Risk of Vascular Injury at the Proximal Tibia for Medial Narrow Locking Plate Fixation: An Anatomical Study Using CT Angiogram

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Objective: *To evaluate possibility of screw-related vascular injury at proximal tibia while using medial narrow tibial locking plate.*

Material and Method: *Cross-sectional images of CT angiographs (33 samples) at levels corresponding with the screw holes of a narrow locking plate were used to evaluate the risk of vascular injury relating to screw insertion. This was performed by measuring the distance and angle between the screw trajectory in each hole and the columns of arteries at the proximal tibia.*

Results: *There is a higher risk of injury to the anterior tibial artery than to the posterior tibial artery in cases of perfect placement of a medial locking plate for osteosynthesis of the tibial shaft fracture. In instance of plate tilting, thus causing a deviation of screw trajectory of up to 20 degrees from the perpendicular axis of the middle 1/3 of medial tibial surface, the posterior tibial artery is also at risk of being injured.*

Conclusion: *Vascular injury relating to locking screw insertion from the medial aspect of the tibia is still a risk. To prevent vascular injury, the plate should be positioned in the middle 1/3 and parallel to the medial tibial surface. Attachment of the instrument beyond the far cortex of the tibia still presents a risk of injuring the tibial artery.*

Keywords: *Vascular injury, Tibia, Fracture, Locking plate, Anatomy*

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The use of locking plates has recently gained more popularity in many fields of ostheosynthesis, especially in osteoporosis. This implant provides angular stability for fracture fixation due to locking mechanism that is located between the screw and the plate. As a result, screw toggling can be eliminated and screw loosening can be minimized. However, screw-related complications, including vascular injury present be a factor of concern as a result of fix-angled screw insertion[1,2]. The trajectory of the drill bit and the screw insertion are normally controlled by the location and angle of plate placement. This potential risk might be increased in the case of minimally invasive plate ostheosynthesis (MIPO) with a limitation of surgical exposure and incorrect positioning of the plate. This study was conducted to demonstrate the position at risk for vascular injury when performing locking plate osteosynthesis at the medial surface of tibia.

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Material and Method

CT angiographs of the adult leg (age more than 15 years) taken between January 2006 and March 2012 were retrieved from the Department of Radiology, Faculty of Medicine Siriraj Hospital, Mahidol University. Cases with deformity or previous fracture of the femur or tibia, vascular disease or abnormality, soft tissue infection, and tumor were excluded from this study. Cross-sectional images at levels corresponding with the screw holes of the narrow locking plate (Synthes, Switzerland) were selected for date collection, starting from the tibial tubercle all the way down to 14 cm distally.

In each image, the middle 1/3 of the medial surface of the tibia (by measuring the width and deduct the lateral 2/3 of the width by mathematical calculation) was determined as the location for plate placement. Therefore, the mid-position of this area was used as a starting point to draw the trajectory of locking screw insertion (Fig. 1). "Work station" version 4.2 was used for parameter measurements. The closest distance between the trajectory of the locking screw and the

outer surface of the anterior and posterior tibial artery (SA distance) (Fig. 2) was measured as the first parameter in every 2 centimeters from the tibial tubercle representing the screw holes of a narrow locking plate. The second parameter was angle deviation between the screw trajectory and the outer surface of the arteries (SA angle) (Fig. 2). The last parameter was the shortest distance between the tibial cortex and the arteries.

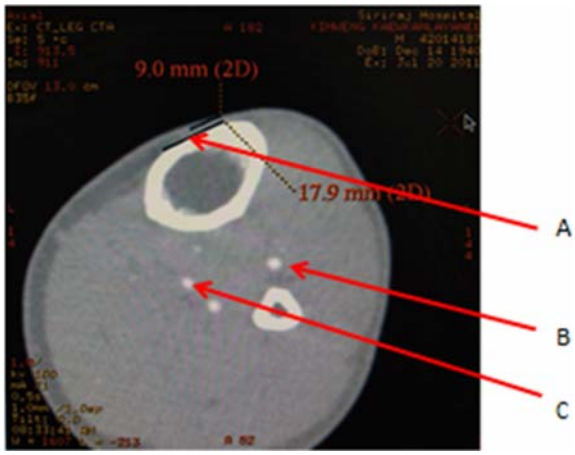

Fig. 1 Demonstration of a cross sectional CT angiography of the tibia: (A) middle of the medial surface of the tibia, (B) anterior tibial artery, (C) posterior tibial artery.

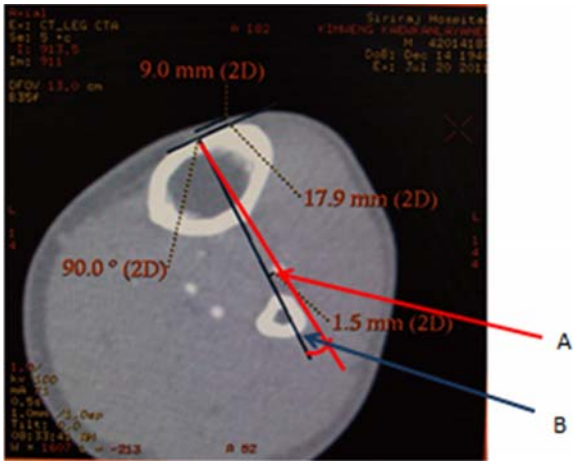

Fig. 2 Demonstration of the measurement of each parameter: (A) distance between the tibial artery and perpendicular line of the medial tibial surface (SA distance of anterior tibial artery), (B) the angle between the tibial artery and perpendicular line of the medial tibial surface (SA angle of anterior tibial artery).

Results

Thirty-three CT angiographs were included in this study. The anterior tibial artery and posterior tibial artery were found in all cases. Both arteries originated from the popliteal artery in which the origin was located below 20 mm from tibial tubercle. All angiographic images have enough intensity of the contrast media to identify the anterior tibial and posterior tibial arteries. There was no abnormal shape or size of the anterior or posterior tibial arteries in any of the specimens. The frequency of specimens categorized into three different groups of SA distance of anterior tibial artery is shown in Table 1. The frequency of specimens categorized into three different groups of SA distance of posterior tibial artery is shown in Table 2. The frequency of the specimens in Group A (distance of expected screw trajectory to the anterior tibial artery, SA distance, Table 1) as compared to Group A of posterior tibial artery show a big difference in the number at risk. The sample in Group A of SA distance of anterior tibial artery shows 37% (77 of 207) of the overall sample at risk of injury. A deviation of more than 2 mm of the screws, that intent to apply, could injure the anterior tibial artery in 37% of cases. Contrary to the risk of injury to the posterior tibial artery in malangulated screw insertion, it had no chance to injure even if the arch of screw displacement were 2 mm.

The frequency of specimens in Group A of SA angle below 5 degrees (Tables 3, 4) illustrates the high-risk of arterial injury only in the anterior tibial artery. The sample at risk of anterior tibial artery injury, which could hit by the expected screw in combination with locking plate applied, was 30% (63 in 207). As for posterior tibial artery injury, there was no risk if the expected screw trajectory was within 5 degrees deviation.

Discussion

The accuracy of screw placement plays an important role in determining the risk of vascular injury, especially the anterior tibial artery. At least one-third of the minimal screw mal-position could cause anterior tibial artery injury. Further, a greater degree of screw mal-position could cause two-thirds of vascular injury in relation to the anterior tibial artery. Contrary to the posterior tibial artery, the injury could occur mostly from greater degree of deviation form expected trajectory. A deviation greater than 20 degrees could hit the posterior tibial artery.

The distance from the cortex of the tibia to the anterior tibial artery ranges from 5.46 to16.17 mm in the

Table 1. SA distance of anterior tibial artery

Distance from tibial tuberosity (mm)	Group A (SA distance <2mm)	Group B (SA distance 2-10 mm)	Group C (SA distance >10 mm)
0	-	-	-
20	5/15	10/15	-
40	11/32	20/32	1/32
60	10/32	21/32	1/32
80	11/32	21/32	-
100	13/32	19/32	-
120	14/32	18/32	-
140	13/32	19/32	-

Table 2. SA distance of posterior tibial artery

Distance from tibial tuberosity (mm)	Group A (SA distance <2mm)	Group B (SA distance 2-10 mm)	Group C (SA distance >10 mm)
0	-	-	-
20	-	1/4	3/4
40	-	2/10	8/10
60	-	4/29	25/29
80	-	2/32	30/32
100	-	-	32/32
120	-	-	32/32
140	-	-	32/32

Table 3. SA angle of anterior tibial artery

Distance from tibial tuberosity (mm)	Group A (SA angle <5 degree)	Group B (SA angle 5-20 degree)	Group C (SA angle >20 degree)
0	-	-	-
20	4/15	11/15	-
40	9/32	23/32	-
60	9/32	23/32	-
80	10/32	22/32	-
100	10/32	21/32	1/32
120	12/32	20/32	-
140	9/32	22/32	1/32

group of SA angle less than 5 degree. The distance from the cortex of the tibia to the posterior tibial artery can be measured only in group SA angle 5-20 degree as a result of there not being any cases in group SA angle of less than 5 degree. A distance range from 5.05 to 20.35 mm was the range of the tibia cortex to the posterior tibial artery. The range of the distance between the posterior tibial artery and the tibial cortex results in a lower risk of injury as compared to anterior tibial artery distance.

The expected position and location of the plate (mid-tibia) that will apply for treatment of the proximal tibial fracture can cause injury to the vessel, as shown in the results. The deviation of the expected plate position will deter the results which the authors could not apply to the present study. The deviation of the screw from the mid position of plate can only define the risk of the injury from this study. The plate corresponds to the distance of 20 mm in each screw hole has several manufacturers. The locking plate that

Table 4. SA angle of posterior tibial artery

Distance from tibial tuberosity (mm)	Group A (SA angle <5 degree)	Group B (SA angle 5-20 degree)	Group C (SA angle >20 degrees)
0	-	-	-
20	-	3/4	¼
40	-	6/10	4/10
60	-	4/29	25/29
80	-	1/32	31/32
100	-	-	32/32
140	-	-	32/32

Table 5. 95% confidence interval of distance from anterior tibial artery to tibial cortex

Distance from tibial tuberosity (mm)	Group 1 (SA angle <5 degree)	Group 2 (SA angle 5-20 degree)
0	-	-
20	6.93-12.72	9.27-13.22
40	11.61-16.17	10.65-13.31
60	9.44-14.83	12.22-14.36
80	9.84-14.78	12.81-14.19
100	8.97-13.60	12.17-14.23
120	7.91-12.37	10.66-12.52
140	5.46-8.81	8.97-11.29

Table 6. 95% confidence interval of distance from posterior tibial artery to tibial cortex

Distance from tibial tuberosity (mm)	Group 1 (SA angle <5 degree)	Group 2 (SA angle 5-20 degree)
0	-	-
20	-	5.05-20.35
40	-	9.53-15.33
60	-	5.12-16.53
80	-	-
100	-	-
120	-	-
140	-	-

we intend to apply in this study was a narrow straight locking plate. The first hole for locking screw application will have the risk to injure the artery corresponding to the location of the Steinman pin application for skeletal traction[3]. The locking plate application on the lateral side also presents a risk of injury the popliteal artery. The risk increased in 6 of 6 specimens when using a 4.5 mm plate[4]. Medial application can also injure the popliteal artery on the level of the tibial tubercle, next to which the popliteal artery is situated. The branching pattern of the popliteal artery was also a condition potentially causing injury to the vessel. But the normal branching pattern was found in 89.2% of cases[5], which should be considered. Abnormal branching, like trifurcation, high division of popliteal artery and hypoplastic of branching, was still found in 10.8% of cases[5].

The increase in the popularity of fixation at the proximal tibial fracture by subcutaneous applying plate was also one of the risks for plate mal-positioning[6]. The application of the plate with fluoroscopic guidance still shows some deviation of the plate position. The expected plate location, facilitated by fluoroscopic guidance, has to be verified before insertion of the screws to avoid tibial artery injury. The less invasive stabilization system (LISS) has also been adapted for use in proximial tibial fractures[7]. The location of plate application was

dependent on the fracture configuration. The LISS also has an aiming device for screw fixation, but the distance of the screw holes did not correspond to this study. In order to avoid anterior and posterior tibial injury, physicians should only apply the plate at the mid point of the medial surface of the tibia. Furthermore, screw length and trajectory should be accurately determined, with no deviation for either. There are several treatments and techniques for the fixation of proximal tibial fracture. Thus, the treatment outcomes depend on the type of treatment and the nature of the fracture[8-12]. Failure of fixation also occurs sometimes after the intent plate and screws fixation was applied. The initial complication from the intent plate and screws position in order to get secure fixation should has to weight with the stability of construct[13]. The more secure will have more risk to injure a vulnerable structure. Optimal plate and screws fixation, in combination with the bone quality itself, will allow us to achieve secure fixation. The degree of success will largely depend on the choice of treatment for each diagnosis.

Conclusion

Vascular injury resulting from locking screw insertion from the medial aspect of the tibia is still a risk. To prevent vascular injury, the plate should be positioned in the middle 1/3 and parallel to the medial tibial surface. The drill bit should be stopped immediately after perforating the far cortex. The length of the screw must be accurately determined; the insertion of screws exceeding the determined accurate length must be avoided.

Potential conflicts of interest

None.

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ความเสี่ยงต่อการบาดเจ็บของหลอดเลือดจากการดามกระดูกหน้าแข้งส่วนต้นด้วยแผ่นดามกระดูกชนิดที่สกรูยึดตรึงกับแผ่นดาม: การศึกษาทางกายวิภาคจากภาพถ่ายรังสีส่วนตัดอาศัยคอมพิวเตอร์ทางหลอดเลือด

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วัตถุประสงค์: เพื่อศึกษาความเสี่ยงต่อการบาดเจ็บของหลอดเลือดจากการดามกระดูกหน้าแข้งส่วนต้น ด้วยแผ่นดามกระดูกชนิดที่สกรูยึดตรึงกับแผ่นดาม โดยศึกษาจากลักษณะทางกายวิภาคที่ปรากฏบนภาพถ่ายรังสีส่วนตัดอาศัยคอมพิวเตอร์ทางหลอดเลือด

วัสดุและวิธีการ: ภาพตัดขวางจากภาพถ่ายรังสีส่วนตัดอาศัยคอมพิวเตอร์ทางหลอดเลือดของกระดูกหน้าแข้งส่วนต้น ในระดับเดียวกับรูสกรูบนแผ่นดามโลหะกระดูกถูกนำมาศึกษาโดยการวัดระยะห่างและมุมเบี่ยงเบนระหว่างแนวของสกรูที่จะใส่กับตำแหน่งของหลอดเลือดแดงด้านหน้าและด้านหลังกระดูกหน้าแข้ง

ผลการศึกษา: หลอดเลือดแดงด้านหน้าของกระดูกหน้าแข้งมีความเสี่ยงที่จะได้รับบาดเจ็บจากการใส่สกรูผ่านโลหะดามชนิดที่สกรูยึดตรึงกับแผ่นดามได้มากกว่าหลอดเลือดแดงส่วนหลังหน้าแข้ง แต่กรณีที่การใส่สกรูมีมุมเอียงที่เบี่ยงเบนไปในช่วง 5 ถึง 20 องศา จะมีความเสี่ยงต่อการบาดเจ็บของหลอดเลือดแดงส่วนหลังหน้าแข้งเพิ่มมากขึ้น

สรุป: การใส่สกรูผ่านแผ่นโลหะดามกระดูกชนิดที่สกรูยึดตรึงกับแผ่นดามได้ อาจมีความเสี่ยงต่อการบาดเจ็บของหลอดเลือดแดงด้านหน้าของกระดูกหน้าแข้งได้ เพื่อลดโอกาสการเกิดภาวะแทรกซ้อนนี้ส่วนเจาะกระดูกควรต้องหยุดทันทีหลังทะลุกระดูกแล้วและการวัดความยาวสกรูต้องทำด้วยความระมัดระวังเพื่อหลีกเลี่ยงการใส่สกรูที่ยาวเกินไป