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Lumbopelvic transpedicular fixation of vertically unstable pelvic ring injuries

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Introduction Identification of a proper fixation of the posterior pelvic ring is of paramount importance in treatment of patients with vertically unstable pelvic injuries. **Material and methods** Outcomes of 29 patients with polytrauma and vertically unstable pelvic injuries treated at Level I Trauma Center between 2013 and 2017 were analyzed. The mean age of the patients was 34.8 ± 9.9 years. The severity of the injuries and patients' condition were evaluated using Injury Severity Score (ISS), VPKh-P (MT), VPKh-SP, and Yu. N. Tsibin scales (1975) to determine the sequence of treatment and diagnostic procedures. Classification offered by Pape H. C. (2005) was used to evaluate physiological condition. The ISS score was 27.1 ± 9.9 . All patients underwent computed tomography (CT) scan of pelvis for preoperative planning. Lumbopelvic transpedicular fixation (LPTF) was employed as a definitive treatment of vertically unstable pelvic ring fractures in all clinical observations. Posterior half-ring morphology, a need for decompression of the nerve roots of the sacral plexus, timing of surgery were considered to decide on LPTF configuration. **Results** Three-month-to-six-year follow-ups of 22 patients showed good and excellent results achieved in 72.7 % of the cases that are in line with findings reported in the literature. **Discussion** Biomechanically adequate method of internal fixation is the method of choice in the definitive treatment of vertical unstable pelvic injuries with the possibility of decompression of compromised neural structures. Lumbopelvic fixation with the possibility of simultaneous access for decompression of neural structures is the most optimal technique for these complicated injuries.

Keyword: unstable pelvic ring injury, sacral fracture, lumbosacral fixation, minimally invasive osteosynthesis

INTRODUCTION

Vertically unstable pelvic injuries include a large group of posterior hemipelvic lesions that are associated with complete loss of the bony connection between the spine and pelvis (spinopelvic dissociation). The injuries are characterized by a high rate of untimely diagnosis that is reported in 30 % of the cases, neurological complications in 98 % and disability in 50 % [1, 2, 3]. Poor outcomes occur in 20 to 60 % of vertically unstable

pelvic injuries that explains the relevance of research [4, 5]. The choice of fixation technique would largely rely on the morphology of posterior hemipelvic injury [1, 6].

The purpose of the study was to evaluate results of treatment of vertically unstable pelvic injuries addressed with lumbopelvic fixation (LPF) using either unilateral or bilateral constructs depending on the morphology of posterior hemipelvic injury.

MATERIAL AND METHODS

The review included 29 patients with vertically unstable pelvic injuries treated at Saint-Petersburg Dzhaneldze Research Institute for Emergency Care (level one trauma center) between 2013 and 2017. Pelvic injuries were classified with M.E. Muller-AO/ASIF classification and consisted of C1 (n = 19; 621 %), C2 (n = 3; 10.3 %) and C3 (n = 7; 27.6 %) types. The injuries were accompanied by different sacral lesions and a rupture of sacroiliac joint in one case. There were 17 (58.6 %) males and 12 (41.4 %) females. The injuries resulted from falls from height

(n = 18; 39.0 %), road traffic accidents (n = 10; 54.3 %) and compression (n = 1; 4.7 %). The study group included patients of working age (range, 18 to 65 years), moderate head injury (AIS ≤ 4) with morphology of pelvic injury that would respond to transpedicular LPF. The severity of vertically unstable pelvic injuries and patients' condition were evaluated using Injury Severity Score (ISS), VPKh-P (MT), VPKh-SP, and Yu. N. Tsibin scales on admission to antishock operation room [7, 8]. Major characteristics of the study group are presented in Table 1.

Table 1
Characteristics of the study group and scoring
of the severity of injury, $M \pm m$

Description	Value
Age, years	34.8 ± 9.9
Severity of injury according to ISS scoring system, scores	27.1 ± 9.9
Severity of injury according to VPKh-P (MT), scores	12.4 ± 5.6
Severity of injury according to VPKh-SP, scores	24.7 ± 8.0
Severity of injury according to Tsibin scale, scores	9.6 ± 3.9
T-criteria of polytrauma scoring system at trauma shock, hours (Yu.N. Tsibin)	3.4 ± 18.9

The clinical status of the patients were evaluated to identify different indications for stabilization of major fractures using tables and diagrams developed by Pape H.C. [9]. According to clinical differentiations patients were categorized into clinical classes: stable ($n = 5$; 17.2 %), borderline ($n = 17$; 58.6 %), unstable ($n = 6$; 20.7 %) and in extremis ($n = 1$; 3.4 %). Emergency surgery was performed for a life-threatening condition. Two and more life-threatening condition was observed in 15 (51.7 %) cases including ongoing pelvic ($n = 3$), intra-abdominal ($n = 6$), external haemorrhage conditions ($n = 2$); one asphyxia of different genesis and pressure pneumothorax ($n = 3$). Four patients sustained multiple pelvic injuries including extraperitoneal urinary bladder rupture ($n = 1$), membranous urethral avulsion ($n = 1$), open pelvic injury - degloving soft tissue injury (Morel-Lavallee) ($n = 2$). Computed tomography (CT) of pelvis and other injured sites was produced preoperatively to evaluate anterior and posterior pelvic ring, acetabulum, anterior-posterior, vertical displacements, external and internal rotation. The system of transpedicular screws was used for lumbopelvic fixation in all the cases. The choice between uni- and bilateral fixation was based on location of sacrum fracture line and joint facet of L_5/S_1 vertebrae. Unilateral LPF was employed for longitudinal sacrum fractures passing laterally off the joint facet of L_5/S_1 vertebrae and complete rupture of sacroiliac articulation. Bilateral LPF standalone or

in combination with sacroiliac screws was used for longitudinal sacrum fractures located internally or through the joint facet of L_5/S_1 vertebrae, bilateral sacrum fractures, H- and U-shaped, in particular. Sacroiliac screws used for primary pelvic stabilization of a longitudinal sacrum fracture were added by LPF during the first 48 hours of injury (so called triangular osteosynthesis) with stable general condition. Sacroiliac screws were supplemented by LPF 2 to 3 weeks of injury in severe conditions during the period of complete recovery of vital functions and elimination of complications. Sacroiliac screws were applied in presence of vacant passage for the placement in vertebral bodies of S_1 and S_2 vertebrae. Bilateral LPF standalone was applied for bilateral comminution or H- and U-shaped sacrum fractures with residual kyphosis of more than 10 degrees despite indirect reduction performed with no possibility for sacroiliac screw stabilization. Transpedicular systems were placed during acute trauma period using less invasive techniques. Open LPF was used in case of open reduction, decompression of nerve structures at sacral area and late periods of traumatic disease with complications arrested and general condition of the patient improved.

Multiple radiological images of pelvis were obtained intraoperatively using the OEC 9900 Elit C-arm (General Electric, U.S.A.). Inlet and outlet views of lesser pelvis at an angle of approximately 90 degrees to each other were additionally used.

Short-term follow-ups were evaluated prior to discharge of the patients from the hospital. Pain was assessed using visual analogue scale (VAS) and time of early verticalization evaluated postoperatively. Neurological deficit was classified with K.J. Gibbons scoring system [10]. Long-term outcomes were followed up from 6 months to 3 years. The S.A. Majeed score was used to interpret functional outcomes [11]. The modified SF-36 questionnaire was employed to measure health-related quality of life in patients with vertically unstable pelvic injuries [12].

Statistical data analysis was performed using Microsoft Office Excel 2010 and the package of BioStat 2009 software application (Analyst SoftInc., U.S.A.).

RESULTS

Pelvic belt (Medplant, Russia) was used for temporary fixation of vertically unstable pelvic fractures on admission to antishock surgical room.

Definitive osteosynthesis of anterior and posterior pelvic ring was produced for stable ($n = 5$) and borderline ($n = 7$) injuries during acute period of

trauma with stable hemodynamic measurements (BP > 90 mm Hg). Bridge-like transiliac transpedicular system (n = 1) or cannulated screws (n = 7) were placed in the anterior acetabular column to address anterior hemipelvic fractures. Pubic rupture was fixed with cannulated screw (n = 1), reconstruction plate (n = 2), transpedicular system (n = 1). Posterior pelvis was additionally stabilized with unilateral (n = 5) and bilateral (n = 7) LPF. An exhaustive reconstructive surgery on the injured pelvic ring was performed in antishock operation room for 7 patients on admission to the trauma center, and the rest had procedure produced within 48 hours (period of relative stabilization of vital functions). Less invasive technique of LPF was applied through small punctured accesses in 8 cases using special guiding systems. Anterior pelvis was temporarily fixed with external fixation device (EFD) in antishock operation room in unstable (n = 6) and borderline (n = 10) injuries with unstable haemodynamics (BP < 90 mm Hg) and three posterior structured were stabilized with Hanz frame (DePuy Synthes, Switzerland). Endopelvic hemorrhage was finally stopped using diagnostic pelvic angiography followed by embolization of damaged vessels in three cases. Posterior pelvic structures were stabilized with sacroiliac screws with the life-threatening events addressed (n = 2), within 48 hours of relative stabilization (n = 4), from them after removal of Hanz frame in 3 patients. Decompression of the sacral canal and repair of dural sack at the level of transverse component of H-shaped sacrum fracture was performed for a patient on day 2 due to compression of cauda equine roots (K.J. Gibbons score 4) [10] and neurological deficit with failed function of pelvic organs; posttraumatic kyphosis was eliminated by open reduction and open bilateral LPF. Definitive osteosynthesis of anterior pelvic ring including unilateral (n = 9) and bilateral (n = 7) LPF was produced during complete stabilization of vital functions 2 weeks after injury, on average.

Cannulated screws placed in the horizontal pubic rami (n = 7), plating in pubic ruptures (n = 5), bridge-like transiliac transpedicular system (n = 1), transpedicular pubic system (n = 2) were used to stabilize anterior pelvic structures. EFD was applied in one observation with concomitant injury to pelvic organs. Less invasive technique of LPF was performed for 7 patients.

Balloon obturator was placed in aorta via femoral artery at the side of injury in antishock operation room to temporarily stop endopelvic bleeding in extremis patient with pelvis stabilized with Hanz frame and anterior EFD followed by extraperitoneal pelvic tamponade. Hanz frame was removed next day and longitudinal sacrum fracture was fixed with two sacroiliac screws. Tamponade was removed from retroperitoneum after 4 days. Anterior pelvic ring was fixed with reconstruction plate after 23 days of complete stabilization of vital functions and unilateral LPF performed.

Pulmonary thromboembolism was a cause of death in one case (3.4 %) during the first two weeks of injury. Complications were observed in 18 (62.1 %) patients with primary borderline and unstable injury and were associated with combined trauma of other parts of the body.

Migration of a transpedicular screw in a patient was caused by inappropriate reduction of posterior pelvis and unstable fixation. Transpedicular system and complicated EFD attached to the pelvis were dismantled due to infected postoperative wound in a patient with unstable injury treated with open LPF during acute period of injury.

Three patients with H-shaped sacrum fracture developed neurological deficit of disturbed functioning of pelvic organs (1 partial, 1 complete) and radicular pain syndrome (n = 1) treated with decompression of the sacral canal.

Mean inpatient length was 41.0 ± 20.8 days. Mean VAS score was 2.2 ± 1.7 on discharge from the trauma center. All patients verticalized from 2 to 4 weeks after definitive stabilization of posterior pelvis.

Follow-ups were evaluated in 22 patients from 6 months to 3 years. The Majeed score was 83.2 ± 19.6 (range, 65 – 100) [10]. Excellent and good anatomic and functional results were obtained in 16 (72.7 %) patients, 5 (22.7 %) and 1 (4.5 %) had fair and poor results, correspondingly. Poor outcomes were associated with secondary displacement of posterior pelvic structures, nonunion of the vertical sacral fracture and neurological deficit of partially disturbed function of pelvic organs. It should be noted that verticalization and ambulation started early with application of triangular osteosynthesis. SF-36 was used to evaluate quality of life of 22 patients with vertically unstable pelvic fractures (Table 2) [12].

Table 2

Major parameters of quality of life evaluated with SF-36 health status survey (n = 22)

Parameters of quality of life	Mean score
Physical functioning, PF	80.5 ± 22.7
Role-physical functioning, RP	69.2 ± 38.7
Bodily pain, BP	72.3 ± 27.2
General health, GH	89.0 ± 3.1
Vitality, VT	68.6 ± 27.4
Social functioning, SF	48.9 ± 15.9
Role-emotional, RE	71.1 ± 37.9
Mental health, MH	70.9 ± 19.8
PH (physical health)	48.4 ± 9.1
MH (mental health)	44.9 ± 9.2

Patients showed good physical and mental health condition according to SF-36 health status questionnaire. Great quantitative values of physical and role-physical functioning indicated to efficacious strategy of operative interventions performed on the posterior pelvic ring early after injury, adequate choice of implants or their combination for definitive pelvic stabilization and timely decompression of involved nerve structures in complicated sacrum fractures.

Clinical instance. Written informed consent was obtained from the patients to publish the clinical observation.

A 38-year-old patient B. was delivered to the trauma center one hour of injury sustained in road traffic

accident. His BP measured 85 and 60 mm Hg, heart rate, 110, the Glasgow Coma Scale scored 12. The patient presented with clinical signs of unstable pelvic ring injury that was temporarily immobilized with pelvic belt (Medplan, Russia). CT scan showed fractures of the left pubic and ischial bones, comminuted transforaminal fracture of the lateral mass of the sacrum on the left and antero-posterior and vertical displacement (**Fig. 1**).

Sacral transforaminal fracture was laterally off the joint facets L5/S1 vertebrae and classified as B. Isler type I [13]. Total ISS score was 29. The patient was categorized as unstable and needed application of Damage Control Orthopedics. Closed reduction of the fracture, extrafocus pelvic fixation with EFD and emergency surgical procedures on the other parts of the body were produced for the case. Sacroiliac screws were placed in the vertebral bodies of S1 and S2 vertebrae to fix lateral mass of the sacrum (**Fig. 2**).

EFD was removed with general condition stabilized after 2 days of injury and pubic bone was fixed with cannulated screw and unilateral LPF with transpedicular system applied to the left hemipelvis (**Fig. 3**).

Walking with crutches with limited loading of 10 % of the body weight on the left lower limb was allowed after 5 days of surgical intervention. The patient was discharged from the center after 20 days of injury in satisfactory condition. An 18-month follow-up showed S.A. Majeed score of 92 [11] indicating to an excellent functional result of the treatment.

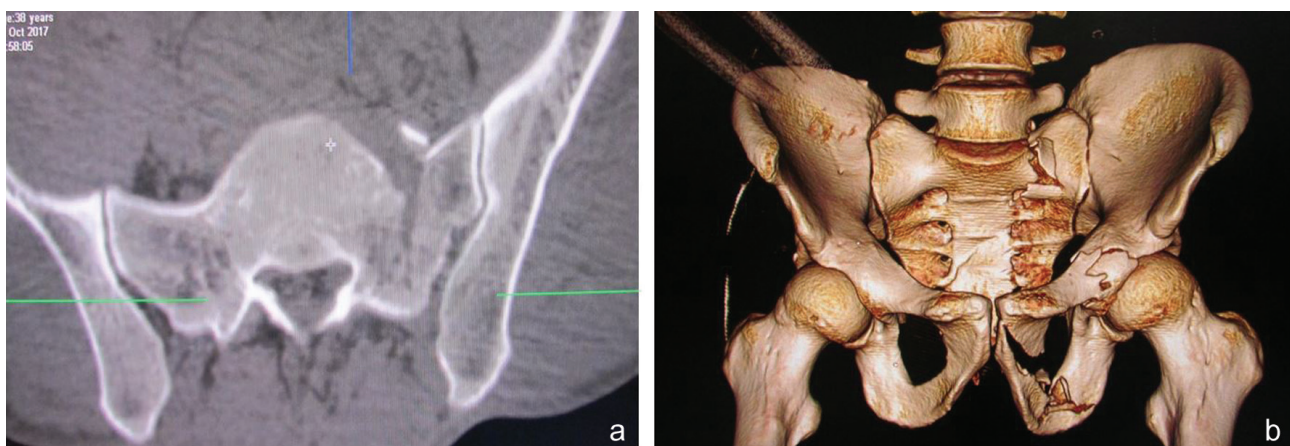


Fig. 1 Preoperative CT scans of patient B. showing (a) axial view and (b) 3D reconstruction

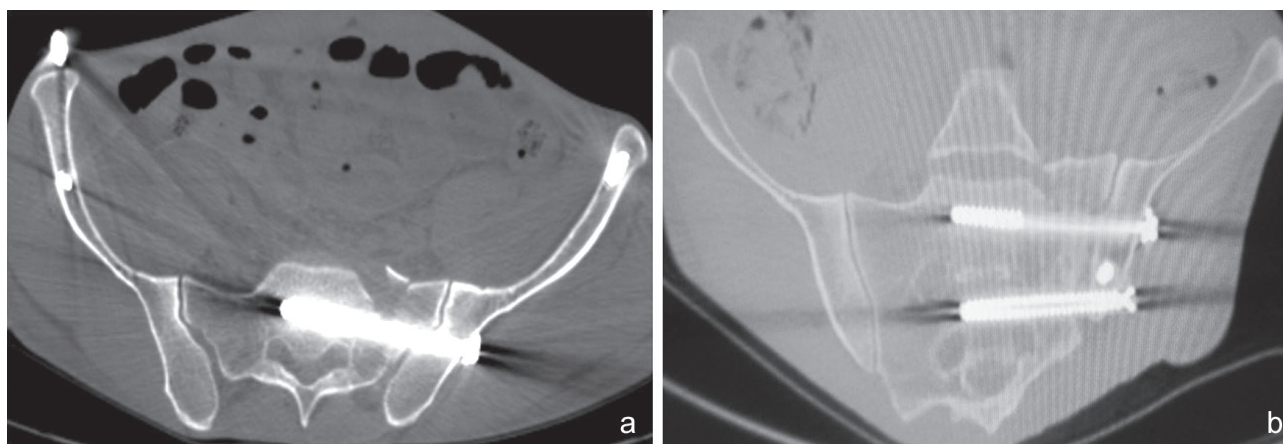


Fig. 2 Postoperative CT scans of patient B. showing (a) axial and (b) coronal views

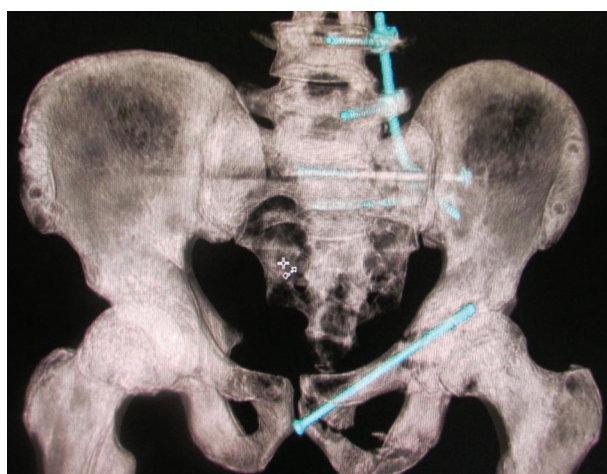


Fig. 3 CT scan of pelvis of patient B. showing 3D reconstruction of LPF

DISCUSSION

Unstable pelvic fractures are primarily repaired with minimally invasive techniques of internal fixation [1, 5]. Pelvic stabilization with EFD early after injury being an element of antishock events remains the gold standard. EFD is practical for pelvic ring fixation but fails to provide stable fixation of posterior pelvic structures in vertically unstable injuries. The Concept of Damage Control Orthopedics designates EFD for temporary fixation among other methods of addressing vertically unstable pelvic injuries that can be replaced by internal fixation with stabilization of the patient's condition [2, 5, 14, 15].

Iliac-iliac fixation includes transiliac bars, transsacral clamps, transiliac plates and half-pin transiliac internal fixators. Fixation with transiliac bars is considered an acceptable and technically simple practice. However, the systems are found to provide insufficient mechanical stability in sacral comminution, in particular. Transsacral clamps can ensure enough stability having greater strength limits to cyclic loading as compared to posterior triangular

osteosynthesis. The principle of compression of posterior structures with clamps cannot be employed for Denis type II sacral fractures and neurological complications. Safe corridors can be absent in sacral dysmorphism to place transsacral clamps [6, 15, 16, 17].

Iliosacral fixation with cannulated screws can be performed early after injury and added by external fixation of anterior hemipelvis. Classical technology of sacroiliac fixation with screws placed in vertebral bodies of S1/S1–S2 vertebrae was offered early 80-es and improved in 90-es [2, 18] and widely used due less invasiveness and good outcomes. However, many authors find an accurate reduction being very important and cannot accept iliosacral screws in a residual displacement of posterior structures measuring more than 0.5 to 1 cm. Denis type II sacral fractures complicated by neurological complications and Denis type III transverse sacral fractures are contraindication for this type of fixation. Even gradual weight-bearing on the lower limb at early postoperative period cannot be advocated for the patients with an iliosacral screw

placed in vertebral body [19]. The risk of malpositioned screw is greater in sacral dysmorphism [20], a screw placed in S2 vertebra and bilateral iliosacral immobilization when the introduced screw is on the way to another placement [19]. There are controversies regarding screw length with no statistically significant differences in stability of iliosacral screws of different length reported [21]. Injury to nerve roots is reported to occur in 20 % of the cases with placement of iliosacral screws [18]. Migration or breakage of screws are observed in 30 % of the cases [19, 21].

Open reduction and fixation of posterior pelvic structures with Matta or Double Cobra plates are practical for concomitant Denis types II and III sacral fractures with the need of decompression of neural structures. However, the techniques has several disadvantages including bilateral implant placement in case of a unilateral injury, difficulty of anatomical contouring, traumatic surgical approach and a high risk of iatrogenic injury to neural structures with screws. Less invasive techniques of plating are reported [22]. Biomechanical bench tests demonstrated satisfactory strength of fixation in plated posterior pelvic structures with no possibility to prevent rotation in the anterior hemipelvis. Transiliac fixation with anterior sacral contouring plated has shown to provide greater stability but with higher risk of iatrogenic complications [6, 16].

Transiliac internal fixation of posterior pelvis with transpedicular screws provides greater strength to posterior rotation with persisted tendency to vertical displacement. Two bridge-shaped connectors are needed for more stability. Bilateral instability of posterior pelvic is reported to be a contraindication to transiliac internal fixation [16, 23].

Lumbopelvic fixation has become most relevant for vertically unstable pelvic injury and been widely used in spinal surgery since 80-es. Lumbopelvic distraction spondylodesis for sacrum fracture fixation was first described in 1994 [24]. There are two known types of LPF with spinal fixation components (screws, hooks, wire) are attached either to (1) iliac wings using contoured rods or anchored superiorly (Galveston technique, STIF) or (2) through the rods with screws placed in pelvic bone. Stability of the implant is not reliable with the first type of fixation. The risk of rod breakage, instability of fixators due a small area contact and greater loading, insufficient

axial fixation is high in both types of fixation [25].

The current technique of LPF involves the usage of transpedicular screws fixed to vertebral bodies of L4–L5 vertebrae and posterior portions of iliac wings connected by rods. Transpedicular screws can be introduced directly either in posterior portions of iliac wings or the body of L2 vertebra, lateral masses of the sacrum or bodies of S1/S2 vertebrae, and a combination of the above. Stability of posterior pelvic structures to rotational loadings cannot be ensured for all the cases. There is a technique of triangular lumbopelvic fixation offered to combine vertical lumbopelvic transpedicular fixation and transverse fixation with iliosacral screws. More data in the literature can be found reporting the successful application for vertically unstable pelvic injuries [1, 4, 26, 27, 28]. Comparative experimental studies showed biomechanical advantages of triangular lumbopelvic fixation over standalone iliosacral or iliosacral fixation with cannulated screws. Biomechanical bench studies showed stability of the combined metal construct to vertical and rotational displacements, so the technique of posterior pelvic fixation was biomechanically substantiated [28].

Disadvantages of early open LPF include likelihood of opening retroperitoneal pelvic hematoma, additional blood loss and local infection [29]. The limitations are not characteristic for less invasive technique of LPF. The procedure is performed using several small approaches to minimize intraoperative injury, perform higher spondylodesis and reduce treatment and rehabilitation length. Specific features of less invasive LPF include inability to attach distractor to the metal construct and bring the broken hemipelvis down, the need to make a separate wound for sacral laminectomy and place transverse connector in bilateral LPF with surgical time and radiation being greater than those in open method [27].

Early sacrum reduction facilitates lower rate of secondary neurological disorders developing due to bone callosity or fibrosis. The early manipulations are helpful for earlier ambulation and favourable neurological prognosis [14].

Current approaches to the treatment of vertically unstable pelvic fractures require biomechanically substantiated techniques of internal fixation with the possibility of decompression of injured neural structures. Lumbopelvic fixation or triangular fixation

with simultaneous approach for decompression of sacral laminectomy or local foraminotomy in cases

of evident neurological deficiency are the methods of choice for vertically unstable pelvic fractures.

CONCLUSIONS

1. Lumbopelvic fixation with transpedicular screws can be advocated in patients with vertically unstable pelvic injuries during acute period of trauma using less invasive technique.

2. A variety of morphological types of injury to posterior pelvic structures requires thorough choice of an implant or the combination.

3. Lumbopelvic fixation can be used standalone or as an addition to triangular osteosynthesis using iliosacral screws.

4. Extended surgery and the use of surgical approaches to posterior pelvic structures are produced if open reduction and decompression of nerve structures are needed.

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