Size of normal and aneurysmal popliteal arteries: A duplex ultrasound study

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Objective: To define diameter at three levels along the popliteal artery and its relation to the inflow arteries in the normal state and in popliteal aneurysms.

Methods: The external diameter of the arteries was determined by duplex ultrasound scanning at the common femoral (CFA), superficial femoral artery (SFA), proximal popliteal artery (PPOP), mid-popliteal artery (MPOP), and distal popliteal artery (DPOP). Examinations were performed in 104 healthy men and 100 women. In addition, patients were screened for the presence of popliteal aneurysms (diameter >10 mm). Findings in healthy male subjects were compared with those with popliteal aneurysms.

Results: Mean arterial diameters in normal men were larger than in women, but the SFA/CFA ratio was smaller in women (0.74 ± 0.08 vs 0.78 ± 0.09; P < .001) and the MPOP/SFA ratio was larger (0.98 ± 0.11 vs 0.94 ± 0.12; P = .001). In both genders, normal popliteal artery diameter was not uniform throughout its length, with PPOP and MPOP being nearly identical, and DPOP was smaller. MPOP diameter correlated most closely with SFA diameter (r = 0.51; P < .001) and less with height, weight and body surface area (r = 0.2 to 0.3) and was not associated with age or the presence of hypertension. In 27 men with 45 patent, fusiform popliteal aneurysms (10 to 44 mm) the site of maximal dilatation was in the region of the MPOP in 39 cases and near the PPOP in only 6 cases. The DPOP was never the largest segment and in only one case was it >10 mm. Arterial diameter in aneurysm patients was larger than normal at all levels but was greatest near the MPOP level (15.7 ± 6.9). Popliteal-to-SFA diameter ratios were increased in the aneurysm group at all three levels but were greatest at the MPOP level (1.85 vs 0.94, P < .001). Comparing 15 popliteal aneurysms >20 mm with smaller ones, distal popliteal artery changed to the least extent but did increase in diameter (6.1 ± 1.2 vs 7.0 ± 1.4, P < .04). In larger aneurysms the MPOP/SFA ratio increased from 1.54 to 2.5 (P < .001).

Conclusion: The diameter of the normal popliteal artery is not uniform throughout its length. In popliteal aneurysms, the region of the MPOP is most commonly the largest diameter. The MPOP/SFA ratio is greater than normal in popliteal aneurysms and increases in larger aneurysms. DPOP does dilate but to a lesser extent then PPOP and MPOP, making endovascular repair anatomically feasible in most popliteal aneurysms. (J Vasc Surg 2006;43:488-92.)

Controversy regarding the appropriate size for intervening in popliteal aneurysms persists. Some advocate observation at large diameter of up to 3 cm, but most consider the threshold for intervention at a diameter of 2 cm. Recently, Ascher et al drew attention to popliteal aneurysms <2 cm that were associated with thrombosis, symptoms, and distal occlusive disease. Underlying this controversy is uncertainty about normal popliteal size, with reports varying between 0.5 and 0.9 cm, and consequently different thresholds for the definition of popliteal aneurysm.

Because popliteal artery aneurysms induce thrombosis and embolize rather than rupture, the notion that intervention should be based only on a threshold of absolute diameter may be ill founded. The size of the popliteal artery relative to the inflow artery, the superficial femoral artery, may be an important determinant of the risk of complications. In addition, evidence of embolic occlusion of crural arteries and the quantity of thrombus within the popliteal aneurysm may be contributory factors.

The popliteal artery is rather long, its diameter is not identical throughout its length, and in assessing popliteal aneurysms, the site of maximal dilatation may be of importance. This is particularly true as endovascular repair of popliteal aneurysms finds its place as an important treatment option, because it requires a relatively normal distal popliteal artery for distal fixation. To define normal and abnormal femoropopliteal size, we conducted a duplex ultrasound study of the femoral and popliteal arteries in healthy subjects and in patients with popliteal aneurysms.

SUBJECTS AND METHODS

Our duplex ultrasound study was conducted in two stages. Initially, we measured the femoral and popliteal arteries in 204 healthy subjects (104 men and 100 women) aged >50 years. The age limit was set arbitrarily to reflect the approximate age range of patients with atherosclerotic and aneurysmal disease. These subjects were referred to the vascular lab for the study from the vascular surgery and general surgery clinics after lower-extremity occlusive disease was ruled out by no history of claudication and a palpable pedal pulse. The mean age of the study cohort was 67.0 ± 9.3 years, with 22% aged <60 years and 8% aged >80 years, and no difference between men and women. Of these, 12% were smokers, 38% were hypertensive by history or medication, and 9% had diabetes mellitus.
### Table 1. External arterial diameters (mm) measured by duplex ultrasound and diameter ratios in 100 healthy women, 104 healthy men and 27 men with 45 popliteal aneurysms (>10 mm)

<table>
<thead>
<tr>
<th>Artery</th>
<th>Healthy women</th>
<th>P*</th>
<th>Healthy men</th>
<th>P*</th>
<th>Men with popliteal aneurysms</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA</td>
<td>8.4 ± 0.8</td>
<td>&lt;.001</td>
<td>9.3 ± 1.1</td>
<td>&lt;.001</td>
<td>11.3 ± 2.6</td>
</tr>
<tr>
<td>SFA</td>
<td>6.2 ± 0.7</td>
<td>&lt;.001</td>
<td>7.3 ± 1.0</td>
<td>&lt;.001</td>
<td>8.4 ± 1.2</td>
</tr>
<tr>
<td>PPOP</td>
<td>6.0 ± 0.6</td>
<td>&lt;.001</td>
<td>6.9 ± 0.9</td>
<td>&lt;.001</td>
<td>11.4 ± 6.6</td>
</tr>
<tr>
<td>DPOP</td>
<td>6.0 ± 0.7</td>
<td>&lt;.001</td>
<td>6.8 ± 0.8</td>
<td>&lt;.001</td>
<td>15.7 ± 6.9</td>
</tr>
<tr>
<td>SFA/CFA</td>
<td>4.4 ± 0.6</td>
<td>&lt;.001</td>
<td>4.9 ± 0.6</td>
<td>&lt;.001</td>
<td>6.4 ± 1.3</td>
</tr>
<tr>
<td>PPOP/SFA</td>
<td>0.74 ± 0.08</td>
<td>&lt;.001</td>
<td>0.78 ± 0.09</td>
<td>NS</td>
<td>0.76 ± 0.12</td>
</tr>
<tr>
<td>MPOP/SFA</td>
<td>0.96 ± 0.07</td>
<td>NS</td>
<td>0.95 ± 0.08</td>
<td>&lt;.001</td>
<td>1.35 ± 0.70</td>
</tr>
<tr>
<td>DPOP/SFA</td>
<td>0.98 ± 0.11</td>
<td>&lt;.001</td>
<td>0.94 ± 0.12</td>
<td>&lt;.001</td>
<td>1.85 ± 0.71</td>
</tr>
<tr>
<td></td>
<td>0.72 ± 0.09</td>
<td>&lt;.001</td>
<td>0.68 ± 0.09</td>
<td>&lt;.001</td>
<td>0.76 ± 0.11</td>
</tr>
</tbody>
</table>

*Calculated by Student’s t test and Kruskal-Wallis test.

The external diameter of the arteries was determined at five predefined levels: common femoral artery (CFA) 3 cm above the bifurcation, superficial femoral artery (SFA) 5 cm below its origin, and popliteal artery at three levels—the proximal popliteal (PPOP) artery about 7 cm above the level of the knee joint, the mid-popliteal (MPOP) artery at the joint level, and the distal popliteal (DPOP) artery about 2 cm above anterior tibial artery take-off. In popliteal aneurysms, the largest diameter closest to these levels was recorded. Height and weight were recorded, and body surface area (BSA) was calculated according to Du Bois’ formula (BSA cm² = weight⁰·⁴²⁵ kg × height⁰·⁷₂⁵ cm × 71.84).

Duplex ultrasound measurements were performed with the ATL HDI 5000 (Philips Medical Systems, Bothell, Wash) by using a linear 4- to 7-MHz transducer. The examination was performed on the supine patient with the knee flexed to 45°. Arterial diameter was measured on transverse images. To avoid errors in measurement, the diameter was measured with the ultrasound beam perpendicular to the artery so that the cross-section was round rather than elliptical. Two sets of measurements of anteroposterior and lateral diameter were averaged. All measurements of normal diameter were performed personally by one of the authors (L. Z.).

During a 1-year period, we screened patients for the presence of popliteal aneurysms, which were defined as a popliteal transverse diameter at any level >10 mm. The patients screened had a variety of indications and were referred to our vascular laboratory and to two affiliated vascular laboratories for elective lower-extremity examination by one of the two technicians and measured according to the protocol mentioned above. The interobserver variability of these technicians was examined previously and was not significant. All findings were personally reviewed by one of the authors (L. Z.). Thrombosed aneurysms and those after surgical repair were excluded.

During this period, we identified 30 patients with patent popliteal aneurysms. Two were women with 20- and 31-mm aneurysms, and one aneurysm in a male patient was multisaccular and morphologically clearly different than the regular fusiform popliteal aneurysm. These three cases were excluded from the analysis. The findings in 27 men with 45 popliteal aneurysms (18 patients with bilateral aneurysms and 9 patients with unilateral aneurysms) were compared with the measurements obtained in healthy male subjects. In addition, we examined arterial size in 10 legs contralateral to a popliteal aneurysm.

Results are expressed as mean ± SD. Mean values were compared using the Student’s t test and the Kruskal-Wallis nonparametric test. Correlation was evaluated with linear regression. P < .05 was considered significant.

### RESULTS

Mean arterial diameters in normal men and women are listed in Table 1. As expected, all arteries were significantly larger in men. Unexpectedly, diameter ratios differed between the sexes. The SFA/CFA ratio was significantly smaller in women, but they had significantly larger MPOP/SFA and DPOP/SFA ratios. This means that the SFA in women was smaller relative to the inflow and outflow arteries compared with men.

Normal popliteal artery diameter was not uniform throughout the length of the artery. The PPOP and MPOP were nearly identical, but the DPOP was consistently and significantly smaller. On single linear regression, the MPOP diameter correlated most closely with the SFA diameter in both men (r = 0.51; P < .001) and women (r = 0.53; P < .001), less with height, weight, and BSA (r = 0.2 to 0.3), and was not associated with age or the presence of hypertension.

Based on a normal diameter of 6.8 mm for the MPOP in men, we defined popliteal aneurysm as a popliteal artery measuring >10 mm (representing the accepted definition of 50% increase in diameter). During a 1-year period, we screened patients in the vascular laboratory and identified 27 men with 45 patent, fusiform popliteal aneurysms (range, 10 to 44 mm). Distribution of maximal popliteal diameter was 10.1 to 15.0 mm in 26 patients, 15.1 to 20.0 mm in 4 patients, 20.1 to 25.0 mm in 9 patients, 25.1 to 30.0 in 1 patient, and popliteal diameter was >30.1 mm in 5 patients.

The site of maximal dilatation was close to the MPOP in 39 cases and near the PPOP in only six cases, but...
included the largest diameter measured. In all but one case, the MPOP was >10 mm. The DPOP was never the largest segment, and only in one case was it >10 mm.

Arterial diameter was larger in the aneurysm group at all levels (Table I), but the greatest mean dilatation occurred at or near the MPOP level. Even though the SFA diameter was larger in the aneurysm group, popliteal-to-SFA diameter ratios at all levels were increased in this group, with the greatest relative increase in the region of the MPOP level and the smallest at the DPOP level (Table I). When popliteal aneurysms >20 mm were compared with smaller ones, the mean MPOP diameter increased to the greatest extent, as did the MPOP/SFA ratio, from 1.53 to 2.5 (Table II). The DPOP artery changed to the least extent but did increase in absolute diameter from 6.1 ± 1.2 to 7.0 ± 1.4 (P > .04). Comparing legs without popliteal aneurysm, contralateral to a leg with a popliteal aneurysm, there was no difference in CFA and SFA diameter with normal patients, and the greatest difference was in the MPOP size and the MPOP/SFA ratio (Table III).

DISCUSSION

The section on popliteal aneurysms in the 2005 6th edition of Rutherford Vascular Surgery reads, “The normal diameter of the popliteal artery is 0.90 ± 0.20 cm (Johnston et al (5)). Other authors have reported smaller mean diameter (0.52 ± 0.11 cm) (Zierler et al (6)).” The diameter of 0.9 appears in the 1991 reporting standards and is based on the paper by Davis et al published in 1977. These measurements, which provide the basis for the statement in a major current textbook of vascular surgery, were performed in the 1970s on 10 healthy men and verified on three men and two women of varying ages. In addition to the measurements by Zierler and Zierler quoted above, there are other, more recent ones:

- Macchi et al in 1994 examined 50 healthy men and women with duplex ultrasound scanning and found a popliteal diameter of 5.1 ± 0.4 in men and 5.0 ± 0.4 in women, very close to Zierlers’ measurements.

- Debasso et al examined 52 healthy men and 56 women and reported a popliteal diameter of 7.4 mm in men and 6.3 in women.

- Sandgren et al examined 121 healthy volunteers and reported a popliteal diameter of 6.9 to 8.4 mm in men and 5.7 to 7.2 mm in women, depending on BSA and age.

- Morris-Stiff et al screened 449 patients for the presence of abdominal aortic aneurysm (AAA) and popliteal aneurysm. They found 30 patients with AAA (aortic diameter >30 mm), and a mean popliteal diameter of 7.4 ± 1.3.

Our measurements of the MPOP of 6.8 ± 0.8 in men and 6.0 ± 0.7 in women are close to the recent studies above, and all report a size smaller than the normal popliteal diameter of 9 mm stated in the textbook.

Our intention was to measure normal femoral and popliteal diameter in men and women. Although we did not measure ankle-brachial index to rule out some degree of atherosclerosis, the absence of claudication and a palpable pedal pulse rule out severe arterial occlusive arterial disease. We did not identify any anatomic abnormalities of the popliteal artery in this study group. It is possible that an occasional high take-off may have been missed because we did not perform any additional studies for verification. However, the anterior tibial artery or posterior tibial artery arising above the knee joint occurs in 5% of cases, so we do not expect this to have influenced the results significantly.

Our comparison of men with women confirmed the well-known fact that women have smaller femoropopliteal arteries than men, but we unexpectedly found that the SFA was narrower relative to the CFA and the MPOP in women than in men. We believe that this difference is real. A type II statistical error is possible but unlikely. P was <.001 and the SFA/CFA and MPOP/SFA ratios differed significantly in opposite directions. This difference may reflect a true anatomic difference or, because there are known gender-related differences in the pattern of atherosclerosis, it may result from more advanced atherosclerosis in the SFA of men with resultant compensatory remodeling.

### Table II. Comparison of arterial diameters and diameter ratios of 15 popliteal aneurysms >20 mm with 30 smaller aneurysms measuring 10 to 20 mm

<table>
<thead>
<tr>
<th>Artery</th>
<th>Aneurysm 10 to 20 mm</th>
<th>Aneurysm &gt;20 mm</th>
<th>Relative increase (%)</th>
<th>Significance (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA</td>
<td>10.9 ± 2.6</td>
<td>12.1 ± 2.6</td>
<td>11</td>
<td>NS</td>
</tr>
<tr>
<td>SFA</td>
<td>8.0 ± 1.0</td>
<td>9.1 ± 1.4</td>
<td>11</td>
<td>.01</td>
</tr>
<tr>
<td>PPOP</td>
<td>9.0 ± 2.1</td>
<td>16.2 ± 9.5</td>
<td>80</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MPOP</td>
<td>12.2 ± 2.4</td>
<td>22.6 ± 7.7</td>
<td>86</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>DPOP</td>
<td>6.1 ± 1.2</td>
<td>7.0 ± 1.4</td>
<td>11</td>
<td>.04</td>
</tr>
<tr>
<td>PPOP/SFA</td>
<td>1.13</td>
<td>1.81</td>
<td>60</td>
<td>.001</td>
</tr>
<tr>
<td>MPOP/SFA</td>
<td>1.53</td>
<td>2.50</td>
<td>63</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>DPOP/SFA</td>
<td>0.76</td>
<td>0.77</td>
<td>1</td>
<td>NS</td>
</tr>
</tbody>
</table>

CFA, common femoral; SFA, superficial femoral; PPOP, proximal popliteal; MPOP, mid-popliteal; DPOP, distal popliteal; NS, not significant.

### Table III. Comparison of arterial diameters and diameter ratios of 104 healthy men and 10 legs without aneurysm, contralateral to a popliteal aneurysm

<table>
<thead>
<tr>
<th>Artery</th>
<th>Normal</th>
<th>Contralateral to aneurysm</th>
<th>Significance (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA</td>
<td>9.3 ± 1.1</td>
<td>9.1 ± 0.9</td>
<td>NS</td>
</tr>
<tr>
<td>SFA</td>
<td>7.3 ± 1.0</td>
<td>7.5 ± 1.0</td>
<td>NS</td>
</tr>
<tr>
<td>PPOP</td>
<td>6.9 ± 0.9</td>
<td>7.5 ± 1.2</td>
<td>.04</td>
</tr>
<tr>
<td>MPOP</td>
<td>6.8 ± 0.8</td>
<td>8.1 ± 1.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>DPOP</td>
<td>4.9 ± 0.6</td>
<td>5.4 ± 0.7</td>
<td>.01</td>
</tr>
<tr>
<td>PPOP/SFA</td>
<td>0.95</td>
<td>1.0</td>
<td>.04</td>
</tr>
<tr>
<td>MPOP/SFA</td>
<td>0.94</td>
<td>1.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>DPOP/SFA</td>
<td>0.68</td>
<td>0.73</td>
<td>NS</td>
</tr>
</tbody>
</table>

CFA, common femoral; SFA, superficial femoral; PPOP, proximal popliteal; MPOP, mid-popliteal; DPOP, distal popliteal; NS, not significant.
The diameter of the normal popliteal artery was not uniform throughout the length of the artery. In both men and women, the PPOP and MPOP were almost identical, but the DPOP was significantly and consistently smaller. Most studies dealing with popliteal diameter report on one measurement, which probably corresponds to what we measured as MPOP. The normal size and the relative measurement, which probably corresponds to what we measured as MPOP. The normal size and the relative measurement, which probably corresponds to what we measured as MPOP. The normal size and the relative measurement, which probably corresponds to what we measured as MPOP. The normal size and the relative measurement, which probably corresponds to what we measured as MPOP. The normal size and the relative measurement, which probably corresponds to what we measured as MPOP.

Normal popliteal diameter has been found to correlate with age and BSA. We have found that the MPOP, PPOP, and DPOP did not correlate with age, but the study group is limited in this respect because we limited healthy subjects to age >50 years, and consequently, 70% of the study cohort were 60 to 80 years old. Popliteal diameters did not correlate with BSA either. Not unexpectedly, the best correlate of the MPOP was the SFA diameter.

The accepted definition of popliteal aneurysm is 1.5 to 2 cm. If the normal size of 9 mm is accepted, then 15 mm represents roughly a 50% increase. However, if normal size is much smaller, as others and we have found, then the definition of popliteal aneurysm should also be correspondingly smaller. Our measurements indicated a size of 10 mm represented a 50% increase from normal size, and we used this as a threshold for defining popliteal aneurysm. This definition has also been proposed by Morris-Stiff et al, based on similar findings and arguments.

Men comprise >95% of popliteal aneurysm patients. Our screening found only two popliteal aneurysms in women and therefore we limited our analysis of popliteal aneurysms to men. The region close to the MPOP was the segment most prone to dilate and was largest in 87% (39 of 45) of aneurysms. The MPOP region also exhibited the largest expansion in legs contralateral to a popliteal aneurysm. Indeed, this localized susceptibility toward dilatation may reflect the special wall properties of the artery at this level. For a single screening measurement, therefore, measurement close to the level of the MPOP will most commonly yield the largest aneurysm diameter.

The SFA was significantly enlarged in patients with popliteal artery aneurysm, but interestingly, was not significantly larger in legs contralateral to such an aneurysm. In popliteal aneurysms, even though the SFA was larger, the MPOP/SFA ratio was still significantly larger than normal. Because the discrepancy between the inflow artery (the SFA) and the popliteal aneurysm may be an important factor in the propensity towards thromboembolic complications, the MPOP/SFA ratio deserves further evaluation as a potential predictor of complications, in addition to single level diameter. We did not record the quantity of thrombus within the aneurysm or the number of patent crural arteries. Both of these may also prove to be predictors of popliteal aneurysm thrombosis.

When larger aneurysms (>20 mm) were compared with smaller ones (Table II), all three popliteal diameters increased significantly; however, the DPOP increased to the least extent (<1 mm in mean difference) and in only one case was it >10 mm. Because this is the distal landing zone for endovascular repair, its preservation is important and may imply that, in this regard, a large percentage of aneurysms may be anatomic candidates for such treatment.

**CONCLUSION**

The diameter of the normal popliteal artery is not uniform throughout its length. In popliteal aneurysms in men, the largest diameter is most commonly close to the level of the MPOP. The MPOP/SFA ratio is greater than normal and increases in larger aneurysms. The DPOP does dilate, but to a lesser extent than PPOP and MPOP regions, making endovascular repair anatomically feasible in most popliteal aneurysms.

**AUTHOR CONTRIBUTIONS**

Conception and design: Y.G.W, Zelmanovich, Z.V.K

Analysis and interpretation: Y.G.W, Zelmanovich, Z.V.K

Data collection: Zelmanovich, Z.V.K

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Critical revision of the article: Y.G.W, Zelmanovich

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Obtained funding: Y.G.W, Zelmanovich

Overall responsibility: Y.G.W

**REFERENCES**


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