Anatomical, radiological and histological investigation of the great and small saphenous veins

Ayla Kurkcuoglu, MD, PhD, Tuncay Peker, MD, Nadir Gulekon, MD, PhD.

ABSTRACT

الأهداف: تقديم المعلومات حول أوردة الطرفين السفليين السطحية كتغييرات تشريحية، وتوزيع الصمام، وأشكال النهايات، والخواص النسيجية لجدارات الوريد.

الطريقة: في هذه الدراسة تم فحص الأوردة الصافنة الكبرى في 200 مريض و 10 جثث. تم استعمال تطبيق الأشعة بالموجات فوق الصوتية بقسم الأشعة بمستشفى أتاتورك الجامعي – تركيا، في الفترة ما بين ديسمبر 2004م وحتى أكتوبر 2005م.

النتائج: تبين وجود الفرع الإضافي الجانبي للأوردة الصافنة الكبرى لدى الأغلبية 75 شخص من الحالات بينما لم يتبين وجود ذلك لدى 48 شخص. بالإضافة إلى ملاحظة الفرع الإضافي الوسطي للوريد الصافن الكبير لدى 17 حالة (8.5%) في كلا الجانبين. تبين وجود النوع المأبضي للنهاية لدى 211 حالة. كما تبين وجود فروع الأوردة الصافنة الصغيرة الثاقبة المأبضية لدى 29 شخصاً. تم قياس جميع أقطار تلك الأوردة على الجانبين للجثث والمرضى الذين أجري لهم التصوير بالموجات فوق الصوتية. أظهر التحليل الإحصائي عدم وجود فرق ملحوظ. صُنف 156 صمام وفقاً للموضع والنوع. تبين وجود العدد الأعلى من الصمامات في الفترة الأولى والعدد الأصغر في الفترة الثانية. كانت معظم الصمامات من تشكيل النوع الثالث.

خاتمة: يمكن أن تكون معرفة تشريح متغيرات وخصائص صمامات الأوردة السطحية للطرفين السفليين مفيدة في الممارسة السريرية، والعمليات الجراحية ذات الصلة بالطرفين السفليين.

Objectives: To provide information on superficial veins of the lower limb such as anatomic variations, valve distribution, termination forms, and histological properties of vein walls.

Methods: Two hundred greater saphenous veins in 200 patients and 10 cadavers were investigated. Ultrasound examinations were performed in the Department of Radiology, Ataturk Hospital between December 2004 and October 2005.

Results: The lateral accessory branch of the great saphenous vein was found in 75 persons while in 48 persons no major branch was encountered. In addition, medial accessory branch of the great saphenous vein was observed in 17 (8.5%) on both sides. The popliteal type of termination was found in 211 cases. The small saphenous vein gave off perforating branches to the popliteal vein in 29 persons. The diameters of such veins were all measured on both sides of the cadavers and ultrasonographically on patients. Statistical analyses revealed no significant difference. One hundred and fifty-six valves were classified according to their position and type. The maximum number of valves was found in the first interval and the minimum number was in the second interval. The valves were mostly in Type III format.

Conclusion: Knowledge on the anatomic variations and characteristics of the valves of the superficial veins of the lower limbs can be helpful in clinical practice and surgical operations concerning the lower extremity.

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From the Department of Anatomy (Kurkcuoglu), Faculty of Medicine, Baskent University, and the Department of Anatomy (Peker, Gulekon), Faculty of Medicine, Gazi University, Besevler, Ankara, Turkey.

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Address correspondence and reprint request to: Dr. Ayla Kurkcuoglu, Department of Anatomy, Faculty of Medicine, Baskent University, 06530 Baglica Ankara, Turkey. Tel. +90 (312) 2341010 Ext. 1524. Fax. +90 (312) 2341180. E-mail: kayla@baskent.edu.tr/ drakurkcuoglu@hotmail.com

The great and small saphenous veins are superficial veins of the lower extremity, which are placed beneath the skin between the 2 layers of superficial fascia. The great saphenous vein, the longest vein in the body, begins in the medial marginal vein of the dorsum of the foot and ends in the femoral vein whereas the small saphenous vein begins behind the lateral malleolus as a continuation of the lateral marginal vein and ends in the popliteal vein.[1,2] The complex structure of the lower extremity anatomy and inadequate information on this system are believed to be the reasons for recurrent varicose veins and post-surgical complications.[3] Additionally, since the superficial veins of extremity are also used as autograft, understanding the distribution of valves is of utmost importance.[4] Of the entire population in Western countries, 1-3% is known to have venous problems at some point in their lives. Seen more frequently in women than men, chronic venous insufficiency is caused by slow blood circulation in the lower extremities. This syndrome may occur due to blockage or valvular insufficiency[5] and, if left untreated, may lead to pulmonary embolism, which can cause sudden death with a mortality rate of 60-85%. Approximately 200,000 patients died every year in the United States due to pulmonary embolism.[6] Venography was the standard method in the demonstration of the venous system until the last decade. Nowadays, Doppler ultrasonography is currently accepted as the gold-standard method in the anatomical and functional assessment of valvular insufficiency.[7] Ultrasonography reveals veins directly and shows blood circulation. The resulting anatomical information is used to choose the appropriate treatment and guides the surgery.[8] Good knowledge of the anatomical structure and variations of insufficient veins ensures more successful surgical outcomes. With the recent advancement of surgical methods (Subfacial Endoscopic Vein Surgery), a good knowledge of venous anatomy has become even more important.[9] Conducted with the help of radiological, anatomical and histological examinations, the present study aims to identify the anatomical structures, variations, endings, valve locations and types of superficial veins of the lower extremity, and to reveal the histological characteristics of vein walls.

Methods. Color Doppler imaging was performed to evaluate the 400 lower extremities in 200 subjects (93 males and 107 females). Age ranges were between 13 and 85 years. The local institutional board of ethics initially approved this study. All the ultrasound images belong to the patients who attended the Radiology Department of Atatürk Hospital with leg pain. None of them was diagnosed of venous insufficiency. The study was completed between December 2004 and October 2005 by using a 5-10 MHz EUB-6000 Hitachi ultrasound. Patients with a history of venous surgery, sclerotherapy and deep vein thrombosis were excluded from the study. The existence of the great saphenous vein medial and anterolateral branches in the saphenofemoral junction of both extremities was assessed and, if existent, their thickness was compared after finding the inguinal ligament. Following this, small saphenous vein examination was performed in the same subjects. The small saphenous vein was scanned throughout its length and sapheno-popliteal junction locations were recorded. The anatomical study was conducted on the 20 lower extremities obtained from 10 cadavers (4 females, 6 males) at the Anatomy Departments of the Medical Schools of Gazi, Baskent, Ankara and Yeditepe Universities. The study aimed to detail the anatomy of lower extremity veins, identify their variations and endings, and find the valve locations. No pathological findings regarding venous disease were obtained in the cadavers. The numbers, locations and types of valves in the great saphenous vein were identified. In order to find the anatomical locations and the number of valves on the great saphenous vein, the part between saphenous opening and the line that joins the medial malleolus to the lateral malleolus was divided into 9 equal segments. The segments were later numbered from 1 to 9, starting at the proximal towards the distal.[10]

1st segment: ¼ proximal part of the distance between the knee and hip. 2nd segment: ¼ proximal part above the femoral midpoint. 3rd segment: ¼ distal part below the femoral midpoint. 4th segment: femoral ¼ distal part. 5th segment: the knee point and patella. 6th segment: ¼ proximal part between the knee and the line connecting medial and lateral malleolus. 7th segment: ¼ proximal part above the leg midpoint. 8th segment: ¼ distal part below the leg midpoint. 9th segment: leg ¼ distal part. Valves were classified into three groups according to the differences in the relationships between venous branches and valves:[1] Type I: no venous branching between valves. Type II: the distance between distal branch and valve shorter than the distance between the valve and proximal branch. Type III: the distance between proximal branch and valve shorter than the distance between valve and distal branch.

Data obtained were recorded and examined comparatively. In order to show the collagen fibers in the structure of the great saphenous vein, samples were stained with Masson trichrome stain. Similarly, Gomori's silver stain was used to show the reticular fibers and Van Gieson stain to show the elastic fibers. The vein walls and valve areas were examined using Leica DM 4000 B microscope.

All statistical analyses were calculated using the chi-square test and Student's t-test. In both the dependent and independent groups, sample averages were compared using the t-test. However, calculations of the same subjects were made using the paired samples test.

Results. *Results of radiological study.* The major branches at the femoral part of the great saphenous vein (v. saphena magna) in 400 lower extremities were compared with Doppler sonography. Of the 200 right lower extremities, 107 (53.5%) had lateral accessory branch of the great saphenous vein, 33 (16.5%) had medial accessory branch of the great saphenous vein, and no major branches were detected in 60 (30%) individuals. On the left side, 89 individuals (44.5%) had lateral accessory branch of the great saphenous vein and 49 individuals (24.5%) had medial accessory branch of the great saphenous vein. No major branches were found in 62 individuals (31%). Right and left legs were compared on both sides. It was observed that 75 subjects (37.5%) had lateral accessory branch of the great saphenous vein on both sides; 17 (8.5%) had medial accessory branch of the great saphenous vein on both sides; 34 (17%) had medial accessory branch of the great saphenous vein on the right and lateral accessory branch of the great saphenous vein on the left; 12 (6%) had no major branches on the right but medial accessory branch of the great saphenous vein on the left; 14 (7%) had no major branches on the right but lateral accessory branch of the great saphenous vein on the left. No major branches were found in 48 (24%) of the subjects (**Figures 1a and 1b**). The diameters of the great saphenous vein near its termination into the femoral vein and those of the small saphenous vein were measured and compared on both sides and both gender (**Table 1**). Termination forms and their numbers of the small saphenous vein were examined on both sides. On the right side, the termination point of the small saphenous vein was the popliteal vein in 108 subjects (54%) whereas in 32 subjects (16%) it was terminating above the popliteal vein. Termination to the great saphenous vein via deep perforating branches was found in 46 subjects (23%) and termination below the popliteal vein was found in 14 subjects (7%). On the left side, this ratio was found to be 54 (27%) and 15 (7.5%).

Results of anatomical study. Irrespective of the valves on the branches in the 20 dissected great saphenous vein, a total of 156 valves were detected throughout the main

Table 1 - Diameters of great and small saphenous veins on ultrasound images of 200 individuals.

Veins/side	Gender	No. of patients	Mean ± SD
Right great saphenous vein	Female	107	6.1627 ± 0.1740
	Male	93	6.2743 ± 0.1885
Left great saphenous vein	Female	107	5.6700 ± 0.1577
	Male	93	5.8333 ± 0.1884
Right small saphenous vein	Female	107	0.8925 ± 0.1180
	Male	93	3.0245 ± 0.1281
Left small saphenous vein	Female	107	2.6529 ± 0.1091
	Male	93	3.0176 ± 0.1217

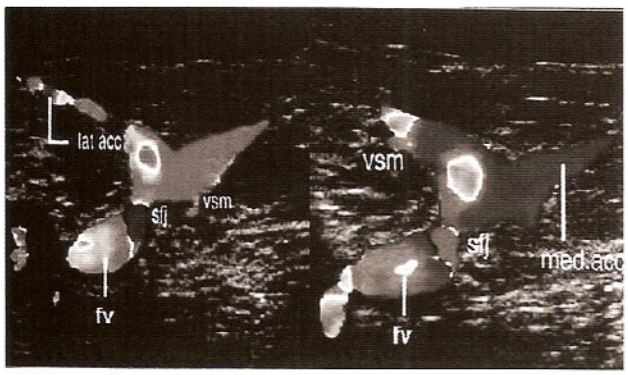


Figure 1 - The termination of the great saphenous vein and its accessory branches at the sapheno-femoral junction. a and b) show the accessory branches joining the great saphenous vein for line a and b indicated in Figure 2. vsm - great saphenous vein, med. acc - medial accessory branch of the great saphenous vein, lat. acc - lateral accessory branch of the great saphenous vein, sfj - sapheno-femoral junction, fv - femoral vein.

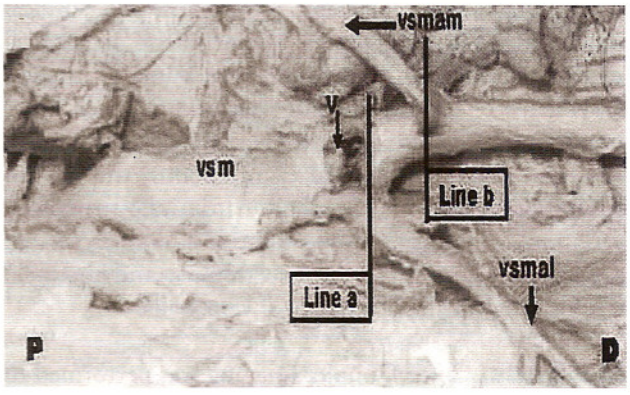


Figure 2 - Valve (small arrow) between the great saphenous vein and one of its accessory branches in the inguinal region. P - proximal, D - distal, vsm - great saphenous vein, vsmam - medial accessory branch of the great saphenous vein, vsmal - lateral accessory branch of the great saphenous vein, v - venous valve.

Table 2 - Segmental distribution of the valves of the great saphenous vein in 10 cadavers. The average number of valves in each saphenous vein is essential. The relation between position of the valves and direction of circulation is important.

Intervals	No. of valve (%)	
1	35	(22.4)
2	9	(5.8)
3	8	(5.1)
4.	19	(12.2)
5.	18	(11.5)
6.	20	(12.8)
7.	21	(13.5)
8.	11	(7.1)
9.	15	(9.6)



Figure 3 - Valve structure of the great saphenous vein (1: endotelial cell nucleii; 2: intimal folds; 3: dense collagen fibers). (Masson trichrome, x 400).

Table 3 - Mode of termination of the small saphenous vein reported by various authors.

Authors	No. of patients	Termination at popliteal fossa (%)	Termination above popliteal fossa (%)	Termination below popliteal fossa (%)
Kosinski[17]	124	57.3	33.0	9.7
Vasdeskis et al[18]	64	60.0	30.0	10.0
Engel et a;[19]	62	78.0	15.4	6.6
Engel et al[19]	104	52.4	46.6	1.0
Labrapoulus et al[11]	383	60.8	19.3	15.4
Present study	400	52.3	40.0	7.7

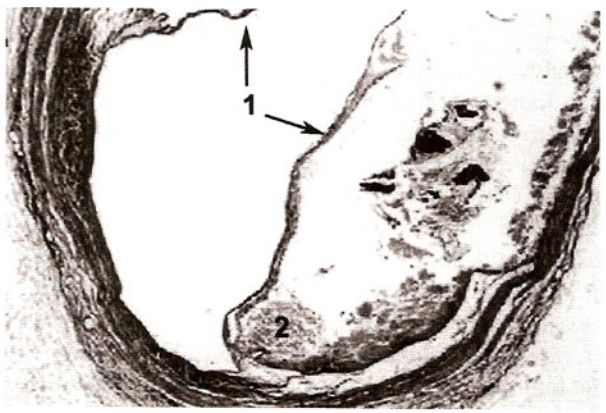


Figure 4 - Cross sectional view of the great saphenous vein. Elastic fibers in the subendotelial layer, between the muscle fiber in tunica media and in the valve. (1, valv; 2, coagulated blood). (Van Gieson, x 40).

vein. In all subjects, there was a valve at the point where the great saphenous vein runs into the femoral vein (**Figure 2**). The number of valves and their percentages are shown in **Table 2**. The valves on the great saphenous vein and the venous branches opening to this vein were classified according to the distance between the valves. Ten valves (6.4%) were labeled Type I, whereas 8 (5.1%) were labeled Type II and 138 (88.5%) were labeled Type III. Type III valves were found to be the most common ones.

Results of histological study. Collagen fibers were stained bright green using the Masson trichrome staining method. It was seen that collagen fibers were on the subendotel layer in tunica intima of the great saphenous vein and between the muscle fibers of tunica media. Tunica adventitia was found to have loose connective tissue and many vasa vasorum. Where the valves contacted the vein wall, collagen fibers were observed in greater numbers (**Figure 3**).

Reticular fibers in the valve structure of the great saphenous vein were stained black with silver stain and had formed an anatomizing net structure. Through all histological layers of the great saphenous vein and on the subendotel layer of the valves, elastic fibers were found stained brown by the Van Gieson method (**Figure 4**).

Discussion. Doppler ultrasound is the preferred method of examination in the demonstration of vascular normal anatomy, variations and pathologies. Labropoulos et al[11] have researched the major branches of the great saphenous vein by using Doppler ultrasound. While they were able to show the existence of medial accessory branch of the great saphenous vein in 9% and lateral accessory branch of the great saphenous vein in 18% of a total of 100 lower extremities, they found no

major branches in 9% of the subjects. In a study on the anatomical variations of the great saphenous vein in the femoral part, Ndiaye et al[12] found the lateral accessory branch of the great saphenous vein in 15/40 cadavers, and medial accessory branch of the great saphenous vein in 5 cadavers. The study concluded that since anatomical variations can be great and widespread, they need to be considered prior to surgical operations. The present study also investigated the great saphenous vein using Doppler ultrasound and the results corroborated the study of Labropoulos et al.[11] The studies performed on cadavers confirmed the existence of medial and lateral accessory branches of the great saphenous vein in all 20 legs. These results are contradictory to those of Ndiaye's, which may be attributed to the difference in the number of subjects. Caggiati and Stefano[12] used Doppler ultrasound to assess the diameters of the great saphenous vein in 121 subjects and the diameters varied between 1.8-6.2 mm and the movement from distal to proximal was observed. Additionally, they also stated that diameters became significantly narrower in areas closer to branching.[13] In the present study, the average diameter of the great saphenous vein in females was 6.16 mm on the right and 5.67 mm on the left. In males, it was 6.27 mm on the right and 5.83 mm on the left. These results suggest no significant difference between the right and left branches between the 2 gender. At the same time, it was noted that while the diameters increased at popliteal level and the point of entry into the femoral vein, they decreased towards the distal. These diameter measurements are similar to those made by Caggiati and Stefano.[13] However, since they did not distinguish between the results of the 2 gender, a healthy comparison could not be made. Watanabe and Nishimato[14] claimed that there was an irregularity in the location of valves. Similarly, Perrin et al[15] reported that the distance between valves was not constant and that they were distally located to the main vein branching points. Upon investigating the great saphenous vein and its branches, Schinohara et al[16] stated that the majority of subjects had medial and lateral accessory branches of the great saphenous vein, and that the valves were located closer to branching points. The distance between valves on the cadavers used in this study were not regular, almost all valves were located closer to branching points. Iimura et al[10] identified 272 valves in 35 cadavers, and a valve in each at the point where the great saphenous vein opens to the femoral vein.[10] They reported the biggest number of valves in the first segment, stating that segements in the 2nd and 3rd segments decreased, and in the 4th and 7th segments it increased. They also classified the valves on the great saphenous vein and the branches opening to this vein according to the distance between the valves. They found 6.3% of the valves as type I, 4.9% as type II and the remaining 88.7% as type III. In the present study, all cadavers were found to have a valve at the point where the great saphenous vein opened into the femoral vein. While majority of all valves were located in the 1st segment, this number decreased in the 2nd and 3rd segments. At the popliteal fossa level, the proportion increased again, thereafter, valve numbers fell. These findings are similar with those obtained in Iimura's study. Likewise, of the 156 valves identified along the great saphenous vein in the present study, 6.4% were labeled as type I, 5.1% as type II and 88.9% as type III. The anatomy of the small saphenous vein, especially the way it ends varies greatly. This has been investigated by many researchers.[17-19] Comparative results are given in **Table 4**. It is worth noting that although the number of participants across these studies varies, the proportions do not vary greatly. Our results are very similar and parallel to those of researchers. Crissmann[20] emphasized the distribution of elastic fibers inside the vein walls of the great saphenous vein. Elastic fibers were present in all layers. Similarly, Kugelgan et al[21] mentioned the presence of elastic fibers forming a net inside the vein wall, which was located longitudinally along the vein in the form of thin fibers. When we investigated the distribution of elastic fibers in the present study, we found a concentrated presence of elastic fibers on the subendotel layer. Therefore, results of the present study are parallel to those of Crissmann and Kugelgan studies.

In conclusion, the results of the radiological examination suggested that the small saphenous vein ended in many different ways. In the anatomical study, the distribution of the valves on the great saphenous vein suggested that they were in highest concentration around the inguinal area, closer to the branches and without a regular distance in-between. Of all the valves that were identified, the one with the thickest wall was found to be located next to the point where the lateral and medial accessory branches opened to the great saphenous vein. We believe that our results may prove to be beneficial in clinical and surgical operations on veins.

References

1. Williams PL, Newell RLM, Davies MS, Collins P. Pelvic girdle and lower limb. In: Standring S, editor. Gray's Anatomy. 39th ed. Edinburgh: ElsevierChurchill Livingstone; 2005. p. 1452-1453.
2. Moore LK, Dalley AF. Clinically oriented anatomy. 4th ed. Washington: Lippincott Williams & Wilkins; 1999. p. 515-530.
3. Engelhorn CA, Engelhorn AL, Cassou MF, Salles-Cunha SX. Patterns of saphenous reflux in women with primary varicose veins. *J Vasc Surg* 2005; 41: 645-651.
4. Vasić DM, Davidović LB, Maksimović ZV, Crni AR, Marković MD, Pejkić S. [Primary varicose veins: frequency, clinical significance and surgical treatment]. *Srp Arh Celok Lek* 2004; 132: 398-403. Serbian.

5. Sarin S, Sommerville K, Farrah J, Scurr JH, Coleridge Smith PD. Duplex ultrasonography for assessment of venous valvular function of the lower limb. ***Br J Surg*** 1994; 81: 1591-1595.
6. Holier HR, Strondness E, Towne BJ, Calligaro K. 2004. Vascular surgery. 5th Ed. New York: Arnold; 2004. p. 1234-1240.
7. Potter MD, Dixon S, Morrison JP, Suliamann AS. Development of an advanced multimode automatic ultrasonic texture measurement system for laboratory and production line application. ***Ultrasonics*** 2006; 44 Suppl 1: e813-817.
8. Pukacki F, Zieliński P, Checiński P, Oszkinis G. [Short saphenous vein incompetence as a cause of recurrent varicose veins]. ***Wiad Lek*** 2003; 56: 28-33. Polish.
9. Yao JST, Pearce WH. Lower limb. Techniques in vascular and endovascular surgery. London (UK): London Bergmand & Boks; 1998. p. 2007-2019.
10. Iimura A, Nakamura Y, Itoh M. Anatomical study of distribution of valves of the cutaneous veins of adult's limbs. ***Ann Anat*** 2003; 185: 91-95.
11. Labropoulos N, Kang SS, Mansour MA, Giannoukas AD, Buckman J, Baker WH. Primary superficial vein reflux with competent saphenous trunk. ***Eur J Vasc Endovasc Surg*** 1999; 18: 201-206.
12. Ndiaye A, Ndiaye A, Diop M, Ndoye JM, Ciss G, Dia A, et al. [About the tributaries of the arch of great saphenous vein. Concerning 40 dissections] ***Dakar Med*** 2005; 50: 41-45. French.
13. Caggiati A, Ricci S. The caliber of the human long saphenous vein and its congenital variations. ***Ann Anat*** 2000; 182: 195-201.
14. Watanabe T, Nishimoto K. Studies on the venous valves and blood flow. Jpn J Physiol 1950; 12: 185-191.
15. Perrin M, Hiltbrand B, Bayon JM. Results of valvuloplasty in patients presenting deep venous insufficiency and recurring ulceration. Ann Vasc Surg 1999; 13: 524-532.
16. Shinohara H, Morisawa S, Toshima M, Mizukami S. Distribution of valves in the great saphenous vein: its clinical implications. ***Okajimas Folia Anat Jpn*** 1990; 67: 219-222.
17. Kosinski C. Observations on the Superficial Venous System of the Lower Extremity. ***J Anat*** 1926; 60 (Pt 2): 131-142.
18. Vasdekis SN, Clarke GH, Hobbs JT, Nicolaides AN. Evaluation of non-invasive and invasive methods in the assessment of short saphenous vein termination. ***Br J Surg*** 1989; 76: 929-932.
19. Engel AF, Davies G, Keeman JN. Preoperative localisation of the saphenopopliteal junction with duplex scanning. ***Eur J Vasc Surg*** 1991; 5: 507-509.
20. Crissman RS. The three-dimensional configuration of the elastic fiber network in canine saphenous vein. A stereo scanning electron microscopic study. ***Blood Vessels*** 1984; 21: 156-170.
21. Kugelgan AV. Additional information of the wall structures of the great veins in human with egard to collagen fiber structures. Z Zellforsch Anat 1956; 44: 121-174.

Ethical Consent

All manuscripts reporting the results of experimental investigations involving human subjects should include a statement confirming that informed consent was obtained from each subject or subject's guardian, after receiving approval of the experimental protocol by a local human ethics committee, or institutional review board. When reporting experiments on animals, authors should indicate whether the institutional and national guide for the care and use of laboratory animals was followed.