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Cadaveric Study of Soleus Muscle and its Application in peri-ankle Reconstruction

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Abstract

Background: Soft tissue defects of the lower limb are a formidable challenge to the plastic surgeon but a soleus muscle flap often provides the solution.

Aim of the work: study the anatomy of the various patterns of arterial supply to soleus muscle based on cadaveric dissection for its application as a pedicle flap for lower leg and peri-ankle reconstruction .

Methodology: The study included 8 adult lower limbs from the Department of Anatomy at Faculty of medicine Al-Azhar University. The study duration was from May 2018 to May 2019. The branches of popliteal, posterior tibial and peroneal arteries were traced till their point of entry into the soleus muscle.These were considered as extra muscular branches (EMB) to the soleus.

Results: Popliteal artery supplies the muscle by 1 perforator at 2 samples , 2 perforator branches at 3 samples and absent at 3 samples .Posterior tibial artery: supplies the muscle by not less than 4 perforators at 8 samples. Peroneal artery: supplies the Soleus muscle by 2 to 4 perforators according to our study 2 samples were supplied by 2 perforators , 4 samples were supplied by 3 perforators and 2 samples were supplied by 4 perforators

Conclusion: The proximal 25 % of length of soleus received EMB from all the three arteries and hence a proximally based soleus muscle flap is better than distally based muscle flap.

Recommendations: Doppler ultrasonography and angiography are useful for detection the actual location and size of soleus perforators.

Key words: *Reconstruction; Lower limb defect; soleus muscle flap; ankle reconstruction.*

INTRODUCTION

Soft tissue defects of the lower limb are a formidable challenge to the plastic surgeon but a soleus muscle flap often provides the solution. Various types of soleus muscle flap have been described, based mainly on the vascular supply. The distance of the origin of the perforators was measured from fixed bony landmarks.[1]

The three major arteries to the leg, anterior and posterior tibial, and peroneal are in closed compartments and they do not have significant communications between them so, a lot of work has been done on the perforators arising from these vessels in the lower third of the leg. The ones from the posterior tibial and the peroneal are significant and could be used for flaps in the region. These perforators may be lost in degloving injuries and such flaps may not be possible.[2]

The posterior Tibial artery is the direct continuation of the popliteal artery and usually the dominant vessel of the trifurcation. It is accompanied by two venae comitantes and through its course in the leg supplies two to four perforators, each accompanied by two venae comitantes which are venous perforators from the greater saphenous vein suppling the distal portion of the soleus muscle.[3]

So, cadaveric dissection is important for detection and determination of various locations of arterial perforators for soleus muscle .

The present work aimed to study the anatomy of the various patterns of arterial supply to soleus muscle based on cadaveric dissection for its application as a pedicle flap for lower leg and peri-ankle reconstruction.

Material And Methods

The present study included 8 adult lower limbs of formalin fixed bodies given to science, obtained from the Department of Anatomy at Faculty of medicine Al-Azhar University.

The present study has been approved by the ethics committee of our institution with respect to the human and animal rights. The study duration was from May 2018 to May 2019.

The limbs with obvious surgical scar in the posterior compartment of the leg and congenital malformations were excluded from the present study. Dissection of specimens was done following the steps of Cunningham's manual of practical anatomy. The vascular branches to soleus muscle were identified and traced till their point of entry into soleus muscle and investigated the distribution, course, origin, number, type, and length of the perforators.

The branches of popliteal, posterior tibial and peroneal arteries were traced till their point of entry into the soleus muscle.

These were considered as extra muscular branches) EMB) to the soleus. They were not further traced intramuscularly.

Inclusion Criteria:

- Adult males & females cadaveric lower limbs both sides .

Exclusion Criteria:

- The limb with obvious surgical scar in post compartment of the leg.
- Congenital Malformations.
- Pervious dissected cadaveric limbs.

Dissection and Marking

A longitudinal midline incision was made along the posterior midline of the leg and the popliteal fossa. After reflection of skin and subcutaneous tissue, the gastrocnemius, soleus and tendoachilles were exposed.

Two heads of gastrocnemius were divided from origin and reflected downwards.

With blunt dissection, the gastrocnemius was separated from the underlying soleus muscle. Soleus was separated from the deeper muscles at its middle third. Soleal arch was cut without damaging the popliteal vessels and tibial nerve passing beneath.

The popliteal artery was identified in popliteal fossa and was traced beneath as it passes below the soleal arch.

The EMB (External Muscular Branch) to the soleus from popliteal artery, when present were noted. The point of division of popliteal artery was identified.

The posterior tibial artery was traced beneath to identify the peroneal artery. The EMB of posterior tibial artery were traced along the medial border and that of peroneal artery were traced along the lateral border of soleus.

The numbers of EMB arising from each artery were noted. A horizontal line that crosses the head of fibula at the level of most proximal attachment of soleal muscle fibers was taken as reference line (RL).

The presence or absences of the cutaneous perforators to the lower third of the leg from these arteries were also noted.

Statistical analysis

Data were analyzed using IBM© SPSS© Statistics version 23 (IBM© Corp., Armonk, NY, USA).Continuous numerical variables were presented as mean and standard deviation (SD).

Figure (1): Showing Posterior view of right leg with a longitudinal midline incisional from horizontal line crossing tibial tuberosity and line crossing medial and lateral malleoli.

Figure(2): showing the two heads of Gastrocnemius muscle were divided from origin and reflected downwards. (L G = Lateral head of Gastrocnemius muscle , M G = Medial head of Gastrocnemius muscle , Sol M = Soleus muscle , AT = Achiles Tendon).

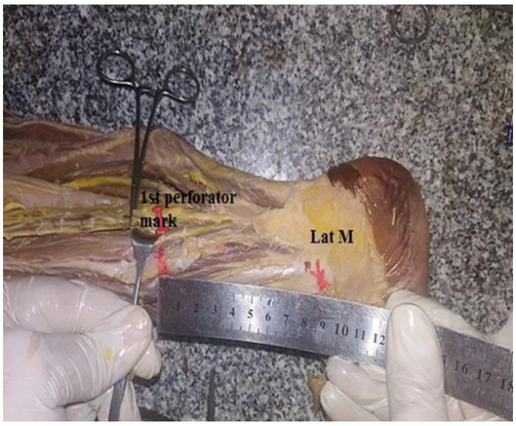

Figure (4): Showing lateral side of lower limbs of cadaver with lateral malleolus mark and 1st perforator of posterior Tibial artery to soleus muscle 9cm above lateral mallus (1st perforator Mark = 1st perforator artery of posterior tibial artery , Lat M = lateral Malleolus)

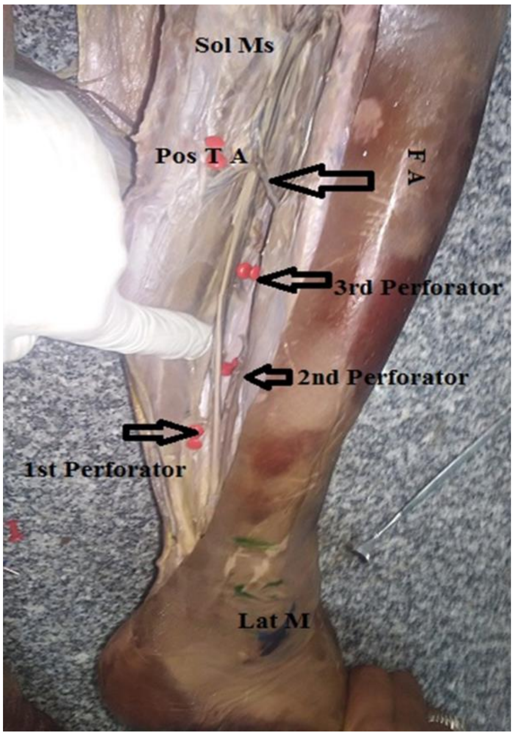

Figure (5): Showing posterior aspect of lower limb of cadaver with soleus muscle perforators from lateral malleus to horizontal line crossing tibial tuberosity. Posterior tibial artery perforators located at 8 cm , 11cm , 17 cm and 21 cm respectively from lateral malleus. (Lat M = lateral malleolus , Post T A = Posterior tibial Artery, Sol Ms= Solues muscle, FA= fibular (peroneal) artery).

Figure (6): Showing lateral aspect of lower limb of cadaver with soleus muscle flap reach to the dorsum of foot according to the 1st perforator of posterior tibial artery from lateral mallus without kinked vessels(Sol M = Solues muscle, Lat M = lateral mallus).

RESULTS

The data were presented as number and percentages for the qualitative data, mean, standard deviations and ranges for the quantitative data with parametric distribution and median with inter quartile range (IQR) for the quantitative data with non- parametric distribution.

Spearman correlation coefficients were used to assess the significant relation between two quantitative parameters in the same group.

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following:

- $P > 0.05$: Non significant (S),
- $P < 0.05$: Significant (S),
- $P < 0.01$: Highly significant (HS),

The average length of the soleus muscle observed in the present study was 35 ± 3.5 cm.

The present study observed that the soleus muscle received its arterial supply from the Extra muscular branch (EMB) of popliteal, posterior tibial and peroneal arteries.

It was observed that, when the EMB from popliteal artery were absent, the posterior tibial and peroneal arteries provided more number of EMB to the soleus. Popliteal artery supplies the muscle by 1 perforator at 2 samples about 25 % of samples , 2 perforator branches at 3 samples about 37.5 % of samples and absent at 3 samples about 37.5 % so that`s mean that the popliteal artery supplies the soleus muscle by 62.5 % and 37.5 % was absent .

Popliteal artery branches distance from horizontal line crossing the tibial tuberosity at maximum distance was 3.8 cm, minimum distance was 1.2 cm.Posterior tibial artery: supplies the muscle by not less than 4 perforators at 8 samples.

We didn`t note more than this number at our study, with no relation between absence of popliteal artery perforators and increasing number of posterior artery perforators.

The distance of perforators of posterior tibial artery from lateral malleolus was 1st perforator range between 8cm to 9.5 cm , the 2nd perforator range between 11.2 cm to 12.5 cm , the 3rd perforator range between 16cm to 18 cm and the 4th perforator range between 21.2 cm to 23 cm, so soleus muscle flap theoretically can reach to the end of metatarsal bone defect and have wide range of coverage of the defects around the ankle provides good vascularized ,easy harvest without micro-vascular technique flap for pre-ankle reconstruction. Peroneal artery: supplies the Soleus muscle by 2 to 4 perforators according to our study 2 samples were supplied by 2 perforators as 25 % of sample, 4 samples were supplied by 3 perforators as 50% of samples and 2 samples were supplied by 2 perforators as 25 % of samples.

This study showed the distance of peroneal artery perforators from lateral malleolus was that the 1st perforator range between 10.8 cm to 13 cm, the 2nd perforator was range between 11.4 cm to 17.3 cm, the 3rd perforator was range between 15.7 cm to 19.3 cm and the 4th perforator was range between 17.8cm to 19 cm with a good relation between absence of popliteal artery perforators and increasing numbers of peroneal artery perforators. At the 3 samples in which popliteal artery perforators was absent, the peroneal artery give 3 or 4 perforator to the soleus muscle.

That's prove the excellent vascularization of soleus muscle and make it good choose for peri-ankle reconstruction.

Tables

Perforators of post tibial artery from lateral malleolus	Min	Max	Mean	SD
First perforator	8	9.5	8.54	0.52
Second Perforator	10.8	12.5	11.39	0.59
Third Perforator	16	18	17.15	0.61
Fourth Perforator	21.2	23	18.96	6.82

Table (1) Statistics of distances of perforators of post tibial artery from Lateral malleolus.

	1st		**2nd**				**4th**	
	r	P value	R	P value	R	P value	r	P value
1st perforator								
2nd perforator	0.530	0.177						
3rd perforator	-0.054	0.899	0.102	0.809				
4th perforator	0.060	0.887	0.482	0.227	0.735	0.038		

Table (2): Correlation between distances of Perforators of post tibial artery from lateral malleolus.

Distances of Perforators of Preoneal artery from lateral malleolus	Min(cm)	Max(cm)	Mean (cm)	SD
First Perforator	8	10.8	13	11.75
Second Perforator	8	11.4	17.3	15.13
Third Perforator	8	0	19.3	12.91
Fourth Perforator	2	17.8	19	18.40

Table (3): Statistics of distance Perforators of Peroneal artery from lateral malleolus.

numbers of Popliteal artery perforators from horizontal line crossing middle of the tibial Tuberosity	No	%
Zero	3	37.5%
One	2	25%
Two	3	37.5%

Table (4): Numbers of Popliteal artery perforators from horizontal line crossing middle of the tibial Tuberosity.

DISCUSSION

The anatomical knowledge of soleus vascularity assists the vascular and plastic surgeons to use many flap in a rational and predictable manner.[4]

The soleus muscle flap is a versatile flap that can be used to cover soft tissue defects in the lower limb. It is grouped as a Type II muscle flap in the classification of Mathes & Nahai.[5]

The muscle is supplied by large and small vascular pedicles. Tobin[6] described soleus as a bipennate muscle with independent neurovascular supplies to its medial and lateral halves. The present study was applied on eight cadaveric lower limbs which was available at the time of study. On other hand, Vani Prathapamchandra et al.[7] study which applied on thirty eight cadaveric lower limbs and Raveendran et al. 1 , which applied on fifty cadaveric lower limbs and study of El Zawawy & El Sekily[8] which applied on Forty cadaveric lower limbs./This number of lower leg dissection gave disadvantage for our study results data analysis .

The present study a longitudinal midline incision was made along the posterior midline of the leg and the popliteal fossa which gave us good exposure of underlying structure of gastrocnemius muscle heads similar to Vani Prathapamchandra et al.[7] and El Zawawy& El Sekily 8 who was different with our study by Injection of latex into the popliteal artery in the popliteal fossa was done after ligation of the artery proximally.

Dissection commenced two weeks after latex injection with a longitudinal incision was made along the posterior midline of the leg./On other hand a longitudinal incision was made from the medial malleolus to the medial condyle of the tibia according to Raveendran et al.[1]

At the present study after reflection of skin and subcutaneous tissue, the gastrocnemius, soleus and tendoachilles were good exposed. The two heads of gastrocnemius were divided from origin and reflected downwards, by blunt dissection, the gastrocnemius was separated from the underlying soleus muscle. Soleus was separated from the deeper muscles at its middle third and Soleal arch was cut the popliteal vessels was passed and exposed directly similar to Vani Prathapamchandra et al.[7] On other hand Raveendran et al.1 dissection of the soleus muscle was identified anterior to the medial head of gastrocnemius. The muscles were separated at the intermuscular plane. Both heads of gastrocnemius and plantaris were detached from the tendocalcaneus and reflected. The deep surface of soleus was separated from flexor digitorum longus at the middle third of the leg. The branches of the posterior tibial artery were identified at the proximal part of the soleus muscle and traced along the medial half of the muscle. The popliteal artery and its branches to the soleus muscle were identified at the popliteal fossa. Our dissection gave more advantages to good exposure of the popliteal vessels and its branches which may have perforators to soleus muscle from one only incision and minimal risk to cut the main vessels which the study based on it.

The present study observed that, EMB of popliteal artery supplied the proximal part of soleus muscle. The EMB from posterior tibial artery and the peroneal artery supplied the medial part and lateral part of soleus, respectively similar to Vani Prathapamchandra et al.[7] and Raveendran et al.[1]

The present study showed the popliteal artery gave the least number of EMB about 12.5 % compared to posterior tibial and peroneal artery which is different to the previous study El Zawawy and El Sekily.[8] who stated that The popliteal artery gave 27.80% of total perforators.

Our study semi agreement about percentage with Vani Prathapamchandra et al.[7] study which gave 11.8 % and Raveendran et al.1 study which gave result 9.0 %. It is observed that in 40 % of cases, when there was no direct EMB from the popliteal artery supplying soleus, the posterior tibial and peroneal arteries gave more number of EMB to the soleus.

On the other hand the previous study Vani Prathapamchandra et al.[7] gave 42.1% of cases with no direct branches from popliteal artery.

The present study showed the following pattern of blood supply to the soleus muscle; the popliteal artery supplied the superficial surface of soleus through one branch about 25% of cases or two muscular branches about 37.5 % to its middle part; this was in agreement with Fathi et al.[9] who found that the vascular supply of soleus is from the popliteal artery and its major divisions in 66.7% of the limbs through two branches to the proximal part of the muscle.

In this study, we found that the medial part of soleus was supplied by large muscular branches of posterior tibial artery through its under surface, this was in agreement with(Raveendran et al.[1] and El Zawawy & El Sekily.[8] who found that the medial part of soleus muscle was supplied throughout its whole length by perforators arising from the posterior tibial artery and they said that this constant feature makes the medial part of the muscle reliable as a proximally or distally based flap, Raveendran et al.[1] also found that the average distances of the lower perforators arising from the posterior tibial artery were 6.5, 11.6 and 16.8 cm from the medial malleolus.

While in El Zawawy and El Sekily.8 study, the mean distance of the muscular branches from the medial malleolus was 14.17 ±6.65 cm in male and 14 ± 7.02 cm in female and the range was from 6 to 24 cm. Fathi et al.[9] stated that The minimum number of branches of posterior tibial artery observed was three with a maximum of six. In 68.9% of the limbs the first branch of the posterior tibial artery was separated from medial malleolus in distance less than 10 cm.

While in this study the mean distance of muscular branches of posterior tibial artery from lateral malleolus was 8.54 cm. In the present work, it was found that the peroneal artery supplied the lateral part of soleus by multiple branches (two to four) and, these perforators pass through the deep surface or the lateral border of the muscle and this was in agreement with the results of Dominique et al.[10] who found a main pedicle for the lateral soleus emerging from the peroneal artery, and in all cases the blood supply of the proximal part of the muscle was of segmental distribution by way of multiple branches originating from the peroneal artery. They raised soleus flaps with distal pivot point represented by the perforating branch of the peroneal artery to cover an ankle and dorsal foot defect up to the metatarsal heads. Raveendran et al.[1]stated that the branches of the peroneal artery were mostly distributed in the upper half of the muscle; these large pedicles allow a composite transfer of the soleus with the fibula, lower perforators were demonstrated to arise from the peroneal artery in 60% of limbs but the scarcity of perforators in this region limits the clinical usefulness of an inferiorly based lateral hemisoleus flap.

On other hand, El Zawawy & El Sekily.[8] stated that in all cases, the soleus muscle was supplied by muscular branches of peroneal artery; two or three perforators supplied the lateral part of the muscle through its deep surface.

In this study we found proneal artery supplies the soleus muscle by two to four branches first bransh from lateral malleolus average about 13 cm, this was in agreement with the results of El Zawawy & El Sekily.[8] who stated The mean distance of the perforators of the peroneal artery from the lateral malleolus was 11.45 ± 4.06 cm in males and 11.56± 4.28 cm in females with no significant difference (P = 0.448) .

On other hand, Fathi et al.9 disagreement with our study who stated that the average number of branches to soleus arising from the proneal artery was 3.8 ± 0.8. The proneal artery gave 2-5 branches to the soleus muscle in the limbs that in 95.6% of the limbs were found three branches from peroneal artery trunk to soleus muscle. In 91.1% of the limbs the first branch of the proneal artery from the proneal artery to the muscle were found to arise 4 Cm below and 10 Cm above the fibular head.

CONCLUSION

The present study concluded and observed that the external muscular branches (EMB) from popliteal artery supplied soleus directly or indirectly by its branches.

When EMB from popliteal artery were absent, the posterior tibial and peroneal artery gave more number of EMB to soleus. The proximal 25 % of length of soleus received EMB from all the three arteries and hence a proximally based soleus muscle flap is better than distally based muscle flap.We suggest that the clinical usage of proximal 25 % of length of soleus for designing a soleus muscle flap.

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