From the New England Society for Vascular Surgery

The radiographic relationship of the femoral head, inguinal ligament, and common femoral artery bifurcation for optimal vascular access

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ABSTRACT

Objective: Common femoral artery (CFA) access is commonly used for endovascular interventions. Access site complications contribute to significant morbidity and mortality. This study characterizes the radiographic variability in the relationship of the femoral head, the inguinal ligament, and the CFA bifurcation, to identify the zone of optimal CFA access.

Methods: Human cadaver dissection of the inguinal ligament and CFA bifurcation was performed. The inguinal ligament and CFA bifurcation were marked with radiopaque pins and plain anteroposterior radiographs were obtained. Radiographic measurements of the femoral head length, the distance of the top of the femoral head to the inguinal ligament, and to the CFA bifurcation were obtained. Results were reported as percentage of femoral head covered by the inguinal ligament or the CFA bifurcation relative to the top of the femoral head. A heatmap was derived to determine a safe access zone between the inguinal ligament and CFA bifurcation.

Results: Forty-five groin dissections (male, n = 20; female, n = 25) were performed in 26 cadavers. The mean overlap of the inguinal ligament with the femoral head was 11.2 mm (range, −19.4 to 27.4 mm). There were no age (<85 vs ≥85 years) or sex-related differences. In 82.6% of cadaveric CFA exposures, there was overlap between the inguinal ligament and femoral head (mean, 27.7%; range, −85.7% to 70.1%), with 55.6% having a >25% overlap. In 11.1%, there was an overlap between the lower one-third of the femoral head and the CFA bifurcation. Cumulatively, heatmap analysis depicted a >80% likelihood of avoiding the inguinal ligament and CFA bifurcation below the midpoint of the femoral head.

Conclusions: Significant variability exists in the relationship between the inguinal ligament, CFA bifurcation, and the femoral head, suggesting the lack of a consistently safe access zone. The safest access zone in >80% of patients lies below the radiographic midpoint of the femoral head and the inferior aspect of the femoral head. (JVS—Vascular Science 2024;5:100196.)

Clinical Relevance: The primary site of access for percutaneous endovascular arterial interventions across multiple specialties remains the common femoral artery. Although femoral artery access is most commonly safe, access-related complications such as retroperitoneal hemorrhage, pseudoaneurysms, or arteriovenous fistulae can contribute to significant morbidity and mortality. Through cadaver dissection, this study highlights significant variability in the relationship between the inguinal ligament, the femoral head, and the common femoral artery bifurcation. The optimal zone of access overlies the lower one-half of the femoral head in most cases.

Keywords: Common femoral artery; Inguinal ligament

The common femoral artery (CFA) remains the main stay of arterial access and is the gateway for percutaneous endovascular interventions across various arterial beds.[1,2] But access-related complications, such as retroperitoneal hemorrhage, pseudoaneurysms, or arteriovenous fistulae, contribute to significant morbidity and mortality associated with these procedures.[3] The widespread availability of access closure devices has increased vascular

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specialists' comfort with femoral arterial access. However, the relationship between the anatomic landmarks in the femoral triangle impacts the safety of percutaneous femoral access and could lead to closure device failure and subsequent hemorrhage.

Several researchers have attempted to identify the ideal puncture site over the CFA through radiographic studies.[4-7] However, the inguinal ligament and the variability of its position compared with the femoral head has not been well-characterized. Access through the inguinal ligament can lead to failure of closure devices because of the tough nature of the ligament fibers. Moreover, bleeding from an arteriotomy created with access through the inguinal ligament can be concealed on physical exam as blood tends to be accumulate in the retroperitoneum, which can accommodate a large volume, and the bleeding patient does not typically develop a groin hematoma. Even though the traditional teaching is to confirm that the puncture site is radiographically anterior to the femoral head to facilitate manual pressure when needed, the position of the inguinal ligament over the femoral head remains elusive and is not easily identifiable radiographically or with the use of ultrasound. In this context, this study aimed to characterize the radiographic relationship between the inguinal ligament, the CFA bifurcation, and the femoral head, to identify the zone of optimal CFA access.

ARTICLE HIGHLIGHTS

- **Type of Research:** Cadaveric dissections of the femoral triangle combined with fluoroscopy of the cadavers
- **Key Findings:** There were 45 femoral artery dissections (male, n = 20; female, n = 25) performed in 26 cadavers. In 82.6% of cadaveric exposures, the inguinal ligament crossed anterior to and covered a percentage of the femoral head (mean coverage, 28%). In more than one-half of the groins dissected (55.6%), there was more than 25% overlap of the inguinal ligament over the femoral head. A heatmap analysis depicted >80% likelihood of optimal access avoiding the inguinal ligament and the common femoral artery bifurcation inferior to the midpoint of the femoral head.
- **Take Home Message:** Significant variation exists in the relationship between the inguinal ligament, the femoral head, and the common femoral artery bifurcation. The optimal zone of access overlies the lower one-half of the femoral head in most cases.

METHODS

Study design. Post-mortem cadaveric dissections were performed for bilateral groins in 26 human cadavers in the anatomy laboratory of Yale School of Medicine. The dissection involved identification of the inguinal ligament and skeletonization of the CFA to the bifurcation into the superficial femoral artery and the profunda femoral artery (Fig 1, *A*). Radiopaque pins were then placed to mark the lower end of the inguinal ligament at the level of the femoral head and the bifurcation of the CFA (Fig 1, *B*). In addition, a radio-opaque ruler was placed next to the femoral head to allow for accurate measurements. Next, a portable fluoroscopic machine was brought to the cadaver laboratory, and plain anteroposterior radiographs were then taken of the dissected groins (Fig 2). As the study was conducted after medical students had completed the anatomy course, cadavers where the groin anatomy was distorted from prior dissection were not included. The dissections were performed during the COVID-19 pandemic where large groups of students in anatomy classes were restricted. Thus, most of the groins of cadavers included in this study were dissected by the research team.

Radiographic analysis. The superior aspect (top) of the femoral head was used a zero coordinate for all measurements. The coordinates were positive if they were inferior/caudad to the top of the femoral head and were negative if they were cephalad/superior to it. All measurements were recorded in millimeters. With the top of the femoral head as a reference point, distance to the bottom of the inguinal ligament (distance 1) and distance to the CFA bifurcation (distance 2) were measured. The length of the femoral head from top to the bottom of the femoral head (distance 3) was also derived. As such, if the inguinal ligament was superior to the top of the femoral head, then distance 1 was a negative measurement. Next, the percentage of overlap over the femoral head was calculated with respect to the total length of the femoral head in each groin dissected (distance 3) (Fig 2). All radiographic measurements were made in Visage (Visage Imaging, Inc).

Determination of the optimal access zone. The optimal zone of access was determined as being over the femoral head, inferior to the inguinal ligament but superior to the CFA bifurcation. A heatmap was derived to identify the zone over the femoral head where a puncture for access is most likely to be in the optimal zone. As shown in Fig 3, the zone between 60% and 90% of the femoral head has more than an 80% chance to be in the optimal zone of access between the inguinal ligament and the CFA bifurcation. On the other hand, staying below the middle point of the femoral head has 65% chance of having access in the optimal zone. Thus, for practical reasons, we considered that staying below the midpoint of the femoral head would probably be the safest approach to avoid access through the inguinal ligament or below the CFA bifurcation.

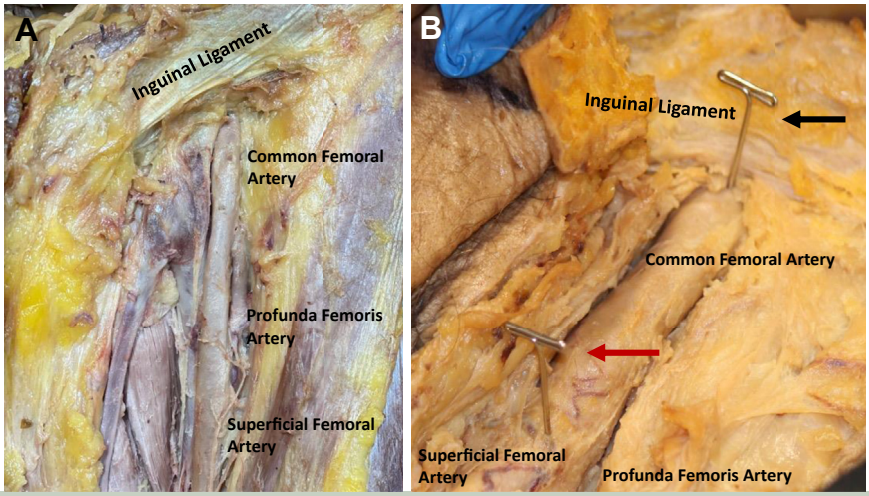

Fig 1. Photographic depiction of human cadaveric dissection of the femoral triangle. **A,** Photographic representation of human cadaveric dissection of the femoral triangle depicting the inguinal ligament, the common femoral artery (CFA), the superficial femoral artery, and the profunda femoris artery. **B,** Radio-opaque pins at the lower border of the inguinal ligament (*black arrow*) and at the femoral artery bifurcation (*red arrow*).

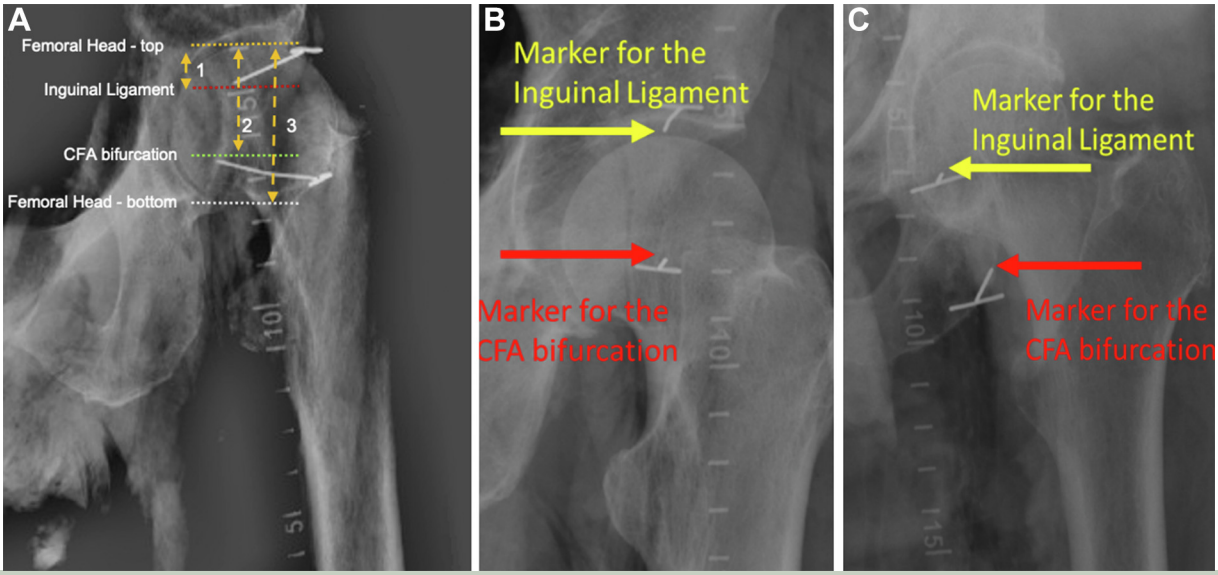

Fig 2. Radiographic depiction of human cadaveric dissection of the femoral triangle. **A,** The top of the femoral head was marked as a reference point, and the distances to the bottom of the inguinal ligament (distance 1: 85 mm in the depicted radiograph), distance to the common femoral artery (*CFA*) bifurcation (distance 2: 253 mm), and to the bottom of the femoral head (distance 3: 350 mm), were measured. **B,** Radiographic depiction showing a configuration where the inguinal ligament is situated at the top of the femoral head. **C,** Radiographic depiction of the human cadaveric femoral triangle, where the inguinal ligament is situated at the center of the femoral head.

Age and sex differences. To evaluate age differences in the position of the inguinal ligament relative to the femoral head, the dissected cadaveric femoral arteries were grouped into age <85 years and age ≥85 years. Similarly, the dissected femoral arteries were grouped into male and female to evaluate the sex differences in the position of the inguinal ligament relative to the femoral head.

Statistical analysis. Baseline age and sex differences were compared using the χ^2 test or Fisher exact test for categorical variables or the Student *t*-test for continuous variables. All tests were two-tailed, and statistical significance was set at $P < .05$. All statistical analysis was performed using Stata 16.0 software (Statacorp LLC).

Table I. Age differences in radiographic measurements

Radiographic measurements	Age <85 years (n = 14)		Age >85 (n = 31)		*P*-value
	Mean	SD	Mean	SD	
Length of femoral head, mm	37.5	6.2	38.5	5.9	.65
Absolute position of inguinal ligament, mm	9.6	15.2	11.9	8.9	.53
Relative position of inguinal ligament, %	22.22	45.43	30.13	23.58	.44
Absolute position of bifurcation, mm	40.8	14.2	44.1	12.0	.43
Relative position of bifurcation, %	109.75	35.85	113.88	24.7	.65

SD, Standard deviation.

RESULTS

Relationship between the femoral artery and inguinal ligament. Only 45 groins in 26 cadavers (male, n = 20; female, n = 25) were included in this analysis. Of these, unilateral dissections were performed in seven cadavers, whereas bilateral dissections were performed in 19 cadavers. The mean length of the femoral head was 38.2 ± 6.0 mm. The mean absolute position of the inguinal ligament relative to the top of the femoral head was 11.2 ± 11.1 mm (range, −19.4 to 27.4 mm). In 82% of femoral artery dissections, there was some degree of overlap of the inguinal ligament over the femoral head. The mean overlap of the inguinal ligament on the femoral head was 27% (range, −85.7% to 71%), with 55.6% having a >25% overlap. Similarly, the femoral artery bifurcation overlapped with the femoral head in 13%, whereas the mean absolute position of the femoral artery bifurcation relative to the top of the femoral head was 43.0 ± 12.6 mm.

Age and sex differences. The demographic details of the cadavers are listed in the Supplementary Table (online only). The mean age of the cadavers at the time of demise was 86.2 years (range, 61-96 years). The majority were >85 years (n = 31; 68.8%). There were no age-related differences in the position of the inguinal ligament or the femoral artery bifurcation relative to the femoral head (Table I). The femoral head was significantly larger in males compared with females (42.0 ± 5.0 mm vs 35 ± 4.7 mm; $P < .01$). However, there were no sex-related differences in the position of the inguinal ligament or the femoral artery bifurcation relative to the femoral head. Other parameters compared are detailed in Table II.

Heatmap to depict optimal zone of common femoral artery access. A heatmap based on the above measurements depicted that common femoral artery access below the radiographic midpoint of the femoral head would avoid the inguinal ligament and the femoral artery bifurcation in >80% of attempts (Fig 3).

DISCUSSION

This study demonstrates significant variability in the relationship between the inguinal ligament, femoral artery bifurcation, and the femoral head, suggesting the lack of a consistently safe zone for femoral artery access. Interestingly, we noted 28% overlap of the inguinal ligament over the femoral head, suggesting that the inguinal ligament is not usually a straight line between the anterior superior iliac spine and the pubic symphysis crossing superior to the femoral head. It is rather a curvilinear structure that overlaps and covers various degrees of the femoral head and can be in the path of needle puncture of the femoral artery, especially if the puncture coincides with the cephalad aspect of the femoral head on fluoroscopy. In most cadaveric dissections, access below the midpoint of the femoral head seemed to avoid the inguinal ligament and the femoral bifurcation. This suggests that access over the lower one-half of the femoral head could serve as the zone of optimal access in most patients.

Femoral arterial access is often used for percutaneous endovascular interventions, with complications noted in up to 11% in contemporary series.[8,9] Although access closure devices are available with the intent to facilitate safe femoral access, the safety ultimately depends on zone of access that avoids the inguinal ligament. Although a position statement from the Society of Hospital Medicine recommends routine use of ultrasound guidance for femoral access, this practice is not prevalent, and, importantly, there are no guidelines from the Society for Vascular Surgery, American College of Cardiology, or the Society for Interventional Radiology.[10-12] Balceniuk et al showed significant variability in the routine use of ultrasound guidance for vascular access in the Vascular Quality Initiative registry.[13] This suggests the reliance on anatomic landmarks such as the inguinal crease, anterior superior iliac spine, and pubic symphysis and possibly fluoroscopy to visualize access over the femoral head.[4] Gopalkrishnan et al, through a review of computed tomography angiography scans, attempted to correlate the position of the inguinal ligament with various surrogates such as the origin and nadir of the inferior epigastric artery and the top of the femoral head.[5] They showed that the inguinal ligament is caudal to the top of the femoral head in most patients and

Table II. Sex differences in radiographic measurements

Radiographic measurements	Male (n = 20)		Female (n = 25)		*P*-value
	Mean	SD	Mean	SD	
Length of femoral head, mm	42.2	5.0	35	47	<.01
Absolute position of inguinal ligament, mm	13.2	9.6	9.6	12.2	.28
Relative position of inguinal ligament, %	30.55	22.12	25.36	37.92	.59
Absolute position of bifurcation, mm	46.2	12.1	40.5	12.8	.13
Relative position of bifurcation, %	108.87	23.01	115.59	32.12	.43

SD, Standard deviation.

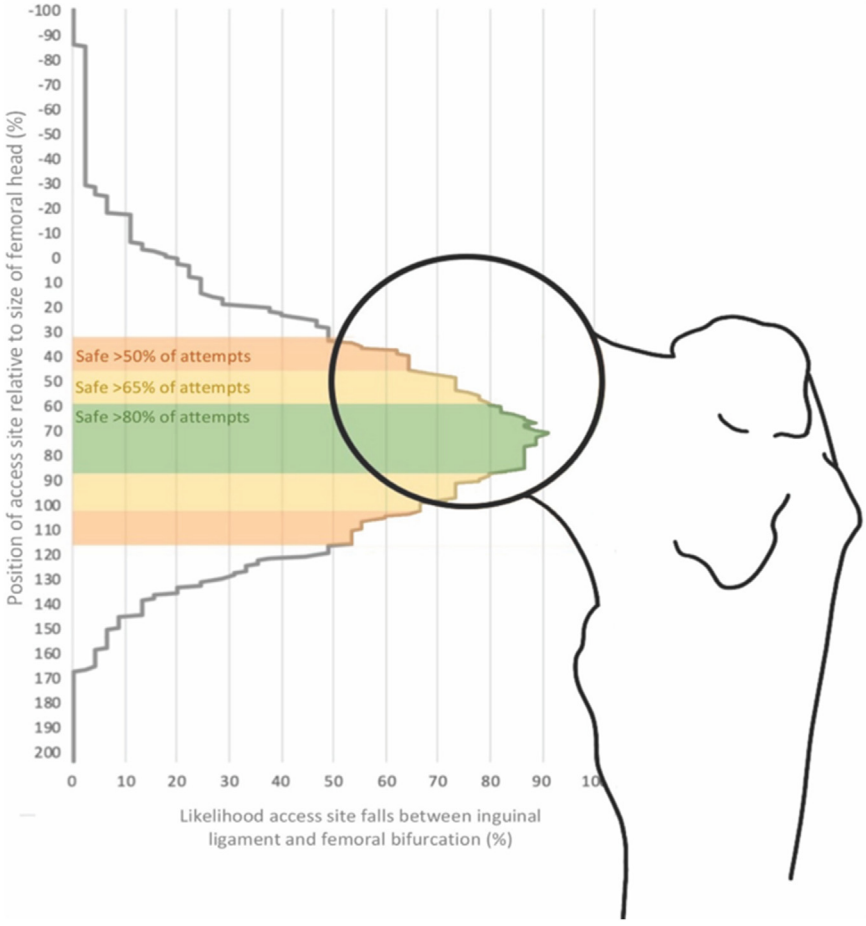

Fig 3. Heatmap derived from radiographic measurements of the distances between the inguinal ligament and femoral artery bifurcation relative to the femoral head. The heatmap depicts that common femoral artery (CFA) access below the radiographic midpoint of the femoral head would avoid the inguinal ligament and the femoral artery bifurcation in >80% of attempts, thus serving as a safe zone of access.

concluded that access over the lower portion of the femoral head could be a safer target. Similarly, through a single-center review of computed tomography angiography studies from China, the authors showed that the femoral artery bifurcation was frequently below the midpoint of the femoral head and above the Shenton's line, an imaginary line drawn along the inferior border of the superior pubic ramus and along the inferomedial border of the neck of the femur.[14] These results are similar to our data, showing that access below the radiographic midpoint of the femoral head would avoid the inguinal ligament and the femoral artery bifurcation in over 80% of cases. Importantly, over one-half the cohort had a >25% overlap of either the inguinal ligament or the femoral artery bifurcation over the femoral head, suggesting that imaging strategies used to visualize the

bony landmarks alone might not be sufficient for safe femoral access.

Multiple studies have established the importance of ultrasound guidance as mainstay during femoral artery access for percutaneous interventions. In the multicenter randomized Femoral arterial Access with UltraSound Trial (FAUST), ultrasound guidance aided safe access in cases of femoral bifurcation overlying the femoral head and resulted in 59% lower complications, compared with fluoroscopic guidance.[15] In a similar randomized trial from Canada, the authors found that ultrasound guidance improved first-pass success, reduced the number of attempts at access, and avoided venous access.[16] Through a retrospective analysis of patients undergoing complex coronary interventions, the authors noted that, compared with fluoroscopy alone, ultrasound guidance for femoral artery access resulted in a 65% relative risk reduction of vascular complications.[17] Specifically, routine ultrasound use resulted in an 86% lower rate of access pseudoaneurysms and a 52% reduction in retroperitoneal hemorrhage.[18] Indeed, these data demonstrate the importance of routine ultrasound utilization during femoral artery access. The addition of results from our study underscores the significant variability in position of the inguinal ligament and the femoral artery bifurcation relative to the femoral head, emphasizing that routine image guidance could enhance the safety of femoral artery access. Importantly, a single imaging modality such as isolated fluoroscopic guidance or isolated ultrasound-guidance may pose the risk of missing some of this variability. Contrarily, concurrent use of two imaging modalities, such as ultrasound and fluoroscopy, to guide femoral arterial access could safely identify the position of the inguinal ligament, femoral artery bifurcation, and the femoral head, and potentially reduce vascular access complications. In fact, our group has developed a technique with a video incorporating the findings from this paper to guide optimization of femoral access and is working on an institutional quality improvement effort with these results.[19]

This study has several limitations, notably that it represents a single-center review of a relatively small sample of cadaveric dissections. The impact of ligament laxity with age is unclear, as most of the dissected cadavers were >85 years of age at the time of demise. The relationships between the inguinal ligament, femoral artery bifurcation, and femoral head in younger individuals and obese individuals was not evaluated and could be different. Although sex was available for analysis, cadaver race, ethnicity, demographic factors, and other important physical characteristics, such as height and weight, were not available, and therefore, differences arising from these parameters could not be accounted for. However, these factors will be important for evaluation in future studies. Radiographic distances measured represent indirect measurements using calibration; however, this method was consistently used, and all measurements were made relative to the top of the femoral head. The measurements based on the position of the radio-opaque pins could be impacted by parallax error. However, all measurements were made as relative distances, suggesting accuracy and consistency of the results. Based on our findings, image guidance with fluoroscopy and ultrasound is advocated to visualize the inguinal ligament, the lower part of the femoral head, and the femoral artery bifurcation.

CONCLUSION

There is significant variability in the relationship between the inguinal ligament, CFA bifurcation, and the femoral head, suggesting the lack of a consistently safe zone for arterial access. In most cases, access below the radiographic midpoint of the femoral head and the inferior aspect of the femoral head could be the zone of optimal vascular access. Reliance on a combination of imaging modalities such as fluoroscopy and ultrasound guidance is advocated to confirm these landmarks and zones of optimal arterial access.

AUTHOR CONTRIBUTIONS

Conception and design: AB, JH, WS, CC
Analysis and interpretation: AB, JH, KB, OS, JC, RG, CC
Data collection: AB, JH, KB, OS, JC, WS, RG, CC
Writing the article: AB, CC
Critical revision of the article: AB, JH, KB, OS, JC, WS, RG, CC
Final approval of the article: AB, JH, KB, OS, JC, WS, RG, CC
Statistical analysis: KB, CC
Obtained funding: Not applicable
Overall responsibility: CC

DISCLOSURE

None.

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