

Location of the Neurovascular Bundle of the Knee during Flexed and Extended Position: An MRI Study

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Background: The popliteal vessels and nerve are the structures most at risk during surgery of the posterior knee compartment. Common procedures that could interfere with or otherwise affect these structures include synovectomy, meniscal repair, proximal tibial osteotomy, knee replacement and fixation around the knee joint. Magnetic resonance imaging (MRI) can be used to locate the neurovascular structures from the posterior bony landmark. MRI imaging is routinely studied in the extended knee, but surgery of the posterior knee compartment is most often performed with the knee in a flexed position.

Objective: The aim of this study was to investigate the location of the posterior neurovascular bundle relative to the posterior aspect of the femur, tibia, and posterior cruciate ligament during fully extended knee position and 90-degree flexed knee position using MRI.

Material and Method: MRI images of 26 knees were obtained from 25 patients. Ten left knees, 14 right knees, and 1 bilateral knees were obtained from 18 males and 7 females. Axial plane and sagittal plane studies were used to measure the shortest distance of the popliteal artery, popliteal vein, and tibial nerve to the posterior bony aspect of the knee and the posterior cruciate ligament using a digital ruler tool from the PACS X-ray system. Measurement was performed at joint line level, 1 cm above joint line level, and 1 cm below joint line level in the fully extended knee position and in the 90-degree flexed knee position. At the joint line level, the mediolateral distance of the popliteal artery, popliteal vein, and tibial nerve to the posterior cruciate ligament were also measured.

Results: At 1 cm above joint line level, mean anteroposterior (AP) distance from the distal femoral condyle to the popliteal artery, popliteal vein, and tibial nerve was 1.83 ± 3.35 mm, 6.44 ± 4.55 mm and 10.29 ± 4.41 mm for full knee extension, and 15.60 ± 5.01 mm, 20.63 ± 4.62 mm and 26.24 ± 7.70 mm for 90-degree knee flexion, respectively ($p < 0.001$). At joint line level, mean AP distance from the posterior tibial cortex to the popliteal artery, popliteal vein, and tibial nerve was 5.43 ± 3.22 mm, 8.75 ± 3.72 mm and 13.10 ± 4.15 mm for full knee extension, and 11.64 ± 5.48 mm, 17.59 ± 6.53 mm and 21.52 ± 10.67 mm for 90-degree knee flexion, respectively ($p < 0.001$). At 1 cm below joint line level, mean AP distance from the posterior tibial cortex to the popliteal artery, popliteal vein, and tibial nerve was 1.98 ± 1.95 mm, 4.26 ± 2.74 mm and 8.66 ± 3.85 mm for full knee extension, and 6.91 ± 2.86 mm, 12.34 ± 5.23 mm and 16.58 ± 9.22 mm for 90-degree knee flexion, respectively ($p < 0.001$). At joint line level, mean distance from the posterolateral border of the PCL to the popliteal artery, popliteal vein, and tibial nerve was 11.12 ± 2.62 mm, 11.30 ± 4.05 mm and 15.14 ± 5.05 mm for full knee extension, and 19.89 ± 5.67 mm, 23.87 ± 6.96 mm and 29.41 ± 10.72 mm for 90-degree knee flexion, respectively ($p < 0.001$).

Conclusion: During 90-degree knee flexion, the neurovascular structures move posterolaterally, as compared to fully extended knee position at joint line level and 1 cm above and below joint line level. To prevent neurovascular injury during surgery, surgeons should avoid or be cautious during blind penetration of the midline joint capsule and 90 degree flexed knee position increases the distance of the neurovascular bundle away from the posterior bony aspect.

Keywords: Popliteal artery, Popliteal vein, Arthroscopy, Knee, Magnetic resonance imaging

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Arthroscopic surgery via the posterior knee compartment is a common approach in procedures,

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such as repair of the posterior horn of the meniscus, posterior cruciate ligament reconstruction or fixation, and synovectomy in pigmented villonodular synovitis (PVNS). Vascular complication after knee arthroscopy is rarely reported, but may lead to severe morbidity including amputation⁽¹⁻³⁾. For open procedure, there are also reports of injury to the popliteal vessel during total knee replacement⁽⁴⁻⁶⁾ and high tibial

osteotomy⁽⁷⁻⁹⁾.

Due to the risk of neurovascular injury during knee surgery, the location of the popliteal artery has been studied using both ultrasonography and MRI^(10,11). Magnetic resonance imaging (MRI) is a valuable tool for identifying lesions of the knee that lie close to posterior neurovascular structures, and MRI may be used to prevent injury to these structures during surgery⁽¹⁰⁾. MRI imaging is routinely studied in the extended knee, but surgery of the posterior knee compartment is most often performed with the knee in a flexed position.

Flexed knee position during surgery might cause the popliteal artery to recede or fall back from the posterior bony aspect^(11,12). The popliteal vein and nerve are not well studied, especially relative to deviation in the mediolateral plane when the knee is flexed. Accordingly, the aim of this study was to investigate the location of the posterior neurovascular bundle relative to the posterior aspect of the femur, tibia, and posterior cruciate ligament in the fully extended knee position and in the 90-degree flexed knee position using MRI. Anteroposterior and mediolateral distances were measured at three different levels of the knee joint (i.e., joint-line level and 1 cm above and 1 cm below joint-line level).

Material and Method

This prospective study was conducted at Siriraj Hospital during 2012 study period. We obtained and reviewed MRI imaging of 26 knees from 25 patients. Ten left knees, 14 right knees, and 1 bilateral set of knees were obtained from 18 males and 7 females that had an overall average age of 31.80 ± 11.55 years (range: 16-56). All patients were sent for MRI due to suspected meniscus or cruciate ligament injuries. Patients with previous injury to the posterior knee compartment, posterior neurovascular structure, or posterior cruciate ligament were excluded. Axial plane and sagittal plane studies were used to measure the shortest distance from the popliteal artery, popliteal vein, and tibial nerve to the posterior bony structures using a digital ruler tool from the PACS X-ray system. Measurement was performed at the joint line level, 1 cm above the joint line level, and 1 cm below the joint line level during both knee extension and 90-degree knee flexion (Fig. 1). To determine the mediolateral location of the neurovascular bundle, we used the posterior cruciate ligament as a reference point at the joint line level. The closest distance of the popliteal artery, popliteal vein, and tibial nerve on the anteroposterior plane and

mediolateral plane to the posterior cruciate ligament were measured during full knee extension and 90-degree flexion (Fig.2, 3).

The protocol for this study was approved by the Siriraj Institutional Review Board (SIRB), Faculty

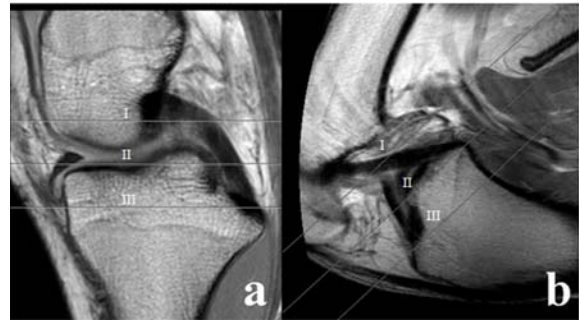


Fig. 1 Sagittal MRI of the knee during extension (a) and flexion (b); showing the measurement plane at 1 cm above joint line level (I), at joint line level (II) and at 1 cm below joint line level (III).

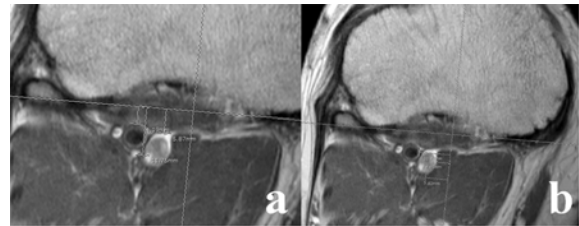


Fig. 2 (a) Axial MRI of the knee showing the anteroposterior distance of the popliteal artery, popliteal vein and tibial nerve to the posterior bony aspect at joint line level; (b) Axial MRI of the knee showing the mediolateral deviation of the popliteal artery, popliteal vein and tibial nerve to the PCL stump.

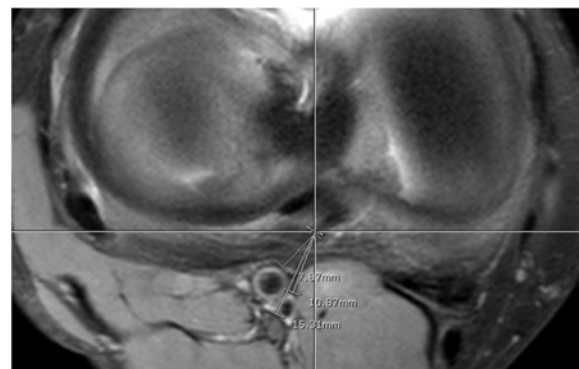


Fig. 3 Axial MRI of the knee showing the shortest distance of the neurovascular structures to the PCL stump.

of Medicine Siriraj Hospital, Mahidol University. Written informed consent was obtained from all study participants.

Statistical analysis

Data are described as mean \pm SD with 95% confidence intervals for mean to indicate statistical precision. Kolmogorov-Smirnov test was performed for testing normality of the distribution. To compare the difference between the two conditions, paired t-test and Wilcoxon Signed Rank test was used when appropriated. A *p*-value less than 0.05 was regarded as being statistically significant. All analyses were performed with the use of the SPSS version 18.0 (SPSS, Inc., Chicago, IL, USA).

Results

At 1 cm above the joint line level, the mean anteroposterior distance of the popliteal artery, popliteal vein, and tibial nerve to the posterior bony aspect in fully extended knee was 1.83 ± 3.35 mm, 6.44 ± 4.55 mm, and 10.29 ± 4.41 mm, respectively; while the same measurement with 90-degrees of knee flexion was 15.60 ± 5.01 mm, 20.63 ± 4.62 mm, and 26.24 ± 7.70 mm, respectively ($p < 0.001$). At 1 cm below joint line level, the mean anteroposterior distance of the popliteal artery, popliteal vein and tibial nerve to the posterior tibial border in fully extended knee was 1.98 ± 1.95 mm, 4.26 ± 2.74 mm and 8.66 ± 3.85 mm, respectively; while the same measurement with 90-degrees of knee flexion was 6.91 ± 2.86 mm, 12.34 ± 5.23 mm and 16.58 ± 9.22 mm, respectively. At the joint line level, the mean anteroposterior distance of the popliteal artery, popliteal vein, and tibial nerve to the posterior bony aspect in fully extended knee was 5.43 ± 3.22 mm, 8.75 ± 3.72 mm and 13.10 ± 4.15 mm, respectively; while the same measurement with 90-degrees of knee flexion was 11.64 ± 5.48 mm, 17.59 ± 6.53 mm and 21.56 ± 10.67 mm, respectively ($p < 0.001$).

The mean anteroposterior distance of the popliteal artery, popliteal vein, and tibial nerve to the posterior cruciate ligament in fully extended knee was 11.12 ± 2.62 mm, 11.30 ± 4.05 mm and 15.14 ± 5.05 mm, respectively; while the same measurement with 90-degrees of knee flexion was 19.89 ± 5.67 mm, 23.87 ± 6.96 mm and 29.41 ± 10.72 mm, respectively ($p < 0.001$). The mean mediolateral distance of the popliteal artery, popliteal vein and tibial nerve to the posterior cruciate ligament in full knee extension was 6.86 ± 3.51 mm, 4.28 ± 4.37 mm, 4.90 ± 4.99 mm, respectively; while the same measurement with 90-

degrees of knee flexion was 9.22 ± 5.51 mm, 8.08 ± 5.92 mm and 13.12 ± 6.61 mm, respectively ($p < 0.001$) (Table 1). For the mediolateral distance of the neurovascular bundle to the PCL, all 3 structures were positioned laterally to the PCL, except in 2 patients who had the popliteal artery located 3.35 mm and 5.18 mm medial to the PCL during 90-degrees of knee flexion.

Discussion

After exiting from Hunter's canal, the popliteal artery runs downward and laterally to the femoral intercondyloid fossa, and then continues to the lower border of the popliteus muscle. The popliteal vein runs alongside the popliteal artery; however, our study found more than one branch of the popliteal vein at the levels being studied. The tibial nerve emerges from the sciatic nerve at the dorsal part of the thigh after innervating the medial hamstring and then enters the popliteal fossa in the dorsal area of the popliteal vessels.

The distance from the popliteal artery to the posterior aspect of the tibia increased with progression of knee flexion; thus, flexed knee position is recommended to reduce the risk of popliteal artery injury during surgery of the posterior knee compartment⁽¹¹⁻¹⁴⁾. Using ultrasonography, Eriksson, et al reported non-significant distance change during knee flexion in osteoarthritic knee⁽¹⁵⁾. Zaidi et al studied the distance of the popliteal artery to the posterior tibial border at 1.5 cm below the joint line using ultrasonography. In 12 knees (60%), they found that the AP distance moved closer to the tibia at 90° of flexion⁽¹⁶⁾. Shetty et al reported variation in high-branching anterior tibial artery that was positioned close to the AP and that moved towards the posterior tibial surface in 6% of subjects⁽¹⁷⁾. The findings of our study show that the popliteal artery, the popliteal vein, and the tibial nerve all move away from the posterior bony aspect during knee flexion on all 3 studied planes.

To protect posterior neurovascular structures during arthroscopic surgery, the working area should remain as close to the posterior bony aspect as possible and penetration of the posterior joint capsule should be avoided. The anatomical structure of most concern is the popliteal artery, because it lies closer to the posterior bony aspect than the popliteal vein and popliteal nerve. Procedures in which the needle or implant needs to pass outside the joint (e.g., meniscus repair), the location of the structure in mediolateral distance should be concern. Keser et al reported that the popliteal artery was located lateral to the central axis in 94.3% of cases and lateral to the central axis in

Table 1. Distance of neurovascular structures to the posterior bony aspect

	Popliteal artery			Popliteal vein			Tibial nerve		
	Extension (n = 26)	Flexion (n = 26)	p-value	Extension (n = 26)	Flexion (n = 26)	p-value	Extension (n = 26)	Flexion (n = 26)	p-value
1 cm above joint line (mm)									
Mean (SD)	1.83 (3.35)	15.60 (5.01)	<0.001	6.44 (4.55)	20.63 (4.62)	<0.001	10.29 (4.41)	26.24 (7.70)	<0.001
95% CI	0.48, 3.18	13.58, 17.62		4.60, 8.27	18.76, 22.49		8.51, 12.07	23.13, 29.35	
Joint line level (mm)									
Anteroposterior									
Mean (SD)	5.43 (3.22)	11.64 (5.48)	<0.001	8.75 (3.72)	17.59 (6.53)	<0.001	13.10 (4.15)	21.52 (10.67)	<0.001
95% CI	4.13, 6.73	9.42, 13.85		7.24, 10.25	14.96, 20.23		11.43, 14.78	17.21, 25.83	
Length to PCL									
Mean (SD)	11.12 (2.62)	19.89 (5.67)	<0.001	11.30 (4.05)	23.87 (6.96)	<0.001	15.14 (5.05)	29.41 (10.72)	<0.001
95% CI	10.06, 12.18	17.60, 22.17		9.66, 12.93	21.06, 26.68		13.10, 17.18	25.08, 33.74	
Mediolateral distance to PCL									
Mean (SD)	6.86 (3.51)	9.22 (5.51)	0.030	4.28 (4.37)	8.08 (5.92)	0.002	4.90 (4.99)	13.12 (6.61)	<0.001
95% CI	5.44, 8.28	6.99, 11.44		2.52, 6.04	5.69, 10.47		2.89, 6.92	10.45, 15.79	
1 cm below joint line level (mm)									
Mean (SD)	1.98 (1.95)	6.91 (2.86)	<0.001	4.26 (2.74)	12.34 (5.23)	<0.001	8.66 (3.85)	16.58 (9.22)	<0.001
95% CI	1.19, 2.77	5.76, 8.06		3.15, 5.36	10.23, 14.46		7.11, 10.22	12.86, 20.31	

5.7% of cases; however, none were found on the medial side of the central axis⁽¹⁰⁾. In the present study, we found the popliteal artery positioned medial to the posterior cruciate ligament in 2 cases (8%; 2 of 25). Moreover, the mean mediolateral distance of the popliteal nerve lies 3.9 mm more medial, as compared to the popliteal artery. Thus, blind penetration of the posterior joint capsule during all inside meniscal repair should be performed with caution.

Conclusion

During 90-degree knee flexion, the neurovascular structures move posterolaterally, as compared to fully extended knee position at joint line level and 1 cm above and below joint line level. To prevent neurovascular injury during surgery, surgeons should avoid or be cautious during blind penetration of the midline joint capsule, and they should be aware that 90-degree flexed knee position increases the distance of the neurovascular bundle away from the posterior bony aspect.

What is already known this topic?

First, the popliteal artery of the knee joint moves away during knee flexion as reported in literatures while the other mentioned the fallen back vessel during knee flexion is not significant. Second, the popliteal artery could be found from the midline of the knee toward lateral side.

What this study adds?

First, this study confirms the fallen back of the popliteal artery during knee flexion. Second, the same finding could be applied to the popliteal veins and nerve. Third, the location of the popliteal artery is varied. In some subject, the popliteal artery could be found medial to the midline of the knee joint.

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This was an unfunded study.

Potential conflicts of interest

None.

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การศึกษาตำแหน่งของหลอดเลือดและเส้นประสาทบริเวณแอ่งข้อพับของเข่าด้วย MRI ในท่าเข่าเหยียดและเข่างอ

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ภูมิหลัง: การผ่าตัดซ่อมเอ็นไขว้หลังหรือการผ่าตัดจัดแนวกระดูกหัวเข่า (High Tibial Osteotomy) โดยทั่วไปมีโอกาสเกิดการบาดเจ็บต่อหลอดเลือดและเส้นประสาทบริเวณแอ่งข้อพับหลังข้อเข่า (Popliteal fossa) ได้การตรวจด้วย MRI (การสร้างภาพด้วยเรโซแนนซ์แม่เหล็ก) ในท่างอและเหยียดเข่าจะสามารถบอกตำแหน่งของหลอดเลือดและเส้นประสาทบริเวณแอ่งข้อพับเทียบกับอวัยวะข้างเคียงได้อย่างแม่นยำ และเพื่อเป็นแนวทางในการป้องกันการบาดเจ็บของหลอดเลือดและเส้นประสาทบริเวณแอ่งข้อพับได้ดียิ่งขึ้น

วัตถุประสงค์: เพื่อหาตำแหน่งหลอดเลือดและเส้นประสาทบริเวณแอ่งข้อพับของเข่าด้วย MRI ในท่าเข่าเหยียดและเข่างอ 90 องศา

วัสดุและวิธีการ: การศึกษาไปข้างหน้าผู้ป่วยจำนวน 25 ราย เป็นเพศชาย 18 คน เพศหญิง 7 คน ที่ได้รับการตรวจ MRI จำนวน 26 เข่า เป็นเข่าซ้าย 10 เข่า เข่าขวา 14 เข่า และมีผู้ป่วย 1 รายที่ได้รับการตรวจด้วย MRI ทั้งสองเข่า ระยะที่สั้นที่สุดจากหลอดเลือดปอปปี้เตียล อาร์เทอร์รี่ (Popliteal Artery) ปอปปี้เตียล เวน (Popliteal Vein) และ ทิเบียล เนิร์ฟ (Tibial Nerve) ถึงกระดูกส่วนหลังของเข่า และเอ็นไขว้หลัง ถูกวัดด้วยดิจิทัลออร์เทอร์ของระบบ PACS X-ray ทั้งในแนวแอกเซียลเพลน (Axial plane) และแนวซาคิตัลเพลน (Sagittal plane) โดยวัด 3 ตำแหน่ง คือ ตำแหน่งจอยท์ไลน์ เหนือจอยท์ไลน์ 1 เซนติเมตร และต่ำกว่าจอยท์ไลน์ 1 เซนติเมตร ทั้งในท่าเหยียดเข่าเต็มที่และเข่างอ 90 องศา

ผลการศึกษา: ที่ตำแหน่ง 1 เซนติเมตรเหนือจอยท์ไลน์ในท่าเหยียดเข่าเต็มที่ ระยะจากติสทอลพีเอนอร์รอลคอนไคล์ (Distal Femoral condyle) ถึง หลอดเลือดปอปปี้เตียล อาร์เทอร์รี่ (Popliteal Artery) ปอปปี้เตียล เวน (Popliteal Vein) และ ทิเบียล เนิร์ฟ (Tibial Nerve) คือ 1.83 ± 3.35 มิลลิเมตร, 6.44 ± 4.55 มิลลิเมตร และ 10.29 ± 4.41 มิลลิเมตร ตามลำดับ เมื่อเทียบกับท่างอเข่า 90 องศา ระยะห่างคือ 15.60 ± 5.01 มิลลิเมตร, 20.63 ± 4.62 มิลลิเมตร และ 26.24 ± 7.70 มิลลิเมตร ตามลำดับ แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.001$) ที่ตำแหน่งจอยท์ไลน์ในท่าเหยียดเข่าเต็มที่ระยะจากโพสทีเรียร์ ทิเบียล คอร์เทกซ์ (Posterior Tibial cortex) ถึงหลอดเลือดปอปปี้เตียล อาร์เทอร์รี่ (Popliteal Artery) ปอปปี้เตียล เวน (Popliteal Vein) และ ทิเบียล เนิร์ฟ (Tibial Nerve) คือ 5.43 ± 3.22 มิลลิเมตร, 8.75 ± 3.72 มิลลิเมตร และ 13.10 ± 4.15 มิลลิเมตร ตามลำดับ เมื่อเทียบกับท่างอเข่า 90 องศา ระยะห่างคือ 11.64 ± 5.48 มิลลิเมตร, 17.59 ± 6.53 มิลลิเมตร และ 21.52 ± 10.67 มิลลิเมตร แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.001$) ที่ตำแหน่ง 1 เซนติเมตรต่ำกว่าจอยท์ไลน์ในท่าเหยียดเข่าเต็มที่ระยะจากโพสทีเรียร์ ทิเบียล คอร์เทกซ์ (Posterior Tibial cortex) ถึงหลอดเลือดปอปปี้เตียล อาร์เทอร์รี่ (Popliteal Artery) ปอปปี้เตียล เวน (Popliteal Vein) และ ทิเบียล เนิร์ฟ (Tibial Nerve) คือ 1.98 ± 1.95 มิลลิเมตร, 4.26 ± 2.74 มิลลิเมตร และ 8.66 ± 3.85 มิลลิเมตรตามลำดับ เมื่อเทียบกับท่างอเข่า 90 องศา ระยะห่างคือ 6.91 ± 2.86 มิลลิเมตร, 12.34 ± 5.23 มิลลิเมตร และ 16.58 ± 9.22 มิลลิเมตร แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.001$) ที่ตำแหน่งจอยท์ไลน์ในท่าเหยียดเข่าเต็มที่ระยะจากโพสทีเรียร์แลทเทอร์รอลของเอ็นไขว้หลัง (Posterolateral border PCL) ถึงหลอดเลือดปอปปี้เตียล อาร์เทอร์รี่ (Popliteal Artery) ปอปปี้เตียล เวน (Popliteal Vein) และ ทิเบียล เนิร์ฟ (Tibial Nerve) คือ 11.12 ± 2.62 มิลลิเมตร, 11.30 ± 4.05 มิลลิเมตร และ 15.14 ± 5.05 มิลลิเมตร ตามลำดับ เมื่อเทียบกับท่างอเข่า 90 องศา ระยะห่างคือ 19.89 ± 5.67 มิลลิเมตร, 23.87 ± 6.96 มิลลิเมตร และ 29.41 ± 10.72 มิลลิเมตร ตามลำดับ แตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.001$)

สรุป: ทำงอเข้า 90 องศา หลอดเลือดและเส้นประสาทมีการเคลื่อนไปทางด้านหลังและด้านข้างมากกว่าทำเหยียดเข้าเต็มที่ในทุกตำแหน่งของกรวัด เพื่อป้องกันการบาดเจ็บต่อหลอดเลือด เส้นประสาทที่บริเวณข้อเข่า การผ่าตัดในทำงอเข้า 90 องศาจะปลอดภัยกว่า
