the epigastric arteries. There are three epigastric arteries supply the abdominal wall–superior, inferior, and superficial epigastric arteries. The superficial epigastric artery supplies the superficial tissue of the abdominal wall; the superior and inferior epigastric arteries make an anastomosis with each other and supply the muscles of the abdominal wall.

Several anatomic studies of the superior epigastric vascular system have been done[1-5]. Hallock[2] was the first to describe a perforator flap based on the superior epigastric artery. At the level of sixth or seventh costal cartilage, the internal thoracic artery divides into two terminal branches. The first is the musculophrenic artery supplies the muscles of the diaphragm. The second terminal branch is the superior epigastric artery. According to some, it passes through a space medially by the sternal part of the diaphragm, laterally by the costal part of the diaphragm, and anteriorly by the musculoaponeurotic plane formed by transversus thoracis and transversus abdominis (Larrey's space or trigonum sternocostale). Before entering the rectus sheath, it divides into a superficial branch and a deep branch. The superficial branch pierces the rectus fascia directly under the xiphoid toward the skin. The deep branch (DSEA) enters the rectus muscle on its deep surface, approximately 7 cm below the costal margin[6]. When entering the rectus sheath, it will run behind the rectus abdominis muscle and give the perforating branch to supplying it.

The DSEA usually anastomoses with the deep branch of the inferior epigastric artery(DIEA) at umbilicus level or more inferiorly depending on different variations of the human body[7]. The perforator branch pierces the rectus muscle or sometimes pierces the sheath beside the lateral border of the muscle to supply the abdominal skin[6]. The artery supplies the diaphragm; on the right small branches reach the falciform ligament to anastomose with the hepatic artery. A xiphoid branch contributes to the supply to the lower sternal region and may be of special importance when used as a conduit in coronary artery by-pass grafts[8]. At the intersections of the rectus abdominis muscle there are transverse arcades arising from either the superior or inferior epigastric arteries, which send branches supplying muscle or the overlying skin[9].

Superior epigastric veins follow alongside their corresponding arteries, and drain to the internal thoracic vein. These structures, like the arteries, are present bilaterally almost symmetrically in the human body[10].

The regional lymphatic drainage follows the flow of veins above the Scarpa fascia. The lymph nodes that follow the superficial aspect of superior epigastric veins above the umbilicus drain toward the anterior (pectoral) group of axillary lymph nodes. Lymph nodes that follow the deep aspect of superior epigastric veins drain back to the parasternal lymph nodes along internal thoracic vessels[11]. There are no nerves that follow the path epigastric arteries like veins and lymph nodes.

PATIENTS AND METHODS

This study was approved by the Hospital's Research Ethics Committee. The anatomical observations were made at the right subcostal incision during open hepatobiliary surgery. The posterior surfaces of the anterior abdominal wall were dissected. The surface anatomy of eight DSEAs and their branches was defined. The position of the DSEA was measured from the xiphoid process to the first branch of DSEA. The danger zone was identified by the position of DSEA, both medially and laterally (Figure 1).

RESULTS

A total of seven patients underwent dissection (Table 1). One patient underwent bilateral subcostal dissection. The mean age was 58.1 years. The mean distance of the DSEA from the xiphoid process to the first branch of DSEA was 3.8 cm (range, 3.6-4.0 cm). We found the DSEA to be in the most lateral position in 1 case, while the rest were more towards the middle position of the rectus muscle. The DSEA was directed towards the posterior to the surface of rectus muscle in 5 cases.

DISCUSSION

One popular technique of breast reconstruction for breast cancer is to use a pedicled TRAM flap with blood supplied by the DSEA[12]. The advantage of using a pedicled TRAM flap is that a very large amount of breast volume can be obtained, avoiding the need for prostheses. The are several types of pedicled TRAM flap.

Popular methods include the Whole Muscle Technique[13] and the Split Muscle Technique[14]. The split muscle technique aims to preserve a part of the rectus muscle, at the medial and lateral side, 1 cm in width on each side.

The preservation of rectus muscle makes the abdominal wall stronger and the smaller pedicle looks better cosmetically[15], But the major disadvantages is occurrence of DSEA injury[16].
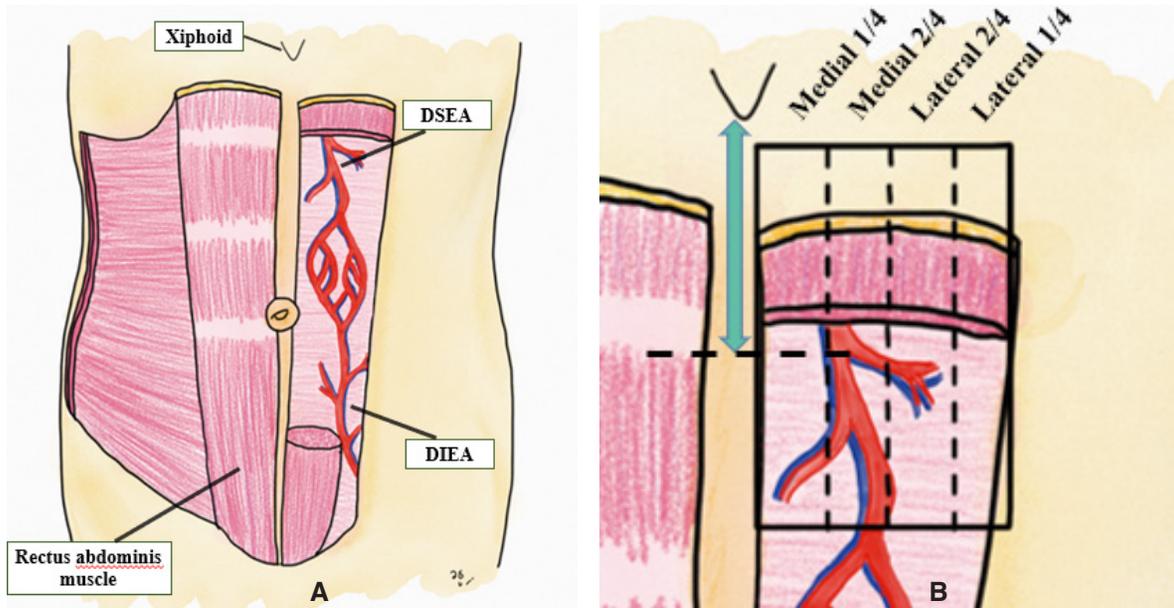

Figure 1 A: Anatomy of the DSEA and DIEA. Distance of the DSEA refers to the distance from xiphoid process to the first branch of the DSEA (green double-ended arrow).
B: Position of the DSEA is reported in accordance to the rectus muscle which is divided into 4 equal parts.

Table 1 Characteristics of the DSEA of seven patients who underwent dissection

Patient number	The mean distance of the DSEA (cm)*	Size of the DSEA (mm)	Position of the DSEA	Direction of the DSEA
1	3.9	2.5	Lateral 1/4	Posterior surface of rectus muscle
Male, 59 y				
2	3.7	1	Lateral 2/4	Middle of rectus muscle
Male, 61 y				
3	3.6	2.5	Medial 2/4	Middle of rectus muscle
Female, 58 y				
4	3.7	3	Medial 2/4	Posterior surface of rectus muscle
Female, 57 y				
5	4.0	2	Medial 2/4	Posterior surface of rectus muscle
Female, 55 y				
6	3.8	2	Lateral 2/4	Posterior surface of rectus muscle
Female, 58 y				
7	3.9	1.5	Medial 2/4	Posterior surface of rectus muscle
Female, 59 y	3.7	2	Lateral 2/4	Middle of rectus muscle
(bilateral subcostal incision)				

* The distance of the DSEA was measured from the xiphoid process to the first branch of DSEA.

Injury to the DSEA may result in abdominal wall hematoma formation, flap necrosis, infection, incisional hernia formation, or major blood loss, depending on where the arterial transection occurs. Therefore, knowing the anatomy of superior epigastric artery may reduce the chance of arterial injury[17].

1. Identification Technique

Many surgeons use the transillumination technique to visualize important vessels coursing through the skin to help reduce DSEA injury. However, this is difficult to do in dark-skinned patients and patients with a thick sub-cutaneous tissue. A study by Quintet et al. showed that blood vessels were visualized using the transillumination technique in only 63% of 103 patients studied[7]. Some surgeons use both unidirectional Doppler flowmetry and colour Duplex scanning, which have been proved to be useful tools in evaluating vascular anatomy pre-operatively, improving surgical planning and reducing operating time and DSEA injury[18].

MDCT-based imaging has provided detailed information on the quality, course, and localization in three-dimensional images to map vessels pre-operatively. The high sensitivity and specificity make it possible to map vessels pre-operatively, effectively improving surgical strategy, reducing valuable operating time, intraoperative injury and postoperative complications[19].

2. "Safety" and "danger" zones

"Safety" and "danger" zones have been defined in various studies on cadavers in different countries[7, 20]. At the level of the xiphoid process, the safe zones are at the midline, along with an adjacent area measuring 3 cm on either side.
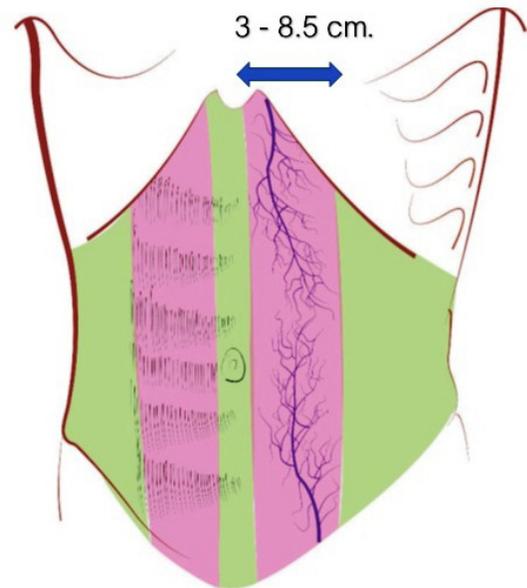

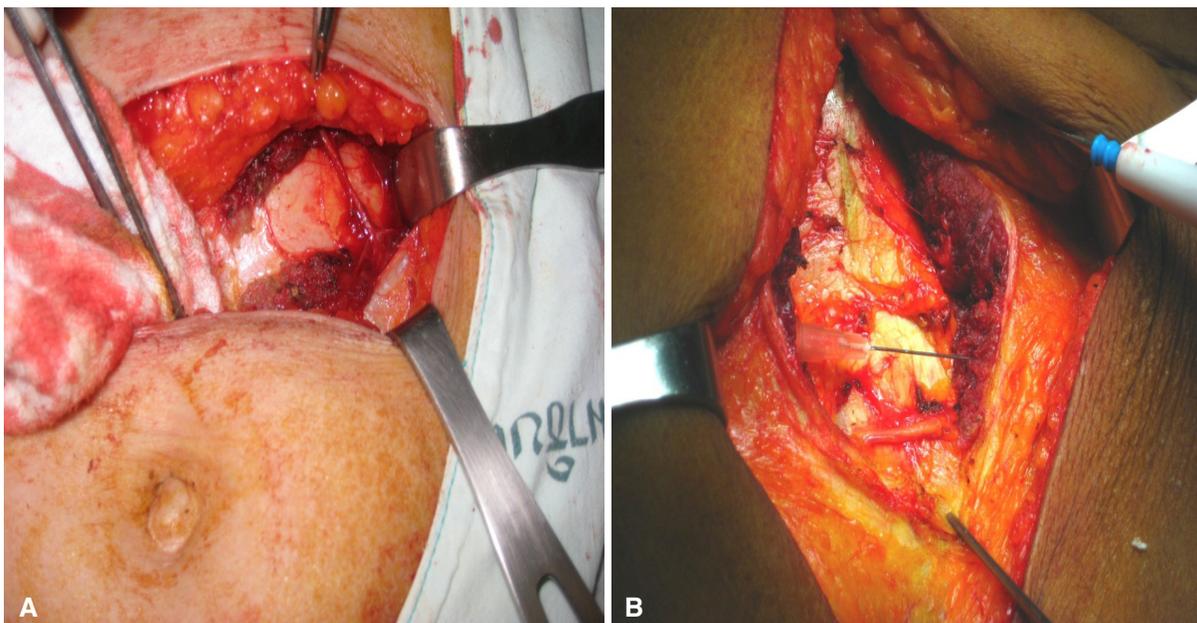**Figure 2** Showing the "safety" (green) and "danger" (pink) zones of DSEA

Figure 3 A: The DSEA enters the middle of the rectus muscle and reaches the lateral 2/4 surface (left side muscle)
B: The DSEA enters the posterior part of rectus muscle and reaches the lateral 1/4 surface (right side muscle).

The danger zone starts from 3 cm from the midline, up to 5 cm from the midline, which should include the main stem of DSEA. The length of the DSEA lies between the xiphoid process and umbilicus, and the danger zone at this site measures a strip starting from 3 to 8.5 cm from the midline on either side. The remaining area is safe, as shown in green in Figure 2. By avoiding these danger zones, the incidence of damage to the major trunks of the DSEA can be reduced. This will not only have immediate benefits including avoidance of hematoma formation, but will also save the trans-rectus abdominis flap for reconstruction.

In our study of "Safety" and "danger" zones (8 DSEAs identified during hepatobiliary procedures), we found the point of first DSEA branching as measured from xiphoid process to range between 3.6 to 4 cm (mean, 3.8 cm) and 50% of the DSEA to lie at the medial 2/4 (Figure 1), which is consistent with other studies. The DSEA entered in the middle of rectus muscle in 3 cases and posterior surface of rectus muscle in 5 cases as shown in Figure 3A. In one case, the DSEA enters the posterior part of rectus muscle and reaches the lateral 1/4 surface (Figure 3B).

Conclusion

The pattern of DSEA is variable. The Muscle Splitting Technique in pedicled TRAM flaps may therefore risk injuring DSEA. Attempting to preserve the entire fascia while harvesting the whole muscle may also be dangerous due to the superficial nature of the blood supply at the muscle surface. The vascular patterns of DSEA are discussed in this article on an anatomical basis. We found the pattern of DSEA to be similar to that previously described, and the usual "safety" and "danger" zones can still be applied to Thai patients.

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