Variability in Locations of Hip Neurovascular Structures and Their Proximity to Hip Arthroscopic Portals

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Purpose: To measure the distances of pertinent neurovascular structures from bony landmarks used during hip arthroscopy and compare them among different demographic groups. **Methods:** The distances from neurovascular structures to bony landmarks often used during hip arthroscopy were measured on magnetic resonance images of the hip in 100 patients. The structures studied include the lateral femoral cutaneous nerve (LFCN), sciatic nerve, femoral nerve, and femoral artery. These distances were then compared across different demographic groups, and statistical analysis was performed. **Results:** The mean anteroposterior (AP) distance from the tip of the greater trochanter to the sciatic nerve was 10.32 mm (range, 0 to 23.8 mm). At the level of the superior tip of the greater trochanter, the mean distances from the anterior superior iliac spine reference line to the LFCN, femoral nerve, and femoral artery were 6.37 mm (range, −9.8 to 35.9 mm) for medial-lateral, 23.24 mm (range, 3.4 to 67.0 mm) for AP, and 26.34 mm (range, 7.3 to 65.5 mm) for AP, respectively. We found significant differences in distances for the LFCN, femoral nerve, and femoral artery for weight ($P = .003$, $P = .041$, and $P = .004$, respectively) and body mass index ($P = .003$, $P = .010$, and $P = .003$, respectively), as well as for the LFCN between whites and Hispanics ($P = .032$). There were also significant differences for the femoral nerve vector between African Americans and whites ($P = .04$), as well as between African Americans and Hispanics ($P = .04$). **Conclusions:** We found the LFCN to be the most at-risk neurovascular structure with hip arthroscopy portal placement. This study also showed that there is wide variability in the locations of pertinent neurovascular structures across different demographic groups, including weight, body mass index, and race or ethnicity. **Clinical Relevance:** -Portal placement during hip arthroscopy carries a risk of neurovascular injury, particularly to the LFCN. The clinician should be aware of the variability in structure location with different patient demographic characteristics.

Arthroscopy of the hip was first attempted in 1931 by Burman,[1] with some difficulty. Further series were not attempted until Gross,[2] in 1977, published his results of a series of arthroscopies in children. With the advent of new technology and surgical techniques, the number of hip arthroscopies being performed has exponentially increased. Although hip arthroscopy has proven to be a relatively safe procedure, it is not without its complications, with some series quoting complication rates from 1.4% to 6.4%.[3-6] One such complication resulting from improper portal placement is neurovascular injury, namely injury to the lateral femoral cutaneous nerve (LFCN), sciatic nerve, femoral nerve, or femoral artery. In a systematic review Kowalczuk et al.[4] found a 4.0% complication rate across 6,962 hip arthroscopies; however, the rate of neurovascular injury was not quoted in the study. Byrd[7] noted a 0.5% rate of LFCN injury in his experience, although no overall percentage of direct neurovascular injury was quoted. Very few studies have been completed examining the arthroscopic anatomy of the hip,[8-13] and only such study has been performed using a non-cadaveric specimen.[14] Previous studies examining the proximity of neurovascular structures have used a relatively small number of subjects. To our knowledge, no study has examined the anatomic relation of the neurovascular structures using magnetic resonance imaging (MRI) of a living specimen.

In this study we sought to measure the distances of pertinent neurovascular structures from bony landmarks

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used during hip arthroscopy and compare them among different demographic groups. We believe that by comparing the relations anatomically, the findings can be applied to the standard portal locations used in hip arthroscopy: anterolateral, anterior, and posterolateral. Our hypothesis is that there would be a significant difference in distance measured when comparing different body mass index (BMI), height, or weight groups but there would be no significant difference among ethnicities. We believe that examining the proximity of neurovascular structures in the hip using MRI in a large number of living subjects will confirm the wide variability found in the locations of these structures.

Methods

To determine the distances between pertinent bony landmarks and neurovascular structures, MRI studies of the hip from 100 consecutive adult patients were retrospectively reviewed. The inclusion criteria were any patient aged 18 years or older who underwent MRI of the hip at the University of Illinois at Chicago Medical Center during the period from January 2010 to December 2012. The exclusion criteria included patients whose anatomic landmarks were not visible (e.g., the anterior skin was not visible on imaging) or patients who had any pathology that altered the normal anatomic relations, such as a tumor or fracture.

The junior authors (J.N.W., V.M., F.B., and Y.E-B.) extracted and tabulated the data. Before data acquisition, they were instructed on locating pertinent neurovascular structures by an attending radiologist. Demographic data, including patient age, gender, ethnicity, height, weight, and BMI, were recorded. MRI studies were reviewed by use of a picture archiving and communication system at the University of Illinois at Chicago Medical Center. On axial images, the anteroposterior (AP), medial-lateral (ML), and vector distances were measured in millimeters from the superior tip of the greater trochanter (GT) to the lateral-most portion of the sciatic nerve, as shown in Fig 1. Our vector distance is defined as the shortest straight-line distance from the representative arthroscopy portal to the pertinent structure. The GT was chosen for sciatic nerve measurements as the most consistently reproducible structure close to the sciatic nerve, as well as because of its clinical use in locating the position of a standard posterolateral portal. By use of image cross-referencing and a combination of sagittal, axial, and coronal images, a reference line was created matching up the anterior superior iliac spine (ASIS) with the axial cut at the superior-most portion of the GT. Next, the distance from this reference line to the LFCN, femoral nerve, and femoral artery was measured in millimeters in AP, ML, and vector distances, as shown in Fig 2. A negative distance was defined when the LFCN appeared medial to the ASIS reference line rather than lateral.

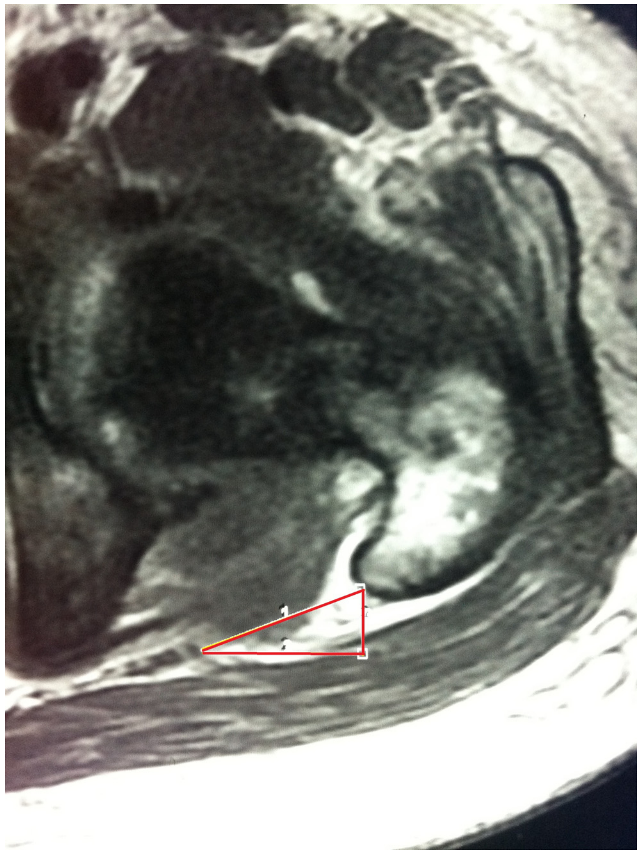

Fig 1. Vector, ML, and AP measurements for sciatic nerve.

Mean distances among demographic groups were compared by gender (male and female), ethnicity (white, Asian, African American, and Hispanic), height ($<$1.69 m and $>$1.69 m), weight ($<$80 kg and $>$80 kg), and BMI ($<$30 kg/m^2 and $>$30 kg/m^2). Statistical analysis was performed with an independent *t* test and analysis of variance (ANOVA) by use of SPSS software (IBM, Armonk, NY). Post hoc analysis was performed after data analysis. Institutional review board approval was obtained before study initiation.

Results

Of the patients, 32% were men and 68% were women. Moreover, 64% of patients were African American, 18% were white, 14% were Hispanic, and 4% were Asian. The mean age was 44.6 years (range, 18 to 80 years), the mean height was 1.69 m (range, 1.31 to 1.98 m), the mean weight was 79.9 kg (range, 47.8 to 136.1 kg), and the mean BMI was 27.9 kg/m^2 (range, 18.3 to 46.6 kg/m^2).

Across all groups, at the level of the superior tip of the GT, the mean distances from the ASIS reference line to the LFCN were 15.85 mm (range, 2.3 to 68.6 mm) for AP, 6.37 mm (range, −9.8 to 35.9 mm) for ML, and 18.15 mm (range, 2.7 to 71.6 mm) for vector. The mean AP distance from the tip of the GT to the sciatic

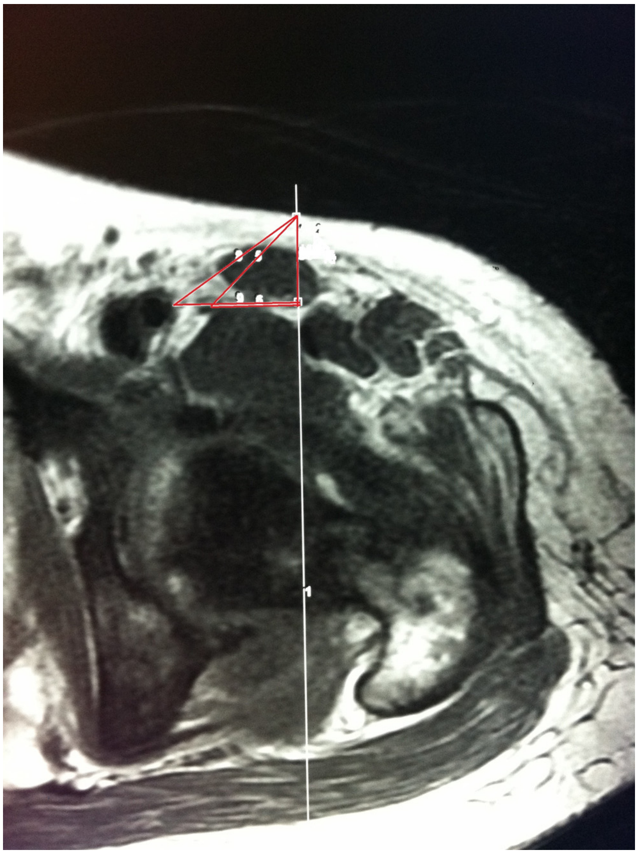

Fig 2. Vector, ML, and AP measurements for femoral neurovascular structures.

nerve was 10.32 mm (range, 0 to 23.8 mm), the mean ML distance was 27.20 mm (range, 5.5 to 52 mm), and the mean vector distance was 29.6 mm (range, 6.5 to 56 mm). The mean distances from the ASIS reference line to the femoral nerve were 23.24 mm (range, 3.4 to 67.0 mm) for AP, 28.67 mm (range, 6.2 to 53.3 mm) for ML, and 38.76 mm (range, 15.9 to 68.9 mm) for vector. The mean distances from the ASIS reference line to the femoral artery were 26.34 mm (range, 7.3 to 65.5 mm) for AP, 37.96 mm (range, 16.0 to 60.9 mm) for ML, and 47.52 mm (range, 26.0 to 73.1 mm) for vector. Further results comparing distances among demographic groups are shown in Tables 1 through 5.

When we compared the neurovascular distances between height groups, the results approached significance for the vector distances to the LFCN and sciatic nerve; however, there was not a significant difference between the groups (P = .052 and P = .059, respectively). With regard to weight, there was a statistically significant difference in the vector differences for the

Table 1. Comparison of Mean Distances to Neurovascular Structures by Gender

	Men (n = 32)		Women (n = 68)	
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)
Sciatic nerve				
AP	10.4	4.9	10.3	4.84
ML	31.3	9.17	25.3	7.7
Vector	33.3	9.83	27.9	7.74
LFCN				
AP	12.2	12.19	17.6	11.73
ML	6.2	6.76	6.4	8.32
Vector	14.5	8.58	19.9	12.67
Femoral nerve				
AP	18.2	8.89	25.6	11.7
ML	31	8.71	27.6	10.37
Vector	37.2	8.21	39.5	10.15
Femoral artery				
AP	22.7	9.28	28.1	11.75
ML	39.6	8.38	37.2	8.45
Vector	46.6	8.31	48	9.31

Table 2. Comparison of Mean Distances to Neurovascular Structures by Ethnicity

	Mean (mm)			
	African American (n = 64)	Asian (n = 4)	White (n = 18)	Hispanic (n = 14)
Sciatic nerve				
AP	10.8	6	11.5	7.7
ML	26.9	24.2	29.1	27.1
Vector	29.5	25.4	31.6	28.6
LFCN				
AP	15.6	14.9	12.1	2.8
ML	7	2.6	2.6	9.4
Vector	18.1	15.8	13.5	24.9
Femoral nerve				
AP	22.5	18.7	20.3	31.8
ML	27.2	30.5	34.6	27.1
Vector	37	36.4	41.1	44.4
Femoral artery				
AP	26	21.5	23.8	33.1
ML	36.6	39.2	43.7	36.4
Vector	46.1	45.5	50.4	50.7

Table 3. Comparison of Mean Distances to Neurovascular Structures by Height

	Height <1.69 m (n = 55)		Height >1.69 m (n = 45)	
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)
Sciatic nerve				
AP	9.6	4.38	11.2	5.26
ML	22.6	6.17	32.8	7.86
Vector	25.1	6.25	35.1	8.36
LFCN				
AP	17.8	12.5	13.5	7.66
ML	6.5	8.47	6.2	7.03
Vector	20	13.52	15.9	8.74
Femoral nerve				
AP	25.7	12.36	20.2	9.33
ML	27.3	10.39	30.4	9.23
Vector	39.5	10.24	37.9	8.78
Femoral artery				
AP	27.7	11.89	24.8	10.36
ML	37.1	8.48	39	8.42
Vector	47.7	9.31	47.3	8.67

Table 4. Comparison of Mean Distances to Neurovascular Structures by Weight

	Weight <80 kg (n = 55)		Weight >80 kg (n = 45)	
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)
Sciatic nerve				
AP	10.3	4.58	10.4	5.18
ML	26.5	8.3	28.1	9.04
Vector	28.9	8.26	30.1	9.44
LFCN				
AP	11.2	6.02	21.6	12.46
ML	4.8	7.25	8.3	8.11
Vector	13.4	7.57	24	13.3
Femoral nerve				
AP	18.7	7.58	28.8	12.8
ML	27.7	10.1	29.8	9.76
Vector	34.9	7.47	43.4	9.91
Femoral artery				
AP	21.6	7.48	32.3	12.36
ML	37.4	8.68	38.7	8.22
Vector	44.1	6.73	51.6	9.72

LFCN ($P = .003$), femoral nerve ($P = .041$), and femoral artery ($P = .004$) with a high association between groups (d [standardized mean effect size] = 0.9 to 0.95). Similarly, independent *t* tests for BMI yielded significant differences in the mean vector distance to important neurovascular structures: LFCN ($P = .003$), femoral nerve ($P = .010$), and femoral artery ($P = .003$). Again, the associations between the 2 groups were high (d = 1.0). ANOVA among ethnicities in our cohort yielded some significant findings with regard to vector distance for the LFCN ($F = 2.6$, $P = .05$) and femoral nerve ($F = 2.9$, $P = .04$). The remaining measures were not statistically significant. The Levene test for homogeneity showed, however, that both values exceeded the level of significance ($P = 0.191$ and $P = 0.732$); hence we could assume that there were equal variances between groups. Post hoc analysis showed which groups in the ANOVA were significantly associated. For LFCN vector distance, whites were significantly different than Hispanics, with a mean difference of 11.3 mm ($P = .032$). Two group comparisons were significantly different for femoral nerve vector distances: African Americans and Hispanics had a mean vector difference of 7.4 mm ($P = .04$), and Whites and African Americans had a mean vector difference of 7.2 mm ($P = .04$). Finally, when we compared men and women, there were no significant differences in distances between the groups.

Table 5. Comparison of Mean Distances to Neurovascular Structures by BMI

	BMI <30 kg/m^2 (n = 66)		BMI >30 kg/m^2 (n = 34)	
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)
Sciatic nerve				
AP	10.8	4.78	9.4	4.87
ML	28.2	8.19	25.2	9.24
Vector	30.7	8.27	27.3	9.47
LFCN				
AP	11.4	6.08	24.6	12.51
ML	4.3	6.82	10.4	8.18
Vector	13.3	7.44	27.6	12.91
Femoral nerve				
AP	18.2	7.34	33	11.6
ML	28.8	9.68	28.4	10.61
Vector	35.4	7.3	45.2	10.31
Femoral artery				
AP	21.6	7.41	35.7	11.7
ML	37.7	8.23	38.5	8.98
Vector	44.3	6.69	53.7	9.68

Discussion

We performed a retrospective review of hip MRI studies to determine neurovascular structure locations in a large sample size. We found that the most at-risk structure was the LFCN with the anterior portal, with the closest distance being a mean of 6.37 mm in the ML direction. Our findings were similar to the results obtained by Byrd et al.[14] and Robertson and Kelly,[12] who found the nerve 2 to 4 mm and 15.4 mm, respectively, from the anterior portal. There was high variability in locations in our study because in some patients, the nearest branch of the LFCN was medial rather than lateral to our reference line. As shown in a study by Grothaus et al.,[15] the LFCN can have a highly variable location and branching pattern. In 27% of patients they found branching of the LFCN proximal to the inguinal ligament, as well as variability in the ML location of the LFCN and its branches. Their study's findings are consistent with our results, as well as those obtained by Byrd et al., showing a large range of branching patterns. The remaining neurovascular structures posed less of an injury risk. Our results are summarized in Tables 1 through 5.

In addition to the overall risk of injury, we found several statistically significant differences in distances among demographic groups. Our results suggest that weight plays more of a factor than height with regard to neurovascular structure locations, given the significant increase in the vector distance for the LFCN, femoral nerve, and femoral artery with a higher weight and BMI. We hypothesize that the increase in fat content displaces the neurovascular structures more deeply and more lateral in the compartment, which would account for our results. Our results also showed a significant difference in LFCN locations between whites and Hispanics. There was also a difference between African Americans and Hispanics, as well as between African Americans and whites, with regard to femoral nerve vector distances.

To our knowledge, this is the first study using MRI to examine the neurovascular anatomy in live subjects. As mentioned previously, Dvorak et al.[8] examined the arthroscopic anatomy using 15 cadaveric specimens;

however, their study was limited to bony and soft-tissue structures, and no neurovascular anatomy was examined. Their study was also limited by a relatively small sample size. Keene and Villar[9] published their anatomic study in 1994 and similarly only examined bony and soft-tissue structures; however, their study was performed in 100 live subjects. In 1995 Byrd et al.[14] completed the first anatomic study regarding hip arthroscopy portal placement and its vicinity to important neurovascular structures. They found that the anterior portal was located within 2 to 4 mm of the LFCN, 3.2 cm from the femoral nerve, and 2 to 4 mm from a terminal branch of the ascending branch of the lateral femoral circumflex artery. The sciatic nerve was located within 2.9 cm of the posterolateral portal on average. However, only 8 paired specimens were used in their study. In 2008 Robertson and Kelly[12] performed a similar study and examined a multitude of portals in cadavers in the central, peripheral, and lateral compartments and their distance to pertinent neurovascular structures. They showed that the anterior portal was 15.4 mm from the LFCN on average and the ascending branch of the lateral femoral circumflex artery was located within 14.7 mm and 10.1 mm of the anterior portal and midanterior portal, respectively, on average. No other structure was located within 20 mm of the portals that were placed. Only 5 paired cadaveric specimens were used, so the sample size was very limited and there was limited variability among the specimens. Recently, Thorey et al.[13] also examined the relation of neurovascular structures to arthroscopic portals in cadaveric specimens. They found the LFCN to be approximately 8 mm from the anterior portal with a wide range (1 to 24 mm), which is consistent with the findings of our study and the previously mentioned studies. They found the sciatic nerve to be 35 mm from the posterolateral portal, which is also similar to our results. Lastly, the femoral nerve was an average of 8 mm from the medial portal. The study had similar limitations, given the small sample size, as well as the limited range of the cadavers' BMI values (20 to 30 kg/m^2).

Our study had several strengths. Our inclusion criteria allowed us to examine a wide variety of demographic characteristics, including age, race, BMI, height, and weight, which we believe strengthened our results. In addition, we had a large sample size, which limited statistical outliers. The study was performed in living patients in the supine position, which could accurately mimic the position of the hip and pelvis while on the operating table; however, no traction or rotation was applied to the extremities. We also obtained multiple measurements with different vector distances using high-quality imaging to accurately determine the locations of the structures.

As stated previously, our study confirms the results of previous cadaveric studies performed by Byrd et al.[14] and Robertson and Kelly,[12] showing high variability in LFCN locations. Given the wide range of possible locations of neurovascular structures among different demographic groups, neurovascular injury during arthroscopic portal placement around the hip is possibly an unavoidable complication. Considering that our study reproduced the results of previous cadaveric studies, it could be possible to visualize the locations of these structures on preoperative MRI scans. However, it would not be very practical to obtain these scans routinely before every hip arthroscopy.

Limitations

Our study also had limitations. Although the reproducibility of our method was not tested with 2 separate datasets, the locations of the structures were confirmed by 2 authors during data collection. Even though our study was completed with patients in the supine position, mimicking surgical positioning, there was no traction, internal rotation, or joint distension applied at the time, which could further alter the anatomic relations of the soft-tissue and neurovascular structures. The distances reported for the sciatic nerve's proximity to a standard posterolateral portal are likely even closer than we reported, given that our measurements were taken at the level of the tip of the GT.

Conclusions

We found the LFCN to be the most at-risk neurovascular structure with hip arthroscopy portal placement. This study also showed that there is wide variability in the locations of pertinent neurovascular structures across different demographic groups, including weight, BMI, and race or ethnicity.

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