Neurovascular Injuries in Acetabular Reconstruction Cage Surgery

An Anatomical Study

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Abstract: Acetabular reconstruction cages are indicated for severe combined segmental and cavitary acetabular bone defects. The purpose of this study was to evaluate the implications of screw placement and drill plunge and the potential insult to anatomical structures when implanting acetabular reconstruction cages. A segmental cavitary defect was reamed into the acetabulum and a cage was implanted in each of the 10 hemipelvises. The relative course of the superior gluteal neurovascular bundle was mapped to assess dissection intervals. When cage screws were placed at least 15 mm longer than needed, 13% and 20% of screws of the superior flange and anterior rim hit the femoral nerve, respectively, and approximately 60% of the screws placed in the posterior rim endangered the obturator nerve. A "safe zone" for screw size may be a 15- and 25-mm screw for the superior flange and posterior rim, respectively.

Key words: neurovascular structures, acetabular defects, pelvic structures.

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The annual number of primary and revision hip arthroplasties has been steadily increasing in recent years [1]. As the number of primary arthroplasties performed increases, close attention must be focused on the increasing burden of revision.

Acetabular reconstruction surgery presents with a unique problem if there is loss of bone stock. Accepted treatment options for acetabular deficiencies have included the use of cement, bulk bone grafting, particulate bone grafting, use of oblong sockets, jumbo sockets, and the use of rings and cages [2-9].

Since 1975, acetabular reconstruction cages with different designs have been used to treat some of the more severe acetabular bone deficiencies [5]. The most common defect for the use of reconstruction cages due to acetabular deficiency is a combined segmental and cavitary defect, a type III defect as defined by the American Academy of Orthopedic Surgeons [5,10-13]. With most designs, fixation requires the drilling of holes and placing of screws in the ilium and ischium. In fact, some cage designs have holes specific for iliac (superior) and ischial (inferior) starting points [5,11,14,15]. In noncemented hemispherical sockets, not only is the thickness of bone available for placing the screws a concern but also the variety of structures at risk for injury with plunging of the drill or overestimating screw length.
The structures at risk for injury with hemispherical cup placement have been previously documented. Published investigations have reported injury to vascular structures such as the external iliac, obturator, superior and inferior gluteal, and internal pudendal arteries and veins [15,16]. Neural structures that can also be compromised secondary to screw placement are the obturator and superior and inferior gluteal, internal pudendal, and sciatic nerves [15,17]. With a broader spread of superior and inferior screw hole options in cages, other structures, such as the deep circumflex iliac, internal iliac, superior vesicular arteries and veins, ureter, bladder, prostate, large and small bowels, and femoral nerve, potentially could be compromised.

Extensive surgical exposure is necessary for placement of cages, which necessitates stripping much of the gluteus medius and minimus from the ilium. Dissection in this area places the superior gluteal neurovascular bundle (SGNVB) at risk for injury [13]. Therefore, to diminish the risk of injury to the superior gluteal nerve, most surgeons attempt to respect a 5-cm “safe zone” around the tip of the greater trochanter [18]. Studying acetabular reconstruction cages, Possai et al [13] reported that of 12 hip revisions, 5 hips dislocated. The authors reported that their patients who had the dislocations demonstrated severe weakness of the gluteus medius. They theorized that this weakness could be associated with disruption of the superior gluteal nerve, which innervates the gluteus medius. This disruption of the nerve probably occurs on the approach to implant the cage.

Studies that examine the risk for neurovascular injury by screw placement during the surgical implantation of acetabular reconstruction cages are limited [15-17]. Due to the increased pelvic bone loss, possible thinner bone width, and the need for placing screws in the ilium, our hypothesis was that there would be an increased risk of injury to neurovascular structures during acetabular cage placement when compared to press-fit acetabular components. Our secondary hypothesis was that there would be intrapelvic and extrapelvic anatomical structures at risk for injury during surgical implantation of these devices.

**Materials and Methods**

Ten cadaveric hemipelvis specimens were obtained. A hemicorpectomy was performed at the L5 level. For all cadaveric specimens, the hip was approached using a triradiate incision, as described elsewhere [19]. During each dissection and before hip disarticulation, measurement of the anatomical path of the superior gluteal neurovascular bundle was completed.

At the time of this study, there were 7 commercially available cages on the US market [14,20]. These cages differ in geometry and material composition. Of the 7 commercially available types at the time, only 4 offered both superior and inferior flanges. Of those 4, only 2 designs had corresponding rim holes. Of these 2 cage designs, the Protrusio Cage (Depuy, Warsaw, Ind) had the greatest number of viable screw hole options. For that reason, we used the Protrusio cage for this present study. Most cage designs have cage sizes ranging from 50 to 54 mm outside diameter (OD). However, the Acetabular Roof Reinforcement Ring with a cranial flange (Sulzer, Winterthur, Switzerland), is one design that has a 60-mm inside diameter. By choosing a 50-mm, 54-mm, or 60-mm cage design, we theorized that the generalizability would be weak, considering the end ranges. Thus, in an effort to maximize our potential to generalize between sizes ranging from 50 and 54 mm, we used a 52-mm-OD cage in our study. Thus, for all cadaveric specimens, a Depuy 52-mm-OD cage was used in both right and left versions.

**Measurements of the SGNVB**

All measurements were done with a calibrated metal scale with sensitivity measured to the nearest millimeter. For each hemipelvis, in every cadaveric specimen, the distance of the SGNVB was measured. The measurement was from the midlateral mark of the tip of the greater trochanter to where the SGNVB passes the superior border of the piriformis. The same point on the greater trochanter was also used to measure the distance of the SGNVB as it passed each of 3 lines that slices the gluteus medius belly into quarters (Fig. 1).

**Standardization of the Defect**

Once the acetabulum was exposed for each hemipelvis, the anterior and posterior columns as well as the acetabular walls were explored. The acetabulum and femoral heads were inspected for evidence of arthritic changes.

In an effort to have good representation of bone stock deficiency present in cage placement, it was necessary to create an acetabular defect in our cadaveric specimens. Because each pelvis was different in size, the defect dimensions necessary for cage placement were of different lengths and widths. To standardize the defect for each acetab-
ulum, we reviewed 50 consecutive revision cases (requiring acetabular reconstruction cages) from the senior author’s practice. These x-rays were digitally formatted, and by using specialized software (Sigma Scan Pro, Aspire Software International, Leesburg, Va), the defect could be measured. The vertical length of the defect was measured from the Kohler’s teardrop to the superior border of the defect. Using the same software technique, the height of each pelvis was measured using the superior border of the iliac crest to the inferior border of the ischium as borders. The vertical dimension of each acetabular defect was expressed as a percentage of pelvic height and was calculated by using the following formula:

\[
\% \text{ of Acetabular defect} = \frac{\text{Length of the defect (mm)}}{\text{Pelvic height (mm)}} \times 100
\]

The average percentage of acetabular defect across all radiographs was calculated. The average acetabular defect was 40% for our sample of radiographs.

For each specimen, a standard anterior-posterior pelvic radiograph was obtained. For each hemipelvis, the vertical pelvic height was measured using a 15% magnified ruler. The average percentage of acetabular defect was measured from the specimen’s radiographic image (40% of vertical pelvic height) and drawn vertically on the radiograph starting from Kohler’s teardrop. To have an easily identifiable gross anatomical structure to measure from, during the dissection, the top of the vertical defect was measured from the superior rim of the acetabulum (Fig. 2). The appropriate height of the acetabular defect was then marked on the pelvis after measuring with a nonmagnified ruler. The acetabulum was reamed superiorly and medially to create a 10-o’clock to 2-o’clock combined defect (Fig. 2). The medial wall was perforated during the reaming process. This procedure was completed for all cadaveric hemipelvic specimens.

**Insertion Technique and Measurements**

To accurately define the areas at increased risk for neurovascular injury secondary to screw placement, the cage design used in this study was divided into 5 zones (Fig. 3). The superior flange compromised zones 1 and 2. Zone 1 contained the 3 most anterior-superior screw holes, and zone 2 contained the 3 most posterior-inferior holes. The rim options were further divided into 2 more zones, 3 and 4. Zone 3 contained the 2 most anterior rim holes, and the more posterior zone 4 housed an additional 3. The ischial flange contained 3 holes and was the separate fifth zone.
All cages were contoured and implanted by the senior author. The defects were grafted with morselized bone obtained during the reaming process. All flange and rim holes were drilled, measured with a depth gauge, and filled with a 6.5-mm-diameter round-headed household screw, which was at least 15 mm longer than required (ie, experimental screw excess length). Placing screws 15 mm longer than what is typically used in patients allowed us to assess the proximity of the drill tip to vital structures if plunging were to occur. Each hole was assigned a number, and each experimental screw excess length was recorded.

The specimens were carefully dissected and the location of each screw identified. The following measurements were performed (in millimeters):

1. experimental screw excess length: the distance from the inner pelvic table to the tip of the screw;
2. structure to screw: the distance the structure lay from the outer thread of the screw and its spatial orientation to the screw (superior, inferior, etc);
3. structure to bone: The distance each structure laid from the inner pelvic table as it passed over the cluster of screws, which was calculated by adding the experimental screw excess length and the structure to screw distance; and
4. bone thickness: calculated for each zone by subtracting experimental screw excess length from the known length of the screw.

From the collected data, the vital structures were classified into 4 categories: (1) those structures hit and perforated by the screw, (2) structures touched
only by the screw tip, (3) structures threatened or near missed (within 5 mm from screw tip but not touching), and (4) not at risk for injury.

Only structures that fell within 20 mm of the pelvic bone and met categories 1 or 2 were considered to be at true risk and were used for further analysis.

**Statistical Analysis**

Statistical analysis was performed using SPSS 10.0 for Windows (SPSS, Chicago, Ill). Descriptive statistics were obtained on all variables collected during the study before the inclusion in the various analyses. If necessary, nonparametric statistical testing was performed based on results of the descriptive statistics. The continuous variables included experimental screw excess length, distance form screw to vital structures, distance from pelvic bone to structure, and bone thickness in each of the 5 zones studied. Percentage of times that a structure was hit as well as the number of times a structure was in danger of being injured (<5-mm distance) was described for each zone. One-way analysis of variance was used to compare bone thickness and the distance from the endangered structure to the screw for those structures within a 5-mm radius of the screw. A P value less than .05 was considered significant. Confidence intervals (95%) were calculated for the measurements of the SGNVB in the areas illustrated above, as well as for bone thickness calculated for each zone.

**Results**

**Approach Measurements**

The SGNVB did not follow an equidistant course around the greater trochanter (Fig. 1). The course of this structure descended from posterior to anterior. The average distance from the intersection of the SGNVB and the superior border of the piriformis to the greater trochanter was 9.97 cm ± 0.68 SE (95% confidence interval [CI], 8.6-11.3). The average distance from the midpoint of the greater trochanter to the SGNVB at points throughout its relationship to the anterior, middle, and posterior quartering lines of the gluteus medius muscle were 3.3 cm ± 0.21 SE (95% CI, 2.9-3.7), 5.2 cm ± 0.25 SE (95% CI, 4.7-5.7), and 7.6 cm ± 0.55 SE (95% CI, 6.5-8.7), respectively.

**Experimental Screw Excess Length and Bone Thickness**

The total number of screws inserted in all 10 hemipelvis was 130 (140 holes). Ten screws could not be inserted because of either lack of bone stock or screw “crowding.” The mean experimental screw excess length was 19.2 mm ± 0.46 SE (range, 9-36 mm). The average bone thickness for each zone is shown in Table 1. Analysis of variance and post hoc testing demonstrated that there was statistically significantly difference between all zones, with zones 3, 4, and 5 having statistically significant differences in average bone thickness when compared to zones 1 and 2 (P < .001). For screws placed in the superior flange of the cage (zones 1 and 2), the mean experimental screw excess length was 16.9 mm ± 0.52 SE (95% CI, 15.9-17.9) and 20.8 mm ± 1.18 SE (95% CI, 18.5-23.1), respectively. There was a statistically significant difference between the experimental screw excess length measurements performed in these zones (P = .004). This suggests inconsistency in obtaining an accurate screw length. When the outlier experimental screw excess lengths were examined, a discrepancy between the bone excess lengths measured with a depth gauge and that which was calculated was noted on only 2 occasions and was no more than a millimeter or two. The limited number of screw sizes to choose from when filling the hole can explain the significant experimental screw excess length difference. For zone 1, the mean bone thickness was 12.2 mm ± 0.63 SE (95% CI, 11.0-13.5 mm). In zone 2, the mean bone thickness was 14.5 mm ± 1.0 SE (95% CI, 13.1-16.6).

<table>
<thead>
<tr>
<th>Zone</th>
<th>No. of screws</th>
<th>Experimental screw excess length ranges (mm)</th>
<th>Average experimental screw excess length (mm)</th>
<th>Bone thickness (mm) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>11.0-26.0</td>
<td>16.9 ± 0.52 SE</td>
<td>12.2 ± 0.63</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>13.0-36.0</td>
<td>20.8 ± 1.2 SE</td>
<td>14.5 ± 1.0 SE</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>9.0-25.0</td>
<td>17.1 ± 1.00 SE</td>
<td>19.4 ± 0.7 SE</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>13.0-27.0</td>
<td>19.8 ± 0.8 SE</td>
<td>32.0 ± 1.2 SE</td>
</tr>
<tr>
<td>5</td>
<td>29</td>
<td>13.0-36.0</td>
<td>20.5 ± 1.2 SE</td>
<td>30.8 ± 1.2 SE</td>
</tr>
</tbody>
</table>

Table 1. Zone-specific experimental screw excess length and bone thickness
This implies that the more posterior and inferior the screw is placed in the superior flange, the better the bone stock will be. This finding was confirmed by examining the screws individually. The screw hole associated with the least bone stock was the most superior screw option with a mean thickness of 11.6 mm. In contrast, the greatest bone thickness was found with the most posterior-inferior screw hole that had a mean thickness of 17.6 mm.

The bone thickness in zone 3 averaged 19.4 mm ± 0.68 SE (95% CI, 18.1-20.8 mm). The experimental screw excess length averaged 17.1 mm ± 1.01 SE (range, 9-25). The average bone thickness in zone 4 was 32.0 mm ± 1.23 SE (95% CI, 29.6-34.4 mm). The average bone thickness in zone 5 was 30.8 mm ± 1.2 SE (95% CI, 28.6-33.0 mm). When compared with the average bone mass of the anterior rim, it was evident that the more posterior the rim screw options had greater bone stock. This was true for the entire posterior column for the ischial bone mass.

**Structures at Risk**

Even under the condition of screw placement, which exceeded 15 mm beyond the typical screw length used in surgery, we found that 70 (54%) of 130 screws did not threaten any vital structure. However, 23% (30/130) of the screws did perforate a vital structure, 11.5% (15/130) hit but only touched a vital structure with the screw tip, and another 11.5% (15/130) came within 5 mm of a vital structure and were designated near threats or near misses. Table 2 indicates, by zone, which vital structures were hit by the screw and average distance from the bone to each vital structure.

The correction for screw excess length was performed, and 8 superior flange screws (13.3%) hit or touched the femoral nerve while the structure was lying within 20 mm of the pelvic bone. In more detail, screws placed in zone 1 hit the structure with 5 of 30 screws placed in the 10 hemipelvises (16.6%). For screws placed in zone 2, 3 (10%) of 30 screws hit the femoral nerve. An additional 5 (8.3%) screws placed in these zones were near misses. No other structure was found to be at risk for injury in zones 1 or 2.

Individual analysis of screws placed in zones 3 and 4 demonstrated that several structures were at risk if screws were to be placed in the rim. The femoral nerve was hit once again by 5 (20%) of 25 of the anterior rim screws (zone 3) and was threatened by an additional 20%. The external iliac artery was not considered a risk in zone 3, whereas the external iliac vein was hit by only 1 (4%) of 25 screws when the structure lay 20 mm or closer to the pelvic bone.

The posterior rim screws (zone 4) endangered the most number of structures. Of 8 screws placed through the most superior screw hole in this zone, 4 (50%) hit the obturator nerve. Two other screws (25%) were near misses. Neither the external iliac vein nor artery was considered at risk in zone 4. Of 16 screws placed in zone 4, 2 (11.7%) also hit the internal iliac vessels and an additional screw near-missed this structure. Of 8 screws placed through the inferior screw hole in zone 4, 2 (25%) also hit the superior vesicular artery. The rectum or bladder were not found to be structures at risk for injury in this zone.

Inferior flange screws (zone 5) showed a strong tendency for the pudendal neurovascular bundle. Of 29 screws placed in this zone, 7 (24.1%) hit this bundle and an additional 4 (13.7%) were near misses. All the screws but one that hit this structure were placed through the inferior most screw hole. During dissection, an inferior trajectory to the screws that hit the pudendal neurovascular bundle was noted. Of 29 screws placed through the inferior flange, 2 also hit the bladder. The rectum, superior vesicular vessels, and the prostate were not found

<table>
<thead>
<tr>
<th>Zone (no. of screws)</th>
<th>Vital structure</th>
<th>Zone (no. of screws)</th>
<th>Vital structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (30)</td>
<td>Femoral nerve</td>
<td>External iliac artery</td>
<td>External iliac vein</td>
</tr>
<tr>
<td>18.6 ± 0.2 (5)*</td>
<td>Not hit</td>
<td>Not hit</td>
<td>Not hit</td>
</tr>
<tr>
<td>2 (30)</td>
<td>19.3 ± 0.3 (3)*</td>
<td>Not hit</td>
<td>Not hit</td>
</tr>
<tr>
<td>3 (25)</td>
<td>16.2 ± 0.2 (5)*</td>
<td>Not hit</td>
<td>Not hit</td>
</tr>
<tr>
<td>4 (16)</td>
<td>Not hit</td>
<td>Not hit</td>
<td>18.0 (1)*</td>
</tr>
<tr>
<td>5 (29)</td>
<td>Not hit</td>
<td>Not hit</td>
<td>Not hit</td>
</tr>
</tbody>
</table>

*Number of screws that perforated vital structures.
to be at risk from screws placed in this zone (the only female cadaver had undergone a total abdominal hysterectomy, and therefore, this cadaver’s reproductive organs could not be assessed for damage or endangerment).

Discussion

Investigators have published several reports on the neurovascular injuries that occur with the placement of acetabular cages [3,5,11-13]. Berry and Muller [5] reported partial sciatic nerve palsies in 3 of 27 patients receiving a cage. Little laboratory data information exists on the resulting positions of screws placed while implanting an acetabular cage. Two situations can occur in screw placement that will damage vital structures: drill plunge and screw placement. In our study where screws were implanted at least 15 mm longer than needed, the femoral nerve was most at risk for injury with placement of the superior flange and anterior rim screws. Medially to zone 1, the femoral nerve is protected by the iliacus, which lies between the nerve and the bone. The medial trajectories of these screws target the iliacus muscle. Superiorly, the iliac bone thins significantly. From our data, screws placed in the posterior-inferior area of the superior flange were less likely to hit the femoral nerve than those placed in the anterior-superior (danger zone) area. This may be due to greater bone thickness in the posterior-inferior area because this region corresponds to the posterior column of the acetabulum. The average bone thickness in the posterior-inferior area was 15 mm. Our data suggest that a safe screw distance in this area would be approximately 15 mm. This recommendation should be tempered by our small sample size. Another important finding in our study was that the closest vital structure in this area was an average of 16.6 mm from the inner pelvic table. Our data clearly show that the more superior bone in the ilium is thinner. We also reported that the structures in danger of being hit by a plunging drill or a medially placed screw differ by those reported by Wasielewski et al [16], particularly in the superior and inferior flanges. This study demonstrates that implanting an acetabular cage is quite different than that of a hemispherical socket. The structures that are in danger of being hit by a plunging drill or a medially placed screw differ significantly from those reported by Wasielewski et al.

Anteriorly placed rim screws (zone 3) were a greater threat to the femoral nerve than screws placed in the superior flange. Screws in the anterior-inferior zone also came closer to the femoral nerve than did the screws in other zones. When viewing the area of these 2 anterior zones in an in situ specimen, there is an appreciation for the path of the vital structures that lay medial to the pelvic wall. In our study, the external iliac vein was closer to the inner pelvic table (19.2 mm) than the artery (21.2 mm).

In addition, we observed that even when the external iliac vein and artery structures were lying within 20 mm of the pelvic bone, the external iliac vein was hit only one time, whereas the artery was not hit by any of the screws.

Of the posterior rim screws (safe zone) the most commonly hit structures were the obturator nerve (hit or near-missed in 66% of the screws placed in the superior screw hole), the internal iliac artery, and the superior vesicular artery. In the posterior half of the pelvis, the obturator nerve is located above the pelvic brim floating in adipose tissue at a variable distance from the inner pelvic table. As the obturator nerve crosses the pelvic brim, it approaches the quadrilateral surface and the obturator vascular vessels. The obturator nerve in our study was most commonly injured in the posterior half of the pelvis with rim screws. The rim screws were therefore more superiorly placed and exited the inner pelvic table above the pelvic brim. These screws also hit internal iliac vessels that present slightly medial and inferior to the external iliac vessels.

The posterior rim screws were placed into the greatest amount of bone stock, averaging 32 mm. Thus, placing screws in the posterior rim is a favorable area for securing the cage. Although bone stock is thick in this area, we are alerted to the fact that there is a significant number of vital structures, especially the obturator nerve. As previously stated, with the limited number of specimens, we were unable to recommend a safe screw size. However, our results do suggest that a 30-mm screw could be used in this area with relative safety.

Pertaining to the posterior-inferior area, the inferior flange screws could put the pudendal vessels and nerve at risk to injury. These structures exit the pelvis and pass posterior to the ischial spine then continue in a fascial tunnel adhered to the perimysium of the obturator internus. The obturator internus is of variable thickness and is the only structure that can impede drill plunge thus minimizing the risk of injury to the pudendal structures. The restriction of the vessels in the facial tunnel and lack of excursion is an additional predisposing factor to injury.
In our study, we noted injury to the pudendal neurovascular bundle when screws were placed with a more inferior trajectory through the ischial flange holes. When fixing posterior acetabular fractures, the internal pudendal neurovascular bundle has been reported to be in a compromised position and at risk for injury when a medially or laterally placed screw is angled medially [21]. It has also been reported that optimal technique of screw placement is in the ischial tuberosity for posterior acetabular fractures [21]. Just inferior to the acetabulum, the ischium flares laterally before the tuberosity begins. Thus, placement of the screw would be directed more inferior and medial. If a mediolized hip center is necessary, contouring the inferior flange would be required, offsetting the lateral flare. This contouring would also direct the screw more inferiorly. The surgeon must attempt to angle the screw in a more transverse plane to avoid placing the pudendal neurovascular bundle at risk to injury. Alternatively, the inferior flange may be angled medially and driven into the ischium, much like a blade plate. This procedure would avoid problems with screw placement; however, it could potentially cause a stress riser at the acute bend in the inferior flange. This unwanted stress could in fact fracture the flange.

Other structures can also be compromised by screw placement. Jacobs and Buxton [18] reported various branching patterns of the superior gluteal nerve in dissections of 10 cadavers. To assess the potential damage to this nerve, they measured the distance from the midlateral point of the greater trochanter to the nerve’s insertion in the gluteus medius muscle. Jacobs and Buxton reported a descending path for the nerve with a median distance of 5 cm. Our statistical analysis shows with 95% CI that the safe zone is in fact 6.5 cm in the posterior one third of the gluteus medius, 4.7 cm in the middle one third, and 2.9 cm in the anterior one third of the muscle. We agree with Jacobs and Buxton on a descending path for the superior gluteal nerve; however, we believe that a 5-cm safe zone is too generous when dissection is completed in the middle third of the gluteus medius muscle belly or anterior to it.

One of the limitations in our study was that the specimens used in our study were formalin-fixed, and the major vessels were casted in thrombus. This prevented us from injecting the circulatory system with radiopaque silicone and obtaining computerized tomography scans before dissection, as performed by Wasielewski et al [16].

It is also possible that the artificial defect we created in the acetabulum may not be representative of that typically seen when performing this operation. We attempted to simulate the defect as much as possible by reviewing revision cases performed by the senior author. One drawback to creating an artificial defect was that we could not simulate the remodeling reaction and selective bony hypertrophy observed in some loose devices. It is not uncommon to observe a large intraosseous granuloma that protrudes medially along with cement fragments and hardware, distorting all the intrapelvic anatomy and producing severe osteolysis of the remaining ilium and ischium. In certain surgical cases, we currently perform a retroperitoneal exposure of the iliac wing to observe and protect the vital structures while we drill, measure, and place the screws.

Although we cannot conclusively recommend a safe screw length, our results indicate that the superior flange screws should be no greater than 15 mm. Moreover, screws in the ischium should avoid an inferior trajectory and may be safely placed up to 30 mm in length. In addition, the danger zone for the superior gluteal neurovascular bundle is less than 5 cm throughout most of its course, and great care must be taken to avoid it.

The present findings provide the surgeon with additional information to assist in the safe placement of acetabular cages. However, considering the limited body of knowledge in this area, future clinical and experimental studies are warranted to further explore methods to reduce the risk for neurovascular and structural injury after cage placement.

Acknowledgment

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