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Neurovascular Structure Proximity to Acetabular Retractors in Total Hip Arthroplasty

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ABSTRACT

Neurovascular injury during total hip arthroplasty (THA) may result in considerable morbidity or mortality. The most common cause of intraoperative neurovascular injury during THA is retractor compression. Our aims were to: 1) determine proximity of common acetabular retractor positions during THA to adjacent neurovascular structures; and 2) determine effect of patient gender on these measurements. Retractor to neurovascular structure distances were measured on 32 preoperative computed tomography images and 16 cadavers. Our data suggest the anterior inferior iliac spine is the safest anterior acetabular retractor position. With inferior progression along the anterior wall, the distance to the femoral neurovascular bundle decreases. Due to its proximity to the sciatic nerve, the position of the posterior retractor should be monitored during acetabular preparation, particularly in women.

Total hip arthroplasty (THA) is among the most effective surgical interventions for improving health-related quality of life [1]. For this reason, and the increasing proportion of the population who are elderly, the demand for primary THA in the United States is estimated to increase dramatically over time [2]. As a result, the consequences of adverse events that occur in a systematic manner during THA are significant, and it is important to develop protocols that minimize the occurrence of these events.

Neurovascular injury during THA is relatively rare, but may result in considerable morbidity or even mortality. The incidence of peripheral neurologic injury in a review of over 54,000 primary and revision THAs was 0.09% to 3.7% and 0.0% to 7.6%, respectively [3]. It is likely that the incidence of neurologic injury during THA is higher than that accounted for by clinical examination alone, and 79% of patients who suffer peripheral neurologic injury retain some degree of persistent neurologic dysfunction [3–6]. Vascular injury in THA, with a reported incidence of 0.1% to 0.2%, is less common than neurologic injury but more emergent [7]. False aneurysm or fistula formation, thromboembolism, loss of limb, or even mortality may result [8–12].

In THA, the most common identifiable cause of intraoperative nerve injury is compression by retractors [13]. In order of decreasing frequency, the sciatic, femoral, and superior gluteal nerves (SGN) are most commonly injured during THA [3,9]. There is evidence suggesting that postoperative sciatic nerve palsies occur largely due to direct trauma from instrumentation [14]. The primary etiology of femoral nerve injury has been shown to be retractor placement along the anterior acetabular rim [15–18]. Multiple studies have found subclinical electromyography-derived evidence of SGN injury [6,19–21]. Female gender is the most well-established risk factor for neurologic injury during THA, with multiple studies reporting that at least 74% of these events occur in women [4,18,22,23].

The external iliac artery and femoral artery are the most frequently injured vascular structures in THA [9]. Acetabular retractors placed too far medially are the most frequent cause of femoral artery injury [7,24,25]. There is venographic evidence that intraoperative manipulation causes femoral vein distortion and damage resulting in thrombus formation [26].

Several studies have shown that surgical approach is not an independent cause of neurovascular injury during THA [4,5,27,28]. Consequently, appropriate retractor placement regardless of surgical approach is critical to minimizing the risk of neurovascular injury. However, safe acetabular retractor positions have not been well established in the literature.

Safe acetabular retractor positions can be determined only by establishing the proximity of neurovascular structures to common sites of acetabular retractor placement during THA. The aims of our study were to: 1) determine the proximity of common acetabular retractor positions during THA to the femoral neurovascular bundle, superior gluteal neurovascular bundle, and sciatic nerve using computed tomography (CT) images as well as cadaveric specimens; and 2) ascertain if gender affects acetabular retractor proximity to neurovascular structures.

Materials and Methods

Study Design

Computed Tomography Data

Computed tomography (CT) scans of the hip performed preoperatively for a primary total hip arthroplasty (THA) computer-guided

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navigation protocol were our data source. All scans were with multiplanar 2-dimensional reformats (coronal and sagittal). CTs of 16 male and 16 female patients performed in 2012 with equal distribution of left and right hips were selected at random from our institutional electronic radiograph archive.

The distance from five common acetabular retractor positions in total hip arthroplasty to the closest neurovascular structure was measured on each hip CT. The distance from three anterior acetabular retractor positions to the femoral neurovascular bundle, the distance from one superior retractor position to the superior gluteal neurovascular bundle, and the distance from one posterior retractor position to the sciatic nerve were determined. The three anterior retractor positions were: 1) the anterior inferior iliac spine (AIIS); 2) along the anterior wall at the 3 o'clock position for the right hip or 9 o'clock position for the left hip (direct anterior); and 3) along the anterior wall immediately superior to the superior pubic ramus (antero-inferior). The superior retractor position was the 12 o'clock position immediately superior to the acetabular rim. The posterior retractor position was along the posterior wall at the 9 o'clock position for the right hip or 3 o'clock position for the left hip. The distance from an inferior retractor position to the obturator neurovascular bundle was not measured, as this structure could not be reliably identified on CT.

Retractor positions were demonstrated on a 3-dimensional pelvis model to the radiologists in this study, who then established corresponding points on digital hip CT images. Distances from these points to the closest neurovascular bundle were measured using a digital caliper tool on an AGFA (Greenville, SC) Impax picture archiving and communication system (PACS). Two blinded, board-certified radiologists served as raters. Each rater made all measurements independently. The measurement protocol for each retractor site was first standardized with 20 training cases by the two raters prior to evaluation of the 32 study cases.

Distances from retractor positions to adjacent neurovascular structures were determined on digital CT images as follows (Fig. 1). The three anterior measurements were performed sequentially on axial images. The AIIS retractor position was determined by first identifying the origin of the direct head of the rectus femoris, and then scrolling inferiorly 0.5 cm. Then, the shortest distance from the medial cortex of the anterior column to the femoral neurovascular bundle was measured. The second anterior retractor position was identified on the same image as above at the inferior-most confluence of the AIIS and the acetabulum. The shortest distance from this point to the femoral neurovascular bundle was measured. The third anterior retractor position was identified by scrolling 1.0 cm inferiorly from the second retractor position. At this level, the distance from the most anterior point of the anterior column medial cortex to the femoral neurovascular bundle was determined. The posterior retractor position was identified on an axial image as the point on the posterior wall 0.5 cm superior to the concavity nadir at the junction of the acetabulum and ischium. From this point, the distance to the sciatic nerve was measured. The superior retractor position was defined as the 12 o'clock position of the acetabulum first on sagittal, then coronal images. Then, the shortest distance from the lateral-most point of the acetabular cortex to the fat plane between the gluteus medius and minimus containing the superior gluteal neurovascular bundle was measured.

Cadaveric Data

Twelve cadavers in our institution's anatomy laboratory with an intact lower extremity were utilized for this study. Six male and 6 female cadavers, with an equal distribution of left and right lower extremities, were randomly selected from the available cadavers.

The ilioinguinal approach was performed by a single surgeon on all cadavers. The anterior acetabular retractor positions were identified, confirmed by two of the co-authors, and the shortest distance to the femoral neurovascular bundle was measured. A single metal ruler was used for all measurements.

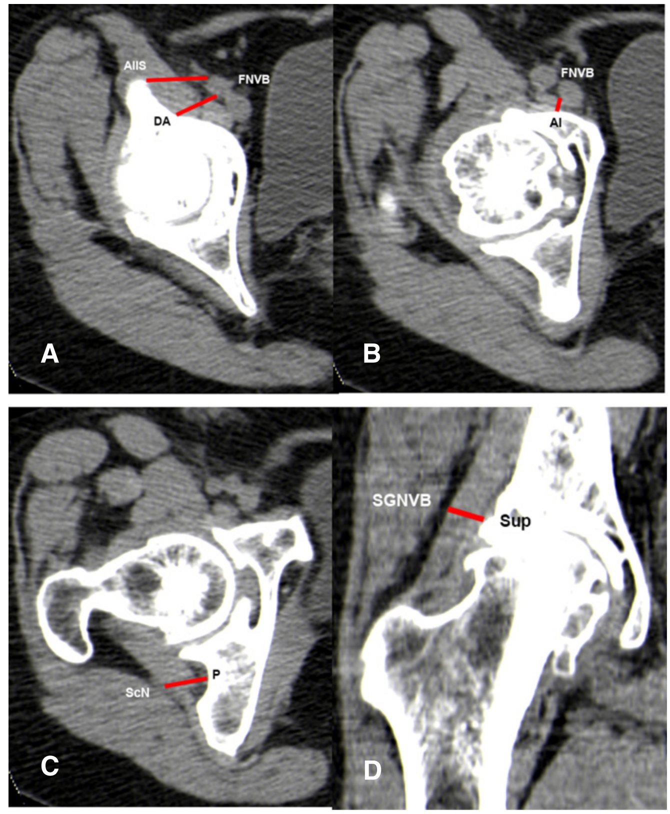

Fig. 1. Computed tomography images demonstrating acetabular retractor positions and adjacent neurovascular structures. (A) Distances from anterior inferior iliac spine (AIIS) and direct anterior (DA) retractor positions to femoral neurovascular bundle (FNVB); (B) distance from antero-inferior (AI) retractor position to FNVB; (C) distance from posterior (P) retractor position to sciatic nerve (ScN); (D) distance from superior (Sup) retractor position to superior gluteal neurovascular bundle (SGNVB).

Distances from the superior retractor position to the superior gluteal neurovascular bundle were not measured, as this anatomic structure could not be consistently identified on the available cadavers. The cadavers were stored in a supine position, which distorted posterior anatomy. As a result, distances from the posterior retractor position to the sciatic nerve were also not measured.

Statistical Analysis

As two independent raters were used in obtaining the CT data, linear mixed-effects modeling was performed to account for variation across raters. Multiple comparisons with the Tukey Method were used to test the difference between any two groups. $P < 0.05$ with a two-sided test was considered significant.

Power analysis was used to calculate sample size. With type I error set at 5%, and desired power >0.90 to detect a 5 mm difference between pairs of retractor positions in distance to the closest neurovascular structure, a sample size of 32 CT scans was required.

Results

Computed Tomography Data (Tables 1a and 1b)

Of all the retractor positions, the AIIS was the farthest from the adjacent neurovascular structure at a mean of 2.65 cm ($P < 0.0001$), followed by the direct anterior and superior retractor positions at a mean of 2.03 to 2.20 cm ($P \leq 0.0135$). The antero-inferior retractor position was the closest to the adjacent neurovascular structure at a mean of 0.95 cm ($P \leq 0.0001$), followed by the posterior retractor position at a mean of 1.75 cm ($P \leq 0.0135$).