กายวิภาคของระบบประสาทและหลอดเลือดของ ดีพ-อินฟีเรีย- อีพิแก็สทริก-เพอโฟเรเทอะ-แฟล็บ เพื่อประยุกต์ใช้ในการผ่าตัดเต้านม

นางสาวภาสินี สงวนสิทธิ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาวิทยาศาสตร์การแพทย์
คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2548

ISBN 974-53-2947-9

NEUROVASCULAR ANATOMY OF THE DEEP INFERIOR EPIGASTRIC PERFORATOR FLAP FOR BREAST RECONSTRUCTION

Miss Pasinee Sanguansit

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science Program in Medical Science

Faculty of Medicine

Chulalongkorn University

Academic Year 2005

ISBN 974-53-2947-9

Thesis Title	Neurovascular Anatomy of the Deep Inferior Epigastric Perforator Flap for Breast Reconstuction
By	Miss Pasinee Sanguansit
Field of study	Medical Science
Thesis Advisor	Associate Professor Tanvaa Tansatit, M.D.
Thesis Co-advisor	Associate Professor Prayuth Chokrungvaranont, M.D.

Accepted by the Faculty of Medicine, Chulalongkorn University in Partial Fulfillments of the Requirements for the Master's Degree

P. Kamolratanakul ..... Dean of Faculty of Medicine

(Professor Pirom Kamolratanakul, M.D.)

Thesis Committee

Vilai Chentanez ..... Chairman

(Associate Professor Vilai Chentanez, M.D., Ph.D.)

Tanvaa Tansatit ..... Thesis Advisor

(Associate Professor Tanvaa Tansatit, M.D.)

..... Thesis Co-advisor

(Associate Professor Prayuth Chokrungvaranont, M.D.)

..... Member

(Associate Professor Suthiluk Patumraj, Ph.D.)

ภาสินี สงวนสิทธิ์ : กายวิภาคของระบบประสาทและหลอดเลือดของ ดีพ-อินฟีเรีย- อีพิแก็สท ริก-เพอโฟเรเทอะ-แฟล็บ เพื่อประยุกต์ใช้ในการผ่าตัดเต้านม (NEUROVASCULAR ANATOMY OF THE DEEP INFERIOR EPIGASTRIC PERFORATOR FLAP FOR BREAST RECONSTRUCTION) อ. ที่ปรึกษา : รศ.นพ.ธันวา ตันสถิตย์, อ.ที่ปรึกษาร่วม : รศ. นพ.ประยุทธ โชครุ่งวรานนท์, 45 หน้า. ISBN 974-53-2947-9.

วัตถุประสงค์ เพื่อศึกษากายวิภาคของระบบประสาทและหลอดเลือดบริเวณหน้าท้องส่วนล่าง สำหรับนำไปประยุกต์ใช้ในการผ่าตัด Deep Inferior Epigastric Perforator Flap ในการทำเต้านมใหม่

วิธีดำเนินการวิจัย ทำการชำแหละศพที่ถูกดองใน formalin จำนวน 31 ศพ โดยศึกษาถึงลักษณะของ deep inferior epigastric pedicles, perforators, intercostal nerves รวมทั้งความสัมพันธ์ระหว่างเส้นประสาทและหลอดเลือดในแต่ละตัวอย่าง

ผลการศึกษา พบ perforator เฉลี่ยเป็น 6.53 เส้นต่อ 1 flap และมีขนาดโดยเฉลี่ย 0.97±0.29 มม. โดยจะพบ perforator หนาแน่นที่สุดใน medial row และ perforator ที่อยู่บริเวณ lateral row จะมีขนาดโดยเฉลี่ยใหญ่ที่สุดคือ 1.01±0.26 มม. lateral row perforators ส่วนใหญ่จะมีลักษณะเป็น rectilinear course (82.7%) ในขณะที่ medial row perforator มักมีลักษณะเป็นแบบ oblique course(86.4%) เส้นประสาทจะทอดตัวอยู่เหนือต่อหลอดเลือดหลักเสมอ โดย nerve ที่วิ่งคู่กับ medial perforator จะวิ่งคู่กับมาตั้งแต่แรก ในขณะที่ nerve ที่วิ่งไปกับ lateral perforator นั้นจะไม่ได้วิ่งสัมพันธ์กันตั้งแต่แรกแต่จะเจอกัน ณ ตำแหน่งที่แทงสู่ rectus sheath

สรุปผล แนะนำให้ใช้ lateral row perforator ในการผ่าตัด DIEP flap เพื่อทำเต้านมใหม่

สาขาวิชา วิทยาศาสตร์การแพทย์ ลายมือชื่อนิสิต ภาสินี สงวนสิทธิ์
ปีการศึกษา 2548 ลายมือชื่ออาจารย์ที่ปรึกษา
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม

477 47648 30: MAJOR MEDICAL SCIENCE

KEY WORDS: DEEP INFERIOR EPIGASTRIC PERFORATOR (DIEP) FLAP/BREAST RECONSTRUCTION: NEUROVASCULAR ANATOMY OF THE DEEP INFERIOR EPIGASTRIC PERFORATOR FLAP FOR BREAST RECONSTRUCTION. THESIS ADVISOR: ASSOC.PROF.TANVAA TANSATIT, MD. THESIS COADVISOR: ASSOC.PROF. PRAYUTH CHOKRUNGVARANONT, MD., 45 pp. ISBN 974-53-2947-9.

Objective: To suggest the best location of the perforator and cutaneous nerve for strategic design of the deep inferior epigastric perforator (DIEP) flap.

Materials and methods: The characteristic of the pedicles, perforators, intercostal nerves and the relationship of nerve to vessel in DIEP flap were studied in 31 formalin-preserved cadavers (62 flaps).

Results: 405 perforator vessels were divided into three vertical rows. These perforators were mostly contained in medial row (45.4 %) while the lateral row perforators were the largest (1.0±0.3 mm). The largest perforator (1.4±0.3 mm) were mostly located within 1 cm horizontally from umbilicus. Lateral row perforators, usually rectilinear course (82.7%), traveled with nerves from the beginning. Whereas medial row perforators, usually oblique course (86.4%), were not related to nerves initially but they joined together before piercing to the rectus sheath.

Conclusion: Our finding suggested that it would be more beneficial to using the lateral row perforators

Field of study Medical Science

Academic year 2005

Student's signature Pasinu Sangvanit

Advisor's signature Tanvaa Tansatit

Co- advisor's signature Prayuth Chokrungvaranont

ACKNOWLEDGMENTS

I would like to thank Associate Professor Tannvaa Tansatit (my advisor) for his valuable, advice, guidance, helpfulness, understanding and intelligential motivation throughout this study. I also would like to express my gratitude to my co-advisor to Associate Professor Prayuth Chokrungvaranont for his valuable suggestions. My grateful appreciation is extended to my thesis committees, Associate Professor Vilai chentanez and Associate Professor Suthtiluk Patumraj, for their valuable discussion and suggestions.

I am really thankful to the staffs at Department of Anatomy, Faculty of Medicine, Chulalongkorn University for their helpful.

Finally, I can not forget to give special thanks to my family for support during graduate study, their kindness and understanding all the time.

TABLE OF CONTENTS

CHAPTER **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

a.	=	artery
cm	=	centimeter
mm	=	millimeter
et al.	=	et alii

CHAPTER I

INTRODUCTION

1. Background and Rationale

Autologous breast reconstruction has been established as a reliable and reproducible technique for reconstruction following mastectomy [1-3]. Among technical options, transverse rectus abdominis myocutaneous (TRAM) flap has the advantages of versatility and thorough study of its anatomy. Despite the cosmetic benefits such as resultant scar and appearance of the donor site, some questions have been raised concerning the rectus abdominis muscle resection [4-10].The known complication are muscle weakness and abdominal hernia [10-12]. In 1994, Allen and Treece introduced the concept of perforator flaps. The development of the deep inferior epigastric perforator (DIEP) flap have brought new modifications to the conventional abdominal flaps [3,13] due to maintenance of well-vascularized tissue and total muscular preservation. Thus, the DIEP flap could reduced likelihood of abdominal bulging or muscular weakness [14]. In addition, dissecting the pedicle of the DIEP flap through the rectus abdominis a considerable increase in pedicle length can be achieved, which allows greater freedom of design [7,10,15-17]. This procedure also has an improvement of the abdominal contour because the abdominal wall is closed as in an abdominoplasty [7, 18]. Despite these advantages, reconstruction with the DIEP flap is not a reproducible procedure, and its main limitation is its operative complexity and longer learning curve. The perforating vessels are small, easily damaged, besides requiring detailed anatomical knowledge [3, 7]. At first, the flap was thought to be devoid of sensation, but recent studies have reported the spontaneous return of sensation in 60%-80% of reconstructed breasts [19-22]. Spontaneous recovery of sensation is, however, inconsistent and unpredictable. Recent attempt to improve the quality and consistency of sensory recovery in flap by coapting segmental nerve from abdomen to cutaneous branch of intercostals nerve [13, 23-26].

Although, it is not difficult to find deep inferior epigastric perforators but we supposed to suggest a location of the best perforator and nerve for strategic design of DIEP flap to reduce the operative time and the risk of vascular and nerve injury.

2. Research Question

Primary Research Question

- What are number, location, diameter, and intramuscular course of perforators and the largest perforators within DIEP flap?

Secondary Research Question

- What are pattern, length, and diameter of deep inferior epigastric pedicles?

- How nerves contribute within DIEP flap?

- How nerve relate to vessel in DIEP flap?

3. Objectives

1. To evaluate number, location, diameter, and intramuscular course of perforators and the largest perforators within DIEP flap.

2. To determine pattern, length, and diameter of deep inferior epigastric pedicles

3. To define nerves pattern within DIEP flap.

4. To investigate the relationship of nerve to vascular in DIEP flap.

4. Hypothesis

Deep Inferior Epigastric perforator will be constant pattern.

5. Assumptions

1. The cadavers have no impairment of abdomen.

2. The measurement has validity and reliability.

6. Operational Definitions

1. Flap: a piece of tissue transplanted from one area to another area. A flap contains are blood vessels, tissue, muscle, skin, fat and fascia.

2. DIEP flap: the tissue transplanted from abdomen to another area. A flap contains are deep inferior epigastris vessels, perforators, fat and skin.

3. Perforator: deviation of small branch from main stem to nourishes muscle and cutaneous.

7. Key Words

1. Deep Inferior Epigastric Perforator (DIEP) Flap

2. Breast Reconstruction

8. Expect Benefits and Applications

A better understanding of the neurovascular anatomy with regarded to number, length, external diameter, course of pedicles and perforators. To report details of sensory and motor nerves of rectus abdominis, besides the relationship of the nerve to the vascular is determined. This detailed knowledge provides a valuable guide for reducing operative time and risk of vascular and nerve injury, is useful in strategic for DIEP flap planning.

CHAPTER II

REVIEW OF RELATED LITERATURES

1. The Anatomy of the Abdominal Wall

The rectus abdominis was a unique muscle that arose from the pubic symphysis and the pubic crest and inserted on fifth, sixth, and seventh costal cartilages above the costal margin.

The deep inferior epigastric artery was more significant than the superior epigastric artery supplying the skin of the rectus abdominal wall. There were also anastomoses between epigastric system, the terminal branches of lower six intercostals arteries, and the ascending branch of the deep circumflex iliac artery [27, 28].

The muscle received a secmental innervation from the terminal branches of the lower six intercostals nerves. These nerves, together with the intercostal arteries, passed between the transversus abdominis and internal abdominal ablique muscle [27].

2. The Anatomy of the Deep Inferior Epigastric Pedicle

2.1 The Pattern of the Pedicle

Early anatomical studies of the rectus abdominis and epigastric arteries were performed in 115 cadavers. In 1960, Frank J Milloy [29] described the deep inferior epigastric artery was present in all bodies bilaterally, most frequently as a single-stem vessel passed superiorly on the posterior aspect of the rectus, and connected directly with superior epigastric.

In 1984, Brian Boyd et al. [28] dissected on 25 fresh cadavers. They described in detail of vascular territory of the deep inferior epigastric system, which provided the major supply to all the layers of the anterior abdominal wall. Commencing at the external iliac artery, the deep inferior epigastric artery coursed upward and medially to reach the lateral border of the rectus abdominis muscle and divided usually into two primary branches. During its course, the artery supplied peritoneal, muscular and cutaneous branch which radiated in all directions from the main stem.

Later in 1993, Itoh and Arai [9] carried out an anatomic study on 17 preserved cadavers to create the efficient surgical technique of elevating the inferior epigastric artery free flap. They described the deep inferior epigastric artery bifurcation in one branch running slightly laterally and the other ran medially to the muscle midline. Moreover, in 88.2 percent of the dissections, the lateral branch was dominant over the medial one.

In 2005, Offman SL et al. [30] studied in 5 fresh cadavers by using a lead oxide-gelatin injection technique, the deep inferior epigastric artery had two main intramuscular divitions which were the lateral branch, communicating through deep anastomosis with the lower four intercostals, and medial branch, which contributing an umbilical branch and deep anastomosis with the superior epigastric artery.

2.2 The Length and Diameter of the Pedicle

In 1994 the DIEP flap was introduced by Allen and Treece [13] as a technique for breast reconstruction. This technique did not sacrifice any part of the rectus abdominis muscle**.** Therefore, the DIEP flap combined the adventages of the free TRAM flap with reduced likelihood of ventral hernia or muscle weakness. Anatomical dissection of 8 fresh cadavers was performed. The average pedicle length was 11.8 cm with a range from 9.7 to 14.5 cm. Average external diameter of the deep inferior epigastric artery was 4.3 mm with a range from 3.0 to 5.7 mm.

Later in 2000, the anatomical basis of the blood supply to the deep inferior epigastric perforator (DIEP) flap was studied on 20 fresh cadavers by Heitmann [10]. The deep inferior epigastric artery was present with an average length of 10.3 cm (range 9.0-13 cm) and an average diameter of 3.6 mm (range 2.8-5.0mm).

In 2005, Offman SL et al. [30] studied in 5 fresh cadavers by using a lead oxide-gelatin injection technique, the diameter at its source of deep pedicle was 3.3±0.4 mm, and its length was between 7.5 and 20.5 cm.

3. The Anatomy of the Perforators

In 1993, Itoh and Arai [9] carried out an anatomic study in 17 preserved cadavers to create the efficient surgical technique of elevating the inferior epigastric artery free flap. There was an

average 6.5 skin perforators of 0.5 mm or larger in diameter arising from the anterior sheath of the rectus abdominis muscle. In analyzing the number of skin perforators, they divided the rectus abdominis into six subdivitions, i.e., superolateral, superomedial, middle-lateral, middle-medial, inferomedial, and inferolateral areas. The number of skin perforators was greatest in the middle-lateral area. On the basis of findings, the authors emphasized that it would be more beneficial to use the lateral branch rather than the medial branch during DIEP pedicle harvesting.

In 1999, Blondeel et al. [34] described a detailed DIEP surgical technique. This article suggested that lateral perforators were dominant and easier to dissect due to a more perpendicular path through the rectus abdominis muscle. Additionally, despite the medial row perforator vessels gave better perfusion for the flap, they had a longer intramuscular course and required a more elaborate dissection.

In 2000, the anatomical basis of the blood supply to the deep inferior epigastric perforator (DIEP) flap was studied on 20 fresh cadavers by Heitmann [10]. There were consistently one or two major perforator vessels for each pedicle and located with in a radius of 8 cm below the umbilicus.

Later in 2002, Vandevoort et al. [18] emphasized the perforator vessel's topography and described different patterns of intramuscular course. In 100 consecutive clinical cases, the authors noted five different pathways: a short intramuscular course, a tendinous intersection, a long intramuscular course, a subfascial course, and a paramedian course. According to the authors, a short intramuscular course of the perforators was by far the most frequent type and easiest to harvested.

In 2002, 20 fixed and fresh cadavers were performed by Hamdy. [14] The lateral perforator vessels were more dominant (80 percent of cases) than medial perforators. An average of 5.4 large perforators (>0.5mm in diameter) were dissected in each case. These perforators were mostly contained in the area lying laterally and below the umbilicus, with an average distance of 4 cm from umbilicus. The musculocutaneous perforators might have a direct or indirect course. The small musculocutaneous perforators (<0.5 mm) mainly supplied the deep subcutaneous plexus, whereas the large perforators (>0.5 mm) fed into the subdermal plexus and supplied the skin and the superficial layers of fat.

In 2004, 30 anatomical dissections of DIEP flap were performed on 15 fresh female cadavers by Alexandre Mendonca Munhoz et al. [3]. The number, location, and intramuscular course of the

perforator vessels were determined. Regarding the course of the intramuscular perforator vessels, two different paths were observed. A rectilinear perforator vessel course from the flap to the deep inferior epigastric vessels was shorter and ran more perpendicularly through the muscle fibers. The muscle was split in a longitudinal direction without muscle resection. An oblique perforator vessel ran in more than one intermuscular septum to reach the subcutaneous tissue. The distance from the flap to the main pedicle was longer, and sometimes some muscle resection was needed to free the perforator vessels. The dissection was more tedious and required extensive longitudinal splitting of the rectus muscle. One hundred and one perforator vessels were detected (6.4 vessels per flap). Thirty-four percent were located in the lateral row, and the rectilinear course was observed in 79.2 percent of these vessels. In the medial row, only 18.2 percent of the perforator vessels presented this configuration.

In 2005, Offman SL et al. [30] studied on five fresh cadavers by using a lead oxide-gelatin injection technique. There were generally 5±2 perforators from the deep inferior epigastric artery concentrating in the peri-umbilical region.

4. The Anatomy of the Nerves of the DIEP Flap

4.1 The Penetrating Location

In previous anatomical studies [25, 28, 32] during the harvest of DIEP flaps, they observed that mixed segmental nerve could enter the rectus abdominis muscle at very variable locations from 1 cm medial to its lateral border on the anterior surface to two-thirds medial to its lateral border on the posterior surface.

Moreover in 1988, Duchateau et al. [27] dissected in 6 fresh cadavers to confirm the segmental innervation of rectus abdominis muscle by the terminal branches of the lower six intercostal nerves. They passed with the terminal branches of the intercostal arteries between the transverses abdominis and the internal oblique muscles and penetrated laterally the sheath of the rectus muscle. They ran between the expansions of the transverses on the posterior fascia of the rectus and entered the deep face of the muscle about 3 cm from its lateral edge. No branch continued more medially under the muscle.

Later in 2002, Yap et al. [19] studied on 4 embalmed and 12 fresh cadavers. The intercostal nerves pierced the lateral angle of the rectus sheath, and ran posteroinferiorly to the rectus muscle for 1-5 cm before entering the muscle. The point of entry of the nerves into the posterior aspect of the rectus muscle was varied. Some nerves passed obliquely behind the muscle as far as the medial third before passing anteriorly. The lower nerves entered the muscle at the lateral border of the rectus, while the terminal branch of T12 typically did not pierce the muscle but lay anteriorly, immediately deep to the anterior leaf of the rectus sheath.

4.2 The Relationship of the Nerves to the Vessels

In 1984, Boyd, J.B and Taylor [28] described mixed nerves were accompanied by segmental blood vessels. In the distal third of the rectus abdominis muscle, these vessels anastomosed with the most lateral vascular axis of the rectus muscle which was often the lateral branch of the deep inferior epigastric vessels. The mixed nerves ran obliquely and anteriorly to the deep inferior epigastric vessels in most people and split into a sensory and motor branch at variable distances. The pure sensory branches joined with the perforating vessels and ran together to the skin.

In 1996, Sakamoto et al. [33] described the nerve also carried sensory fibers from the skin of the anterior abdominal wall, which might travel with either the lateral or the medial vascular perforators or, more commonly, with both.

Later In 2002, Yap et al. [19] studied on 4 embalmed and 12 fresh cadavers. The most frequent pattern comprised three branches: one muscular and two cutaneous. The cutanuous branch quickly became associated with lateral and medial vascular perforators of the deep inferior epigastric vascular axis to form neurovascular bundles, which passed anteriorly. Then they ran through the subcutaneous fat to the skin. Within the muscle, the nerves were closely related to the deep inferior epigastric vascular axis, and might lie either anteriorly or posteriorly to the vessels, depending on the level of the nerve, with nerves higher in the series usually lying posteriorly. While lower nerves tended to lie anterior to the vessels. The commonest pattern of cutaneous nerves was for one nerve to give branches to both the lateral and medial vascular perforators at the same level.

Although the anatomy of vessels and nerves of DIEP flap was described above by many authors, but detailed anatomy of perforators and nerves has been unclear and controversial. While some branches of cutaneous intercostal nerve imitating a perforator has not been mentioned.

The purpose of this research focuses on pattern, length, and diameter of pedicles, number, location, diameter, and intramuscular course of perforators, nerve pattern, and relationship of nerve to vascular. We expect this knowledge could be guideline for the surgeon to imagine the anatomy of vessels and nerve of DIEP flap for reducing operative time and risk of vascular and nerve injury, which are useful in strategy for planning DIEP flap.

CHAPTER III

RESEARCH METHODOLOGY

1. Target Population and Sample Population

Formalin-preserved adult cadavers at Department of Anatomy, Faculty of Medicine Chulalongkorn University.

2. Inclusion Criteria

- Thai adult cadavers
- Unlimited on sexes and ages of cadavers.

3. Exclusion Criteria

- The cadavers have impairment of the abdomen**.**
- The cadavers have a scar at abdomen and a record of the abdominal operation**.**

4. Sampling Techniques

- Non probability sampling by Convenience sampling

5. Sample Size Determination

In previous study of Offman et al.**,** The means perforators per flap were 5±2 perforators. At 95 % CI

$$n = Z^2_{\alpha/2}\sigma^2/d^2$$

Where; $Z_{\alpha/2} = Z_{0.05/2} = 1.96$ (two tail)

σ^2 = Variance = 2^2

d = Acceptable error = 0.5

so ; $n = Z^2_{\alpha/2}\sigma^2/d^2$

$n = (1.96)^2\ 2^2 / (0.5)^2$

$n = 61.46 \approx 62$

∴ The sample size was at least 31 cadavers

6. Materials

- Vernier Caliper precision 0.02 mm.
- Operative knife
- Blade
- Fine Scissors
- Examination gloves
- Probe
- Forceps
- White board and pens

7. Methods

Study was carried out on both sides of 31 formalin-preserved adult human cadavers (11 males and 20 females) at the Department of Anatomy, Faculty of Medicine, Chulalongkorn University. The cadaver was placed supinely. The dissection commenced from the lateral to medial direction. The skin and subcutaneous tissues were dissected together from the rectus sheath. The perforator vessels were identified at their points of piercing the rectus sheath. The rectus sheath was opened around the course of the perforators and then excised using fine scissors to facilitate the dissection. Then, the rectus muscle fibers were gently split vertically around each perforator branches. To study the course of the deep inferior epigastric perforators, the perforator vessels were followed meticulously between the muscle fibers toward their origin from the divisions of the deep inferior epigastric artery. Then the fascia was opened vertically between the external abdominal oblique muscle and the lateral border of the rectus abdominis muscle. The linear alba at the midline was excised, then lifted up the rectus muscle to study the course of the deep inferior epigastric artery. Nerves were identified and follow as they penetrated the anterior rectus sheath, transversed the rectus abdominis muscle and terminated as cutaneous branches. The relationship of these nerves to the vascular perforators and the deep inferior epigastric pedicle were observed. The external diameter and length of the pedicle were recorded, at the distance from its entry into the lateral border of the rectus abdominis muscle to the furthest perforator. All of the perforators were measured the external diameter, at their points of piercing the rectus sheath, by vernia caliper. The locations were recorded, that umbilical and midline were landmarks.

Statistical analysis

Statistical analysis was undertaken with SPSS version 11.5. The data of measurements were analyzed by descriptive statistics as means, standard deviations, ranges, and percentages. Differences between parameter were compared by one-way ANOVA and independent t-test as appropriate.

CHAPTER IV

RESULTS

1. The Deep Inferior Epigastric Pedicle

1.1 The Pattern of the Pedicle

The origin of the deep inferior epigastric artery was a single branch from the external iliac artery. The pedicle approached the rectus abdominis from its lateral aspect approximately 2.0±1.0 cm below the anterior superior iliac spine (ASIS) (range from 1.1 cm rostral to ASIS to 4.2 cm caudal to ASIS). It passed superiorly on the deep aspect, and parallel to the muscle fibers. Then it entered the muscle substance generating a variable number of perforator vessels. After it entered the muscle, it was found to consist of a single main stem in 42 flaps (69.4%) (Fig. 1A, 2A). In 19 flaps (30.7%) were double main stems, the artery was divided into two large divisions, medial and lateral. These were the lateral divisions running roughly laterally to the middle of the muscle and the medial division that had a course medial to the median line of the muscle (Fig 1B, 2B). In 5 flaps of double branches had a specialty, they also had perforator from the trunk before it divided into medial branch and lateral branch (Fig.1C). This type was fewer amounts and it was not important because the lower perforators didn't popular for DIEP flap harvesting.

1.2 The Length and Diameter of the Pedicle

The lateral division was the dominant branch (larger diameter and longer length) in the majority of cases (15 cases, 79%), whereas the medial branch was only dominant in 4 cases (21.1%). The average length and external diameter of the lateral branch, medial branch, double stems and single stem were shown as Table 1. The pedicle external diameter was an average of 3.1±0.5 mm. The pedicle length was an average of 12.1±2.2 mm. The average external diameter of the single pedicle and double pedicles at the lateral border of the rectus abdominis were 3.2±0.4 mm and 2.9±0.5 mm, respectively. The average length of the single pedicle and double pedicles were 12.8±2.2 mm and 11.7±2.2 mm, respectively. There were no statistically significant length and diameter differences between the medial branch and the lateral branch ($p > 0.05$). Whereas, there were significant differences between the diameters of the single stem and double stems ($p < 0.05$). But there were no significant differences between length of single stem and double stems ($p > 0.05$).

Table 1 The length and external diameter of the pedicle, mean ± SD (Range)

	N	Length (cm)	Diameter (mm)
Medial branch of double stems	19	7.6±2.7*	2.1±0.4**
		(2.5-12.4)	(1.3-2.8)
Lateral branch of double stems	19	9.3±2.6*	2.3±0.4**
		(5.0-15.0)	(1.6-3.2)
Double stem	19	12.8±2.2***	2.9±0.5****
		(8.8-17.5)	(2.1-3.7)
Single stem	43	11.7±2.2***	3.2±0.4****
		(7.2-16.0)	(1.3-4.2)

*distance from the origin of the bifurcation to the most distant perforator, ** at its bifurcation, *** distance from its entry into the lateral border of rectus abdominis muscle to the most distant perforator, **** at lateral border of rectus abdominis

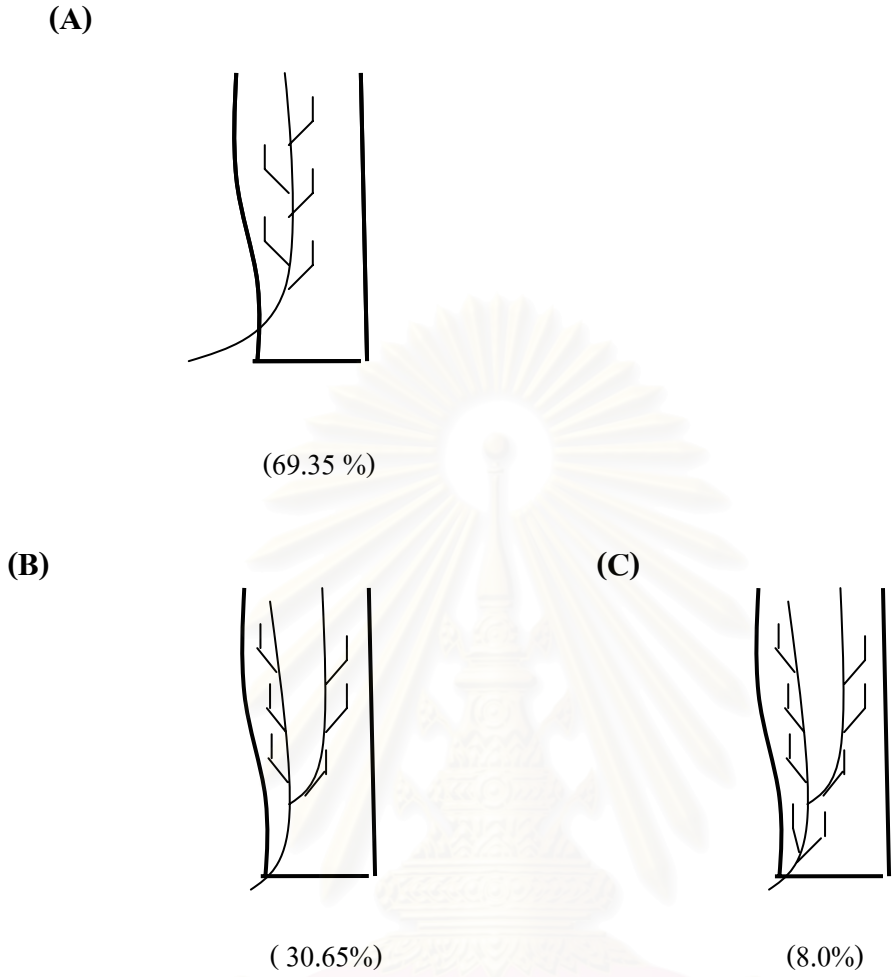


Figure 1 **A;** Example of single main stem of the deep inferior epigastric artery. The pedicle approached the rectus abdominis from its lateral aspect and coursed parallel to the muscle fiber. Then it entered the muscle substance generating a variable number of the perforator vessels. **B;** Example of the double main stems, the artery divided into the medial and the lateral branch. **C**; Example of double branches had a specialty, they also had perforator from the trunk before it divided into medial branch and lateral branch

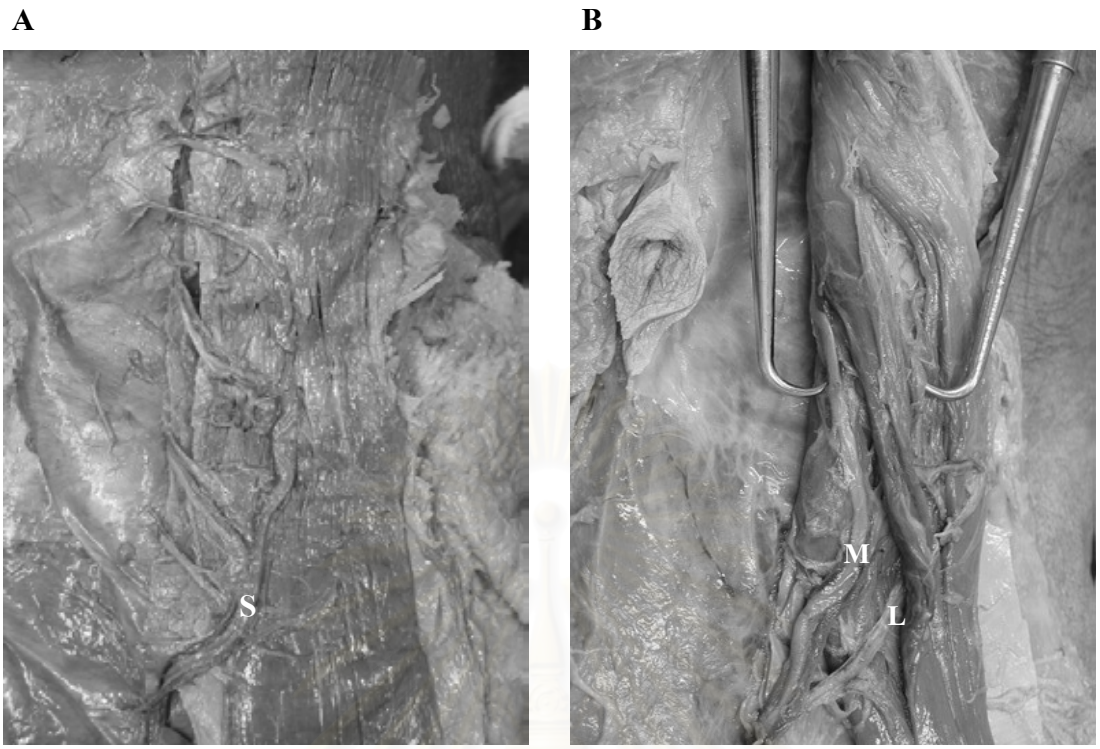


Figure 2 A; The single pedicle (S) approached the rectus abdominis from its lateral aspect. Then passed superiorly on the deep aspect, and parallel to the rectus muscle fibers**. B**; The double main stems, the artery divided into the medial (M) and the lateral branch (L).

2. The Perforators

2.1 The Number, Location and External Diameter of the Perforators

Four hundred and five perforator vessels were dissected from 62 DIEP flaps (6.5 vessels per flap). Three vertical rows of perforator vessels were observed along the anterior rectus abdominis sheath, first in the lateral third, second in the middle third and other in the medial third of the muscle (Fig.3). The medial row contained the greatest number of the perforators (45.4%) (Table 2)

The positions of perforators emerging from the anterior rectus sheath were in the area ranging from 3.8 cm superior to the umbilicus to 11.5 cm inferior to the umbilicus and 0-9.0 cm lateral to the midline. The average distance inferior to the umbilicus were 2.0±3.2 cm and 2.9±1.8 cm lateral to the midline. These perforators were concentrated within 3 cm below umbilicus and 7 cm horizontally from the midline (Fig.4). The average external diameter of perforator was 0.97±0.29 mm. The average external diameter of lateral row perforator was the largest diameter (1.01±0.26 mm). But there were no significant differences among diameters of the lateral, the medial, and the intermediate perforators ($p > 0.05$).

All these perforators were classified by size into three intervals. External diameter of the perforator ranging from 0.5 to1.0 mm was 49.88 %, 1 to1.5 mm was 44.94 %, and $\geq$1.5 mm was 5.18 % (Fig. 5)

2.2 The Location and Diameter of the Largest Perforators

The largest perforator in each flap had the external diameter ranging from 0.9 to 2.0 mm with an average of 1.4±0.3 mm. The largest perforators usually were in the same level horizontally of the umbilicus. The number of perforators was the greatest in the medial row (60%) whereas in the lateral row was 25%, and the least in intermediate row was 15% (Fig. 6). The location of the perforator most frequently found was within 1 cm horizontally from the umbilicus (Fig. 7).

2.3 The Intramuscular Course and Distribution of the Perforators

Regarding the course of the intramuscular perforator vessels, two different paths were observed. A rectilinear perforator vessel course was observed in the intermuscular septum reaching the subcutaneous tissue. In this pathway, the distance from the flap to the deep inferior epigastric vessels was shorter and ran more perpendicularly through the muscle fibers. During flap harvesting, the muscle was split in a longitudinal direction without muscle resection. An oblique

perforator vessel ran in more than one intermuscular septum to reach the subcutaneous tissue. The distance from the flap to the main pedicle was longer, and sometimes some muscle resection was needed to free the perforator vessels. The dissection was more tedious, requiring extensive longitudinal splitting of the rectus muscle.

Concerning location of the perforator vessels and intramuscular course, three distinct patterns were observed. On the lateral row, 82.7 percent of the perforator vessels presented the rectilinear course. However, on the medial row, only 13.6 percent presented this anatomical path and on the intermediate row 50 percent presented the rectilinear course (Table2).

Table2 The number, location, external diameter and intramuscular course of perforator vessels

	Number	Average diameter (mm.)	Oblique course	Rectilinear course
Medial row	184 (45.4%)	0.96±0.32	159 (86.4%)	25 (13.6%)
Intermediate row	94 (23.2%)	0.96±0.27	47 (50.0%)	47 (50.0%)
Lateral row	127 (31.4%)	1.01±0.26	22 (17.3%)	105 (82.7%)
Total	405 (100%)	0.97±0.29	228 (56.3%)	177 (43.7%)

Figure 3 Three vertical rows of perforator vessels were observed along the anterior rectus abdominis sheath, first in the lateral third (L), second in the intermediate third (I) and other in the medial third (M) over the anterior rectus sheath.

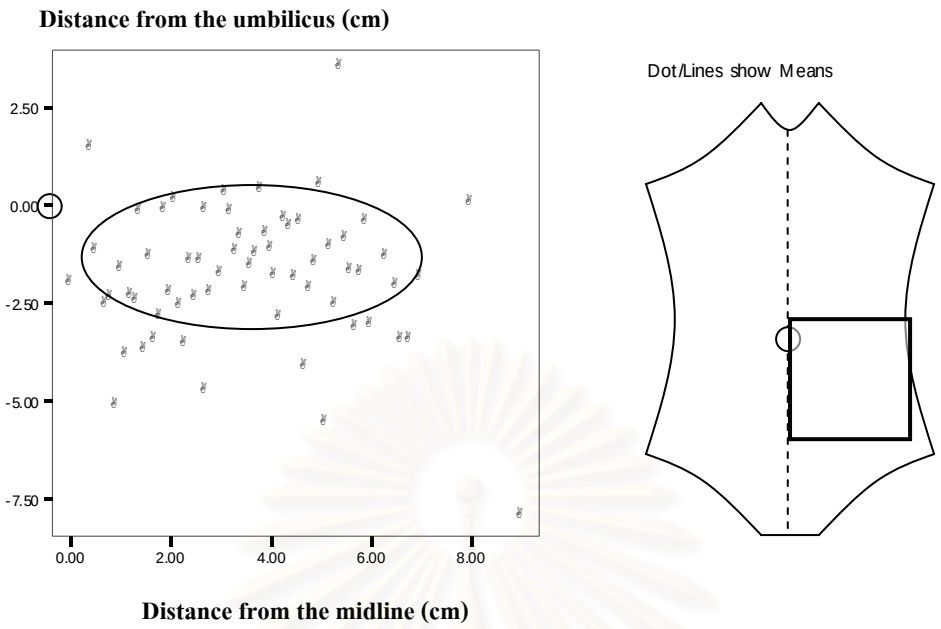


Figure 4 The distribution of all 405 perforators over the anterior rectus sheath. The umbilicus and the midline were landmark. These perforators were concentrated within 3 cm below and within 7 cm horizontally from the umbilicus.

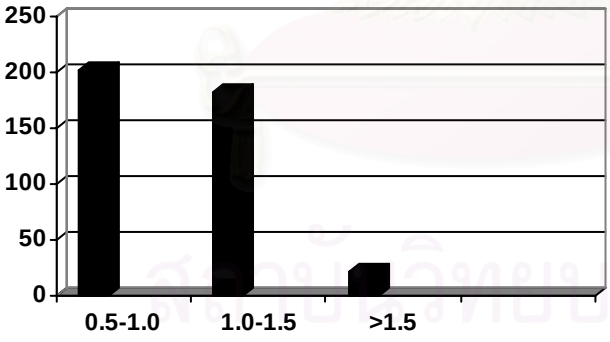


Figure 5 The perforators were classified by size into three intervals.

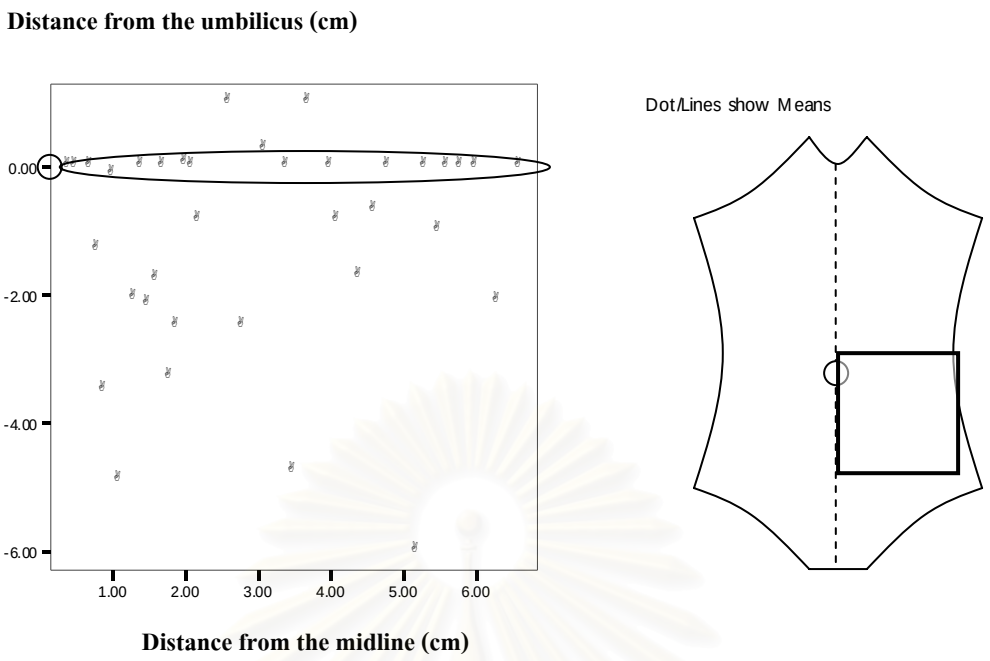


Figure 6 The distribution of 62 largest perforators over the anterior rectus sheath. The umbilicus and the midline were landmark. The largest perforators usually were in the same level horizontally of the umbilicus. The number of perforators was the greatest in the medial row.

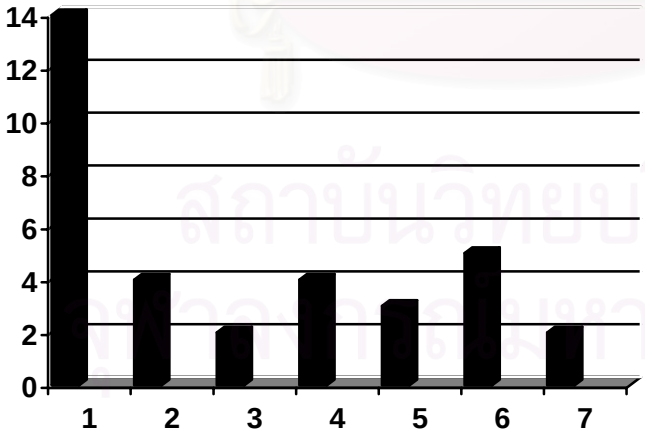


Figure 7 The number of the largest perforator lying horizontally from the umbilicus.

3. The Relationship of the Nerves to the Vascular Perforators

We observed variations of the distribution of the segmental nerves within the flap. There was 3-6 intercostals nerve throughout in each flap with an average of 4.1 nerves per flap. For all 62 flaps, there were 3 nerves per flap on 14 cases (22.6%), the most variation was 4 nerves per flap on 29 cases (46.8%), 5 nerves per flap on 15 cases (24.2%), and only 4 cases (6.5%) were 6 nerves**.**

Intercostal nerves passed between the internal abdominal oblique and the transverses abdominis. The nerves pierced the lateral angle of the rectus sheath, and ran posteroinferiorly to the rectus muscle for 1-6 cm before entering the muscle. The nerves usually ran obliquely and anteriorly to the deep inferior epigastric vessels (Fig.8) and split into the sensory and the motor branches. The motor branches radiated there fiber in all direction within the muscular plane to innervate the muscle (Fig.9). The sensory branches joined with the lateral, the intermediate and the medial vascular perforators of the deep inferior epigastric pedicle. The sensory branches that joined with the lateral and the medial perforators were the most frequent type (Table 3). While some of the cutaneous branch did not travel with the perforator but pierced the rectus sheath to innervate skin alone. The lateral row perforators, which usually were rectilinear course, traveled with nerves from the beginning. Whereas the medial row perforators, which usually were oblique course, were not related to nerves initially but they joined together before pierced the anterior rectus sheath (Fig 10).

Table3 The patterns of intercostal nerves related to the perforators in DIEP flap

Patterns of intercostal nerve	**Frequency**
Accompany with only medial perforator	37 (14.3%)
Accompany with only intermediate perforator	24 (9.3%)
Accompany with only lateral perforator	19 (7.4%)
Accompany with both medial and intermediate perforators	25 (9.7%)
Accompany with both medial and lateral perforators	50 (19.4%)
Accompany with both intermediate and lateral perforators	16 (6.2%)
Accompany with medial, intermediate and lateral perforators	13 (5.0%)
Cutaneous branch did not accompany with perforator but pierced alone	37 (14.3%)
Cutaneous branch pierces alone and accompany with medial, intermediate or lateral perforators	20 (7.8%)
Non cutaneous branch	17 (6.6%)

Figure 8 The Intercostal nerves (I) pierced the lateral angle of the rectus sheath, and ran posteroinferiorly to the rectus muscle for 1-6 cm before entering the muscle. The nerves usually ran obliquely and anteriorly to the deep inferior epigastric pedicle (P).

Figure 9 The motor branches (m) radiated there fiber in all direction within the muscular plane to innervate the muscle.

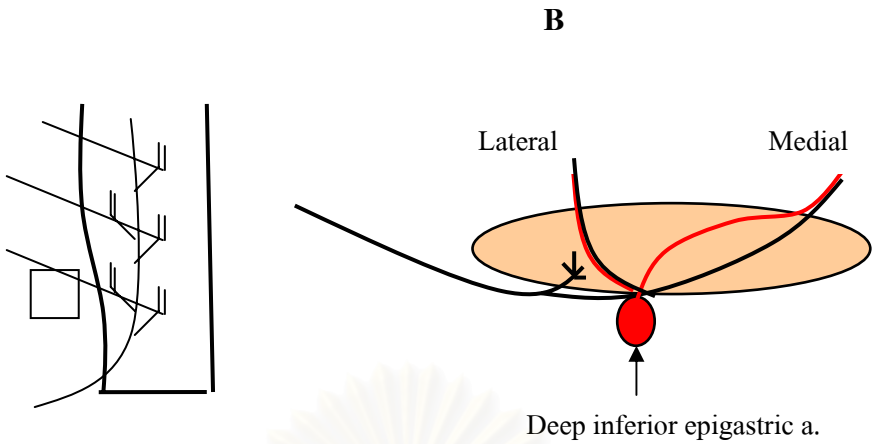


Figure 10 Relationship of intercostal nerves to the vascular tree (A) coronal section (B) cross section

The nerves usually ran obliquely and anteriorly to the deep inferior epigastric vessels and split into the sensory and the motor branches. The sensory branches usually joined with both lateral and medial perforators. Lateral row perforators, which usually were rectilinear course, will travel with nerves from the beginning. Whereas medial row perforators, which usually were oblique course, were not related to nerves initially but they joined together before pierced to the anterior rectus sheath.

CHAPTER V

DISCUSSION AND CONCLUSION

Tissue transplantation by free flaps was the method of choice for breast reconstruction, combining the quantity and quality of autologous tissue with the mobility of free flaps to mimic the contralateral breast tissue in shape and volume. Further modifications in harvesting free flaps, which were based on detailed anatomical studies, the relevance of donor-site morbidity, became a key element in selecting procedures and tissues for reconstruction. This was the reason for the great interest in perforator flaps, in which functional deficit was avoided by harvesting just adipocutaneous tissue rooted on musculocutaneous perforators, leaving the muscle and supplying motor nerves intact. Many of the virtues of the deep inferior epigastric flap have been described earlier. But these were lots of variations.

In this study, we presented the largest number of complete data of anatomical dissections from 62 flaps and compared the data with previous studies to clarify the locations of the neurovascular perforators for DIEP flap harvesting.

1. The Deep Inferior Epigastric Pedicle

1.1 The Pattern of the Pedicle

Anatomic assessment of the deep inferior epigastric artery running within the rectus abdominis muscle were reported by Brian Boyd et al. [28] in 1984, by Itoh and Arai [9] in 1993 and by Offman SL et al in 2005 [30]. All described the deep inferior epigastric artery bifurcation in one branch running slightly laterally and the other running medially to the muscle midline (Table 4).

Contrast with above anatomical studies, Frank J milloy [29] described from large dissections that the most frequently pedicle as a single-stem vessel passed superiorly on the posterior aspect of the rectus muscle. In our study, a similar result was obtained, after deep inferior epigastric artery entered the muscle, it was found to consist of a single main stem in 43 flaps (68.3%). In 19 flaps (31.7%) were double main stems (Table 4). The different result probably came from the number of specimens of previous studies less than Frank's study and ours.

1.2 The Length and Diameter of the Pedicle

The previous studies of Allen and Treece [13] in 1994, Heitmann [10] in 2002, and Offmann et al. [30] in 2005 reported about average length and diameter of pedicle as Table 5. They did not separate the results as the medial branch and the lateral branch. Whereas, our results reported the length and diameter of the pedicle into two parts (Table 5). One was a part of the single pedicle and the other was double pedicles, the lateral division was the dominant branch (larger diameter and longer length) in the majority of cases (15 cases, 79%), whereas the medial branch was only dominant in 4 cases (21.1%). But comparing the length and diameter of the lateral branch to the medial branch demonstrated no significant difference ($p > 0.05$). Therefore, it did not make a difference when using the lateral branch or the medial branch in DIEP flap harvesting. Contrast with the study of Itoh and Arai [9], who stated that it seemed more efficient if the flap used the skin perforator belonging to the lateral branch because the lateral branch was dominant over the medial branch. But they did not report any numerical data of the length and the diameter of the pedicle.

Table 4 The pattern of the pedicle

Year	Author	Cadavers	Pattern of pedicle
1960	Frank J Milloy [19]	115	Single branch (86%)
1984	Brian Boyd et al. [28]	25	Double branch
1993	Itoh and Arai [9]	17	Double branch (82.4%)
2005	Offman SL et al. [30]	5	Double branch
2005	Our study	31	Single branch (69.3%)

Table 5 The length and diameter of pedicle

Year	Author	Cadaver	Length(cm)	Diameter(mm)
1994	Allen&Treece [13]	8	11.8	4.3
2000	Heitmann et al. [10]	20	10.3*	3.6**
2005	Offman et al. [30]	5	7.5-20.5	3.3**
2005	Our study	31	- Single 11.7***	- Single 3.2****
			- Double	- Double
			medial 7.6*****	medial 2.0*****
			lateral 9.3*****	lateral 2.3*****

*distance from origin to the most distant perforator, ** at its origin

*** distance from its entry into the lateral border of the muscle to the most distant perforator

**** at the lateral border of the muscle, *****at its bifurcation

2. The perforators

Although several authors have studied and described lower abdominal wall vascularization as number, location, course, and distribution of perforator vessels, there was no detailed anatomical study regarding the location and diameter of the largest perforator.

2.1 The Number of the Perforators

Our study presented four hundred and five perforator vessels were dissected from 62 DIEP flaps. Therefore, it was not difficult to find deep inferior epigastric perforators (6.5 vessels per flap). Our finding was similar to those of Itoh and Arai[9], Hamdy [14], Alexandre [3] and Offmann [30] as Table 7.

2.2 The Location of the Perforators

In our results, three vertical rows of perforator vessels were observed along the anterior rectus abdominis sheath, first in the lateral third, second in the middle third and other in the medial third of the muscle. These perforators were mostly contained in medial third (45.4 %). Our finding was similar to study of Alexandre [3]. It was also close to the study of Offmann [30] that perforators concentrated in the peri-umbilical region but differed from those Itoh and Arai [9], who found that the number of the skin perforators was the greatest in the middle-lateral from the umbilicus. It also differed from Hamdy [14], who found that the perforator were mostly contained in the area lying laterally and below the umbilicus, with an average distance of 4 cm from the umbilicus (Table 7).

2.3 The Diameter of the Perforators

In addition, we were concerning about external diameter of perforators. We found that the lateral row perforators were the largest external diameter (1.0±0.3 mm) but there were no significant differences among diameter of the lateral, the medial, and the intermediate perforators ($p > 0.05$). Therefore, it did not make a difference when using the lateral or the medial or the intermediate perforators.

2.4 The Location and Diameter of the Largest Perforators

Moreover, the location and external diameter of the largest perforator of each flap were observed. The largest perforator in each flap had external diameter with an average of 1.4±0.3 mm and it was mostly found within 1 cm horizontally from the umbilicus (Fig 7). This area was very close to the umbilicus. During flap harvesting, preservation of the umbilicus at its usual site would increase risk of the vascular injury. So we suggested that the second large perforator, which average diameter of 1.1±0.2 mm (0.8-1.7 mm.) and usually were within 3.0 cm below the umbilicus of the lateral third row (Table 8), should be chosen for DIEP flap harvesting.

Breast reconstruction was operated in female patients. Although our observations were based on dissections of both male and female cadavers, but there were no statistically significant number, diameter and location differences between males and females. Our finding was similar to the study of Allen and Treece, who stated that age, sex and weight were not found to affect perforator location or number.

2.5 The Intramuscular Course

According to our results, that the lateral row perforators usually were rectilinear course (82.7%). Whereas the medial row perforators usually were oblique course (86.4%). The dissection was more tedious, requiring extensive longitudinal splitting of the rectus muscle. Therefore, the lateral row perforator is selected during DIEP harvesting, it would be easier to dissect, because in most cases this vessel ran perpendicularly through the rectus muscle. The muscle was split in a longitudinal direction without muscle resection. Our finding was similar to the study of Alexandre et al. [3].

Table 6 The number of the perforators

Year	Author	Number of cadaver	Number of perforator per flap
1993	Itoh and Arai [9]	17	6.5 perforators /flap
2002	Hamdy et al. [14]	20	5.4 perforators /flap
2004	Alexandre et al. [3]	15	6.4 perforators /flap
2005	Offmann et al. [30]	5	5 perforators /flap
2005	Our study	31	6.5 perforators /flap

Table 7 The location of the perforator

Year	Author	Number of cadaver	Concentrated location of perforator	
1993	Itoh and Arai [9]	17	Middle-Lateral	
2000	Hamdy et al. [14]	20	Inferior-Lateral	
2004	Alexandre et al. [3]	15	Medial row	66%
2005	Offmann et al. [30]	5	Peri-umbilical	
2005	Our study	31	Medial row	45.4%

Table 8 The location of the second large perforators

Location	Frequency	Percent
Medial row perforator	17	27.4
Intermediate row perforator	10	16.1
Lateral row perforator	35	56.5
Total	62	100.0

3. The Relationship of the Nerves to the Vascular Perforators

In our results, we found all of the nerves usually ran obliquely and anteriorly to the deep inferior epigastric vessels and split into the sensory and the motor branches. The motor branches were spread to innervate muscle. The sensory branches could join with the lateral, the intermediate and the medial vascular perforators of the deep inferior epigastric vascular. Some of the cutaneous branches from 11^{th} and the subcostal nerves did not travel with perforator but pierced alone. They usually were in lower part of the rectus abdominis. It seemed that this region may be supplied by superficial inferior epigastric artery. This finding had not been previously reported. The sensory branches that joined with the lateral and the medial perforators were the most frequent type. These were similar to finding of Boyd and Taylor [28], who described the mix nerves ran obliquely and anteriorly to the deep inferior epigastric vessels in the most people and split into the sensory and the motor branches at variable distances. The pure sensory branches joined with the perforating vessels and ran together to the skin. Contrast with Yap et al.'s study [19], they reported that the nerves were closely related to the deep inferior epigastric vascular axis, and might lie either anterior or posterior to the vessels, depending on the level of the nerve, with the higher nerves in the series usually lie posterior. While lower nerves tended to lie anterior to the vessels (Fig.11). In this study, we did not find the nerves crossing the deep inferior epigastric vascular axis posteriorly. Our findings also implied that lateral row perforators, which usually were rectilinear course, would travel with nerves from the beginning. Whereas medial row perforators, which usually were oblique course, were not related to the nerves initially but they jointed together before piercing to the anterior rectus sheath (Fig.10B). Yap et al. [19] did not notice this relationship. So, we suggested that the lateral neurovascular perforator should be chosen for DIEP flap harvesting because nerve and vessel ran together through the course. This would be easy to dissect and minimize the damage to muscle, the nerves and the vessels. Whereas, Yap et al. [19] suggested that one way to maximize the area of skin innervated by the selected nerves would be to include both the medial and the lateral neurovascular perforator. But this procedure required a full transaction of the muscle.

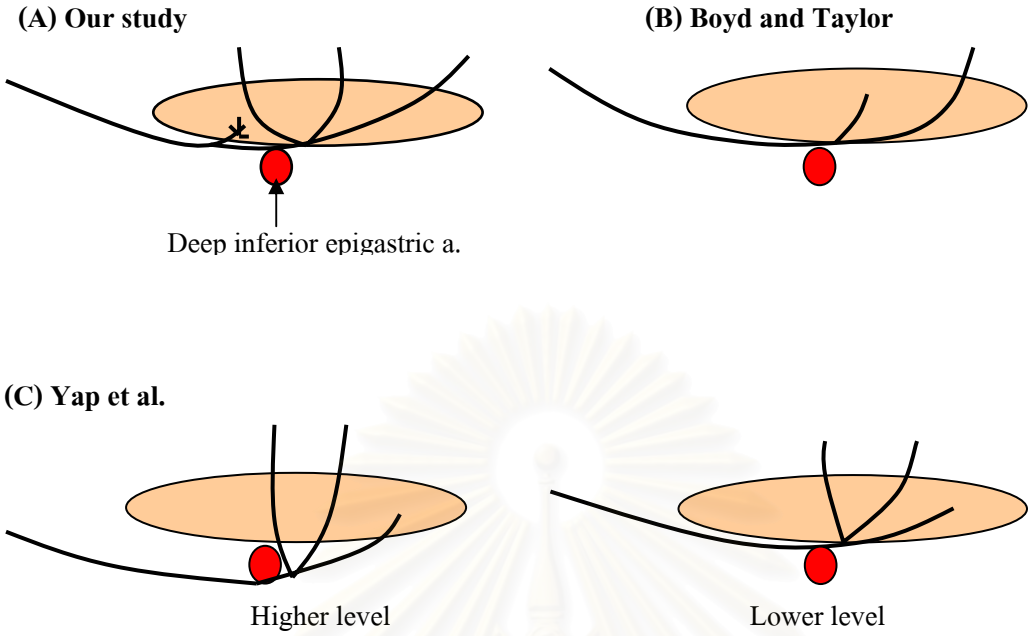


Figure 11 Relationship of the intercostal nerve to the pedicle (A) We found all of the nerves usually ran anteriorly to the deep inferior epigastric vessels and split into the sensory and the motor branch. The sensory branches joined with the lateral, the intermediate and the medial vascular perforators. (B)[28] The mix nerves ran anteriorly to the deep inferior epigastric vessels in most people and split into the sensory and the motor branch. (C)[19] The nerves might lie either anterior or posterior to the vessels, with nerves higher in the series usually lying posterior. While lower nerves tended to lie anterior to the vessels.

CONCLUSION

Our finding suggested that it would be more beneficial to use the lateral row perforators, which located within 3.0 cm below the umbilicus, rather than located on the medial row or the intermediate row perforators during DIEP flap harvesting. Because 1) Appropriate perforators usually were in the lateral row, which were concentrated within 3.0 cm below umbilicus, 2) lateral row perforators usually were rectilinear course and 3) lateral sensory nerves traveled with lateral row perforators through the course. For these reasons, the anatomical features of the lateral row perforator vessels favored the dissection, which possible reduced operative time and risk of the vessels and the nerves injury.

REFERENCES

1. Elliot LF, Hartrampf CR. Breast reconstruction: Progress in the past decade. World J Surg 1990;14 :763-75.

2. Petit J, Rigout L, Gareer W, Michel G, Lehmann A. Breast reconstruction without implants: Experience with 52 cases. Eur J Surg Oncol 1987;13:219.

3. Alexandre MM. Importance of lateral row perforator vessels in deep inferior epigastric perforator flap harvesting. Plast Recon Surg 2004;113:517-24.

4. Hartrampf CR, Bennett GK. Autogenous tissue reconstruction in the mastectomy patient: A critical review of 300 patients. Ann Surg 1987;205:508.

5. Hartrampf CR, Scheflan M, Blank PW. Breast reconstruction with a transverse abdominal island flap. Plast Recon Surg 1982;69:216-25.

6. Holmstrom H. The free abdominoplasty flap and its use in breast reconstruction: an experimental study and clinical case report. Scand J Plast Reconstr Surg 1979;13:423-7.

7. Alex K. The deep Inferior Epigastric perforator free flap for breast reconstruction. Ann Plast Sure 2001; 46:474-80.

8. Robbins TH. Post-mastectomy breast reconstruction using a rectus abdominis musculocutaneous island flap. Br J Plast Surg 1981;34:286.

9. Itoh Y, Arai K. The deep inferior epigastric artery free skin flap: Anatomic study and clinical application. Plast Reconstr Surg 1993;91:853-64.

10. Heitmann C, Felmerer G, Durmus C, Matejic B, Ingianni G. Anatomical features of perforator blood vessels in the deep inferior epigastric perforator flap. Br J Plast Surg 2000;53:205-8.

11. Kroll SS, Schusterman MA, Reece GP, Miller MJ, Roob G, Evans G. Abdominal wall strength, bulging, and hernia after TRAM flap breast reconstruction. Plast Reconstr Surg 1995;96:616-19.

12. Mizgala CL, Hartrampf CJ, Bennett GK. Abdominal function after pedicled TRAM flap surgery. Clin Plast Surg 1994;21:255-72.

13. Allen RJ, Treece P. Deep inferior epigastric perforator flap for breast reconstruction. Ann Plast Surg 1994;32:32-8.

14. Hamdy H, Mrakby EL, Richard H. The vascular anatomy of the lower anterior abdominal wall: A microdissection study on the deep inferior epigastric vessels and the perforator branches. Plast Reconstr Surg 2002;109:539-47.

15. Donaldson DR, Hafarty JH, Brennan TG, et al. The lateralparamedian incision-experience with 850 case. Br J Plast Surg 1982;69:630-32.

16. Arnez ZM, Valdatta L, Tyler MP, Planinsek F. Anatomy of the internal mammary veins and in free TRAM flap breast reconstruction. Br J Plast Surg 1995;48:540-5.

17. Blondeel PN, Boeckx WD. Refinements in free flap breast reconstruction: the free bilateral deep inferior epigastric perforator flap anastomosed to the internal mammary artery. Br J Plast Surg 1994;47;495-501.

18. Vandevoort M, Vranckx JJ, Fabre G. Perforator topography of the deep inferior epigastric perforator flap in 100 cases of breast reconstruction. Plast Reconstr Surg 2002;109:1912-18.

19. Yap LH, et al. The anatomical and neurophysiological basis of the sensate free TRAM and DIEP flaps. Br J Plast Surg 2002;55:35-45.

20. Lehmann C, Gumener R, Montandon D. Sensibility and cutaneous reinnervation after breast reconstruction with musculocutaneous flaps. Ann Plast Surg 1991;26:325-7.

21. Place MJ, Song T, Hardesty RA, Hendricks DL. Sensory innervation of autologous tissue TRAM flaps after breast reconstruction. Ann Plast Surg 1997;38:19-22.

22. Liew S, Hunt J, Pennington D. Sensory recovery following free TRAM flap breast reconstruction. Br J Plast Surg 1996;49:210-13.

23. Slezak S, McGibbon B, Dellon AL. The sensational transverse rectus abdominis musculocutaneous TRAM flap: return of sensibility after TRAM breast reconstruction. Ann Plast Surg 1992;28:210-17.

24. Yano K, Matsuo Y, Hosokawa K. Breast reconstruction by means of innervated rectus abdominis myocutaneous flap. Plast Reconstr Surg 1998;102:1452-60.

25. Blondeel PN, Demuynck M, Mete D, et al. Sensory nerve repair in perforator flaps for autologous breast reconstruction: sensational or senseless? Br J Plast Surg 1999;52:37-44.

26. Hamdi M, Weiler-Mithoff EM, Wedster MHC. Deep inferior epigastric perforator flap in breast reconstruction: experience with the first 50 flaps. Plast Reconstr Surg 1999;103:86-95.

27. Duchateau J, Declety A, and Lejour. Innervation of the rectus abdominis muscle: Implications for rectus flaps. Plast Reconstr Surg 1988;82:223-8.

28. Boyd JB, Taylor GI, Corlett R. The vascular territories of the superior epigastric and the deep inferior epigastric system. Plast Reconstr Surg 1984;73:1-15.

29. Frank JM, Barry JA. The rectus abdominis muscle and the epigastric arteries. Surg Gynecology and Obstetrics 1960:293-302.

30. Offman SL, et al. The vascular basis of perforator flaps based on the source arteries of the lateral lumbar region. Plast Reconstr Surg 2005;115:1651-9.

31. Moon HK, Toylor GI. The vascular anatomy of rectus abdominis musculocutaneous flaps based on the deep inferior epigastric system. Plast Reconstr Surg 1988;82:815-32.

32. Hammond DC, Larson DL, Severinac RN, Marcias M. Rectus abdominis muscle innervation: implication for TRAM flap elevation. Plast Reconstr Surg 1995;96:105-10.

33. Sakamoto H, Akita K, Sato T. An anatomical analysis of the relationships between the intercostal nerves and the thoracic and abdominal muscles in man. Acta Anat 1996;156:132-42.

34. Blondeel PN, Van LK, Monstrey PN. Surgical-technical aspects of the free DIEP flap for breast reconstruction. Oper Tech Plast Reconstr Surg 1999;6:27-31.

APPENDICES

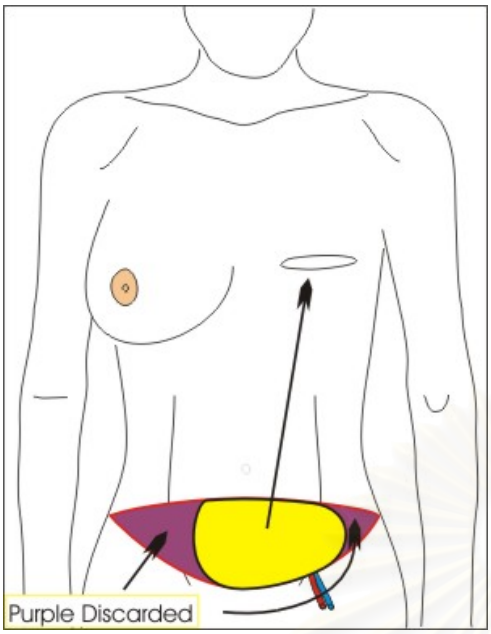
APPENDIX A

The Operative Procedure of the DIEP Flap

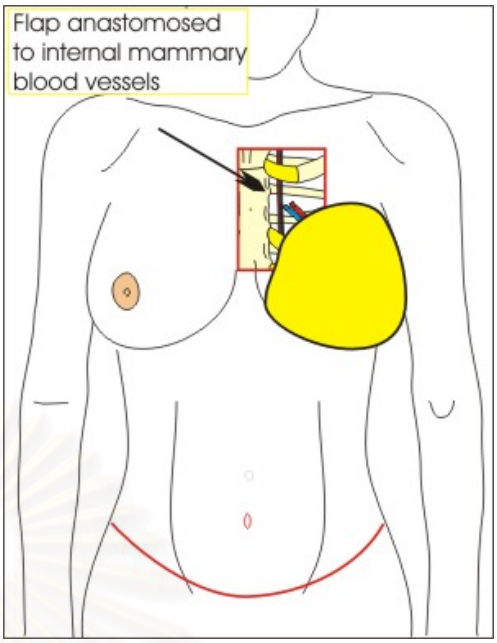
The patient was placed in a supine position, and general anesthesia was administered. A two-team approach was necessary to reduce the operative time. The skin was incised down to the rectus abdominis muscle and external abdominal oblique fascia. Skin and subcutaneous tissue were lifted off the external oblique muscle up to the lateral border of the rectus abdominis muscle. The dissection was continued to the largest perforator previously selected by the unidirectional Doppler. Once a perforator vessel was found, the subcutaneous fat around it was immediately dissected through the fascia. The anterior rectus sheath through which the perforator passed was opened, and the vessel was dissected from the rectus muscle fibers through a longitudinal direction split. At this time, the motor nerve of the rectus abdominis muscle was left intact to avoid muscular denervation.

The dissection was continued from the lateral border of the rectus muscle in its distal portion. The plane posterior to the rectus muscle was dissected, and the deep inferior epigastric vessels were exposed. The umbilicus was incised circumferentially down to the fascia, and the entire skin and the subcutaneous flap were raised carefully to prevent damage to the perforator vessels and the pedicle. The flaps were transferred to the thorax, placed in the mastectomy region, and then sutured to the anterior chest wall. A conventional end-to-end anastomosis was performed with 10-0 interrupted nylon sutures under surgical microscope enlargement.

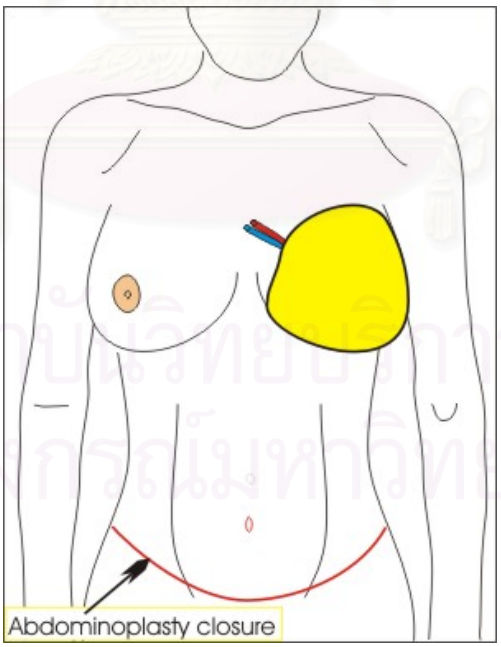
Both the rectus abdominis muscle and the sheath were preserved during the DIEP flap dissection. Therefore, no tension during abdominal wall closure was observed, which permitted primary closure with continuous mattress nylon sutures. The skin and subcutaneous tissue of the upper abdominal wall were undermined to the costal margin, and skin closure was performed as a conventional abdominoplasty.



1



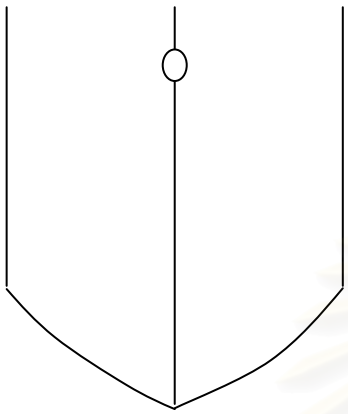
2



3

APPENDIX B

Data Collection



No. _____ Sex _____ Rt / Lt

DIEA.penetrate in rectus far from imaginary line between

Lt.and Rt. ASIS _____cm

Muscular width _____ cm

Diameter of pedicle_____ mm

Length of pedicle _____ cm

Length of lateral pedicle____cm /Diameter____mm

Length of medial pedicle ___cm / Diameter____mm

Distance from umbilicus to pubis _____ cm

Perforators

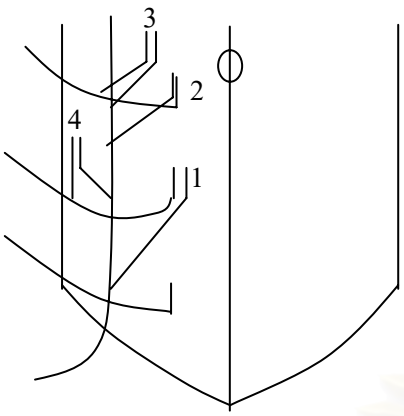
No.	From umbilicus(cm)	From midline(cm)	Diameter(mm)	Course	Row

Nerve

No.	Length (cm)	With perforator	Relation	Remarks

*No. is a number of nerves

Example of Data Collection



No. __**1355**_____ Sex __**F**__ Rt /Lt

DIEA.penetrate in rectus far from ASIS _**-1**__cm.

Muscular width ___**6.0**___ cm

Diameter of pedicle____**3.4**___ mm

Length of pedicle ____**10.5**____ cm

Length of lateral pedicle_**-**__cm / Diameter__**-**__mm

Length of medial pedicle _**-**__cm /Diameter _**-**__mm

Distance from umbilicus to pubis ____**15**_____ cm

Perforators

Number	From umbilicus (cm.)	From midline (cm.)	Diameter (mm.)	Course	Row
1	-4.2	1.3	0.8	O	M
2	0	0.4	1.1	O	M
3	+1.0	3.5	0.9	O	I
4	-1.9	4.7	0.8	R	L

* O is oblique, R is rectilinear

M is medial row, I is intermediate, L is lateral

Nerve

No.	Length (cm.)	With perforator	Relation to the pedicle	Remarks
1	4.3	2, 3	anterior	-
2	4.0	1, 4	anterior	-
3	4.5	-	anterior	Pure nerve

*No. is a number of nerves

BIOGRAPHY

Miss Pasinee Sanguansit was born on January 19, 1982 in Bangkok, Thailand. She received her Bachelor degree of Science (Physical therapy) with the second class honours in 2003 from the Department of Physical therapy, Faculty of Allied Health Science, Thammasat University, Bangkok, Thailand. She has enrolled in graduate program for Master degree of medical Science at Chulalongkorn University since 2003.