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Valve distribution of the popliteal vein: A structural basis for deep venous thrombosis?

Innocent Ouko[1], Moses M Obimbo[1,2], James Kigera[1] and Julius A Ogeng'o[1]

Abstract

Objective: To describe the relationship between number and distribution of valves.

Methods: Sixty-six popliteal vein specimens were used for the study after routine dissection at the Department of Human Anatomy, University of Nairobi. The extents of the popliteal vein were identified at the adductor hiatus and soleal arch, cut at these points and then longitudinally sliced open. The number and distribution of valves were then recorded. Data were presented using photomacrographs and tables.

Results: The median number of valves was 1 (mean 0.8; range 0–2), with the lower part of the popliteal vein as the most consistent valve position. Most striking was the valve absence noted in 27 (41%) of the veins.

Conclusion: These findings suggest that a significant proportion of popliteal veins do not have valves thus providing a credible structural link that may predispose the popliteal vein to deep venous thrombosis in the study population.

Keywords

Popliteal vein, deep venous thrombosis, valve

Introduction

The popliteal vein is a deep vein of the lower limb, located at the popliteal fossa that extends from the soleal arch to the adductor hiatus.[1] The vein is formed by the union of anterior tibial, posterior tibial and peroneal veins, and the soleal and gastrocnemii veins.[2] It also receives short saphenous vein and perforators from the great saphenous vein.[1] For this reason, the popliteal vein accounts for up to 90% of drainage of the distal lower limb.[3]

Popliteal vein returns blood to the heart, against gravity, in spite of its highly mobile anatomical location.[1] Thus to ensure efficiency of this role, the vein has to be appropriately adapted. One of the adaptations is the presence and distribution of valves.[1,3] Valves reduce the venous return effort by breaking the weight of hydrostatic blood column and therefore reducing the chances of venous stasis that could lead to thrombosis. On the contrary, absence of or presence of a single valve would be more taxing to vein increasing a tendency towards stasis and particularly deep venous thrombosis (DVT).[2,4,5]

In Kenya, the popliteal vein accounts for 38.9–63% of patients suspected to have DVT[6,7] and may be related to anomalous distribution of popliteal valves which is reported to vary between populations.[4] Knowledge of the popliteal valves and their distribution is undocumented within the Kenyan population. There may be a link between popliteal valvular distribution and these high DVT rates. Thus, we conducted this study to describe the valve distribution of popliteal vein within a sample Kenyan population.

[1]Department of Human Anatomy, University of Nairobi, Nairobi, Kenya
[2]Department of Obstetrics and Gynecology, University of Nairobi, Nairobi, Kenya

Corresponding author:
Innocent Ouko, College of Health Sciences, University of Nairobi, PO Box 13098, Nairobi, Kenya.
Email: innoholmes@gmail.com

Materials and methods

The study was a cadaveric, descriptive cross-sectional study conducted at the Department of Human Anatomy, University of Nairobi. In total 66 cadaveric veins from adult subjects of all genders ranging from 20 to 50 years were obtained. Ethical approval was sought and obtained from the Department of Human Anatomy.

To access the vein, the cadaver was laid in prone position. A longitudinal incision from the distal third of the thigh to the proximal half of the calf was made and the skin reflected. Contents of the popliteal fossa were then systematically retracted to access the vein. The extent of the popliteal vein from the level of the soleal arch to the adductor hiatus was identified. These extents defined the lower and upper segments, respectively. The knee was then partially flexed to identify the middle segment at the level of the tibiofemoral interface. The full demarcation of the extents of the upper (UPV), middle (MPV) and lower (LPV) segments are shown in Figure 1, modified from Volpato et al.[8] The UPV was from the adductor hiatus to upper border of the patella, the MPV from the upper border of the patella to the lower end of the tibiofemoral interface and the LPV from the lower end of the tibiofemoral interface until the venous bifurcation or trifurcation.

The vein was then split open to check for presence of valves at these three segments. The total number and distribution of valves at the three segments was thereafter recorded. The specimen was further categorised based on sides (right and left) and gender (male and female). Specimen with evidence of popliteal venous reconstruction or venous punctures was excluded.

Data were recorded and analysed using Statistical Package for Social Sciences (SPSS v.21 IBM) software. Photomacrographs were then taken using a Sony Cybershot^{R} (DSC W20, 16 MPS) digital camera. The results were presented in photomacrographs and tables.

Results

The popliteal vein showed differences in the presence and distribution of valves.

The median number of valves of the popliteal vein was 1 (mean 0.8; range 0–2). This range displayed indifference of valve distribution to the limb laterality (left – median 1, mean 0.84, range 0–2; right – median 1, mean 0.76, range 0–2) and gender (males – median 1, mean 0.8, range 0–2; females – median 1, mean 0.82, range 0–2).

Valve absence (Figure 2) was noted in 41% of the veins (Table 1) with more females (54%) lacking valves compared to the males (38%) (males (21/55), females (6/11)).

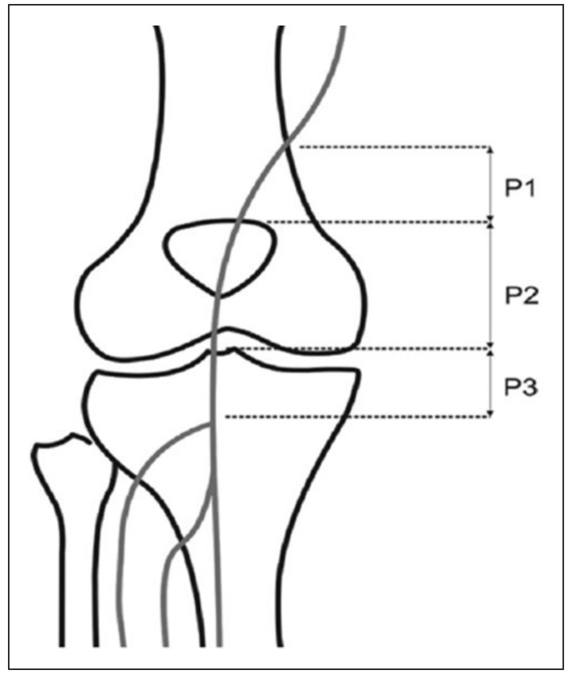

Figure 1. Sampling protocol employed to harvest tissue sections for UPV (P1), MPV (P2) and LPV (P3). Modified from Volpato et al.[8] UPV: upper popliteal vein; MPV: middle popliteal vein; LPV: lower popliteal vein.

With regard to valve distribution, the most consistent position was the LPV (27 valves; 50.95%), followed by the MPV (15 valves; 28.30%) and then UPV (11 valves; 20.75%) as shown from Figures 3 and 4.

Discussion

Our findings show that there are differences in the distribution and presence of valves within the study population.

Atypical distribution of valves

The median number of valves was 1 (mean 0.8; range 0–2). This range is consistent with the reports from previous studies in Caucasian populations (Table 2). However, the maximum valve number in the present study was 2, unlike the some of the previous studies that reported up to four valves (Table 2). Since the methodology used is similar to the previous studies, our result presents a statistic particular to the study population.

A significant proportion (41%) of the veins in the study population was valveless. In other populations, absence of valves in the popliteal vein was previously reported by Kwakye[10] and Moore et al.[4] The percentage absence was, however, not specified by these workers. Below and above the popliteal vein, respectively,

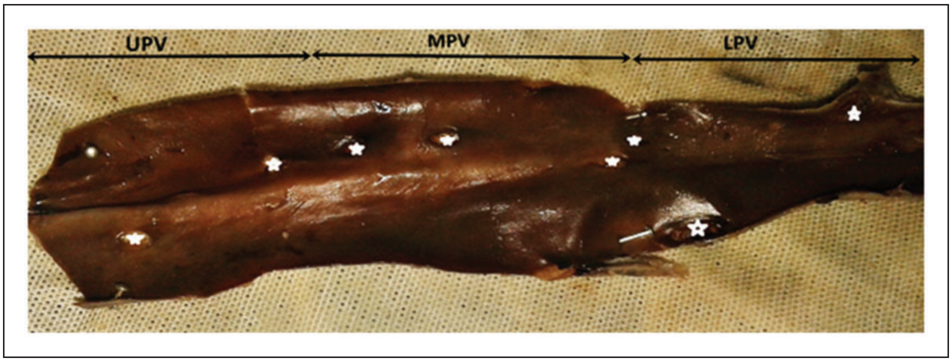

Figure 2. Photograph showing the spread-out luminal side of a valveless popliteal vein. Notice the absence of valves despite the numerous tributaries (white stars) mostly at the MPV. MPV: middle popliteal vein.

Table 1. Frequency distribution of valves.

Number of valves ($N=66$)	Frequency	Frequency percentage
No valve	27	41
One valve	25	38
Two valves	14	21

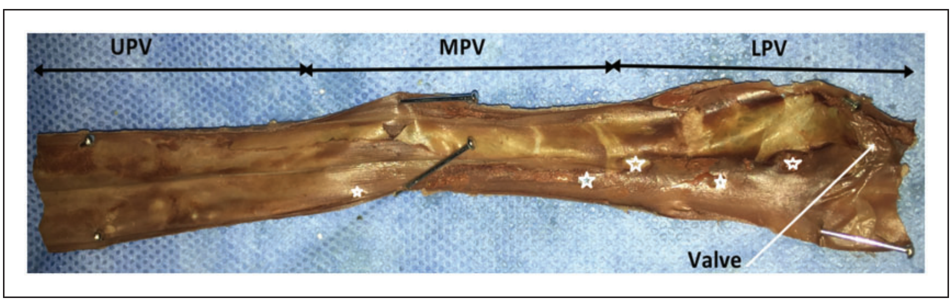

Figure 3. Photograph showing the spread-out luminal side of the popliteal vein. Notice the presence of valves only at the LPV. Note the convenience of the valve at this section following the numerous tributaries (white stars) at the LPV. LPV: lower popliteal vein.

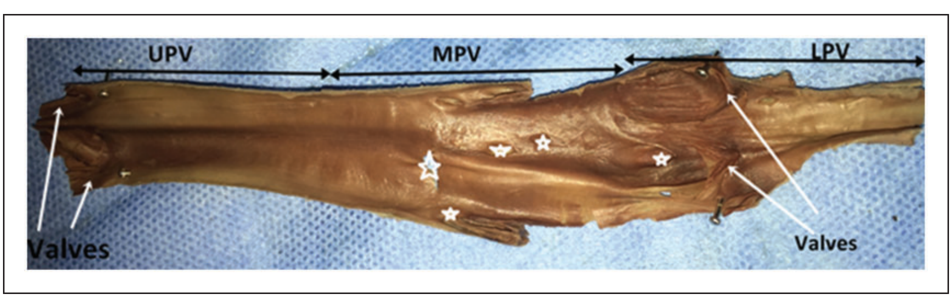

Figure 4. Photograph showing the spread-out luminal side of the popliteal vein. Notice the presence of valves at the UPV and the LPV while more tributaries (white stars) are centred at the valveless MPV section. UPV: upper popliteal vein; MPV: middle popliteal vein; LPV: lower popliteal vein.

the tibial veins and femoral veins report presence of high numbers of valves.[1,4] However, the external iliac vein, which is a proximal extension of the femoral vein, has been reported to lack valves in 24% of the cases and has been associated with increased cases of venous reflux and DVT.[15] In spite of the documented valves present in the femoral vein, valve absence in the external iliac still contributes to DVT formation. The higher rates of missing valves in the popliteal vein could also imply higher chances of reflux and DVT formation in

Table 2. Prevalence of valves in the popliteal vein among different populations.

Reference	Population	Method	*N* (limbs)	Number of valves
Powell and Lynn[9]	–	Cadaveric	54	1
Kwakye[10]	Netherlands	Cadaveric	50	0–4
Santili et al.[11]	USA	Cadaveric	47	0–3
Genovese[12]	Italy	Cadaveric	2	1–2
Cagiatti[13]	Italy	Cadaveric	–	1–2
Geersen and Mowatt-Larssen[14]	–	–	–	1–2
Present study	Kenya	Cadaveric	66	0–2

spite of the high number of valves in the tibial veins. That this study presented proportionally more valveless females than males could be attributed to the small sample size used.

The location of the popliteal vein may further contribute to the structural predisposition to venous thrombosis. The popliteal vein is located in the popliteal fossa, a relatively amuscular region. This region lacks the functional pumps seen in the muscular femoral and soleal regions located above and below the popliteal fossa, respectively.[1] The muscular pumps aid in the cephalad propulsion of blood. Furthermore, the valves in these muscular regions are numerous. High-valve frequency breaks the hydrostatic blood column reducing the weight of the blood column needed for cephalad propulsion.[3] Therefore, the more the valves, the less the effort required to propel blood against gravity. Thus, the veins in these regions have the double advantage of muscular propulsion and high-valve frequency. The popliteal vein, however, lacks theses structural advantages.

Further, in the Kenyan population, studies on patients who were not under the influence of anaesthesia still reported high popliteal DVT rates (38.9%–63%).[6,7] This may be in part due to structural absence of valves within the popliteal vein. It has previously been thought that valves were focal areas for thrombus formation.[3,4] However, this is only correlated with the focal stasis at the valve sinus.[4] Absence of valves can also result in the exposure of veins to thrombus through reflux and subsequent stasis. Early postoperative ambulation and the use of graduated compression stockings are therefore recommended as a safety prophylaxis.[16–18]

In addition, absence of popliteal valves may explain the reported cases of DVT among the young African age-groups. Aduful and Darko[19] reported cases of DVT among patients that lie within the age-group used in the present study. Their findings, done in the Ghanaian population, was among patients who were both exposed to sedentary and actively ambulatory occupations, and whose history recorded no chemically or genetically predisposing factors of DVT. Furthermore, the isolation of DVT was mostly in the popliteal vein.[19]

Predominant mono-consistency of valves

The most consistent valve position was the LPV followed by the MPV, with the UPV being the least consistent position. By mono-consistency, we refer to consistency of valves within a single popliteal venous segment. This is in variance with findings in various Caucasian populations, which reported the absence of valves at the UPV and LPV segments.[11,12] Other Caucasian studies reported both the UPV and the LPV as the most consistent position.[4,9,10,20] The differences noted among these Caucasian studies may imply that the consistency of valve position is population-specific. The results of this study, however, contrast with those of Banjo,[21] who reported 100% presence of valves within the UPV segment among black Africans. This result is consistent with the proposed mechanism of venous return by Uhl and Gillot.[22,23] Nevertheless, the results from our study highlight a possible unique morphology among a significant fraction of the Kenyan population. Additionally, since the methodology used in this study was similar to the study applied among the Caucasian population, it is plausible that interracial differences in valve consistency exist.

Differences in consistent valve location may be attributed to venous length. Long veins such as the saphenous and femoral veins are reported to have more valves[1,3] with more consistent locations than shorter ones.[4] Since the popliteal vein is shorter than these veins, the number of consistent locations may be reduced to as low as one, as seen in the present study. Furthermore, in a systematic review, Moore et al.[4] reports of more than one consistent popliteal valve locations in Caucasians than other races. This may be related to the length of lower limb that positively correlates with popliteal venous length. Since the work by Shan and Bohn,[24] reported longer lower limbs in the Caucasians than the Africans, the same might explain the predominating mono-consistency in our study.

A dominating mono-consistency at the LPV translates to longer hydrostatic column across the entire vein. Since the popliteal vein drains up to 90% of the lower limb, this venous load can pose functional difficulties for such a vessel. The strain imposed on the valve can lead to pathological consequences, inclined towards venous disease through reflux and stasis.

Some of the limitations encountered in this study were the focus of the popliteal vein, when it is essentially an extended vessel stretching through to the external iliac. A reference of the total number of valves in the proximal veins of the lower limb would have offered a better comparison. Our sample size was also small with particular regard to gender and side stratification. The study findings, however, translate to plausible increased level of hydrostatic column in the popliteal segment of the vessel but not in the femoral segment. Division of the vein was also due to arbitrary anatomical positions and not due change in the vein calibre, as this might be affected by different variations. A correlative study between patients admitted for DVT at the popliteal vein and their anatomy might therefore be recommended.

Conclusion

The findings of this study show presence of LPV valve location and absence of valves in a significant number of popliteal veins. This may provide a meaningful explanation to the high rates of DVT in this vein.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical approval

Ethical approval was given by the Department of Human Anatomy according the Human Anatomy Act of the Constitution of Kenya. The Act is in line with the Declaration of Helsinki.

Guarantor

There are no guarantors for this research publication.

Contributorship

Innocent Ouko – concept formation, proposal writing, data collection and analysis, manuscript writing. Moses Obimbo – principal supervisor, concept formation, data analysis, critical review. Julius Ogeng'o – concept formation, critical review. James Kigera – concept formation, critical review, data analysis.

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ORCID iD

Innocent Ouko https://orcid.org/0000-0002-1543-2338

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