



Original research

Do Acetabular Buttress Augment Pose Risk to the Superior Gluteal Nerve? A Cadaveric Study

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ABSTRACT

Background: Management of acetabular defects in total joint reconstruction can be challenging. Various algorithmic approaches have been developed, with some recommending using posterosuperior acetabular buttress augments for severe defects. The superior gluteal nerve lies in close proximity to their application, and damage to it results in deterioration of hip stability and gait mechanics. There has been investigation into the relationship of the superior gluteal nerve to various anatomic points. To our knowledge, no study exists examining the relationship between the acetabular rim and the superior gluteal nerve for the application of these particular devices.

Methods: Ten adult cadaver specimens were examined. A reproducible technique in relation to the typical placement of a buttress augment was used. From a distance of 20 millimeters (mm) lateral to the greater sciatic notch, the distance from the superior gluteal nerve to the posterosuperior acetabular rim was measured.

Results: The average distance between the posterosuperior acetabular rim and the superior gluteal nerve was found to be 52 mm, ranging from 48 mm to 60 mm.

Conclusion: With proprietary acetabular augments measuring up to 68 mm in length, the superior gluteal nerve could be at substantial risk with placement of these devices. Surgeons should take great care with dissection for and intraoperative placement of these devices, and particularly strive for optimized prosthetic hip stability to mitigate the risk of dislocation from nerve injury. To our knowledge, this study is the first of its kind and provides valuable anatomic and operative knowledge during these highly complex cases.

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Introduction

Management of bony acetabular defects in total joint reconstruction, either from traumatic fracture or atraumatic etiologies, can be challenging. Acetabular buttress augments are becoming more frequently used for severe posterosuperior bone loss. In order to combat the amount of acetabular deficiency, these augments can be rather sizable. An illustrative clinical case is shown in [Figures 1 through 5](#). The senior author has long thought their application significantly threatens the integrity of the superior gluteal nerve

leading to an increased risk of prosthetic dislocation. The precise anatomic relationship regarding this theory has yet to be studied.

Various algorithmic approaches have been developed to aid in the surgeon's solution of acetabular defects, with the most popular being that developed by Paprosky et al. [1]. The type of bone defect aids in the decision-making regarding the requisite surgical technique [2-4]. Perhaps the most-recently proposed device with promising outcomes has been the acetabular buttress augment, typically applied posterosuperiorly from above the acetabular shell up the ilium underneath gluteus minimus along the posterior column just in front of the greater sciatic notch. These augments of substantial length (inferior-to-superior) have been developed by a number of implant companies with the goal of creating a load-bearing construct (for the acetabular shell) to span the bony defect [5]. This length varies by company from 50 mm to 68 mm with screw options throughout, and polymethylmethacrylate

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Figure 1. Anteroposterior (AP) pelvis X-ray of a 98-y-old active female that sustained a superior right acetabular fracture, dislocation in a ground-level fall.

cement can be applied for further support along the shell and buttress interface.

Iatrogenic nerve injury is a significant risk during total hip arthroplasty with the potential for devastating outcomes. The incidence has been reported to range from 0.7% to 3.5% [6]. Clinical superior gluteal nerve injury is generally considered less common in traditional total hip arthroplasty than sciatic, femoral, or obturator nerve injury [7]. However, the prevalence of subclinical damage has been reported to be as high as 77% of cases in arthroplasty [8], and altered abductor function as a result of injury has been reported by some to be as high as 23% [9–12]. In complex reconstructive surgery with periacetabular bone loss, this nerve is in close relation to acetabular buttress augment placement and, consequently, is at higher risk of injury during these revision-style cases. As the gluteus medius and minimus muscles are the major abductors of the hip, denervation can lead to weakness, a Trendelenburg gait, difficulty with stance, and, most-distressing to arthroplasty surgeons, dislocation. These sequelae can significantly reduce a patient's quality of life [13–16].



Figure 2. AP pelvis X-ray of suboptimal anterior fixation and bone substitute placement with residual subluxation that was referred to the senior author.

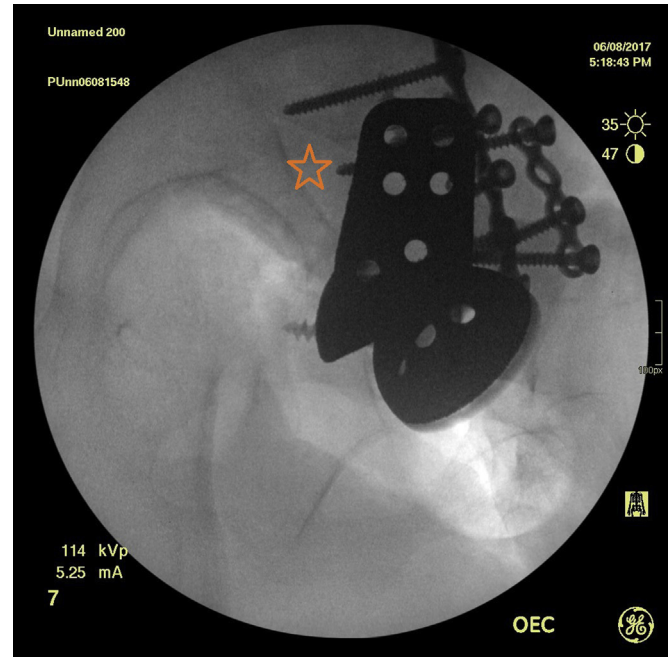


Figure 3. Intraoperative lateral fluoroscopic view with the star in the greater sciatic notch of the operative right hip during conversion to total hip arthroplasty. The posterosuperior augment extends quite high up the pelvic outer table and below is nestled against the press-fit hemispherical acetabular component with polymethylmethacrylate cement.

The anatomy of the superior gluteal nerve has been studied in relation to hip arthroplasty because of the devastating outcomes that may result with injury. Several reference points have been investigated in the literature to reliably identify the nerve's specific course. The vast majority have been in relation to various locations on the femur's greater trochanter [17]. The iliac crest, anterior-superior iliac spine, posterior-superior iliac spine, and superior acetabular rim have also been used [12,13,18]. Many postulate there is a “safe zone” in relation to the tip of the greater trochanter [17]. The original 50-mm zone defined by Jacobs and Bruxton has been challenged more recently with some authors speculating this to be as low as 30 mm [7,9,12,19–23].

There has been limited examination of the relationship between the acetabular rim and the superior gluteal nerve, but its application to acetabular augments has not been studied. In the placement of the acetabular buttress augment during complex arthroplasty, the posterosuperior acetabulum is directly visualized. The aim of this study is to describe the relationship of the superior gluteal nerve to this region with a reproducible method and apply these measurements to the placement of posterosuperior acetabular augments. We believe that the location of the superior gluteal nerve naturally lies close enough to the acetabular rim such that it could be easily injured during this procedure.

Material and methods

Ten high-index glutaraldehyde-preserved cadavers were available for use in this study by the institution's affiliated medical school anatomy laboratory. There were 4 male and 6 female cadavers with an average age of 68 years (range, 39–88 years). There was an equal number of each laterality, left and right. Exclusion criteria included previous surgeries to the hip (as indicated by cutaneous scars or findings consistent with such during dissection) and evidence of previous injury to the acetabulum.

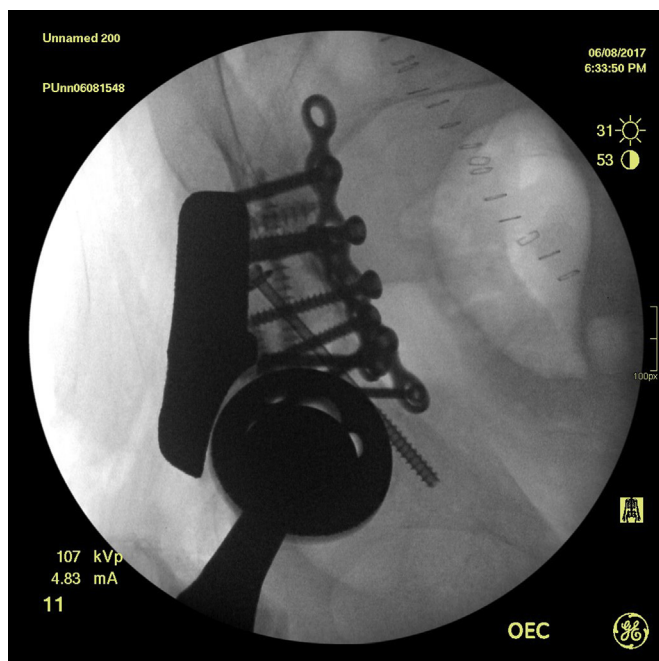


Figure 4. Intraoperative obturator-oblique view of the right hip again showing the relationship between the augment (stabilized with screws), pelvis, and press-fit hemispherical acetabular components.

The cadavers were positioned prone on the dissection table, and a classic Kocher–Langenbeck (posterior) incision was used [24]. The superior gluteal bundle was visualized between the gluteus minimus and medius muscles. The nerve (and any vasa nervorum) was isolated from the surrounding areolar tissue. The greater sciatic notch was exposed to reveal the location where the nerve exits the pelvis. We then detached and reflected the piriformis and short external rotators from their insertions on the proximal femur and made a capsulotomy. The acetabular rim, particularly posterosuperiorly, was exposed for subsequent measurement including the elevation and lateral reflection of the gluteus minimus inferior to the nerve. Care was taken to not disrupt the natural lying



Figure 5. Postanesthesia care unit AP pelvis X-ray of her complex right total hip arthroplasty.

position of the nerve while doing the dissection. Our dissection allowed visualization of the underlying posterosuperior acetabulum and retroacetabular surface above where an acetabular buttress would be placed. Of note, additional anatomy including the sciatic nerve was exposed on select cadavers for photographs to allow better representation of anatomic relationships.

A flexible ruler measuring to the nearest mm was used. Sharp-tipped teasing needles and surgical markers were used for marking the points described previously for specific values, and final measurements were agreed upon by all 3 authors present. A point was measured and marked 20 mm directly lateral to the apex of the greater sciatic notch. The acetabular rim was outlined, and the site of confluence between the posterior and superior curvatures was marked. It was felt this is the most reproducible anatomical location that lies at the typical location of the most inferior portion of an acetabular buttress augment. In addition, this is where a line straight down from our greater notch's mark intersected the acetabular rim. We simply measured from the inferior-most portion of the superior gluteal nerve to the acetabular location described, as demonstrated in Figure 6.

Results

In the 10 cadavers studied, none met exclusion criteria. The mean distance between the 2 aforementioned points, essentially the distance from the superior gluteal nerve outside of the greater sciatic notch to the posterosuperior acetabular rim to the nerve was 52 mm (range, 48 to 60 mm). The mean distance for males was found to be 54 mm (range, 48 to 60 mm) with the mean distance for females 51 mm (range, 48 to 60 mm). The complete quantitative data are shown in Tables 1 and 2.

Discussion

The results of this study confirm that the superior gluteal nerve is highly at risk when performing acetabulum reconstruction using buttress augments. Many of the cadavers examined in this study possessed a superior gluteal nerve at a distance within where an acetabular buttress augment covers. Extreme care should be taken to ensure careful subperiosteal dissection and manipulation underneath gluteus minimus during insertion and screw placement to prevent stretch damage, compression upon, or frank transection of this vital nerve.

Managing Paprosky Type IIIA defects, where severe posterosuperior acetabular bone loss exists, necessitates complex surgical techniques. While various ones have been evaluated, many have shown poor results. Hemispherical porous coated acetabular cups alone may not be reliable for stable fixation [3]. Oblong cups, or “jumbo cups” (those with a minimum diameter of 66 mm in men or 62 mm in women), can result in destruction of the posterior column due to the asymmetry of bone loss [25]. The use of structural allograft and bone substitutes with reconstruction cages is difficult to fix biologically and has poor longevity [25]. In addition, morselized bone grafting used in conjunction with cemented components may result in iatrogenic fractures and loss of component position. Acetabular buttress augments have recently appeared to be an effective alternative to these less-promising options. These implants are designed for ingrowth and are thus void of the potential for resorption and disease transmission and are structurally sound. Buttress augments used in conjunction with revision acetabular cups (ie, multihole and larger sizes with biologic metal) can restore very well the natural hip center and improve gait mechanics [5,25,26]. This center of rotation has been shown to be lowered as much as 3.5 centimeters from preoperative values in

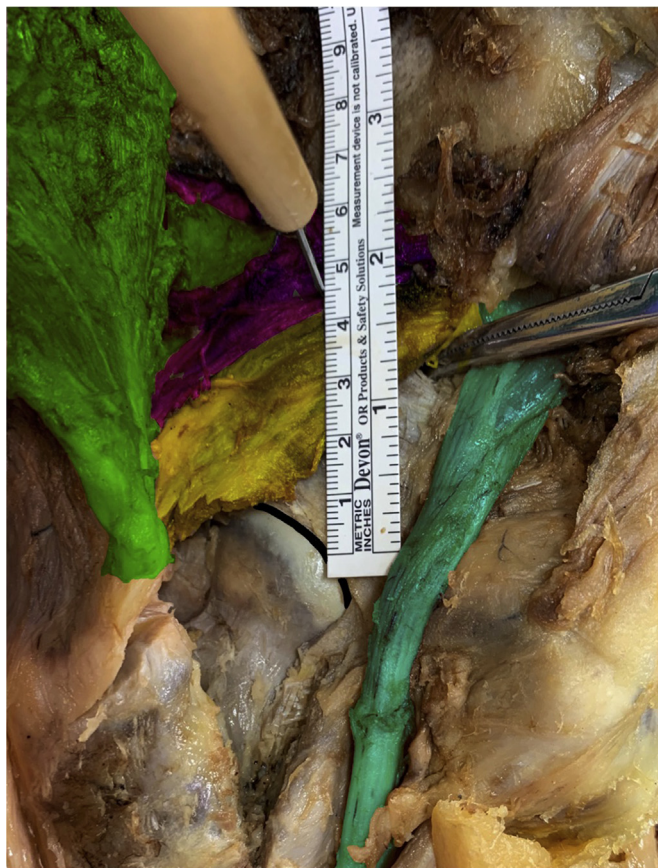


Figure 6. Measurement from the superior gluteal nerve to the acetabular rim. The hemostat is in the greater sciatic notch. The dissecting probe identifies the location of the superior gluteal nerve 20 mm directly lateral to the apex of the greater sciatic notch. Superior gluteal neurovascular bundle. Sciatic nerve. Gluteus minimus (reflected). Gluteus medius. Acetabular rim (posterosuperior aspect).

revision cases [2]. This alteration of hip biomechanics has displayed improvements in quality of life and satisfaction scores [4].

Despite the promising results acetabular revision buttress augments have shown thus far in short follow-up studies, there remains inherent risk. With the superior gluteal nerve traversing above the acetabulum between the gluteus minimus and medius muscles, iatrogenic damage is an apparent and likely often unrecognized danger [7]. The oblique course of the superior gluteal nerve branches and their variability results in difficulty defining the exact position of the nerve and its risk in arthroplasty [12,21]. In addition,

Table 1
Basic demographic breakdown of our cadaveric specimens and their measurement from the posterosuperior acetabular rim to the superior gluteal nerve.

Cadaver #	Gender	Hip laterality	Measurement (mm)	Age (y)
1	M	L	48	66
2	M	R	60	88
3	F	R	48	74
4	F	R	49	39
5	F	L	48	72
6	F	L	56	62
7	F	L	48	83
8	F	R	60	63
9	M	R	51	77
10	M	L	56	56
Average			52	68

2 patterns of the superior gluteal nerve have been described: a spray-type pattern at the proximal portion of the nerve and a transverse-neural trunk pattern where the majority of the branching is more peripheral [17,19-21]. Thus, various reference points have been investigated as mentioned previously. The vast majority of these studies have evaluated the distance from the greater trochanter to the superior gluteal nerve. Although the distance from the greater trochanter may be useful in total joint arthroplasty, direct relation from the acetabulum to the superior gluteal nerve would be most applicable for placement of an acetabular buttress augment. Only one study has investigated the superior gluteal nerve's relation to the acetabulum. Tahir and David used the relationship of the superior margin of the acetabulum in a cadaveric study of 44 hips, investigating the risk posed with a direct lateral approach to the hip [9]. They found an average distance of 32 mm from the inferior portion of the nerve to the superior rim of the acetabulum. In our study, the superior rim of the acetabulum would lie even closer to the nerve than the location we used for measurement and therefore would align well with the values provided by their investigation [9]. However, buttress augments typically lie posterosuperior (not straight superior). Thus, our dissection and measurements are more applicable to the procedure of acetabular buttress augment placement.

Various companies have developed acetabular buttress augments. The most commonly used buttress augments include the Zimmer Trabecular Metal Acetabular Revision System Buttress (ZimmerBiomet, Warsaw, IN) with a straight and column buttress design, the DePuy Synthes Gription TF Acetabular Revision System Buttress (DePuy Synthes, Raynham, MA), and the Smith and Nephew Redapt Blade Augment (Smith and Nephew, Watford, UK). No augments were able to be procured for our research. The thickness and width of each design varies; however, only one company publishes the thickness options of the product (8 mm to 24 mm), and none provide width (posterior-to-anterior) measurements. Most important in relation to the superior gluteal nerve though is the length, which each system does publish. In these 3 systems, lengths of the augments range from 50 mm up to 68 mm. Components are placed at the location of the bony deficit, which is posterosuperior in Paprosky Type IIIA defects. The reproducible measurements used in this study correlate best with the distance the superior gluteal nerve lies from the buttress augments. As demonstrated in Table 1, our results indicate the superior gluteal nerve could unquestionably be at risk during this procedure. Five of the 10 cadavers were found to have nerves that would be at risk with even the shortest augment (50 mm). All cadavers were found to have values that would be at risk with the longest available augment (68 mm). However, these results are in setting of a native, uninjured hip without taking into account any bone loss including any native rim compromise from reaming preparation for the hemispherical shell. Even though the augment attempts to restore the hip's center of rotation, the significant bone loss in these patients necessitates a larger cup size, and thus, the starting point of the augment is actually more superior than that in a native hip (and thus even closer to the superior gluteal nerve than reported here).

It is important to discuss how damage to the superior gluteal nerve could result. Injury could be a consequence of a variety of mechanisms including compression, traction, ischemia, or

Table 2
The average distance and range from the posterosuperior acetabular rim to the superior gluteal nerve between male and female specimens.

(mm)	Male (4)	Female (6)
Average	54	51
Min.	48	48
Max.	60	60

transection [9,27]. During the procedure of acetabular buttress augment placement, the gluteus minimus is elevated from the ilium's retroacetabular surface. As discussed previously, it is important to remember that the superior gluteal nerve runs obliquely over (or superficial to) the gluteus minimus. During the procedure of elevating this muscle, and with the placement of a thick buttress augment underneath, it is understandable how the superior gluteal nerve could be injured through the aforementioned mechanisms. Simply put, the augment could be placed directly on top of the nerve if the minimus were not properly dissected, or the nerve could be stretched and even torn by over-aggressive retraction underneath gluteus medius for proximal screw placement. The results in this study support that the gluteus minimus must be elevated to a distance more proximal than that of the superior gluteal nerve in most cases to place an acetabular buttress augment directly on bone. Careless dissection could result in partial or complete injury. If these mechanisms result in partial nerve palsy, the majority would be expected to resolve spontaneously [28]. Zappe et al. [29] retrospectively reviewed patients with various nerve palsies for 2 years in a cohort of 2255 patients who underwent total hip arthroplasty, with the superior gluteal nerve composing 15%. The study found that partial injuries reached full recovery in 91%, whereas the more severe cases showed full recovery in only 43% [29]. Complete and persistent denervation of the superior gluteal nerve has been seen in up to 11% of arthroplasty cases even without the use of acetabular augments [10]. Farrell et al. [30] investigated various nerve palsies in relation to total hip arthroplasty and found just 36% of those with complete neurologic injuries recovered fully. With effects as severe as recurrent dislocations, the functional deviations generated from these injuries can significantly reduce the patient's quality of life [13,16]. And even if the nerve is only partially and/or transiently injured, the hip is destabilized by its lack of full abductor moment (and at increased risk of dislocation) while it recovers.

The importance of knowing the risk of damage to the superior gluteal nerve with acetabular buttress placement is even further emphasized with the cumbersome treatment an injury entails. In the setting of substantial superior gluteal nerve injury, treatment involves a complicated and prolonged course. Nonoperative options include physical therapy, extended bracing, and expectant waiting. Electromyography may be used to evaluate the potential of recovery [7,16,28]. If the conservative course fails, typically after 18 months, surgical alternatives may be considered [7]. However, there seems to be fewer and fewer patients undergoing surgical intervention, possibly because of modification of lifestyle or the reluctance of the surgeon and/or patient to perform/undergo the procedure [28]. Local tendon transfer has traditionally provided the best outcomes, and transfer of the anterior portion of the gluteus maximus, which has similar orientation to the horizontal fibers of the gluteus medius and minimus, has seen promising results [16,31]. In addition, a technique involving both the gluteus maximus and tensor fascia latae has been described [32].

There are definite limitations to this cadaveric study. We agree with Putzer et al. [13] that the use of a flexible ruler could lead to some measurement deviation. However, we made each measurement through consensus with all 3 authors before documentation. The use of cadaveric specimens preserved in high-index fluid (glutaraldehyde in this study) is known to reduce hydration and could potentially underestimate distances. However, this solution also fixes the tissues, whereas fresh cadavers have no muscular tone and may not provide application to live patients [17]. The low number of specimens could also contribute to error. At our institution, we were limited to the number provided due to cadaver availability. We did consider obtaining data from each cadaver's other hip which would have provided a total of 20 measurements.

However, the initial 3 cadavers we evaluated had identical contralateral values, so we did not include them to seek as much variation as we could between patients. In addition, we did not have any actual acetabular buttress augments available to measure anatomic relationships. We did attempt to acquire samples for use, but these requests were denied by industry. Nonetheless, companies publish highly detailed product measurements that were used to extrapolate our data. Also, as touched on previously, we conducted our study on native hips without even the preparation for and application of an acetabular shell which could have altered our length measurements. Finally, we administered our posterior approach in the prone position while posterior arthroplasty approaches are done in the lateral position clinically. We did this as our cadaver laboratory did not have the equipment to allow for lateral positioning. Despite our atypical positioning, we do not feel our distance was compromised between the fixed nerve and its corresponding static landmark at the acetabulum.

Conclusions

With some acetabular augments measuring up to 68 mm in length, our results demonstrate that the superior gluteal nerve is at risk with the use of these devices as it lies an average of only 52 mm above the posterosuperior acetabular rim. To our knowledge, this is the first study investigating the relationship of the superior gluteal nerve to acetabular buttress augments and the inherent danger that exists. Great care should be taken with intraoperative placement of these devices to avoid potentially disastrous consequences from damage to this crucial nerve.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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