4 Pelvic Osteotomies: The Periacetabular Osteotomy Technique for Patients with Developmental Dysplasia of the Hip

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4.1 Introduction

Numerous osteotomies have been described in an attempt to improve hip joint mechanics in young patients with symptomatic dysplasia in the absence of secondary arthritis [1]. The Bernese periacetabular osteotomy (PAO) which was first described by Prof. Reinhold Ganz for the treatment of symptomatic hip dysplasia has become the pelvic osteotomy of choice at many institutions [2]. There are several well-described advantages associated with the PAO technique, particularly the ability to perform an optimal deformity correction in all planes through a single incision [2, 3]. Additionally, as the posterior column remains intact, the osteotomy is inherently stable, and in conjunction with the preservation of the abductor mechanism, accelerated rehabilitation with early weight bearing is possible after PAO [4].

As the anatomy of patients with dysplasia can vary significantly it is useful to be able to perform both large and small corrections in any plane. In dysplastic patients the major deformity is usually on the acetabular side. Generally the acetabulum is shallow and excessively anteverted with a lateralized hip center (Fig. 4.1; [5]). This deformity results in an anterior superior deficiency. However the acetabulum may also be deficient posteriorly secondary to acetab-

Fig. 4.1 AP pelvic radiograph demonstrating classic dysplasia of the right hip. The acetabulum is shallow, and the hip center is lateralized with both anterior and superior deficiency

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ular retroversion in up to 40% of patients [6]. On the femoral side, excessive anteversion and a high neck-shaft angle are common. Overall these anatomic abnormalities result in decreased contact area between the weight-bearing dome of the acetabulum and the femoral head.

Patients with dysplasia often have activity-related groin pain that is related to both instability of the femoral head and higher joint reactive forces secondary to the lateralized hip center. Trochanteric pain is also common and often associated with abductor fatigue while catching and mechanical symptoms may be indicative of chondral and/or labral pathology [7]. With an appropriate correction, the reoriented acetabular fragment allows a more normal load transmission through the cartilage surface area, and medialization of the hip center when needed lessens the joint reactive forces in the hip joint. By correcting the anatomic abnormalities and improving the biomechanics of the hip, a PAO in the right patient can reliably improve symptoms and result in excellent long-term survivorship (Table 4.1; [8–13]).

While there may be variations in patient anatomy and surgical technique, the overall goal of the procedure remains the same: Obtain adequate exposure of the innominate bone to safely enable four separate osteotomies to be performed, thereby allowing a complete detachment of the acetabulum from the intact pelvis while leaving the posterior column intact to reorient the acetabulum in all required planes. It is critical that these goals be achieved while minimizing the risk of intraoperative complications as PAOs are not without risk and complications can be high particularly when performed by surgeons without the appropriate training or while still in their learning curve [8, 14].

By having an intimate knowledge of the anatomy around the pelvis and recognizing the structures at risk, in general a PAO can be performed safely and in a reproducible fashion [15, 16].

4.1.1 Anatomic Structures at Risk

1. The lateral femoral cutaneous nerve (LFCN): Is at risk both during exposure and closure. Symptoms associated with the LFCN can occur in 75% or more of patients although symptoms resolve in most patients [15]. As such all patients should be made aware of this potential complication.
2. Obturator neurovascular structures: Are at risk during the dissection down to the ischium and during the superior pubic ramus osteotomy.

Table 4.1 Literature results of the Bernese periacetabular osteotomy for patients with hip dysplasia

Authors	Year	Number of hips	Mean patient age in years (range)	Mean follow-up in years (range)	Success rate (%)[a]	Results[b]
Trousdale et al.	1995	42	37 (11–56)	4 (2–8)	86	HHS improved by 24 points
Siebenrock et al.	1999	75	2 (13–56)	11 (10–14)	82	–
Clohisy et al.	2005	16	18 (13–32)	4 (2–8)	100	Merle d'Aubigné improved by 15 points
Cunningham et al.	2006	52	27	2 (2–8)	90	HHS improved by 6 points
Peters et al.	2006	83	31	3	96	WOMAC improved by 33 points
Garras et al.	2007	58	38 (13–48)	6 (1–13)	95	Merle d'Aubigné improved by 3 points
Steppacher et al.	2008	68	29 (13–56)	20 (19–23)	60	Merle d'Aubigné improved by 0.6 points

HHS Harris hip score, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index
[a]Success is defined as procedures not requiring conversion to a total hip arthroplasty
[b]All results are mean values and indicate improvement from preoperative to postoperative

3. Medial femoral circumflex artery: Is at risk during exposure of the inferior ischial cut if dissection during the blind exposure of the ischium is carried distal from the cephalad edge of the obturator externus [17, 18].
4. Femoral neurovascular structures: Are at particular risk during the exposure of the superior pubic ramus and when excessive tension is applied to the psoas during exposure.
5. Sciatic nerve: Is at risk during the ischial and posterior iliac osteotomies if care is not taken to prevent the osteotomes from migrating too far laterally as these are blind cuts.

4.2 Alternative Treatments

The appropriate indication for a PAO is essential as there is a wide spectrum of anatomic abnormalities in dysplastic hips which vary based on the severity and type of deformity [1, 19]. Initially patients should be treated nonsurgically with physical therapy, anti-inflammatory medications, and activity modifications. The natural history of dysplasia should be discussed with the patient, and radiographs should be obtained every couple of years to monitor for the development of subsequent osteoarthritis. Surgical management should be reserved for patients with persistent symptoms in conjunction with marked structural abnormalities.

While a pelvic realignment osteotomy is the procedure of choice for most patients with symptomatic dysplasia, other surgical procedures should also be considered when appropriate. Poor candidates for a PAO include those patients with a lack of joint congruency on abduction films, significant cephalad migration of the femoral head, an open triradiate cartilage, and osteoarthritis with Tönnis grade two or higher [20]. While there is not a defined upper age limit, in general PAOs are rarely performed in patients greater than 45 years. Excellent long-term survivorship and maintenance of functional gains after PAO have been reported when performed in well-selected patients [9, 10].

4.3 Surgical Technique

Although the PAO technique has already been extensively described in the literature, the technique continues to evolve and the following is our preferred and current surgical technique.

4.3.1 Preoperative Planning

- In addition to a detailed history and clinical examination, standard AP pelvic and false-profile-view radiographs are obtained for all patients.
- Although not routine, a computerized tomography (CT) scan (1 mm slices and 3-dimensional reconstruction) of the pelvis with knee cuts can also be obtained and is particularly helpful in evaluating the femoral neck torsion if a femoral osteotomy is being considered in conjunction with the PAO. This would be considered in patients with severe dysplasia (possibly varus osteotomy), increased antetorsion (derotational retroverting osteotomy), or significant limitations in range of motion (derotational anteverting osteotomy).

4.3.2 Setup and Positioning

- The patient is placed on an image table.
- Regional spinal anesthesia is the preferred anesthetic option for most patients undergoing a PAO in conjunction with a local periarticular anesthetic.
- Intraoperative cell saver is routinely used rather than preoperative autologous blood donation.
- Tranexamic acid is administered intravenously (1 g prior at incision, and 1 g at closure).
- Intraoperative electromyography monitoring (EMG) of both the sciatic and femoral nerve is utilized to identify intraoperative pressure and tension on these structures (Fig. 4.2; [21]).
- Specialized osteotomes have been developed and are helpful at various stages of the procedure (Fig. 4.3).

Fig. 4.2 Intraoperative photograph showing a patient draped for a periacetabular osteotomy to manage hip dysplasia with both fluoroscopic imaging and electromyographic monitoring equipment

Fig. 4.3 Intraoperative photograph showing the back table setup for a periacetabular osteotomy with the various retractors and specialized osteotomes routinely used

4.3.3 Skin Incision and Exposure

- A modified Smith-Petersen approach, with a superficial Hueter approach, is utilized which spares the abductor muscles as the osteotomies are performed through the inner aspect of the pelvis [3].
- The incision begins just lateral to the border of the iliac crest and is carried distal and lateral to the anterior superior iliac spine (ASIS). The incision ends approximately 3 cm distal and anterior to the greater trochanter.
- The fascia is incised distally to the ASIS over the tensor fasciae latae (TFL), and the interval between sartorius and the TFL is developed with blunt dissection down to the anterior inferior iliac spine (AIIS).
- The entire origin of sartorius is subperiosteally reflected off the ASIS with electrocautery and tagged with a suture for later repair.
- The hip is flexed and adducted after which an angled Cobb elevator is utilized to expose the inner table of the pelvis from the sciatic notch to the quadrilateral surface.
- With the hip flexed and the inner table of the pelvis exposed, the iliopsoas tendon can be retracted medially to expose the pubis medial to the iliopectineal eminence. In order to protect the femoral neurovascular structures, the iliopsoas tendon should not be tenotomized. Once the iliopectineal eminence is clearly visible a sharp Hohmann can be placed medial in the pubis to aid in retraction.
- At this point the direct head of the rectus femoris can be reflected distally off the AIIS and an arthrotomy can be performed to address any central compartment pathology. However a rectus-sparing approach is currently our preference.
- Blunt dissection with curved scissors is carried out medial to the direct head of the rectus femoris and distally to develop a plan between the iliocapsularis and hip capsule. The scissors should be able to palpate the ischium at this point.

4.3.4 Procedure

- Utilization of intraoperative fluoroscopy at several critical points has made performing the pelvic osteotomies relatively routine and predictable.
- The osteotomies include a partial osteotomy of the ischium, a complete pubic osteotomy, and a biplanar osteotomy of the ilium ensuring that the posterior column remains intact.
- For the authors, the intraoperative fluoroscopy is critical throughout the entire procedure and makes the operation safe, teachable, and reproducible.
- An anterior-posterior (AP) image is used to ensure proper medial-lateral placement of the curved osteotome on the ischium as well as proper orientation (Fig. 4.4).
- An oblique 55°–65° (65° preferred except in heavy-set patients) image is used while making the ischial osteotomy to determine the appropriate depth of the osteotomy (Fig. 4.5).

Fig. 4.4 Intraoperative AP fluoroscopic image demonstrating the appropriate placement of the ischial osteotome. A Hohmann retractor is in the medial aspect of the pubis

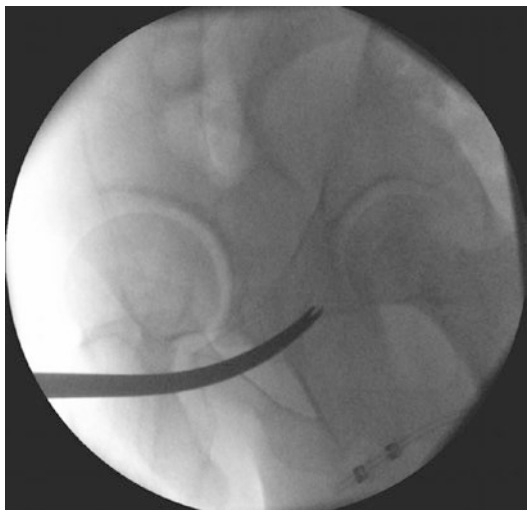

Fig. 4.5 Intraoperative oblique fluoroscopic image demonstrating the appropriate depth of the ischial osteotome

- Once the ischial osteotomy is completed, the osteotome can be left in place to serve as a guide while the posterior iliac osteotomy is performed as the medial aspect of the osteotome can often be palpated over the quadrilateral surface. However leaving this osteotome in place can cause increased tension on the femoral nerve, and as such the leg should remain flexed as long as the osteotome is in place (Fig. 4.6).
- If a rectus-sparing PAO is performed then we would always recommend removing the osteotome from the ischium.
- The pubic bone can now be fully exposed and if needed another sharp Hohmann retractor can be placed more medially in the pubis if needed. Blunt retractors should be placed around the superior and inferior aspect of the pubis to protect the obturator neurovascular structures while making this osteotomy.
- The proper orientation of the pubic cut is critical to allow mobilization of the acetabular fragment. The osteotomy should be oriented from proximal-medial to distal-lateral away from the joint.
- An AP image is used to determine the level of the iliac cut which is typically just distal to the ASIS. This osteotomy must be proximal enough to allow for satisfactory fixation of the acetabular fragment. In cases of severe dysplasia the cut may sometimes be above the ASIS.
- Once the level of the iliac cut is determined with an AP image, the oblique 55°–65° image is used to determine the depth of the cut. The oblique image may need to be adjusted depending on the patient's bony morphology and habitus to ensure that the posterior column and articular surface are clearly visible.

Fig. 4.6 Intraoperative photograph of the ischial osteotome in place with a Hohmann retractor in the pubis and the image intensifier in the background

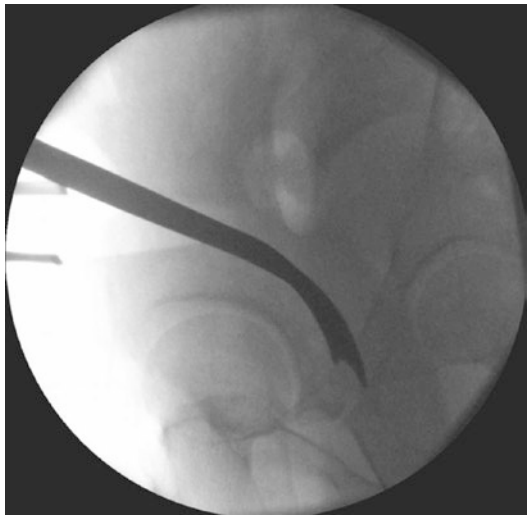

Fig. 4.7 Intraoperative oblique fluoroscopic image demonstrating the posterior iliac cut as it joins the ischial cut. Both the articular surface and posterior column are intact and clearly visible

- With clear radiographic visualization of the posterior column and articular surface, the posterior iliac osteotomy can be safely performed. Often several passes are required to complete this osteotomy (Fig. 4.7).

4.3.5 Mobilization and Correction of the Acetabular Fragment

- After completion of the osteotomies the posterior column should remain intact, and the acetabular fragment must now be freely mobilized.
- The two most common sites where the fragment is restricted are the pubic osteotomy and the junction of the posterior column and ischial osteotomy.
- A 4 mm Schanz pin is placed in the acetabular fragment to assist in mobilization. The 4 mm Schanz pin can be exchanged for a 6 mm one if fixation is lost.
- Obtaining the proper correction is the most challenging aspect of the procedure. For a typical correction in a dysplastic patient, the acetabular fragment is displaced medially, rotated anteriorly and laterally (with care taken to maintain proper anteversion), and provisionally fixed with two smooth 3.2 mm Steinmann pins.
- After provisional fixation an intraoperative AP radiograph of the pelvis is obtained to assess the correction. Care must be taken to ensure that the pelvis is not tilted in any direction as this will alter the assessment of acetabular correction.
- A satisfactory correction is obtained when the weight-bearing surface of the acetabulum is between 0° and 10° off horizontal, the femoral head is congruous, and the anterior wall covers less of the femoral head than the posterior wall; they meet at the lateral edge of the sourcil ensuring proper acetabular version, and the femoral head is medialized within 5 mm of the ilioischial line (Fig. 4.8).
- Care must be taken to ensure that the fragment is not overcorrected laterally as this can lead to impingement and the fovea coming into the weight-bearing surface.
- The hip should be taken through a complete range of motion. The hip should be able to flex up to 110°–115° without impingement of the head-neck junction on the acetabular rim. If there is impingement, we ensure that the fragment has not been inadvertently retroverted. If the socket is not retroverted the head-neck junction ratio can be improved by performing an osteochondroplasty.
- Once the correction is satisfactory, the acetabular fragment is fixed with fully threaded

Fig. 4.8 Postoperative AP pelvic radiograph demonstrating satisfactory correction of classic hip dysplasia on the right side

4.5 mm cortical screws. In some patients with smaller bony anatomy, 3.5 mm screws can be utilized. The screws may be countersunk to decrease their prominence, but in our experience this has not resulted in a lower rate of hardware removal.

- Due to the morbidity associated with taking down the rectus to address intra-articular pathology, the central compartment is only evaluated if there is a high index of suspicion for symptomatic intra-articular pathology. Hip arthroscopy prior to the PAO is a safe aid to evaluate and treat the central compartment.

4.3.6 Wound Closure

- After correction there is often a prominent AIIS which may be trimmed and used as bone graft in the anterior gap of the iliac osteotomy.
- If a capsulotomy was performed the capsule is repaired with resorbable suture while the rectus femoris is reattached to the AIIS with nonresorbable suture.
- With the hip flexed the sartorius muscle is repaired to the ASIS through a bone tunnel using the tag suture as a guide.
- A deep drain is placed intrapelvic and removed on postoperative day 1. The deep fascia is closed with buried interrupted sutures, and skin closure is performed in a routing fashion with resorbable suture and glue.

4.4 Postoperative Regimen

Postoperatively patient mobilization with ambulatory aids begins on the day of surgery. Most patients receive scheduled acetaminophen and oral narcotics as needed for pain in conjunction with their intraoperative periarticular injection. For venous thromboembolism (VTE) prophylaxis in low-risk patients, low-dose aspirin twice daily is used for 6 weeks. A structured physical therapy regimen typically starts 2 weeks after surgery, while full weight bearing is not permitted until 6 weeks. Abduction exercises, water therapy, and stationary bike exercises are started after 4 weeks.

4.5 Avoiding Pitfalls and Complications

Pelvic osteotomies, particularly a PAO, are complex procedures with significant potential complications. The overall experience of the surgeon performing the procedure is a major factor as the learning curve for this procedure is steep with a high risk of complications early on [14, 22]. These procedures should be performed by surgeons that have had dedicated training in the technique by surgeons who routinely perform the procedure. Additionally, we have found that utilization of cadaveric lab is extremely helpful for surgeons prior to independently performing a PAO.

Complications after PAO include but are not limited to neurovascular injuries, intra-articular extension of the osteotomies, infection, nonunion, heterotopic ossification, and VTEs. A body mass index (BMI) greater than 30 kg/m^2 is a known risk factor for complications after a PAO with a 22% rate of major complication reported in the literature compared to a 3% rate in patients with a BMI under 30 kg/m^2 [23].

While major nerve injuries after PAOs are rare with one study reporting a complication rate of 2.1% for major femoral or sciatic nerve dysfunction, it is a devastating complication [21]. Because of this risk, the use of intraoperative EMG is standard in our practice. Minor nerve-related injuries on the other hand are common with up to 75% of patients reporting paresthesia in the lateral aspect of the thigh after surgery related to either direct injury or traction to branches of the lateral femoral cutaneous nerve [21, 22]. Most of these patients do not require further treatment, but patients should be made aware of this complication prior to the procedure due to the high incidence.

The incidence of stress fractures after PAOs is controversial. Previous reports have placed the incidence between 2 and 3%, but more recent lit-

erature has reported the rate to be much higher at 18% [24]. Although most stress fractures heal uneventfully, nonunion of the pubic osteotomy is much more common in these patients. Fortunately most nonunions of the pubis are an asymptomatic radiographic finding. Bone grafting or plate fixation of stress fractures and nonunions is rarely required.

Although much less common with the use of intraoperative fluoroscopy, inadvertent extension of an osteotomy into an undesired location can occur. Intra-articular extension of the ischial osteotomy can occur particularly in patients with cephalad migration of the femoral head. While this intra-articular extension does not cause a joint incongruity, it can interrupt the blood supply to the acetabular fragment [25]. Intra-articular extension of the vertical limb of the iliac osteotomy on the other hand can create a joint incongruity after correction leading to secondary arthrosis. The iliac osteotomy can also be inadvertently extended through the posterior column which can destabilize the pelvic ring.

By far the most common complication after PAO remains poor positioning of the acetabular fragment with both overcorrection and retroversion being common. Overcorrection of the acetabular fragment can result in impingement symptoms or posterior subluxation of the femoral head. Anterior impingement can be a sign of excessive anterior correction or retroversion of the acetabular fragment. Obtaining a true AP pelvic radiograph and taking the hip through a range of motion intraoperatively can help the surgeon recognize these problems. If recognized intraoperatively, the acetabular fragment can be repositioned, and extra-articular impingement can be addressed. Although the learning curve is steep and potential complications for this procedure are high, in our hands a well-done osteotomy in properly selected patients is a relatively reliable and successful procedure for patients with symptomatic hip dysplasia.

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