Surgical treatment of pelvic ring fractures

Jan Lindahl and Eero Hirvensalo
Department of Orthopaedics and Traumatology, Helsinki University Central Hospital, Helsinki, Finland

Unstable pelvic ring disruptions result from high energy trauma and often are associated with multiple concomitant injuries (1–3). Hemorrhage, head injury, pelvic soft tissue trauma (open fractures), and primary system complications are responsible for high mortality rates (4–6). If the patient is hemodynamically unstable the primary goals are to control airways, to establish adequate ventilation and to maintain circulation. The external fixation frame may play a role in partial stabilization of the pelvic ring, reducing pelvic volume, increasing tamponade, and thereby reducing bleeding (7–10). Once patients are stabilized, careful assessment and definitive treatment of the pelvic ring injuries can be done.

In the 1970s, external fixation devices became popular as definitive treatment of unstable pelvic ring injuries (11–14). Later, it became clear that an external frame applied anteriorly could not restore enough stability to an unstable (Type-C) disruption of the pelvic ring to allow mobilization of the patient without risking redisplacement of the fracture (15–19). Therefore, methods of open reduction and internal fixation (ORIF) were introduced (20–25). More recently, closed reduction and percutaneous screw fixation techniques have been developed (26–28). Internal fixation has become the preferred treatment for unstable posterior pelvic ring injuries (3,21,24,29), but the indications for fixation of the anterior pelvic ring injuries have varied (27,30–32).

Classification

According to AO/ASIF classification system the pelvic ring fractures are graded into three types, A, B, and C, in order of increasing severity (18). Type-A injuries are stable including avulsion fractures, fractures of the iliac wing and transverse fractures of the sacrum. Type-B injuries are rotationally unstable but vertically and posteriorly stable. They may be caused by external rotatory forces (open book injuries) or internal rotatory forces (lateral compression injuries). Type-C unstable injuries are complete disruptions of the posterior sacroiliac complex, involving vertical shear forces. Posterior pelvic ring injuries form the basis of the subgroups; fractures of the ilium C1-1, sacroiliac dislocation or fracture dislocation C1-2, and sacral fractures C1-3. The posterior injury may be bilateral. The bilateral posterior lesion may be vertically stable on one side and unstable on the other (Type C2), or unstable on both sides (Type C3).

Anterior external fixators

Clinical applications of pelvic external fixators comprise the resuscitation phase, initial fracture stabilization and sometimes definitive fixation. Blood loss following pelvic fracture can be reduced through the early application of anterior external fixator. It can also prevent undesirable movement at the site of the fracture and reduce pain. Pins can be inserted into the iliac crest percutaneously or through small incisions. Guidewires (K-wires) applied along the inner and outer aspects of the iliac wing helps the insertion of the pins into the bone. The frame that connects the pin groups (two pins on each side) can be assembled very

quickly.

Closed reduction of the displaced Type-C pelvic ring injury can be achieved by simultaneous manual distraction of the lower extremity by an assistant and bilateral compression at the level of the trochanters. In open book injuries the diastasis of symphysis pubis is most frequently reduced by manual compression utilizing the attached frame components. Reduction is also possible to achieve by rolling the patient into the lateral decubitus position.

In a comparison of the stiffness of current external fixation systems with a human pelvic replica of aluminium with a type C injury Ponsen ym. (33) found that stability provided by any external fixator was low. Single bar systems were stiffer and performed better than frame configurations. This difference was ascribed to the use of 6 mm pins instead of 5 mm ones (2 pins of 6 mm gave 15% more stiffness than 3 pins of 5 mm), and also to the use of stiffer bars instead of the more slender rods of the frames. The position of pins, cranial or ventral, did not play an important role (33).

C-clamps

The pelvic C-clamp designed by Reinhold Ganz has a sliding bar design and is intended for application to the posterior aspect of the pelvis opposite the sacroiliac joints. The pelvic stabilizer has two aluminium arms attached and is connected by a central ratchet gear. The specially designed pins attached to the end of this device through additional articulation are intended for insertion either at the back of the pelvis or anteriorly in the dense column of bone above the acetabulum (34).

Biomechanical studies have shown that these devices are more effective in Type-C pelvic ring injuries than the standard anterior external fixator in achieving compression at the sacroiliac joints (34). On the other hand the data of a cadaveric study showed that anterior external fixator and pelvic clamps were effective equally at reducing pelvic volume and pubic diastasis in open book injuries (35). Most severe complications associated with the application of the c-clams have been penetration of the fixation pin into the confines of the pelvis and cut-out into the sciatic notch (35). Surgeon practice on cadavera or with a pelvic model before clinical use will help ensure safe application of both devices. Special surgical skills are needed, if a c-clamp in used in the trauma (emergency) room.

Definitive treatment

An external fixator applied anteriorly cannot restore enough stability to an unstable Type-C disruption of the pelvic ring to allow mobilization of the patient without risking redisplacement of the fracture (15,16,17,18). Therefore open reduction and internal fixation (ORIF) has become the method of choice for stabilization of Type-C pelvic injuries. All Type-C injuries, most of Type-B open book injuries and severely displaced Type-B lateral compression injuries are treated operatively. Concomitant urological injuries, rupture of the bladder and urethra, are treated operatively in the early phase. If a patient has a lumbosacral plexus injury the operative treatment including decompression of the nerve roots should be carried out once the patient has been stabilized hemodynamically.

Internal fixation techniques in Töölö Hospital

Posterior Fixation

Injuries of the posterior part of the pelvic ring are operated on first if vertical displacement of the injured hemipelvis is severe. If the initial displacement of the disruption of the symphysis pubis (diastases and/or translation) or the rami fractures are wide (> 10 mm), a subsequent anterior approach is done. Also if displacement is > 10 mm in the anterior pelvic ring injury after posterior fixation, an anterior approach and fixation is carried out. One option in patients with Type C1-1 or C1-2 injuries is a simultaneous ORIF of both sides through two anterior approaches.

Sacral fractures are stabilized with the patient in the prone position with one or two cannulated 7.0-mm partially threaded or fully threaded iliosacral screws across the fracture line into the S1 vertebral body under fluoroscopic guidance (24). The posterior longitudinal skin incision is made slightly medial to the posterosuperior iliac spine without releasing the gluteal muscles from the outer side of the iliac crest. The sacral fracture is observed and reduced with forceps. Iliosacral screws are inserted through a separate small lateral skin incision percutaneously to avoid large soft tissue stripping on the lateral aspect of the iliac wing and wound complications. In minimally displaced lateral sacral fractures (< 10 mm) a closed reduction with forceps and percutaneous iliosacral screw fixation has been used. The screws should be placed

at least past the midline of the sacrum. In some patients with a comminuted sacral fracture a threaded compression rod has been used to anchor the injured hemipelvis to the contralateral ilium to help supplement screw fixation.

Sacroiliac dislocation and sacroiliac fracture dislocation are fixed with the patient in the prone position with iliosacral screws (Figure 2) or with the patient in the supine position with anterior 4.5-mm reconstruction or DC-plates or both using an incision at the iliac crest and exposing the internal aspect of the wing and the sacroiliac joint (18,24). Transiliac fractures are fixed with anterior 3.5-mm reconstruction plates or screws or both using the same approach.

Anterior Fixation

Disruption of the symphysis pubis are exposed through either a vertical or a transverse Pfannenstiel's incision (24). A vertical incision is chosen when the anterior fixation is combined with laparotomy. Because of cosmetic reasons, a transverse incision is otherwise the choice for symphyseal disruption or juxtasymphyseal fractures of the rami. The midline between the rectus abdominis muscles is opened and the prevesical area is exposed. The insertions of the rectus abdominis muscles are incompletely detached from the pubis on their inner aspects, whereas their lateral and outer parts of attachments are left intact (36,37).

The more lateral fractures of the superior rami are exposed through the lower midline approach by extending the dissection laterally as described by Hirvensalo ym. (30). The dissection below the rectus muscle is continued subperiosteally and laterally on the superior ramus following the inner aspect of the pelvic brim. The corona mortis vessels are ligated whenever they are present. The external iliac vessels, the femoral nerve, and the iliopsoas muscle are lifted slightly anteriorly with a retractor and left undisturbed. No dissection or separation of these vulnerable structures is necessary. The underlying obturator nerve and vessels entering the obturator foramen are identified and protected. By remaining close to the brim and by using subperiosteal stripping only, the risk of injuring all essential structures can be avoided. The iliopectineal fascia is detached in lateral rami fractures to facilitate exposure of the juxtaacetabular area of the superior ramus and the supraacetabular brim in the most lateral fractures. If a concomitant acetabular fracture is present the anterior column and the quadrilateral surface also could be exposed. In bilateral rami fractures both sides are exposed.

Displaced (> 10 mm) fractures of the pubic rami are fixed internally with a curved reconstruction plate with 3.5-mm screws placed along the pelvic brim (linea terminalis). Fixation of lateral fractures of the superior ramus with a long intramedullary 3.5-mm screw has been done only in some cases. Bilateral fractures of the rami are fixed by using by two separate plates, one on each side. In patients with severe open fractures or severe comminution and osteoporosis, fixation of the anterior injury can be done with an anterior external fixator. The fixator is removed after 6 to 10 weeks. Bladder injury is not considered a contraindication to anterior internal fixation.

Postoperative Treatment

Mobilization with crutches is started within 1 - 2 days in Type-C1 injuries without weight-bearing on the injured side, and if the associated injuries of the lower extremities allow it. Full weight-bearing is started after 8 to 12 weeks. The load is increased gradually based on the fracture type and radiographic follow-up. In Type-C3 injuries and in most Type-C2 injuries the walking exercises with crutches are started after 8 to 12 weeks based on the type of the posterior pelvic ring injury.

Outcome of surgically treated type-C pelvic ring injuries

We evaluated 101 consecutive patients with Type C1-C3 pelvic ring injuries who had been treated with standardized reduction and internal fixation techniques (36). Our results suggest that there is a correlation between excellent reduction followed by sufficient fixation of the pelvic ring and functional outcome. Unsatisfactory reduction (displacement > 5 mm), failure of fixation, loss of reduction and a permanent lumbosacral plexus injury were the most common reasons for an unsatisfactory functional result. All 40 patients with an associated lumbosacral plexus injury showed at least some evidence of neurologic recovery. 14 achieved complete neurologic recovery. 8 had only sensory deficits and the remaining 18 also had motor deficits at the final follow-up. Complications were rare but some of them were severe, loss of reduction in 8%, malunion in 10%, deep wound infection in 2%, and a lesion of L5 nerve root in 1%.

Discussion

The stability of the pelvic ring depends mainly upon the integrity of the posterior weightbearing sacroiliac complex. However, biomechanical studies have shown that in Type-C injuries the symphysis pubis and pubic rami are important for the overall stability of the pelvic ring, contributing approximately 40 % of the total stability of the ring (18). Biomechanical studies also showed that an anterior external fixator could not restore enough stability to an unstable Type-C injury to allow secure mobilization of the patient without risk of redisplacement of the fracture (18,38,39). In the 1980s this led to a change in treatment protocols and methods of ORIF of sacroiliac injuries and symphyseal disruption were introduced (20,21,22,23,24). Moreover, several operative techniques for reduction and fixation of fractures of the pubic rami were described (25,27,30–32).

Internal fixation has become the method of choice of unstable posterior pelvic ring injuries, but the question how much residual displacement is acceptable is still controversial. Tornetta and Matta (29) suggested that 10 mm was an acceptable reduction for injury to the posterior pelvic ring, and they suggested that a more anatomic reduction of posterior injuries did not result in less posterior pain. McLaren ym. (40) and Lindahl ym. (19) reported that greater than 10-mm residual displacement of the posterior pelvic ring was a poor prognostic sign. In the Hannover score the outcome was graded fair if the residual posterior displacement was greater than 5 mm. However, in the present study an excellent radiologic result (maximal residual displacement 0-5 mm in the posterior or anterior pelvic ring injury) showed a clear association to the excellent or good functional outcome.

Iliosacral screw fixation is recommended for fixation of sacral fractures and sacroiliac dislocations and sacroiliac fracture dislocations (18,24,32,41). However, care has to be taken when inserting cannulated screws to the sacrum medially to the sacral foramina. One L5 nerve root injury occurred in a patient in the current study. The most unstable and comminuted sacral fractures are clinical problems, because it might be impossible to achieve adequate stability of the pelvic ring with iliosacral screws only. Those 6 patients with secondary displacement after screw fixation were examples of this. The most severe posterior pelvic injuries need special attention and careful preoperative planning. 5 of our patients with sacral fractures did not have fixation because the initial displacement was minimal. The posterior injury pattern likely was evaluated incorrectly as being more stable than it was which resulted in worsening of the position in 2 patients although the anterior injury to the pelvic ring was fixed with plates. This supports the use of internal fixation also in high-energy minimally displaced sacral fractures. Minimally displaced lateral sacral fractures seem to be well suited to percutaneous fixation techniques with cannulated screws placed under fluoroscopic guidance.

The anterior plating technique through a lower midline or Pfannenstiel's incision as described by Hirvensalo ym. (30) and more closely by Lindahl and Hirvensalo (36) provides good extraperitoneal access to the inner surface of the pubic rami and to the anterior column of the acetabulum. Cole and Bolhofner (42) have used a limited Stoppa intrapelvic approach in the treatment of acetabular fractures, and later Cole ym. (43) used it for treatment of pelvic fractures as it provides a similar intrapelvic view. With the current technique there was no need for dissection or separation of the inguinal neurovascular structures as there is in the ilioinguinal approach (44). The anterior approach could be combined with the approach along the iliac crest so that every anterior part of the pelvic ring and even the anterior side of the sacroiliac joint could be reached. We found this technically easier and less invasive for the patient. However, protection of the external iliac vein as well as the obturator vessels and nerve is of major importance. This combined approach can be recommended for stabilization of simultaneous iliac fractures or sacroiliac dislocations or fracture dislocations and injuries to the anterior pelvic ring. Knowledge of the extraperitoneal intrapelvic region is mandatory.

The anterior pelvic ring was mainly stabilized with reconstruction plates with 3.5-mm screws. The fixation with plates can be considered accurate and reliable. Loss of reduction was seen in 1 / 75 patients who underwent anterior fixation with plates. Matta (31) also found in his series of 127 patients that the 72 fixations of the anterior pelvic ring were safe and reliable, and he recommended it for symphysis pubis dislocations, but only for the most severe pubic rami fractures. In the current study in 2 / 16 patients the position of the initially minimally displaced (< 10 mm) and unfixed fracture of the pubic rami worsened although the posterior injury was adequately fixed.

In the current study the overall functional results were excellent or good in 83% of the patients, and were positively affected by stable anatomic or nearly

anatomic reduction. Unsatisfactory reduction, failure of fixation and loss of reduction (maximal residual displacement > 5 mm) showed a statistically significant association to the unsatisfactory functional result. Malreduction or loss of reduction might be corrected in a reoperation even later than 6 weeks after the trauma. In all our 5 reoperations a clear radiologic correction was achieved with a satisfactory functional result in 4 of them. A permanent neurologic injury showed also an association to unsatisfactory functional outcome when single prognostic factors were analysed. A relationship between unsatisfactory radiologic and functional results was first reported by Lindahl ym. (19) when analysing long-term outcome after definitive treatment of Type-C injuries with an anterior external fixator. In 4 patients in our study the reason for an unsatisfactory functional result was unclear because all of these patients had a good reduction result and they did not have any neurologic injuries. Lumbosacral plexus injuries were the main reason for an unsatisfactory functional result in patients with concomitant urologic injuries.

Most of the patients in our series showed a clear recovery of the neurologic deficiencies. Similar results were obtained by Reilly ym. (45), and Tornetta and Matta (29). Early reduction of the posterior pelvic ring seems to reduce the neurologic injury. It can be presumed that recovery of the lumbosacral nerves depends on the amount of initial damage to the nerve roots and also on mechanical factors, such as traction or compression of the neurologic structures by fragments of bone (46,47). Reduction of the hemipelvis, prevention of traction of the injured neural structures by stabilizing the ring and decompression of the sacral nerve roots seems to be essential to the neurologic recovery. This should be done urgently in the primary phase (within 1 or 2 days), whenever the neural injury has been suspected and the patient has been stabilized hemodynamically.

The good reduction together with proper stabilization allow early mobilization, prevent complications and thereby lead to a short hospital stay and to an early start of rehabilitation.

Our results suggest that there is a relationship between the radiologic and functional outcome. However, a permanent neurologic injury may aggravate the functional outcome even if the reduction of the pelvic ring fracture is anatomic. Unsatisfactory reduction, failure of fixation, loss of reduction and a permanent lumbosacral plexus injury were the most common reasons for an unsatisfactory functional result. Unstable pelvic ring injuries with progressive distraction or compression of the nerve roots with neurologic deficits are indications for operative treatment in the primary phase once the patients are stabilized hemodynamically. Special attention should be paid to preoperative planning and fixation of the most severe sacral fractures. The results of the current study seem to favour reduction and internal fixation of symphyseal disruptions and displaced (>10 mm) and unstable pubic rami fractures in conjunction with adequate posterior fixation to achieve better stability for the whole pelvic ring.

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