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Vascular anatomy for rotational acetabular osteotomy: cadaveric study

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Abstract Rotational acetabular osteotomies are performed to correct dysplastic hips in young adults. However, there is a potential risk of intrapelvic vascular injury. To define the relation of these vascular structures to the bone around the acetabulum, we measured the distance and direction from the anteroinferior iliac spine to the external iliac artery and from the base of the superior pubic ramus to the obturator artery in 34 cadaveric hemipelves (17 male, 17 female; 19 left, 15 right). The distance to the external iliac artery was significantly shorter in females (average 31.7 mm) than in males (average 38.2 mm); and the distance to the intrapelvic entry portal of the obturator canal, through which the obturator artery passes, was significantly shorter in females (average 27.2 mm) than in males (average 33.4 mm). In addition, the external iliac artery was located significantly more ventral and closer to the anteroinferior iliac spine in right hemipelves than in left hemipelves. The intrapelvic entry portal of the obturator canal was located more caudodorsal to the base of the superior pubic ramus in females than in males. Care should thus be taken during surgery in light of our findings.

Key words Cadaver study · Pelvic osteotomy · Vascular complication

Introduction

Developmental dysplasia of the hip is characterized by insufficient superolateral and anterior coverage of the femoral head and malposition of the proximal femur. It can be treated surgically in adolescents and young adults by performing a pelvic osteotomy whereby the acetabular fragment is osteotomized from the pelvis and reoriented to provide more lateral and anterior coverage of the femoral head. A rotational acetabular osteotomy is widely performed for this purpose in Japan.[5] The procedure is basically the same as for Wagner's spherical acetabular osteotomy or Eppright's dial osteotomy,[3,7] in which a circumacetabular osteotomy is done. Satisfactory clinical results have been obtained in most cases after a rotational acetabular osteotomy.[4]

When performing a rotational acetabular osteotomy, the osteotomy is done from the lateral surface of the pelvis with the patient in a lateral position. The anterior iliofemoral and posterior approaches are used and are made from the outside inward. Therefore, there is no visual monitor to reduce the potential danger of intrapelvic vascular injury (e.g., to the external iliac artery when excessive drilling is done for fixation of the transferred acetabulum or to the obturator artery when the osteotome is incorrectly inserted to perform the pubic osteotomy). To minimize such risks, it is helpful to define the relation of these intrapelvic vascular structures to the bone around the acetabulum, which the surgeon is able to identify during surgery.

Therefore, using cadaveric specimens, we measured the distance and direction from the the anteroinferior iliac spine to the external iliac artery and from the base of the superior pubic ramus to the obturator artery with special reference to a rotational acetabular osteotomy.

Materials and methods

A group of 34 Japanese embalmed cadavers were used in this study. There were 17 males and 17 females. The mean age at the time of death was 71.5 years (range 47–98 years). The average height was 161.5 cm (range 148–168 cm) in males and 149.3 cm (range 142–160 cm) in females. The average intercristal diameter was 27.2 cm

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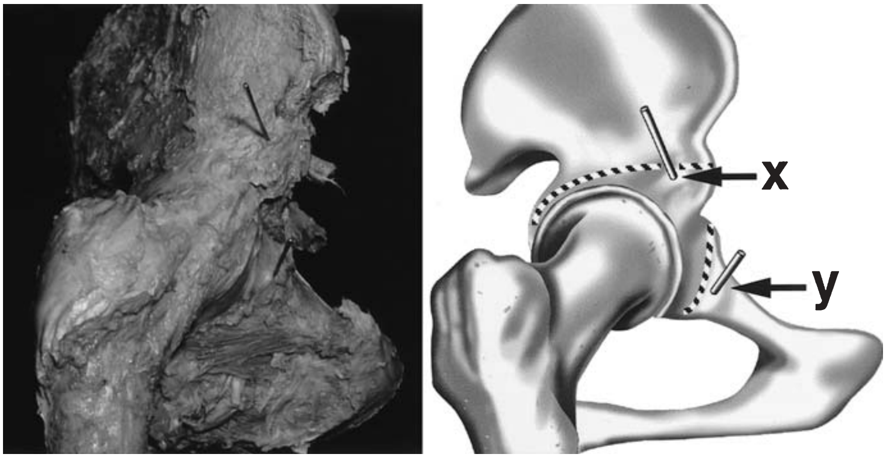

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Fig. 1. **a** Photograph of an anatomically dissected right pelvis in a lateral position showing the location of the Kirschner wire (K-wire) relative to the bone around the acetabulum. **b** Matching illustration. Point *x* shows the entry point of a K-wire 1 cm posterolateral to the anteroinferior iliac spine on the outer surface of the ilium. Point *y* shows the entry point of a K-wire in the central portion of the longitudinal ridgeline on the superior pubic ramus base between the iliopsoas and pectineal muscles. *Dotted* lines show the iliac and pubic osteotomies

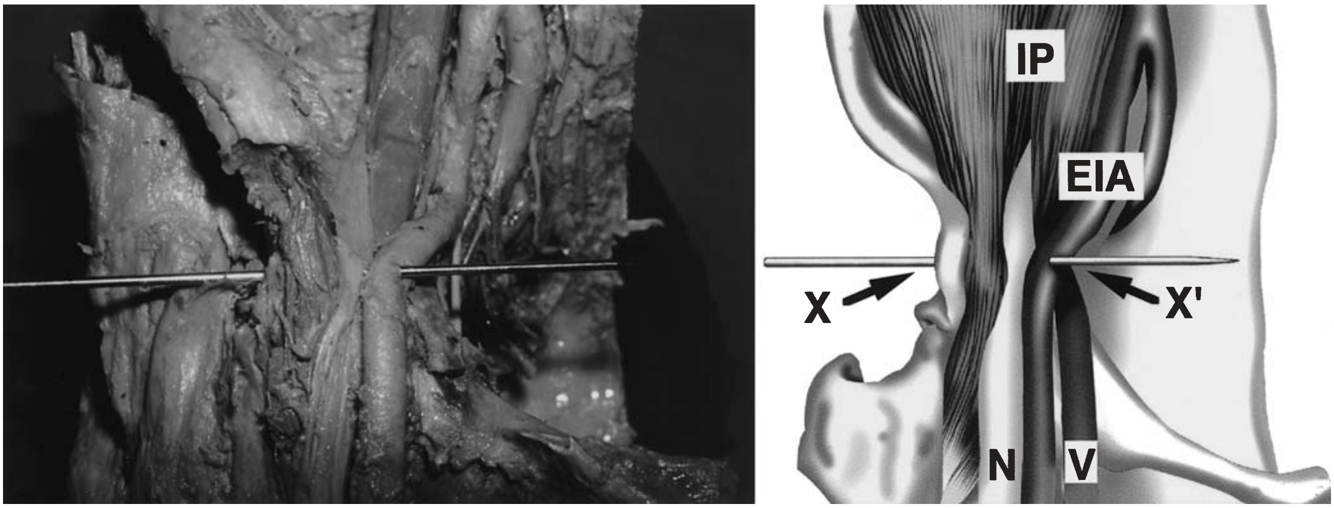

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Fig. 2. **a** Anterior-view photograph of an anatomically dissected right pelvis showing the location of the K-wire relative to the major intrapelvic structures. **b** Matching illustration. Point x' shows the point of a K-wire inserted through point *x*, penetrating the external iliac artery (*EIA*). *IP*, iliopsoas muscle; *V*, femoral vein; *N*, femoral nerve

(range 24–30 cm) in males and 27.1 cm (range 25–29 cm) in females. The average true conjugate was 11.0 cm (range 10.0–12.5 cm) in males and 11.5 cm (range 9.5–13.4 cm) in females. The average transverse diameter of the superior pelvic aperture was 10.8 cm (range 8.0–11.8 cm) in males and 12.0 cm (range 11–13 cm) in females.

Following intestinal evisceration, each specimen was transected between the fourth and fifth lumbar vertebrae, and the lower part of each body was bisected in the median plane. The hemilateral lower body of each cadaveric specimen was utilized. After stripping back and removing the muscles peripheral to the hip joint, the specimens were placed in a lateral position. Each hemipelvis was fixed with wooden blocks by making the posterior surface of the bisected sacrum parallel to the sideline of the table and by contacting the longitudinal section of the sacrum and symphis pubis closely to the surface of the table. A total of 19 specimens (11 male, 8 female) were from the left side, and 15 specimens (6 male, 9 female) were from the right side.

External iliac artery

Because the anteroinferior iliac spine is palpable during surgery, a point *x* was determined 1 cm posterolateral to the anteroinferior iliac spine on the outer surface of the ilium (Fig. 1). A Kirschner wire (K-wire), 2 mm in diameter, was inserted through point *x* toward the external iliac artery, keeping the K-wire in the horizontal plane. The entry point of the K-wire penetrating the center of the external iliac artery was termed point x' (Fig. 2). The angle of inclination of the K-wire in the horizontal plane was measured. Ventral inclinations of the tip of the K-wire were allocated positive values and dorsal inclinations negative values (Fig. 3). Next, we measured the thickness of the ilium in this region and the distance *xx′*, or the distance from the outer surface of the ilium to the external iliac artery. The K-wire is usually inserted from anteroinferior to the shifted acetabulum toward the sacroiliac joint to transfix it to the ilium during surgery. In this study we used the K-wire to determine the distance and direction from the anteroinferior iliac spine to the external iliac artery. Figure 2 demonstrates that the external iliac artery is penetrated on purpose, with the K-wire inserted from the outer surface of the ilium.

Obturator artery

Next, point *y* was determined at the central portion of the longitudinal ridgeline, which is made between the iliopsoas and pectineal muscles on the superior pubic ramus base (Fig. 1). The peritoneum was stripped and the internal wall of the pelvis exposed. The intrapelvic entry portal of the obturator canal was then determined as point *y′*, through which the obturator artery passes (Fig. 4). A K-wire was inserted through point *y* and directed toward point *y′*. The angle of the K-wire in the sagittal and horizontal planes was measured. In the sagittal plane, cephalad inclinations of the tip of the K-wire were allocated positive values and caudal inclinations negative values (Fig. 5a). In the horizontal plane,

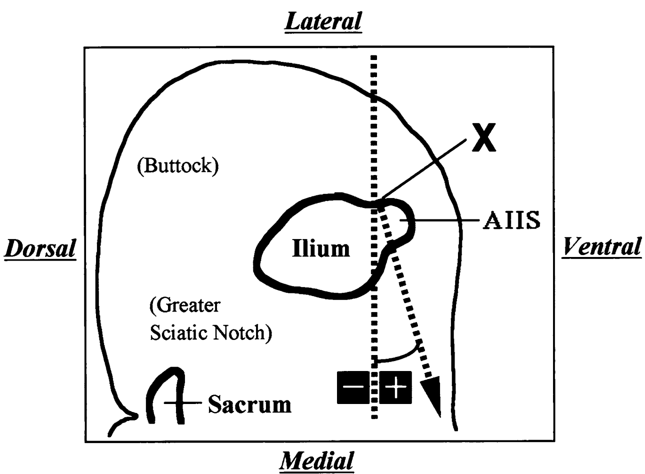


Fig. 3. Right pelvis in a lateral postion when viewed from below, sectioned horizontally at the level of the anteroinferior iliac spine. It shows the insertion angle of a K-wire. ±, ventral inclinations of the tip of the K-wire; −, dorsal inclinations; *AIIS*, anteroinferior iliac spine

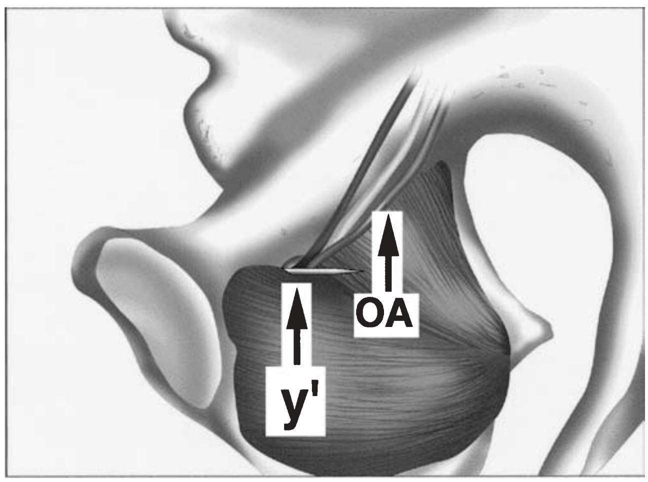
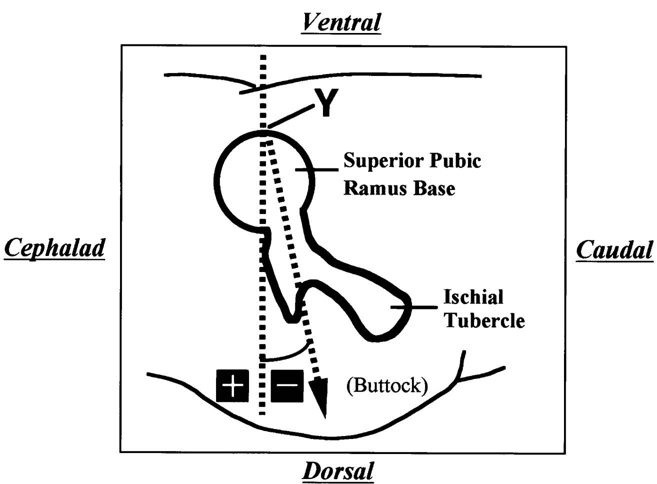


Fig. 4. Right pelvis showing the anteroinferior quadrant of the intrapelvic surface. Point *y′*, or the intrapelvic entry portal of the obturator canal, shows the exit point of a K-wire, which is inserted through point *y*. *OA*, obturator artery



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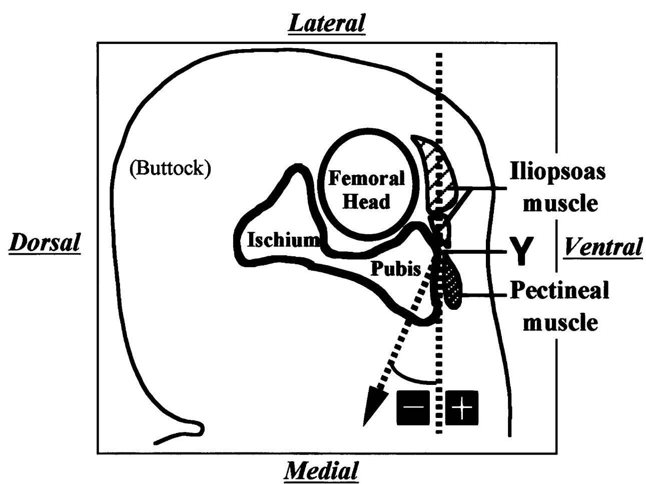

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Fig. 5. Right pelvis in a lateral postion, sectioned at the level of the superior pubic ramus base. It shows the insertion angle of a K-wire. **a** Sagittal plane in the lateromedial view. +, cephalad inclinations of the tip of the K-wire; −, caudal inclinations. **b** Horizontal plane when viewed from below. +, ventral inclinations of the tip of the K-wire; −, dorsal inclinations

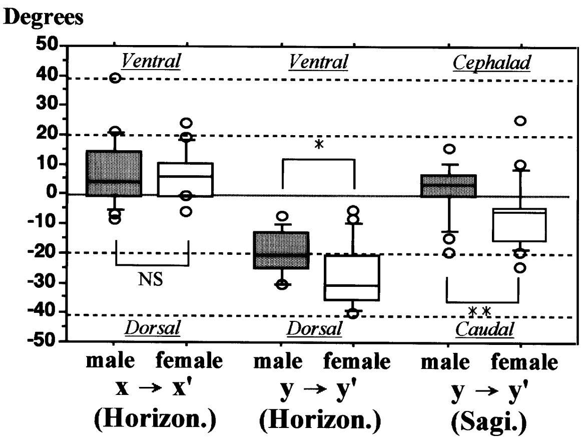

Fig. 6. Directions from the anteroinferior iliac spine to the external iliac artery and from the base of the superior pubic ramus to the obturator artery. $x \to x'$ *(horizon.)*, inclination angle of the tip of the K-wire in the horizontal plane when the K-wire is inserted through point *x* to *x'*; $y \to y'$ *(horizon.)* and $y \to y'$ *(sagi.)*, inclination angle of the tip of the K-wire in the horizontal and sagittal planes when the K-wire is inserted through point *y* to *y'*. $P < 0.05$; $^{**}P < 0.01$; *NS*, not significant. *Lower transverse line* of each box shows the 25% value; *upper transverse line* shows the 75% value; *transverse line* shows the median

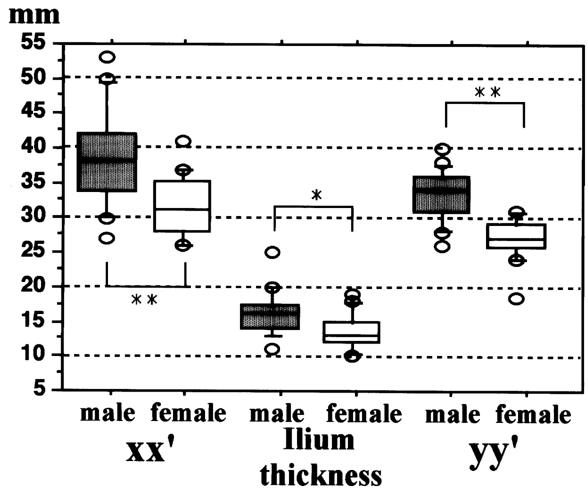

Fig. 7. Thickness of the ilium at the anteroinferior iliac spine, the direction from the anteroinferior iliac spine to the external iliac artery, and the direction from the base of the superior pubic ramus to the obturator artery. *xx'*, distance between points *x* and *x'*; *Ilium thickness*, bony thickness at point *x*; *yy'* distance between points *y* and *y'*. $^{*}P < 0.05$; $^{**}P < 0.01$. *Lower transverse line* of each box shows the 25% value; *upper transverse line* shows the 75% value; *transverse line* shows the median

ventral inclinations of the tip of the K-wire were allocated positive values and dorsal inclinations negative values (Fig. 5b). The distance *yy'* was then measured.

Statistical analyses

Statistical analyses were carried out using the Mann-Whitney U-test. Statistical significance was selected as a probability of less than 0.05. Correlation analyses were carried out using Pearson's correlation coefficient. Statistical significance was selected as a probability of less than 0.05.

Results

External iliac artery

At point *x* the external iliac artery was penetrated when the K-wire was inserted with an average inclination of 8.9° (range −8° to 40°) in males, and 7.6° (range −5° to 25°) in females (Fig. 6). There was no significant difference between the sexes. The average thickness of the ilium in this region was 16.1 mm (range 11–25 mm) in males and 13.4 mm (range 10–19 mm) in females (Fig. 7), indicating a significant difference between the sexes ($P < 0.05$). The average distance of *xx'* was 38.2 mm (range 27–53 mm) in males and 31.7 mm (range 26–41 mm) in females, also indicating a significant difference between the sexes ($P < 0.01$). These results suggest that the distance *xx'* was significantly shorter and that the thickness of the ilium was significantly thinner in females than in males.

We then analyzed correlations of the height with the distance *xx'*, the intercristal diameter, the true conjugate, and the tranverse diameter of the superior pelvic aperture. A significant positive correlation was found only between the height and distance of *xx'* ($P < 0.05$; $r = 0.346$).

Next, right and left hemipelves were compared in terms of the distance and the direction from point *x* to point *x'* (Fig. 8). A significant difference ($P < 0.01$) in the insertion angle of the tip of the K-wire, which averaged 3.7° (range −8° to 20°) in left hemipelves, and 13.9° (range 0°–40°) in right hemipelves. The distance *xx'* was also significantly different ($P < 0.05$), averaging 37.6 mm (range 28–53 mm) in left hemipelves and 31.6 mm (range 26–39 mm) in right hemipelves. On the basis of these observations, point *x'* was found to be located closer and more ventral to point *x* in right hemipelves than in left hemipelves. In Figure 8 the area from the 20% value to the 80% value of each measured distance and direction is shaded to represent the danger zone for external iliac arterial injury.

Obturator artery

At point *y* there was a significant difference ($P < 0.01$) between the sexes in terms of the inclination of the K-wire in the sagittal plane, which averaged 1.5° (range

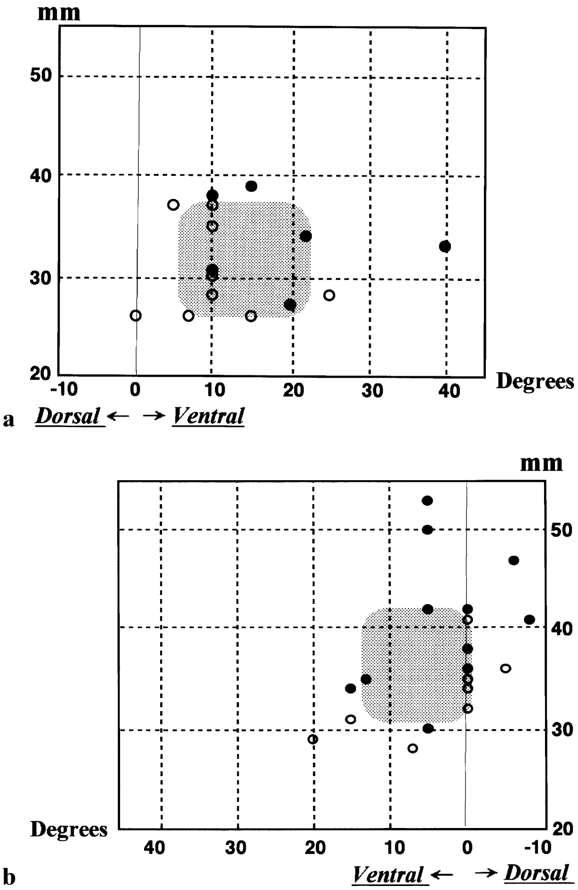

Fig. 8. Danger zone for external iliac arterial injury. **a** Right pelvis. **b** Left pelvis. The area that covers from the 20% value to the 80% value of the measured distance and direction is *shaded*. *Filled circles*, males; *open circles*, females

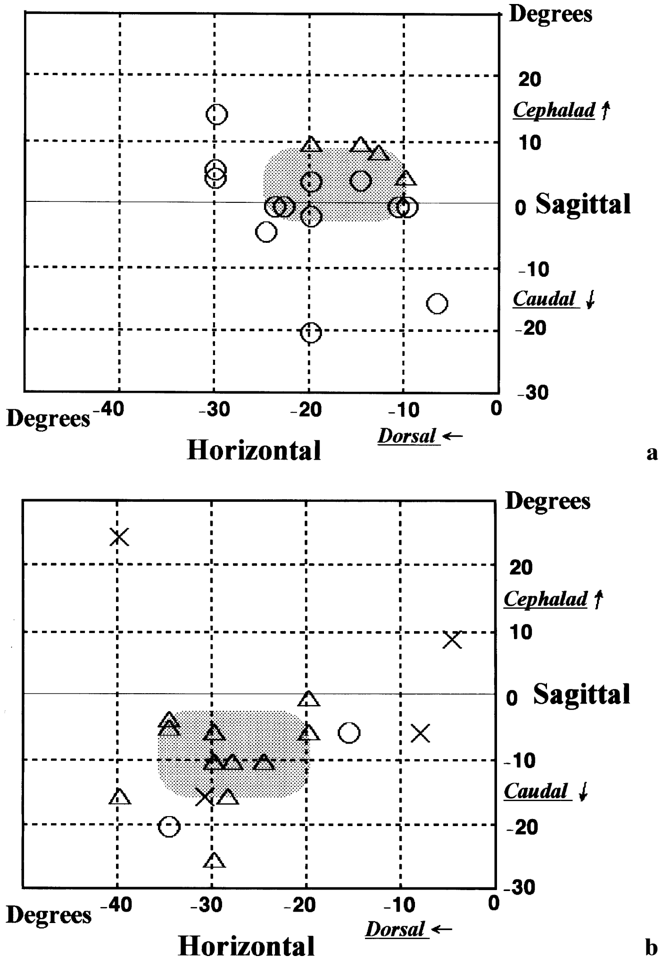

Fig. 9. Danger zone for obturator arterial injury. **a** Males. **b** Females. The area that covers from the 20% value to the 80% value of measured sagittal and horizontal directions is *shaded*. The distance is marked as described below. *Circles*, ≥31 mm; *triangles*, 26–30 mm; ×, ≤25 mm

−20° to 15°) in males and −6.6° (range −25° to 25°) in females (Fig. 6). The inclination in the horizontal plane, on average, was −18.9° (range −30° to −7°) in males, which was significantly different ($P < 0.05$) from the −26.9° (range −40° to −5°) in females (Fig. 6). For that reason, point y' was located more caudodorsal to point y in females than in males. The average distance of yy' was 33.4 mm (range 26–40 mm) in males and 27.2 mm (range 19–31 mm) in females (Fig. 7), indicating a significant difference between the sexes ($P < 0.0001$). Point y' was located significantly closer to point y in females than in males.

We then analyzed correlations of the height with the distance yy', the intercristal diameter, the true conjugate, and the tranverse diameter of the superior pelvic aperture. A significant positive correlation was found only between the height and distance of yy' ($P < 0.01$; $r = 0.480$).

Next, right and left hemipelves were compared in terms of the distance and direction from point y to point y'. The insertion angle of the tip of the K-wire in the sagittal plane averaged −3.7° (range −25° to 15°) in left hemipelves and −1.1° (range −15° to 25°) in right hemipelves. The insertion angle in the horizontal plane averaged −22.8° (range −40° to −5°) in left hemipelves and −23.0° (range −40° to −8°) in right hemipelves. The distance yy' averaged 31.2 mm (range 24–40 mm) in left hemipelves and 29.1 mm (range 19–38 mm) in right hemipelves. No significant differences were found between these two groups. In Fig. 9 the area from the 20% value to the 80% value of each measured direction is shaded to represent the danger zone for obturator arterial injury.

Discussion

Vascular injuries are an uncommon yet potentially devastating complication of pelvic osteotomy. Tönnis et al. reported on 216 hips that had undergone a triple pelvic osteotomy.[6] Of the 216 hips, one sustained an injury to the femoral vein that had to be sutured. Davey and Santore reported on 70 hips that had undergone periacetabular osteotomy.[1] Of the 70 hips, one suffered massive bleeding from avulsion of a branch of the external iliac artery.

Anatomical investigations of the vascular structure of the pelvis have seldom been undertaken. De Kleuver et al. reported on the anatomic basis of Tönnis' pelvic osteotomy using 12 cadaver hips.[2] They described the practical surgical implications of Tönnis' pelvic osteotomy with respect to the requirements of meticulous subperiosteal dissection and accurate placement of retractors, but we could find no other comparable anatomical studies. Therefore, utilizing Japanese cadavers, we studied the locations of the major intrapelvic vascular structures relative to the bone around the acetabulum.

We found that the distance from the outer surface of the ilium to the external iliac artery was significantly shorter and the thickness of the ilium significantly thinner in females. These findings suggest that there is a greater risk of external iliac arterial injury in females than in males. We also measured the direction from the anteroinferior iliac spine to the external iliac artery in the horizontal plane. There was no significant difference between the sexes. On the other hand, the external iliac artery was located closer and more ventral to the anteroinferior iliac spine in right hemipelves than in left hemipelves. To our knowledge, no previous studies have described a significant difference in the location of this artery between the right and left sides. This finding indicates that a right pelvic osteotomy seems to be potentially more dangerous in regard to the risk of vascular injury to the external iliac artery than that on the left side.

The external iliac artery diverges from the common iliac artery, goes down along the medial margin of the psoas major muscle, and runs over the iliopubic eminence. The femoral artery follows it. The external iliac artery comes ventrally, climbing over the iliopubic eminence at the level of the anteroinferior iliac spine. Our results also show that the external iliac artery is located ventral to the anteroinferior iliac spine in most cases. For that reason it is important that the K-wire be inserted dorsally, or toward the sacroiliac joint, while drilling to transfix the transferred acetabulum to the iliac bone according to the standard procedure.

By measuring of the distance and direction from the base of the superior pubic ramus to the obturator artery, we found that the intrapelvic entry portal of the obturator canal, through which the obturator artery passes, was located more caudodorsal and closer to the base of the superior pubic ramus in females than in males. This is thought to be due to the fact that, compared with the male pelvis, the female pelvic cavity is more oval and cylindrical, and female bones are thinner.[8] In consideration of the reproducibility of the study, the K-wire was inserted at the central portion of the longitudinal ridgeline, which is made between the iliopsoas and the pectineal muscles on the superior pubic ramus base. However, osteotomy of the pubis is usually performed more adjacent to the acetabulum. Consequently, the distance to the intrapelvic entry portal of the obturator canal from the osteotomy site of the pubis must be shorter than our results. We estimate that the distance to the obturator artery would average approximately 20 mm in females. Therefore, when performing a pubic osteotomy the chisel must be directed cephaladoventrally in females and caudodorsally in males, with adequate placement of a blunt retractor.

As for the frame, it is thought that a more cautious procedure is necessary in patients with short stature because positive correlations were found between height and distances to the external iliac artery and to the entry portal of the obturator canal.

Conclusions

The location of the external iliac artery differed between the sexes and between the left and right sides. The location of the obturator artery also differed between the sexes. These findings may be helpful for surgeons performing a rotational acetabular osteotomy, but it must be remembered that, these conclusions were drawn from the study of Japanese cadavers with normal hips. Additional studies are needed on specimens with developmental dysplasia of the hip.

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