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ORIGINAL ARTICLE

The management of pelvic ring fractures in low-resource environments: review

Yoshi Pratama Djaja[1] · Jamot Silitonga[1] · Ismail Hadisoebroto Dilogo[2] · Océane J. Mauffrey[3]

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Abstract

Although improvement of pelvic trauma care has been successful in decreasing mortality rates in major trauma centers, such changes have not been implemented in low-resource environments such as low-middle-income countries (LMICs). This review details the evaluation and management of pelvic ring fractures and recommends improvements for trauma care in low-resource environments. Prehospital management revolves around basic life support techniques. Application of non-invasive pelvic circumferential compression devices, such as bed sheet or pelvic binders, can be performed as early as the scene of the accident. Upon arrival at the emergency department, rapid clinical evaluation and immediate resuscitation should be performed. Preperitoneal pelvic packing and external fixation devices have been considered as important first-line management tools to achieve bleeding control in hemodynamically unstable patients. After patient stabilization, immediate referral is mandated if the hospital does not have an orthopedic surgeon or facilities to perform complex pelvic/acetabular surgery. Telemedicine platforms have emerged as one of the key solutions for informing decision-making. However, unavailable referral systems and inaccessible transportation systems act as significant barriers in LMICs. Tendencies toward more "old-fashioned" protocols and conservative treatments are often justified especially for minimally displaced fractures. But when surgery is needed, it is important to visualize the fracture site to obtain and maintain a good reduction in the absence of intraoperative imaging. Minimizing soft tissue damage, reducing intraoperative blood loss, and minimizing duration of surgical interventions are vital when performing pelvic surgery in a limited intensive care setting.

Keywords Pelvic · Pelvic fracture · Low-resource environment · Pelvic trauma

Introduction

Injuries are a major health concern worldwide, causing around 4.4 million injury-related deaths every year. Among them, unintentional or accident-related injuries contribute to around 3.16 million deaths annually. About 90% of these deaths occur in low- and middle-income countries (LMICs), as the death rates are higher in low-income countries than in high-income countries. Some possible causes are poorer access to quality emergency trauma care and rehabilitation services [1].

Pelvic ring fractures are among the most challenging injuries due to the high mortality rate and high frequency of associated injuries [2, 3]. Although improvement of pelvic trauma care has been successful in decreasing mortality rates in major trauma centers, such changes have yet to be implemented in low-resource environments. This review details the evaluation and management of pelvic ring fractures and gives some recommendations for improvements to trauma care in low-resource environments.

✉ Yoshi Pratama Djaja
yoshipratamadjaja@yahoo.com

[1] Department of Orthopaedic and Traumatology, Fatmawati General Hospital, Jakarta, Indonesia

[2] Department of Orthopaedic and Traumatology, Rumah Sakit Umum Pusat Nasional Dr Cipto Mangunkusumo, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia

[3] University of North Carolina School of Medicine, Chapel Hill, NC, USA

Acute management

Principles for prehospital care at the scene of the accident

Prehospital care at the scene of the accident and during transportation to a medical facility is the first step in managing an injured patient. Most LMICs have no organization responsible for providing prehospital care to trauma patients. Basic life support (BLS) provided by the paramedics is the most common prehospital care system in these countries. The major role of prehospital care in this system is to transport the patients and to keep them alive during transport by providing them with non-invasive supportive care [4].

In most developed countries, the prehospital care system has shifted to advanced life support (ALS) systems to initiate the highest level of care at the scene and during transport. Furthermore, some countries such as France and the USA have adopted the most advanced form of prehospital trauma care where physicians are involved immediately at the scene of injury (Doc-ALS system). This system has led to a 30% mortality rate decrease in severe trauma cases [5]. Unfortunately, this system is only possible in countries with a high enough number of physicians, reflected by high doctor-population ratios not commonly found in LMICs. The density of medical doctors per 10,000 people in the LMICs has not achieved the World Health Organization's recommended doctor-to-population ratio of 1:1,000 [6].

Nevertheless, controversy persists regarding which prehospital system is superior. Present studies have failed to show any advantages of ALS prehospital care in trauma patients compared to BLS [7, 8]. Limited number of studies, small number of selected patients, and lack of control groups for appropriate comparison were all major issues in clearly establishing which prehospital care system is better at reducing mortality rates in trauma patients. Due to limited data supporting the superiority of the ALS system and the lack of facilities available in LMICs, the BLS "scoop and run" approach is more appropriate in these countries.

BLS techniques, such as external hemorrhage control, spine protection, breathing and circulation support, and supplemental oxygen therapy, are easy to perform, require less on-scene time, and can be performed during transport by minimally trained emergency medical technicians or paramedics. The "scoop and run" concept of the BLS system focuses on reducing the on-scene time and the time to definitive care [8]. This approach is clearly different from the "stay and stabilize" concept of the ALS system that includes more advanced and invasive procedures such as endotracheal intubation, intravenous access, administration of medications and fluid therapy. In Trunkey's description of the trimodal distribution of trauma death, 50% occurred on the scene, 30% within a few hours of injury and the other 20% within days or weeks due to sepsis or multi-organ failure [9]. The aim of the BLS approach is to provide supportive care and rapid transport to the second group of patients where timely surgical intervention will make the greatest difference in patient outcome [8].

In a prehospital setting, clinical pelvic examination can be performed rapidly on scene or during transport. Clinical examination plays a significant role in detecting pelvic fractures especially in blunt trauma patients. Clinical examination by a trained team in stable and alert trauma patients will detect pelvic fractures with nearly 100% sensitivity. Sauerland et al. summarized the criteria used by previous studies to rule out relevant pelvic fractures: (1) patients age over 3 years old; (2) conscious; (3) no other major distracting injury; (4) no pelvic pain; (5) no signs of fracture during inspection; (6) no pain on iliac or pubic compression; and (7) no pain on hip flexion or rotation. In their review, there were 47 missed cases from 441 patients with pelvic fracture among 5,235 blunt trauma patients. But among them, only three missed cases were clinically relevant. Most missed cases seemed to be a single fracture of the pubic rami or the acetabulum [10].

Physical examination of the pelvis should include a thorough inspection of the flanks, lower abdomen, groin, perineum, and buttocks to detect any wounds or bruises. Any clinical deformity of the pelvis, leg length discrepancy and malrotation also suggested that the patient had a pelvic fracture. Other findings that point to a pelvic fracture include a ruptured urethra as indicated by scrotal hematoma or blood at the urethral meatus. The traditional pelvic compression test, which was commonly performed to determine the stability of the pelvic ring, should be abandoned. It is not only unreliable (as it will only detect major pelvic disruption) but also possesses a significant risk of dislodging any present clots, promoting further bleeding [11].

Early detection of pelvic fractures in a prehospital setting is helpful in guiding emergency therapy and triage. However, the accuracy of short clinical examinations in prehospital settings is questionable, especially for patients with shock or altered consciousness (Glasgow Coma Scale [GCS] < 13). Therefore, after a prehospital pelvic screening, a complete examination should be performed when the patient arrives at the emergency department.

Pelvic sheet/binder

Since pelvic fractures may cause massive blood loss, early stabilization and compression to quickly reduce bleeding are vital resuscitative measures. The reduction in pelvic fracture fragments decreases the pelvic volume, therefore reducing

the potential space for bleeding [12]. Previous literature has reported effective pelvic volume reduction with pelvic binders [13]. Croce et al. described less blood loss upon application of pelvic binders compared to invasive pelvic stabilization, which resulted in lower transfusion requirements. But no significant difference in terms of mortality rates was found [13].

Application of non-invasive pelvic circumferential compression devices (PCCD), such as bed sheets, pelvic binders or other specially designed commercial devices, can be placed as early as the scene of the accident. With pelvic binders in place, patients can be transported to the hospital in a safer manner [14]. Although some studies contradict this and suggest avoiding the use of pelvic binders in B2-B3 fracture types since it may increase the fracture displacements, there is no association between prehospital pelvic binder placement and increasing mortality rates [15]. Pelvic binders have also been associated with skin complications, especially in thinner, male, and elderly patients. This should be recognized early, especially if the binder will be placed for a long period of time [14].

Application of pelvic binders is recommended in prehospital settings for patients with clinically suspected pelvic fractures after a high-energy trauma (especially in patients suspected of having pubic symphyseal diastasis—"open book" fracture) and patients who are hemodynamically unstable without an obvious etiology. The most common technique for pelvic binder application is a bed sheet wrapped around the pelvis at the level of greater trochanters, followed by crossing the sheet and clamping it at four different points. Afterward, the knees should also be bound together with a sheet or bandage [16].

Golden hour–getting the patient to the hospital ASAP

The concept of the golden hour has been commonly used to emphasize the importance of the first 60 min after injury to determine a critically injured patient's chance of survival. It has also been criticized due to lack of evidence supporting this specific timeframe. More important than the exact 60-min delineation, the concept of the golden hour emphasizes the urgency of care required by major trauma patients to prevent early death predominantly caused by hemorrhage [17].

The major issue in rural and LMIC settings is that prehospital times can be significantly prolonged. This lengthened response time can be due to inadequate prehospital/formal trauma systems [18, 19] or long scene to hospital time due to traffic, limited air transport, or scarcity of trauma centers. The correlation between prehospital time and patient mortality remains unclear due to the broad spectrum of trauma and the variety of prehospital care services around the world. Furthermore, most of the previous studies were conducted in urban/high-income country trauma systems with short (< 30 min) prehospital times, which is not reflective of the often longer times to definitive care experienced in rural/LMIC settings [20]. Fatovich et al. compared the urban and rural trauma patients in Western Australia and found that the mortality risk was two times higher in rural trauma patients. The rural population experienced a significantly longer time to definitive care of 11.6 h versus 59 min in the urban population [21].

Arriving at the emergency department—ATLS principles

Upon arrival at the emergency department, rapid clinical evaluation and immediate resuscitation should be performed in accordance with the Advanced Trauma Life Support (ATLS) protocol. Primary surveys should focus on the immediate assessment of the airway and breathing while maintaining spinal precautions. Then, attention should be shifted to the cardiovascular system, specifically finding the source of hemorrhage. Volume resuscitation is initiated after the intravenous access has been obtained as an adjunct to aggressive hemorrhage control. Volume resuscitation without bleeding control will not be effective and may lead to secondary iatrogenic complications such as hypothermia or coagulopathy [22].

Bleeding control can be achieved by applying direct pressure at the source of the bleeding and aggressively finding the location of internal bleeding. Plain chest and pelvic radiographs are ordered to detect major blood loss in the thoracic cavity and pelvic instability. Then, assessment of intra-abdominal bleeding by direct peritoneal lavage (DPL) or focused assessment sonography for trauma (FAST) examination is performed. Based on these examinations, the emergency department team should decide upon different bleeding control options, either surgical or radiological intervention (embolization) [22].

Control of pelvic bleeding can be achieved by mechanical closure of the pelvic ring (pelvic binder, external fixation, or C-clamp), angiographic embolization, or surgical pelvic preperitoneal packing. Angioembolization in hemodynamically unstable patients is highly effective since it can identify the bleeding without opening the patient. However, its effectiveness is time-dependent since the time-to-successful embolization is independently associated with mortality. Mortality increases from 16 to 64% if embolization requires more than 60 min after diagnosis has been made [23]. Furthermore, it requires an angiography suite and specific technical staff, which may not be readily available in most hospitals in LMICs.

Therefore, other alternatives such as mechanical closure of the pelvic ring or surgical pelvic preperitoneal packing

should be considered in these areas. In a recent randomized controlled trial, there is no difference in terms of mortality and complication when comparing the pelvic packing and angioembolization in massive hemorrhage control related to pelvic fractures [24]. Preperitoneal pelvic packing has been considered as an important first-line management tool to achieve bleeding control in hemodynamically unstable patients. It has been found safe, requiring minimal specialized equipment and basic surgical training, which is practical and applicable in limited-resource settings.

Basic principles of critical care

In a low-resource environment, the assessment of hypovolemia relies on clinical and simple laboratory assessment. Tachycardia and cool peripheries are early indicators, followed by narrowed pulse pressure which indicates major blood loss. Only focusing on systolic blood pressure is often misleading since more than 30% of the patient's blood volume would need to be lost to induce hypotension. Evaluation of the hourly urine output is the simplest way to evaluate whether adequate perfusion has been obtained.

Although their reliability as markers of shock is questionable, hemoglobin and hematocrit examination are available even in low-resource environments. A very low hematocrit may indicate a massive blood loss; however, a normal hematocrit may not rule out blood loss altogether. Arterial blood gases and lactate examination can be performed in a more advanced environment, which provides a better indicator for quantifying the degree of shock and probability of survival. Base deficit in metabolic acidosis indicates a severe shock and should be used as a guideline for volume resuscitation [25].

The initial management of hemodynamically unstable pelvic fracture patients revolves around patient resuscitation to prevent or treat the classic "lethal triad" (hypothermia, coagulopathy, and acidosis). In terms of restoring blood volume, high volume crystalloid solutions were generally used for fluid resuscitation in LMICs as it is readily available. However, this approach has been replaced by early resuscitation with blood products, which has been associated with increased survival rates in more severe patients [26, 27]. In such patients, crystalloid-based resuscitation may worsen their outcomes by inducing dilutional coagulopathy and possibly by disrupting the premature blood clots at the site of injury, leading to further blood loss. Massive transfusion protocol has been introduced to prevent coagulopathy in patients requiring large blood volumes [28]. Improved survival has been observed and attributed to increased fresh frozen plasma to red blood cell ratio. However, implementation of massive transfusion protocol on pelvic fracture patients has failed to show any effect on early, late, or overall mortality [29]. Nevertheless, early blood transfusion is the mainstay for the treatment of acute blood loss and coagulopathy. Damage control resuscitation with early coagulation factor replacement, limiting the use of crystalloids, reversal of acidosis and hypothermia, and early control of bleeding have been demonstrated to improve patient survival [30].

Once the patient is alive, what do we do?

When and where to transfer is so important in rural areas

After the patient has been hemodynamically stabilized, the definitive care should be based on the state of the patient. In polytrauma cases, it is not recommended to perform definitive fracture fixation surgery between day 2 and 4. During these days, sustained immunologic changes are ongoing and fluid shifts have not yet normalized. Prolonged surgical intervention in this period may act as a potential "second hit" that may induce excessive inflammatory response and multiorgan dysfunction. Definitive surgery can be performed during the window of opportunity period (day 5–10) and after the immunosuppression phases (after day 21).

Early definitive surgery is recommended for pelvic acetabular fractures, which are usually performed after day 4 or during the window of opportunity period. Delay in the definitive management of pelvic/acetabular fracture increased the difficulty of operative treatment and significantly reduced both functional and radiological outcomes. Postoperative complications such as sciatic nerve palsy, avascular necrosis of the femoral head and late osteoarthritis were also more prevalent [31]. The timing of surgery plays an vital role in determining both clinical and radiological outcomes.

In LMICs or rural areas, immediate referral is mandated if the hospital does not have an orthopedic surgeon or facilities to perform complex pelvic/acetabular surgery. Theoretically, the patient can be transferred as soon as their condition has been stabilized. However, this has been an issue in most LMICs due to limited transport infrastructure and underdeveloped referral systems. A case study by Nakahara et al. described the trauma referral system in Cambodia, which may also represent the conditions of the other low-income countries. Formal trauma referral systems do not function well (insufficient communication and underutilization of ambulances). Moreover, while informal systems are frequently involved (non-ambulance patient transfer, treatment by traditional healer, etc.), they are not well integrated into the referral network [32].

Unavailable systems and transportation are the main barrier to emergency referral. Most emergency trauma patients reach the health facilities by private vehicles, taxis, non-motorized vehicles or even on foot. The scarcity of available tertiary trauma centers/national hospitals where

complex pelvic surgery can be performed has made long-distance travel either by land, water, or air transport inevitable. Longer distance transfer to tertiary trauma centers has also been a significant obstacle in LMICs, increasing travel costs and patient burden before even reaching the hospital. A study in Uganda reported that relatives often have to obtain money by selling assets or borrowing before initiating a patient transfer [33]. This issue is found in most LMICs since health insurance usually covers medical costs but not auxiliary expenses such as private transportation. In some areas, ambulances covering longer distances even charge patients for fuel and maintenance, whereas free ambulances only cover short distances [32].

Use of technology to inform decision-making

Lack of communication between medical institutions has also been an issue in LMICs. The communication method has long been limited to the traditional referral and feedback letter. Rapid expansion of cell phone networks worldwide has facilitated better communication at the time of referral. Communication between the transfer also allows referring facilities to obtain advice for patient stabilization. However, such advice may not be beneficial without adequate resources at the referring hospital [34].

Many countries have commonly used mobile smartphone applications such as WhatsApp. In South Africa, some WhatsApp chat groups have been created between non-orthopedic doctors from community health clinics and the orthopedic team from a first-level hospital to manage traumatic fractures. Using this platform, the orthopedic referral group provides free tele mentoring for non-orthopedic doctors to successfully manage traumatic cases at community health clinics [35]. A similar network has been established in Malawi, where this network facilitated quick access to specialist consultation about surgical patient management in remote areas and helped physicians decide whether to refer the patient immediately or not [36].

Telemedicine platforms have emerged as one of the solutions for informing decision-making in rural areas. The telepresence of a surgeon may instill the confidence of the local emergency team and be used to identify the knowledge gaps of rural health care providers. Although it does not solve the issue of poor facilities, patient stabilization for safe transportation and early definitive care after transport can be achieved through this platform [37].

Definitive surgery in a poorly resourced environment

As mentioned before, the scarcity of tertiary trauma centers/national hospitals and poor transportation infrastructure are the main issues for patient transfer in LMICs. These issues are further aggravated by the socioeconomic issues that prevent patients and their relatives from consenting to their transfer to a distant hospital. In such unfortunate circumstances, definitive pelvic fracture surgery is performed in the local hospital with limited equipment.

The current state-of-the-art pelvic fracture management involves careful preoperative planning using computed tomography and subsequent intraoperative imaging, especially in minimally invasive techniques. Advanced intensive care units are also reserved for frail patients or patients with complex fracture that requires prolonged surgical duration. Although these facilities may be available in tertiary trauma centers, they are not commonly found in most rural hospitals. Thus, most orthopedic surgeons in these poorly resourced areas are reluctant to perform a definitive fracture surgery and treat their pelvic fracture patients conservatively. A series from a university hospital in Ethiopia revealed that only 15% of their pelvic fracture patients were treated by surgical means. On the other hand, more than 53% were managed with nonoperative intervention, and the remaining 31% were referred to a higher center [38].

Nonoperative pelvic fracture management

The nonoperative treatment of pelvic fracture is indicated for stable fractures with minimal displacement. Previously, Tile A, LC1 and APC1 fractures with minimal displacement were mostly treated conservatively, regardless of the presence of occult instability. However, there has been a treatment shift toward surgery for such cases in the recent decades. Recent studies recommend fixing the fracture if occult instability was found during examination under anesthesia [39].

However, in a low-resource environment, such examinations may not be feasible due to the unavailability of intraoperative fluoroscopy. Therefore, in this condition, tendencies toward a more "old-fashioned" protocol, consisting mainly of conservative treatments, are often justified. Tile and Pennal in 1980 described the classic management principle of pelvic disruption (Table 1). An AP compression fracture of the pelvis (open book fracture) can be treated by simple reduction followed by immobilization in a pelvic sling, plaster spica or external fixation. The lateral compression fractures type produces some degree of internal rotation of the hemipelvis and requires external rotation forces to reduce the fracture. Immobilization using external fixators is the recommended means of immobilization. Vertical shear fractures

Table 1 Fracture classification and subsequent method of treatment (adapted from Tile et al. 1980)

Fracture type	Method of treatment
AP Compression	
Open book type	Pelvic sling Hip spica: internal rotation through the femur held for 6–8 weeks External skeletal fixation Internal fixation
Bilateral rami	Bed rest in the semi-flexed position
Lateral Compression	
Stable types	
Minimal displacement	Bed rest
Gross displacement	Closed reduction quickly after injury; maintained by supracondylar traction in slight external rotation or external fixator
Unstable types	Traction through a supracondylar pin External skeletal fixation following closed reduction Open reduction (rarely indicated)
Vertical Shear	Closed reduction by applying traction through a supracondylar pin Open reduction

can be reduced with traction through supracondylar pins or with external fixators. However, maintaining the reduction is proven to be difficult since these fractures require a long period of immobilization [40].

Nonoperative treatment is not indicated for major pelvic disruption. Unstable pelvic fracture with > 1 cm posterior displacement has a poor prognosis when treated nonoperatively [41]. Acceptable outcome for nonsurgical treatment has been recorded for milder subsets of pelvic fracture patients. Gaski et al. reviewed 53 cases of LC1 pelvic fracture with "intermediate severity" characterized by complete sacral fracture and < 1 cm initial displacement. Acceptable functional outcomes can be expected in these groups of patients after nonsurgical treatment [42]. Soles et al. presented a report of 117 patients with LC pelvic fracture with less than 1 cm displacement treated nonoperatively by immediate weight bearing. They found that 99% of patients healed without further displacement [43].

Assessment of the occult instability in minimally displaced pelvic fracture has gained traction as a method of determining whether surgical/minimal invasive fixation is needed. Stress test under anesthesia has been promoted as a means to detect occult instability in pelvic fracture, however, this test cannot be performed without fluoroscopy guidance. Occult instability is hypothesized as a major risk factor for late displacement, however, its correlation with the functional outcome itself is not well established [39]. On the other hand, many authors have reported improved functional outcomes when the displacement is minimal, whether it is already < 1 cm initially or after reduced anatomically/near-anatomically [44, 45].

In a low-resource environment, we suggest that more conservative measures should be taken when possible. Nonoperative treatment should be indicated for minimally displaced cases regardless of their classification. In cases with more displacement, closed reduction may be attempted. If a good reduction can be obtained, the clinician should determine whether the fracture pattern is stable enough to be maintained using conservative means. Although theoretically, all fracture patterns can be maintained by various conservative means, there are several possible complications. The use of pelvic binders is associated with the risk of pressure necrosis [46]. External skeletal fixation and supracondylar pins have been associated with the risk of pin tract infection. Therefore, the risk and benefit assessment should be considered if the patients require a specific method for immobilizing their fracture fragments.

What can be treated by an external fixator and how to place pins safely

The external fixator is often used as a temporary or definitive fixation method in unstable pelvic fractures. However, prolonged external fixator as a definitive fixation method has been associated with patient discomfort, skin problems and local infection. It is usually performed in the acute phase as part of resuscitation protocol to stabilize and reduce the pelvic volume.

Although it is safer to insert the pin using fluoroscopy guidance, the pin insertion can be performed without it. In some instances, it can also be performed at the bedside, especially the iliac crest pin. The iliac crest pins should be inserted at least 15 mm posterior from the anterior superior iliac spine (ASIS) to avoid injuring the lateral femoral cutaneous nerve. The iliac crest is easily palpable if the patient is not obese and wide enough to accommodate the pin placement. K-wire may be placed along the outer and inner table of the ilium to aid the placement of the pins. Using

oscillate mode during pin pre-drilling may help maintain the drill between the table of the ilium and avoid an in–out or in–out-in pins. The second pin is usually placed at least 1 cm from the first one. After two pins have been placed on each side, the connecting rods are placed. The number of rods is determined based on the patient's habitus as it should allow adequate room for the patient's abdomen and for sitting—by confirming that the hip can be flexed to 90°.

As for the supra-acetabular pins, the anterior inferior iliac spine (AIIS) is used as a starting point. Although it is generally recommended to use fluoroscopy for inserting these pins, some authors have described the techniques for placing these pins safely without fluoroscopy guidance. The starting incision is made of two fingerbreadths distal and one medial from the ASIS. After blunt dissection between sartorius and tensor fascia lata, the AIIS can be palpated and used as a landmark for pin insertion. The ideal entry point is located just above rectus femoris insertion at the AIIS. The pin is inserted in approximately 40 degrees medial and 40 degrees cephalad, aiming for the sacroiliac joint [47]. It should be noted that the lateral femoral cutaneous nerve and hip joint were at risk. Therefore, the use of appropriate soft tissue sleeve and pin insertion at least 2 cm superior from the hip joint are recommended.

Besides their frequent use in the acute phase, external fixators can also be used as a form of definitive treatment. Scaglione et al. used an external fixator as a definitive treatment for most pelvic fractures with limited/partial posterior involvement. In fractures with a severe posterior instability, an external fixator alone does not provide adequate mechanical stability. Supra-acetabular pins were placed during the acute phase because of their biomechanical advantages over iliac pins [48]. They allow pelvic reduction in the transverse plane of the deformity and improve reduction in the posterior elements. After the patient has been stabilized, the external fixator must be reviewed, and subsequent changes must be made to reduce the fracture site. Patient compliance for pin track care and the timing of weight bearing plays an important role in avoiding infection and other complications attributed to the of external fixator use [48].

Surgical management: Open reduction and internal fixation

The pelvic fracture surgery should be carried out as soon as the patient's condition allows, which is usually within the first window of opportunity (day 4–10). The surgery involves reduction in the fracture and fixation of the pelvis. The reduction can be achieved percutaneously or through an open approach. Percutaneous approach requires intraoperative imaging to evaluate the fracture reduction and to safely guide the minimal invasive fixation of the pelvis. However, such facilities may not be available in a limited setting, therefore open approaches are preferred in these instances.

Major initial fracture displacement or instability of the pelvis is the main indication for surgical fixation. Anterior fixation of the pelvic ring using a plate and screw system can be achieved by using simple Pfannenstiel incision which can be further extended into classic ilioinguinal approach or the anterior intrapelvic/modified Stoppa approach. Posterior fixation commonly involves iliosacral screw insertion, however, this technique is not recommended in the absence of intraoperative fluoroscopy. Open reduction and internal fixation using anterior sacroiliac joint plating through the first window of the ilioinguinal approach are recommended for treating sacroiliac joint fracture/dislocation. Meanwhile, for the sacral fractures, posterior fixation using transiliac (posterior tension band) plate fixation can be used as an alternative for transiliac sacral screw fixation [49, 50].

The surgical approach for anterior fixation of the pelvis starts with a Pfannenstiel incision. In the deep dissection, a vertical split in linea alba may help preserve the remaining rectus abdominis muscle. Exposure of the pubic symphysis and pubic tubercle is usually sufficient for a simple symphyseal disruption. Reduction instruments such as a pointed clamp, Farabeuf or Jungbluth clamp can be used to hold the reduction. For anterior ring disruption involving ramus fracture, the exposure can be extended through the intrapelvic approach or ilioinguinal approach [50].

For fractures of the ilium and sacroiliac joint disruption, either anterior or posterior approaches can be used in as determined by the type of fracture. For the anterior approach, the first/lateral window of the ilioinguinal approach may provide better access for exposure and plate placement. The incision is made along the iliac crest and can be extended depending on the necessary exposure. The ilium is exposed by subperiosteal elevation of external oblique and iliac muscle. Further medial dissection can be extended up to 1–2 cm of the lateral section of the sacrum due to the proximity of L5 nerve root. Reduction can be performed by applying manual lateral compression, longitudinal traction, use of pointed clamp on the iliac crest, sacrum or across the sacroiliac joint. For anterior sacroiliac joint fixation, it is recommended to use two short dynamic compression plates. The plates are contoured to fit across the sacroiliac joint with one screw in the sacrum and two in the ilium. Ideally, the screws should be divergent with one screw in the sacrum lateral to the foramina [49].

The sacroiliac joint can also be accessed through a posterior approach. This approach relies solely on iliosacral screws for its fixation method since the anatomy of the posterior sacroiliac joint does not allow plate placement. However, it still allows plate placement for appropriate crescent fractures and for transiliac plates in the presence of sacral fractures. Involvement of sacral fractures requires

a neurologic assessment for further decision-making. For sacral fractures with minimal displacement (< 5 mm) and no neurologic deficit, reduction is not necessary and transiliac fixation is indicated to prevent loss of alignment. In the presence of neurologic dysfunction, decompression of the sacral nerve root should be performed before the definitive reduction. To place the transiliac plate, bilateral exposure of the posterior sacroiliac joint is needed and followed by removal of the tip of S2-S3 spinous process to accommodate plate placement. The plate is contoured in accordance with the posterior anatomy and inserted by sliding it underneath the paraspinal muscles. The initial screws are inserted into the sciatic buttress and tightened to compress the plate against the ilium. The ends of the plates are contoured in situ, and additional screws are inserted [49].

It is important to visualize the fracture site to obtain and maintain a good reduction in the absence of intraoperative imaging. Sufficient blood replacement must be available prior to the surgery. Minimizing soft tissue damage, reducing intraoperative blood loss, and decreasing length of surgical intervention are vital when performing pelvic surgery in a limited intensive care setting [49].

Conclusion

Despite numerous limitations of low-resource environments, the basic principles of pelvic ring fracture care can still be applied. Basic life support in prehospital care and immediate resuscitation when the patient arrives in the health care facility are important steps in minimizing mortality rates in these patient populations. External fixation and preperitoneal pelvic packing can be applied even in limited settings. However, due to a lack of resources, definitive surgery is often shifted to a more extensile approach for fracture visualization or a more conservative approach for less displaced fractures.

Declarations

Conflict of interest Ismail Hadisoebroto Dilogo have served as editorial members of EJOST and thus should be excluded from the review process. The authors have no other competing interests to declare that are relevant to the content of this article.

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