Case Report

An Anatomical Study of Vascular Supply of the Distally Based Sural Artery Flap: A Cadaveric Study

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Objective: *In this study we conducted the vascular anatomy of sural flap to determine the peroneal artery perforator contribution relative to anatomical landmark of tip of lateral malleolus, include the first peroneal artery perforator to identify safely pivot point of the flap.*
Material and Method: *A retrospective study of an anatomical study of Vascular supply of the Distally Based Sural Artery Flap was performed by dissection on 12 fresh adult cadavers legs. We recorded number of the perforator, location of each perforators in relationship to the tip of lateral malleolus and location of first peroneal artery perforator.*
Results: *The anatomical of vascular supply of the distally based sural artery flap, anatomical of peroneal artery perforators was identified and measured from anatomical landmark is tip of lateral malleolus. The mean number of perforators was 3.4 (range, two to five), grouped in 5 perforators at the following average locations proximal to the tip of lateral malleolus: first, at 6.3±0.9 cm; second, at 8.5±1 cm; third, at 11.17±1.4 cm; fourth, at 12.7±1.2 cm; and fifth, at 14.6±0.2 cm proximal to the tip of the lateral malleolus.*
Conclusion: *Complete vascularization of venoneurofasciocutaneous sural flap was accomplished by peroneal perforator, the blood supply of the distally based sural venoneurofasciocutaneous flap can be pivoted at the lowest perforators in the posterolateral region, which are about 5.4 to 7.2 cm proximal to the tip of lateral malleolus.*

Keywords: *Sural artery flap, Anatomical study, Peroneal artery perforator, Vascular supply*

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Complex wounds of the distal third of the leg are challenging to treat. Despite today's preference for free tissue transfer, local pedicled flaps remain a valuable option[1].

Coverage of soft tissue defects of the lower leg and heel of foot remains a challenging problem in reconstructive surgery[1]. The frequency of the procedure has increased with the increasing incidence of chronic diseases (diabetes, hypertension, vascular disease, etc.) that affect this location. There are various options for covering soft tissue defects. Therapeutic options include the local, regional, and free flaps, with each method having drawbacks that limit its clinical application. The use of local flaps, including transposition and advancement flaps with random vascularity, is restricted because of the limited amount of tissue movable from areas adjacent to the defect and limited flap mobilization[2].

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Thus reconstruction by a free flap transfer is superior to other methods, as it can provide well vascularised tissue of any size with minimal donor site morbidity. However, it has the disadvantage of being a sophisticated and lengthy procedure, involving a high price, advanced equipment, a microsurgical team, and the application to chronic disease patients, for small to moderate defects[2,3].

For these reasons, we have considered other options including musculocutaneous flaps and muscle flaps; the distally based superficial sural artery fasciocutaneous flap has been identified as a good alternative. The use of a fasciocutaneous flap from the sural angiosome in the repair of soft tissue defects was first reported by Ponten in his 1981 report on the use of 23 proximally based fasicocutaneous flaps. The distally based sural fasciocutaneous flap was introduced by Donski and Fogdestam 2 years later. In 1983, Taylor and Palmer introduced the angiosome concept. Furthermore, the sural angiosome, as one of the four angiosomes of the leg, was introduced by Taylor and Pan about 11 years later[3]. The skin, the bones, and most muscles received branches from two or more

angiosomes, thus revealing one of the important anastomotic pathways through which the circulation is reconstituted when a source artery is interrupted by disease or trauma[2,5].

The distally based superficial sural artery flap (referred to throughout as "sural flap") has become major tool for reconstruction of the distal leg, ankle, and foot[4] since its original description by Masquelet et al. The concept of neurocutaneous flaps gave rise to a number of neurocutaneous flaps, including the sural flap. Neurocutaneous flaps are vascularized by the arteries supplying the sensory nerves within the flap. However, Nakajima et al described the sural flap without the sural nerve, with only the lesser saphenous vein included in the flap (venoadipofascial flap)[7]. This raised questions regarding the contribution of the sural nerve to the vascularization of the distally base sural flap[4]. Manchot and Salmon described the fundamentals of skin vascular anatomy. McGregor and Morgan defined random and axial pattern flaps; Cormack and Lamberty detailed the vascularization of the fasciocutaneous flaps, and Taylor and Palmer proposed the concept of angiosomes. Recently, Saint-Cyr et al proposed the perforasome theory which defines vascular territories, perfused by a single perforator, based on three- and four-dimensional computed tomographic angiography and venography[4].

This anatomical study contributes further information to help design or redesign flaps in the lower leg. Since then, a variety of anatomical studies have contributed to our knowledge of the procedure.

The goal of this study was to further evaluate the vascular anatomy of the sural flap and to determine the perforator contribution of each tissue component of the distally based sural flap. Based on these results, the authors propose a modification of the distally based sural flap harvest sequence to minimize donor site morbidity.

Objective

In this study we conducted the vascular anatomy of sural flap to determine the peroneal artery perforator contribution relative to anatomical landmark of tip of lateral malleolus, include the first peroneal artery perforator to identify safely pivot point of the flap.

Material and Method

Cadavers

An anatomical study of Vascular supply of the Distally Based Sural Artery Flap was performed by dissection on 12 fresh adult cadavers legs acquired from the Anatomy Department, Faculty of Medicine, Khon Kaen University.

Flap Harvest and Preparation

Anatomical landmarks defining the boundaries of the sural flap included the popliteal crease (superior border), the lateral and medial malleoli, and the peroneal and posterior tibial crests. All flaps included the entire posterior leg surface and were harvested using a standard technique from proximal to distal, sparing the distal perforators from peroneal and posterior tibial arteries. The anatomical components studied included the following: skin [entire skin of posterior leg from the popliteal crease to the posterior tibial and peroneal crests; skin island flap (10x10 cm skin paddle) with the upper edge of the skin island 5 cm distal to the popliteal crease], adipose tissue, lesser saphenous vein, deep fascia, and sural nerve. Different flaps were generated with various combinations of these tissue components.

After flap harvest, total cutaneous-venoneuroadipofascial (n = 12) are identified perforator of peroneal arteries, total number of the perforator, distance between the perforators and distance between first perforator and tip of lateral malleolus were recorded.

Inclusion and Exclusion criteria

Inclusion: all Thai soft cadaver in Anatomy Department, Faculty of Medicine, Khon Kaen University.

Exclusion: the cadaver had severe injury at lower leg.

Statistical analysis

Standard despriptive test were performed. Report with mean values and their respective standard deviation.

Results

In this study, the population was 12 fresh adult cadavers legs. The anatomical of vascular supply of the distally based sural artery flap, anatomical of distal peroneal artery peorators was identified and measured from anatomical landmark is tip of lateral malleolus (Table 1).

The mean number of perforators was 3.4 (range, two to five), grouped in 5 perforators at the following average locations proximal to the tip of lateral malleolus: first, at 6.3$\pm$0.9 cm; second, at 8.5$\pm$1 cm; third,

at 11.17±1.4 cm; fourth, at 12.7±1.2 cm; and fifth, at 14.6±0.2 cm proximal to the tip of the lateral malleolus. Anatomical of perforators represent the most clinically relevant perforators.

Discussion

There are the study of distally based sural flap, Keith E. Follmar et al[5] the pivot point should typically be kept at least 5 to 6 cm above the lateral malleolus, although lower pivot points are possible. The pedicle should be kept as wide and as short as is necessary to repair the defect[10]. Ali Mojallal et al[4] described the proximal communicating branches from the neural arterial plexus were linked with the lesser saphenous vein arterial network, which gave off branches to the adipose arterial network, which contributed to the skin vascular perfusion[7,8]. Distal peroneal artery perforators (cluster analysis), the mean number of perforators was 2.8 cm (range 2 to 5); grouped in three major cluster at average locations proximal to the tip of lateral malleolus: first, at 5+1.3 cm; second, at 7+1.4 cm; and third, at 9.9+1 cm proximal to the tip of the lateral malleolus. The lesser saphenous vein and deep adipose tissue are only two necessary and critical components for arterial supply of the sural flap. The sural nerve contributes to the vascular network, but

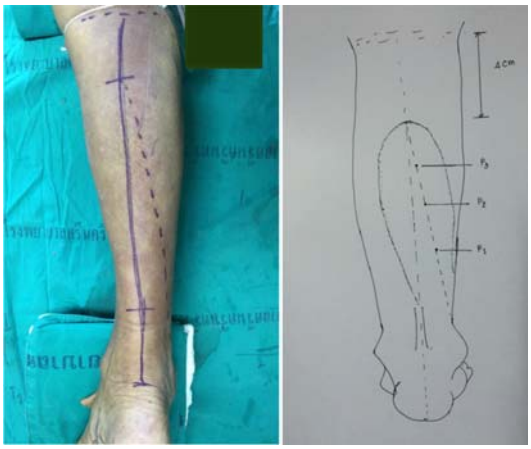

Fig. 1 Anatomical landmark of the perforator of peroneal artery in dot line. The dot line is a imaginary line drawn from tip of lateral malleolus to the midline of posterior leg. Design of distally based sural venoneurofasciocutaneous flap, in which the most distally of the flap was not beyond 4 cm below the popliteal crease.

Fig. 2 A) A cadaveric model of a raised venoneurofasciocutaneous sural flap. B) Peroneal artery perforators (PAP) first to fourth are presented.

Table 1. Number of perforators and distance of the perforators from anatomical landmark of proximal to the tip of lateral malleolus

No.	No. of perforators	P1 (cm)	P2 (cm)	P3 (cm)	P4 (cm)	P5 (cm)
1	3	8.5	10.5	14.0		
2	3	6.3	8.7	11.5		
3	5	5.7	7.8	9.5	11.0	14.5
4	3	7.0	9.3	12.5		
5	4	5.5	7.6	10.5	13.5	
6	2	6.5	7.9			
7	5	5.0	7.2	9.5	12.0	14.8
8	4	7.5	9.8	11.5	13.8	
9	3	5.2	7.5	10.0		
10	3	6.0	9.2	11.7		
11	2	5.9	8.0			
12	4	6.2	8.5	11.0	13.5	

sural nerve inclusion in the flap does not increase the vascular territories, but does increase the arc of rotation of the flap.

The principal arterial supply to the sural flap is provided by septocutaneous perforators from the peroneal artery[6,9], which from two parallel networks: one for the sural nerve and one for the lesser saphenous vein. Grouped of three clusters, located approximately at 5, 7 and 9 cm from the tip of the lateral malleolus.

Zhang et al and Chang et al[11,12] showed that the lateral malleolar artery and the lateral calcaneal artery (terminal branches of the peroneal artery) could serve as the main perforators for a very low flap pivot point. Considers that the pivot point should be set at approximately 7 to 8.5 cm proximal to the lateral malleolus to retain all major perforators.

In this study, the distal peroneal artery perforators measured from the tip of the lateral malleolus, mean number of perforators was 3.4 (range, 2 to 5). Grouped in 5 perforators, located approximately at 6, 8, 11, 12 and 14 cm from the tip of lateral malleolus. Our group considers that the pivot point should be set at approximately 8 to 9.5 cm proximal to the lateral malleolus to retain all major perforators for maximizes vascular supply of the flap, but should consider about the pivot point to lower as possible for reconstruction soft tissue defect far as the heel, thus the pivot point should be set to lower approximately 5.4 to 7 cm proximal to the lateral malleolus to retain at least the first perforator of peroneal artery, for reliable of flap vascularity and decrease distal flap necrosis.

Conclusion

Complete vascularization of venoneurofasciocutaneous sural flap was accomplished by peroneal artery perforator, the blood supply of the distally based sural venoneurofasciocutaneous flap can be pivoted at the lowest perforators in the posterolateral region, which are about 5.4 to 7.2 cm proximal to the tip of lateral malleolus. It is a practical and versatile flap for reconstruction of the foot and ankle. Elevation of the flap is safe, easy, short operative time and no need to sacrifice a major leg artery. This distally based sural venoneurofasciocutaneous flap should be considered among flaps as a good choice for distal one-third of leg, ankle and hindfoot reconstruction.

What is already known on this topic?

The distally based sural flap is the flap of choice for lower leg and hindfoot reconstruction, this flap based on peroneal artery perforators. The pivot point of the flap depend on the lowest perforator location.

What this study adds?

This is the first data of vascular anatomy of distally based sural flap of thai adult cadavers from the Anatomy department, Faculty of Medicine, Khon Kaen University. Complete data about number of perforator of peroneal artery include the pivot point at the lowest perforator in distance from the tip of lateral malleolus.

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Potential conflicts of interest

None.

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การศึกษากายวิภาคของหลอดเลือดที่เลี้ยง Distally based sural flap จากร่างอาจารย์ใหญ่

ปัทมา ปัญญาวงศ์, เก่งกาจ วินัยโกศล, กมลวรรณ เจนวิถีสุข, พลากร สุรกุลประภา, บวรศิลป์ เชาวน์ชื่น

ภูมิหลัง: *การปิดแผลที่บริเวณส่วนปลายขาข้อเท้าและส้นเท้ายังคงเป็นสิ่งท้าทายสำหรับการผ่าตัดเสริมสร้าง Distally based sural flap เป็นทางเลือกที่ดีสำหรับการผ่าตัดปิดแผลในบริเวณที่ความยากนี้ในผู้ป่วยที่มีข้อห้ามในการผ่าตัดที่นานและซับซ้อนการออกแบบและการกำหนดจุดหมุนของแฟลบขึ้นกับตำแหน่งของ peroneal perforator ที่ต่ำที่สุด ซึ่งการศึกษากายวิภาคหลอดเลือดของ sural flap ยังไม่เคยมีศึกษาในประชากรกลุ่มคนไทยจึงได้มีการศึกษานี้ขึ้น*

วัตถุประสงค์: *เพื่อศึกษากายวิภาคหลอดเลือดของ sural flap เพื่อดูจำนวนและตำแหน่งของ peroneal artery perforator โดยวัดจากจุดสูงสุดของตาตุ่มนอกเพื่อเป็นประโยชน์ต่อการออกแบบและการกำหนดจุดหมุนของ sural flap*

วัสดุและวิธีการ: *การศึกษาแบบย้อนหลังจากการศึกษาทางกายวิภาคหลอดเลือดที่เลี้ยง distally based sural flap ที่ศึกษาจากร่างอาจารย์ใหญ่ 12 ขาโดยบันทึกจำนวนและตำแหน่งหลอดเลือดโดยวัดจากจุดสูงสุดของตาตุ่มนอกรายงานผลโดยใช้ค่าเฉลี่ย*

ผลการศึกษา: *ผลการศึกษาทางกายวิภาคหลอดเลือดที่เลี้ยง Distally based sural flap จากร่างอาจารย์ใหญ่ 12 ขา Peroneal artery perforator มีจำนวนเฉลี่ย 3.4 (ระหว่าง 2-5) แบ่งออกเป็น 5 กลุ่มโดยมีค่าเฉลี่ยของแต่ละ perforator เทียบกับจุดสูงสุดของตาตุ่มนอกเรียงตามลำดับดังนี้ 1) 6.3±0.9 ซม., 2) 8.5±1 ซม., 3) 11.17±1.4 ซม., 4) 12.7±1.2 ซม. และ 5) 14.6±0.2 ซม. เหนือต่อจุดสูงสุดของตาตุ่มนอก*

สรุป: *หลอดเลือดที่มาเลี้ยง Distally based sural flap อย่างสมบูรณ์นั้นมาจาก Peroneal artery perforator และจุดหมุนของแฟลบที่ปลอดภัยกำหนดโดยตำแหน่ง perforator ที่ต่ำที่สุดคือระยะทาง 5.4-7.2 ซม. เหนือต่อจุดสูงสุดของตาตุ่มนอก*