DOI: https://doi.org/10.17816/vto34523

Surgery of unstable pelvic ring injuries. Trends, issues and perspectives

Ruslan I. Zakirov, Ildar F. Ahtyamov

Kazan State Medical University, Kazan, Russia

ABSTRACT

Unstable pelvic ring injures can lead to unsatisfactory long-term results of up to 60% on average. Incorrect interpretation of radiological results, underestimation of the severity of pelvic injures during polytrauma lead to the rejection of urgent stabilization of the pelvis. Despite the presence of many effective methods of stabilization of the pelvic ring injures, a rather large percentage of reoperations remains both as a result of relapse displacement an as a result of nonunion of fracture and loss of fixation. The review is devoted to the analysis of the problem of diagnosis, treatment and the result of applying various methods of stabilization of the pelvic ring.

Keywords: pelvis fractures; pelvic ring injures; polytrauma; perspectives of pelvic ring injuries; literature review.

To cite this article:
Zakirov RI, Ahtyamov IF. Surgery of unstable pelvic ring injuries. Trends, issues and perspectives. *N.N. Priorov Journal of Traumatology and Orthopedics.* 2021;28(4):31–38. DOI: https://doi.org/10.17816/vto34523

Received: 03.06.2020 **Accepted:** 22.12.2021 **Published:** 24.03.2022

ЭКО•ВЕКТОР

DOI: https://doi.org/10.17816/vto34523

Хирургия нестабильных повреждений тазового кольца. Тенденции, проблемы и перспективы

Р.И. Закиров, И.Ф. Ахтямов

Казанский государственный медицинский университет, Казань, Россия

АННОТАЦИЯ

Нестабильные повреждения тазового кольца могут приводить к неудовлетворительным долгосрочным результатам в среднем до 60% случаев. Неправильная трактовка рентгенологических результатов, недооценка тяжести повреждения таза при политравме приводят к отказу от срочной стабилизации таза. Несмотря на наличие множества эффективных методов стабилизации тазового кольца, сохраняется достаточно большая доля повторных операций вследствие как рецидива смещения, так и несращения переломов и потери фиксации. Обзор посвящен анализу проблем диагностики, лечения и результатов применения различных методов стабилизации тазового кольца.

Ключевые слова: перелом костей таза; нарушение целостности тазового кольца; политравма; перспективы лечения повреждений таза; обзор литературы.

Как цитировать:
Закиров Р.И., Ахтямов И.Ф. Хирургия нестабильных повреждений тазового кольца. Тенденции, проблемы и перспективы // Вестник травматологии и ортопедии им. Н.Н. Приорова. 2021. Т. 28, № 4. С. 31–38. DOI: https://doi.org/10.17816/vto34523

Рукопись получена: 03.06.2020 **Рукопись одобрена:** 22.12.2021 **Опубликована:** 24.03.2022

ECO•VECTOR

Despite the achievements of contemporary traumatology, mortality in unstable pelvic ring injuries reaches 30%, and it ranks third among the fatal causes of craniocerebral and chest trauma. Disability in pelvic injuries occurs in 22%–36% of the cases, and poor outcomes occur in 20%–80% [1]. Despite the developments and improvements of surgical treatment methods using advanced implants, poor long-term results reach an average of 60%.

Significant difficulties are induced by the treatment of unstable fractures of the pelvic bones with multiple and concomitant injuries.

Active surgical approach and early functional osteosynthesis are modern principles for the treatment of unstable lesions of the pelvic bones. The therapy mainly aims at restoration and stabilization of the pelvic bones and decompression and revision of the pelvic plexus elements in case of neurological lesions. The priority of osteosynthesis has been recognized; however, discussions about the treatment of pelvic ring lesions are still relevant. Several Russian specialists emphasize external fixation in the treatment of pelvic lesions, whereas international authors tend to perform stable and functional internal osteosynthesis [2].

The patient's condition is one of the indicators to the risk of surgical intervention owing to additional consequences of surgical trauma. This cannot only worsen the patient's condition, but also lead to lethal outcomes. Currently, the "gold standard" for the medical care for polytrauma is "damage control," which includes a progressive program of surgical treatment [3]. In relation to fractures, the method includes early temporary fixation of bone fragments using less traumatic methods and subsequent final osteosynthesis to stabilize the patient's general condition.

The treatment of pelvic fractures starts with the initial stage of immobilization, which can be implemented using a pelvic band, C-clamp, or other external fixation methods. The stabilization of the anterior and posterior pelvic half-rings allows patient mobilization in the early period without the risk of reposition loss, which is of fundamental importance in polytrauma [4]. A typical example of such an approach is the treatment of type B and C pelvic fractures according to the Association for Osteosynthesis/Association for the Study of Internal Fixation, where the most important stage of anti-shock measures is urgent stabilization of the pelvis using external fixators. In vertically unstable injuries of the pelvic ring, the fixation strength of the dorsal pelvis with anterior external fixation devices is insufficient; skeletal traction and bed rest were also employed [5]. Surgical intervention is recommended within the next few hours after the injury. Kukuruz et al. (2003) used an external fixation device (EFD) for type B pelvic injuries. In the case of unstable injuries of the pelvic bones (type C fracture), after urgent surgical interventions on the organs of the chest, abdomen, and other extrapelvic structures, a basic modular EFD was applied, which later (days 2–3) could be expanded and stabilized [6].

The world famous inventor, traumatologist, and orthopedist G.A. Ilizarov introduced methods of extrafocal treatment of patients with pelvic ring injuries, which improved significantly the quality of treatment. The external fixation of the pelvic ring in polytrauma has several advantages. First, the method is less traumatic and can be used in the most severe period, and second, it has a significant anti-shock effect and enables resetting of bone fragments at all stages of treatment [7].

Nowadays, two methods are employed in the surgical treatment of pelvic injuries, namely, external fixation (C-clamp, wire, rod, and wire-rod structures) and/or internal fixation.

The C-clamp is widely used for temporary fixation of the pelvic ring in the early period of polytrauma. It provides reliable stabilization and interfragmentary compression with a force of up to 350 N. After bringing the patient out from shock, the C-shaped clamp is removed, and the pelvic ring is further stabilized by internal osteosynthesis [8].

When providing emergency care to patients with unstable injuries of the pelvic bones in the first hours, the gold standard is early stabilization of the pelvis using the EFD or pelvic forceps.

Many researchers recommend applying EFD for fractures of the anterior half-ring in the first hours after admission to the intensive care unit in patients with pelvic ring instability, Ganz forceps for fractures of the posterior half-ring, and Ganz forceps and EFD for fractures of the anterior and posterior half-rings. Most specialists immobilize the patient's pelvis with a device immediately upon admission.

Active surgical approach has become a priority in Russia in the past 20–25 years. It is associated with the intensive development of pelvic surgery, including its unstable injuries.

Stabilization of pelvic fractures in polytrauma has been proven to be an integral part of anti-shock measures [9]. External fixation with devices is simple and minimally traumatic. It not only provides early stabilization of the pelvic ring, but also promotes the arrest of intrapelvic bleeding [10]. EFD allows patient transport, care for the patient in the resuscitation period, and early walking.

Moreover, external fixation of the pelvis has several significant disadvantages. There is a risk of inflammation of the insertion area of the retaining elements and their loosening, which result in the loss of fixation stability. The external structure is bulky, making it difficult to lay the patient in bed, complicates patient care, and reduces quality of life. In this regard, according to indications, EFD is replaced by internal fixators at the stages of treatment.

An alternative intervention is internal osteosynthesis. This method has several advantages, including the possibility of anatomical restoration of the pelvic ring and stable fixation that facilitates patient care and treatment of polytrauma.

When choosing open reduction, the degree of pubic articulation divergence and fragment displacement should be considered. To restore the anterior half-ring, specialists used

DOI: https://doi.org/10.17816/vto34523

bone grafting, screws with a tightening loop, a plate of the appropriate shape, or a U-shaped bracket. However, final open interventions are possible after stabilization of the patient's hemodynamic parameters, which is achieved using EFDs, pelvic tamponade, and angio-embolization. Thirteen studies of a total of 24,000 patients were analyzed. Maximum safety is ensured when using pelvic tamponade. External fixation is recognized as the most effective for controlling blood loss and primary stabilization. Angio-embolization is presented as an additional, but not an alternative method of fixation [11].

Burlew et al. asserted performing retroperitoneal pelvic tamponade in combination with angio-embolization in patients with unstable hemodynamics and active pelvic bleeding [12].

Osteosynthesis with reconstructive plates with angular stability, widely used by specialists, is also relevant. Extramedullary synthesis provides stable fixation of the fragments. To increase its rigidity, a pair of plates can be used, while the long one is placed above the pubic articulation, the short one is placed anteriorly.

According to some authors, the external fixation device in the case of internal osteosynthesis should be replaced within the first 3 days with the patient in a stable condition [13]. The introduction of emergency temporary stabilization has led to an increase in survival after pelvic fracture. Tile et al. revealed that early pelvic fixation is useful in acute resuscitation, but is of limited value in the final management of unstable type C fractures or even open injuries [14].

Primary internal fixation in patients with severe injuries is used relatively rarely owing to the risk of serious complications [15]. However, Pereira et al. demonstrated the successful use of primary fixation of articulations and bone fragments with screws and a plate in the first 6 h for unstable pelvic injuries in patients with polytrauma. Several traumatologists consider the initial fixation of the pubic symphysis with a laparotomic approach as a staged surgery for retroperitoneal lesions of the bladder [16].

Internal osteosynthesis in the surgical treatment of pelvic ring lesions has several advantages, namely, the ability to move fragments accurately, under visual control, and restore anatomy, and stability of fixation, which prevents delayed or incorrect union and improves significantly the anatomical and functional outcomes of treatment. However, internal fixation also had disadvantages, which include additional surgical aggression, blood loss, and risk of infectious complications in the postoperative wound. Internal osteosynthesis is often impossible in the early stages because of the patient's condition severity and subsequently technical difficulties.

Minimally invasive internal fixation techniques for unstable pelvic lesions are gaining popularity nowadays. For example, for the restoration and fixation of the pubic symphysis, the synthesis of the pubic rami is performed using reconstructive plates through a short-scar incision. Lockable nails for osteosynthesis of the pubic bones have been developed and implemented. In the case of damage to the sacroiliac joints, the sacrum is stabilized using cannulated screws, reconstructive bridge plates, and transpedicular systems [17]. Thus, specialized designs are being developed, such as the less invasive stabilization system or anterior pelvic internal fixation. Wong et al. prefer this method because it reduces the risk of infectious complications and is convenient for surgeons who may need access to the abdominal cavity [18].

Nowadays, the combination of internal and external methods of fixing pelvic fractures remains relevant. For example, the anterior half-ring can be secured with an external fixator, whereas internal structures can be used to restore the posterior half-ring. Thus, combined osteosynthesis offers the advantages of each of the methods and minimizes the risk of complications.

Proper repositioning with the restoration of the anatomy and effective fixation of unstable pelvic lesions not only enables the use of early functional loading but also reduces the risk of surgery, blood loss, and infectious complications. The surgeon must have sufficient knowledge of the pelvic anatomy and experience in using the pelvic fixation technique with the highest level of safety. According to international publications, minimally invasive methods of pelvic stabilization minimize soft tissue damage; however, the risk of iatrogenic damage to the neurovascular bundles is quite high. There are also cases of traction injury of the sciatic nerve during thigh traction to bring down fractures of the sacrum with displacement of >1 cm caudally [19]. In percutaneous fixation of the sacroiliac joints with a screw, both the experience of the surgeon and quality of intraoperative X-ray control are of great importance.

Various anesthesia methods allow several authors, after fixation of the posterior structures of the pelvis, or in cases when the posterior half-ring fixation was not required, to conduct clinical tests for assessing the stability of the anterior half-ring. In cases without fragment mobility or were assessed to be insignificant, only load with additional support for 12 weeks was allowed. Within 6 weeks, displacement of fragments from 6 to 12 mm was noted in these patients, which persisted until union [20].

Many authors propose their methods developed for the surgical treatment of pelvic lesions using various combinations of external and internal fixators. Two-stage osteosynthesis reduces the surgical injury rate and offers adequate repositioning and reliable fixation of the pelvis. The feasibility of improving the method of surgical treatment of pelvic ring lesions is justified by their diversity, although high-impact fractures occur in predictable places.

In urgent surgery, a fundamentally new direction is ongoing, that is, percutaneous pelvic fixation, which helps avoid complications of extensive surgical approaches. Such fixation is performed after preoperative planning and indirect repositioning of the fragments. Specialized software is being developed for virtual reconstruction of all

surgical stages, i.e., for determination of the safety zones for mounting, precise planning of screw sizes, and testing the possibility of using percutaneous technology as an alternative to open access.

Osteosynthesis of pelvic fractures is necessarily preceded by accurate closed reduction; therefore, to achieve better results in this area, improving the closed reduction technique is being attempted [21]. Intraoperative control of reduction and fixation with a C-clamp are the main rules. Recent developments have provided physicians with new options for managing three-dimensional imaging during surgery.

The introduction of high-tech methods at all stages of surgery and their combination can make the surgery with percutaneous access to the pelvis and acetabulum easier, safer, and more accurate. However, even with the latest and most sophisticated technologies, proper surgical evaluation and experience in pelvic and acetabular surgery are necessary and indispensable.

Stable osteosynthesis using contemporary methods of fixation of complicated pelvic fractures in patients with polytrauma enables their mobilization much earlier and attaining of good anatomical and functional results in 78% of cases [22].

Quite effective results were obtained in a combined prospective study conducted by Shetty et al. in 2017. The efficiency of a minimally invasive anterior subcutaneous internal fixation system and percutaneous ileosacral screws for unstable pelvic ring fractures was evaluated. Accordingly, minimally invasive pelvic stabilization with these designs is easy to master and use, provides good fracture reduction and final stabilization with minimal complications, and gives excellent functional results within a follow-up period of >31 months (level of evidence IV) [23].

Various combinations of fixators (ileosacral screws, transiliac screws, and reconstructive plates) were analyzed. A study revealed that repositioning is the most significant. All combinations of fixation options provided the same reliability of fixation [24].

Osteosynthesis with percutaneous ileosacral screws proved to be a relatively safe method, which is confirmed by numerous clinical series. Compared with open methods, their application reduced the risk of hemorrhage and infection. Functional results also improved, pain indicators decreased, and displacement of the pelvis became smaller. The overall accuracy of the insertion of percutaneous ileosacral screws was good, with a mispositioning rate of approximately 2.5% [25].

Breuil, Roux, and Carle investigated the use of an external fixator in three patients. The patient was in the prone position; locking nails (Schanz screws) were placed percutaneously in the L5 and/or S1 pedicles and posterior iliac crests and were used as levers for compression–distraction maneuvers. After apposition, they maintain repositioning while placing the ileosacral screws [26].

The principles of reduction are adequately applicable to both anterior and posterior lesions. The fixation of the posterior section is an integral part of the injured pelvis stabilization. Posterior ring fractures include sacral, sacroiliac, and iliac fractures.

Unstable injuries of the posterior pelvic ring, such as a dislocation of the sacroiliac joint, are always complicated by significant disability. Unsatisfactory treatment outcomes include the leg-length discrepancy, impaired rotation, residual neurological deficits, and chronic pain. Many methods to overcome these problems have been described in the literature, including precise indirect reduction and stabilization using various internal systems [27].

In some cases, to stabilize the posterior half-ring of the pelvis, specialists use bridge-like transpedicular fixators; therefore, the authors obtained good clinical outcomes [28]. However, these options have drawbacks, such as insufficiently strong fixation and possibility of migration.

In addition, to stabilize the posterior half-ring, plates are used, which are fixed to the posterior surface of the iliac wings and above the sacrum. However, owing to the anatomical aspects of this section, which has almost no muscle mass, such an arrangement of plates poses the risk of bedsore formation, exposure of the fixator, and wound infection.

Mears et al. (1986) developed a C-clamp for the surgical stabilization of the posterior pelvis from an appropriate approach. However, the massiveness of the fixator and surgery injury rate hinder its widespread use in traumatology [29].

The failures and complications associated with open approach to the posterior pelvic ring have led to the active use of percutaneous fixation. Percutaneous closed osteosynthesis with cannulated screws has become widespread. The method is often used in combination with osteosynthesis of the anterior half-ring in unstable pelvic injuries. However, the difficulty of inserting the screws and the risk of damage to the nerve roots are limiting factors.

According to Vigdorchik et al., on the pelvis model, the variants of fixation of sacral fractures were recreated using one or two ileosacral screws and a transpedicular fixator with the screw installed in the S1 or S2 pedicle and posterior iliac spine. Empirically, the use of a transpedicular fixator with ileosacral screws ensures maximum reliability of fixation. Such placement of pedicle screws without an ileosacral fixator provides the least rigid fixation. This method ensures the connection of the sacroiliac joints and the sacral fracture zone without the use of large surgical approaches [30].

According to numerous clinical series, osteosynthesis with percutaneous ileosacral screws proved to be a relatively safe method. Compared with open methods, they reduced the risk of bleeding and infection. Functional outcomes also improved, pain indicators decreased, and displacement of the pelvis became smaller. The overall accuracy of percutaneous ileosacral screw insertion was revealed to be good, with a mispositioning rate of approximately 2.5% [31].

For osteosynthesis in sacral fractures and lumbosacral dislocation, certain rules should be followed, namely, the patient's position on the orthopedic table should allow partial or complete reposition, and the later the repositioning is

DOI: https://doi.org/10.17816/vto34523

performed, the more difficult it is [32]. Therefore, the intervention should be performed within 2 weeks after the injury. Repositioning is practically impossible after 3 weeks, which explains the high level of disability in such cases. Effective intraoperative X-ray control during repositioning is required.

CONCLUSION

An analysis of relevant publications revealed characteristic trends in providing assistance to patients with pelvic bone injuries in the presence of polytrauma. Moreover, there is no consensus on the optimal time, methods, and scope of treatment for pelvic lesions in the acute period of severe polytrauma [33]. Thus, it is necessary to improve the technique of surgical treatment for multiple pelvic injuries to restore functionality, reduce disability, and prevent general and local complications in patients with combined and multiple injuries [34].

The approach of surgical treatment of patients with pelvic trauma, timing, and methods of fixation are not yet established. Various combinations of fixators are being studied to improve clinical outcomes. With respect to unstable injuries of the posterior pelvic half-ring, two main methods of fixation are formed, namely, minimally invasive installation of ileosacral screws and stabilization of the lumbar–pelvic junction using various types of transpedicular fixators [35].

All of the above determines the need to expand scientific research and to improve the treatment outcomes of patients with unstable pelvic fractures in polytrauma.

ADDITIONAL INFO

Author contribution. Thereby, all authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

Funding source. Not specified.

Competing interests. The authors declare that they have no competing interests.

REFERENCES

1. Neufeld ME. The longitudinal short-, medium-, and long-term functional recovery after unstable pelvic ring injuries. *J Orthop Trauma*. 2019;33(12):608–613. doi: 10.1097/bot.0000000000001588

2. Semyonov PV, Grigoryev AV, Ratyev AP, et al. Peculiarities of treatment of unstable pelvic injuriesin patients with polytrauma (current state of the problem). *Trudnyi patsient*. 2016;14(1):49–54. (In Russ).

3. Samohvalov IM, Borisov MB, Kazhanov IV, et al. Intrahospital emergency medical care feature of the first stage of damage control surgery tactics in unstable pelvis fractures. *Skoraya meditsinskaya pomoshch'*. 2016;17(3)39–45. (In Russ). doi: 10.24884/2072-6716-2016-17-3-39-45

4. Dulaev AK, Kazhanov IV, Manukovsky VA, et al. Lumbopelvic transpedicular fixation of vertically unstable pelvic ring injuries. *Genii ortopedii*. 2018;24(3):282–289. (In Russ). doi: 10.18019/1028-4427-2018-24-3-282-289

5. Dulaev AK, Kazhanov IV, Manukovsky VA, et al. Minimally invasive lumbopelvic fixation for stabilization of the posterior pelvic ring in victims with polytrauma. *Khirurgiya pozvonochnika.* 2017;14(3):40–46. (In Russ). doi: 10.14531/ss2017.3.40-46

6. Kusturova AV, Kusturov VI. Polytrauma: vertically unstable pelvic injuries, early surgical treatment. *Kafedra travmatologii i ortopedii*. 2018;(3):36–39. (In Russ). doi: 10.17238/issn2226-2016.2018.3.36-39

7. Shah D, Bates T, Fowler J, et al. Minimally invasive lumbopelvic fixation for unstable U-type sacral fractures. *Cureus*. 2019;11(9):e5621. doi: 10.7759/cureus.5621

8. Kassymov KT, Tlemissov AS, Zhunussov ET, et al. Surgical treatment of unstable injuries of the posterior pelvic ring. Literature review. *Nauka i zdravookhranenie*. 2019;21(5):11–22. (In Russ). doi: 10.24412/FgWvKl5kQZI

9. Stahel PF, Burlew CC, Moore EE. Current trends in the management of hemodynamically unstable pelvic ring injuries. *Curr Opin Crit Care*. 2017;23(6):511–519. doi: 10.1097/mcc.0000000000000454

10. Tutynin KV, Shnyakin PG, Shubkin VN. The experience with surgical treatment of vertical instable injuries to the pelvic ring with distant triangular lumboiliac fixation. *Politravma.* 2017;(4):38–43. (In Russ).

11. Khapilin AP, Solod EI, Snetkov DA, et al. Internal fixation of instability pelvic fracture. *Klinicheskaya praktika.* 2018;9(1):18–22. doi: 10.24412/FgWwDaPQ1sA

12. Agadzhanyan VV. The issue of development of polytrauma registry in the Russian Federation. *Politrauma.* 2018;(1):6–9. (In Russ).

13. Tang J, Shi Z, Hu J, et al. Optimal sequence of surgical procedures for hemodynamically unstable patients with pelvic fracture: a network meta-analysis. *Am J Emerg Med*. 2019;37(4):571–578. doi: 10.1016/j.ajem.2018.06.027

14. Sobhan MR, Abrisham SM, Vakili M, Shirdel S. Spinopelvic fixation of sacroiliac joint fractures and fracture-dislocations: a clinical 8 years follow-up study. *Arch Bone Jt Surg*. 2016;4(4):381–386. doi: 10.22038/abjs.2016.7537

15. Tile M. *Fractures of the pelvis and acetabulum: principles and methods of management*. Stuttgart: Thieme; 2016. doi: 10.1055/b-0035-121619

16. Lazarev AF, Borozda IV. Massive retroperitoneal bleeding in pelvic fractures. *N.N. Priorov Journal of Traumatology and Orthopedics*. 2016;(2):68–76. (In Russ). doi: 10.32414/0869-8678-2016-2-68-76

17. Pereira GJC, Damasceno ER, Dinhane DI, et al. Epidemiology of pelvic ring fractures and injuries. *Rev Bras Ortop*. 2017;52(3):260–269. doi: 10.1016/j.rboe.2017.05.012

18. Bondarenko AV, Kruglykhin IV, Plotnikov IA, et al. External fixation as a basic and final method for treatment of pelvic ring injuries in polytrauma. *Politravma.* 2018;(2):41–50. (In Russ).

19. Wong JM, Bewsher S, Yew J, et al. Fluoroscopically assisted computer navigation enables accurate percutaneous screw placement for pelvic and acetabular fracture fixation. *Injury.* 2016;46(6):1064–1068. doi: 10.1016/j.injury.2015.01.038

20. Albracht BG, Jenkins MD. Sciatic nerve palsy after distal femoral traction for vertically unstable pelvic fracture in a neurologically intact patient. *J Am Acad Orthop Surg Glob Res Rev*. 2019;3(9):e045. doi: 10.5435/jaaosglobal-d-19-00045
21. Avilucea FR, Archdeacon MT, Collinge CA, et al. Fixation strategy using sequential intraoperative examination under anesthesia for unstable lateral compression pelvic ring injuries reliably predicts union with minimal displacement. *J Bone Joint Surg Am.* 2018;100(17):1503–1508. doi: 10.2106/jbjs.17.01650
22. Burlew CC, Moore EE, Stahel PF, et al. Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures. *J Trauma Acute Care Surg*. 2017;82(2):233–242. doi: 10.1097/ta.0000000000001324
23. Kleweno C, Bellabarba C. Lumbopelvic fixation for pelvic fractures. *Oper Tech Orthop*. 2016;25(4):270–281. doi: 10.1053/j.oto.2015.09.001
24. Shetty AP, Bosco A, Perumal R, et al. Midterm radiologic and functional outcomes of minimally-invasive fixation of unstable pelvic fractures using anterior internal fixator (INFIX) and percutaneous iliosacral screws. *J Clin Orthop Trauma*. 2017;8(3):241–248. doi: 10.1016/j.jcot.2017.05.009
25. Cavalcanti Kußmaul A, Greiner A, Kammerlander C, et al. Biomechanical comparison of minimally invasive treatment options for Type C unstable fractures of the pelvic ring. *Orthop Traumatol Surg Res*. 2020;106(1):127–133. doi: 10.1016/j.otsr.2019.09.032
26. Breuil V, Roux C.H., Carle G.F. Pelvic fractures: epidemiology, consequences, and medical management. Curr Opin Rheumatol. 2016 Jul;28(4):442-7. doi: 10.1097/BOR.0000000000000293.
27. Li S, Meng X, Li W, et al. Effects of minimally invasive plate-screw internal fixation in the treatment of posterior pelvic ring fracture. *Exp Ther Med.* 2018;16(5):4150–4154. doi: 10.3892/etm.2018.6670
28. Bo QIAO, Weidong NI, Zhiqiang GAO, et al. Lumbopelvic fixation of vertically unstable Tile type C pelvic fractures combined with complex sacral fractures. *Chinese Journal of Trauma*. 2017;(12):510–515.
29. Tempelaerea C, Vincentab C, Courta C. Percutaneous posterior fixation for unstable pelvic ring fractures. *Orthop Traumatol Surg Res*. 2017;103(8):1169–1171. doi: 10.1016/j.otsr.2017.07.024
30. Wong JML, Bucknill A. Fractures of the pelvic ring. *Injury*. 2017;48(4):795–802. doi: 10.1016/j.injury.2013.11.021
31. Vigdorchik JM, Jin X, Sethi A, et al. A biomechanical study of standard posterior pelvic ring fixation versus a posterior pedicle screw construct. *Injury*. 2016;46(8):1491–1496. doi: 10.1016/j.injury.2015.04.038
32. Koshimune K, Ito Y, Sugimoto Y, et al. Minimally invasive spinopelvic fixation for unstable bilateral sacral fractures. *Clin Spine Surg*. 2016;29(3):124–127. doi: 10.1097/bsd.0000000000000090
33. 33. Giannoudis PV, Pape HC. Principles of damage control for pelvic ring injuries. In: Pape HC, Peitzman A, Rotondo M, Giannoudis P, editors. *Damage control management in the polytrauma patient*. Cham: Springer; 2017. doi: 10.1007/978-3-319-52429-0_21
34. El-Desouky II, Mohamed MM, Kandil AE. Percutaneous iliosacral screw fixation in vertically unstable pelvic injuries, a refined conventional method. *Acta Orthop Belg*. 2016;82(1):52–59.
35. Lazarev AF, Gudushauri YaG, Kostiv EP, et al. Challenging issues of the doctrine of the pelvis polytrauma. *Tikhookeanskii meditsinskii zhurnal*. 2017;(1):17–23. (In Russ). doi: 10.17238/PmJ1609-1175.2017.1.17-23

СПИСОК ЛИТЕРАТУРЫ

1. Neufeld M.E. The longitudinal short-, medium-, and long-term functional recovery after unstable pelvic ring injuries // J Orthop Trauma. 2019. Vol. 33, N 12. P. 608–613. doi: 10.1097/bot.0000000000001588
2. Семенов П.В., Григорьев А.В., Ратьев А.П., и др. Особенности лечения нестабильных повреждений таза у больных с политравмой (современное состояние проблемы) // Трудный пациент. 2016. Т. 14, № 1. С. 49–54.
3. Самохвалов И.М., Борисов М.Б., Кажанов И.В., и др. Скорая медицинская помощь в стационаре особенности первого этапа тактики многоэтапного хирургического лечения (damage control) при нестабильных переломах таза // Скорая медицинская помощь. 2016. Т. 17, № 3. С. 39–45. doi: 10.24884/2072-6716-2016-17-3-39-45
4. Дулаев А.К., Кажанов И.В., Мануковский В.А., и др. Пояснично-тазовая транспедикулярная фиксация // Гений ортопедии. 2018. Т. 24, № 3. С. 282–289. doi: 10.18019/1028-4427-2018-24-3-282-289
5. Дулаев А.К., Кажанов И.В., Мануковский В.А., и др. Стабилизация заднего отдела тазового кольца у пострадавших с политравмой способом минимально-инвазивной пояснично-тазовой фиксации // Хирургия позвоночника. 2017. Т. 14, № 3. С. 40–46. doi: 10.14531/ss2017.3.40-46
6. Кустурова А.В., Кустуров В.И. Политравма: вертикально нестабильные переломы таза, раннее хирургическое лечение // Кафедра травматологии и ортопедии. 2018. № 3. С. 36–39. doi: 10.17238/issn2226-2016.2018.3.36-39
7. Shah D., Bates T., Fowler J., et al. Minimally invasive lumbopelvic fixation for unstable U-type sacral fractures // Cureus. 2019. Vol. 11, N 9. P. e5621. doi: 10.7759/cureus.5621
8. Касымов К.Т., Тлемисов А.С., Жунусов Е.Т., и др. Хирургическое лечение нестабильных повреждении заднего полукольца таза. Обзор литературы // Наука и здравоохранение. 2019. Т. 21, № 5. С. 11–22. doi: 10.24412/FgWvKl5kQZI
9. Stahel P.F., Burlew C.C., Moore E.E. Current trends in the management of hemodynamically unstable pelvic ring injuries // Curr Opin Crit Care. 2017. Vol. 23, N 6. P. 511–519. doi: 10.1097/mcc.0000000000000454
10. Тутынин К.В., Шнякин П.Г., Шубкин В.Н. Опыт хирургического лечения вертикально-нестабильных повреждений тазового кольца методом дистантной триангулярной пояснично-подвздошной фиксации // Политравма. 2017. № 4. С. 38–43.
11. Хапилин А.П., Солод Э.И., Снетков Д.А., и др. Внутренняя фиксация нестабильных переломов таза (опыт оперативного лечения) // Клиническая практика. 2018. Т. 9, № 1. С. 18–22. doi: 10.24412/FgWwDaPQ1sA
12. Агаджанян В.В. К вопросу о создании реестра политравмы в Российской Федерации // Политравма. 2018. № 1. С. 6–9.
13. Tang J., Shi Z., Hu J., et al. Optimal sequence of surgical procedures for hemodynamically unstable patients with pelvic fracture: a network meta-analysis // Am J Emerg Med. 2019. Vol. 37, N 4. P. 571–578. doi: 10.1016/j.ajem.2018.06.027
14. Sobhan M.R., Abrisham S.M., Vakili M., Shirdel S. Spinopelvic fixation of sacroiliac joint fractures and fracture-dislocations: a clinical 8 years follow-up study // Arch Bone Jt Surg. 2016. Vol. 4, N 4. P. 381–386. doi: 10.22038/abjs.2016.7537
15. Tile M. Fractures of the pelvis and acetabulum: principles and methods of management. Stuttgart: Thieme, 2016. doi: 10.1055/b-0035-121619
16. Лазарев А.Ф., Борозда И.В. Массивное забрюшинное кровотечение при переломах таза // Вестник травматоло-

гии и ортопедии им. Н.Н. Приорова. 2016. № 2. С. 68–76. doi: 10.32414/0869-8678-2016-2-68-76
17. Pereira G.J.C., Damasceno E.R., Dinhane D.I., et al. Epidemiology of pelvic ring fractures and injuries // Rev Bras Ortop. 2017. Vol. 52, N 3. P. 260–269. doi: 10.1016/j.rboe.2017.05.012
18. Бондаренко А.В., Круглыхин И.В., Плотников И.А., и др. Внешняя фиксация как основной и окончательный метод лечения повреждений тазового кольца при политравме // Политравма. 2018. № 2. С. 41–50.
19. Wong J.M., Bewsher S., Yew J., et al. Fluoroscopically assisted computer navigation enables accurate percutaneous screw placement for pelvic and acetabular fracture fixation // Injury. 2016. Vol. 46, N 6. P. 1064–1068. doi: 10.1016/j.injury.2015.01.038
20. Albracht B.G., Jenkins M.D. Sciatic nerve palsy after distal femoral traction for vertically unstable pelvic fracture in a neurologically intact patient // J Am Acad Orthop Surg Glob Res Rev. 2019. Vol. 3, N 9. P. e045. doi: 10.5435/jaaosglobal-d-19-00045
21. Avilucea F.R., Archdeacon M.T., Collinge C.A., et al. Fixation strategy using sequential intraoperative examination under anesthesia for unstable lateral compression pelvic ring injuries reliably predicts union with minimal displacement // J Bone Joint Surg Am. 2018. Vol. 100, N 17. P. 1503–1508. doi: 10.2106/jbjs.17.01650
22. Burlew C.C., Moore E.E., Stahel P.F., et al. Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures // J Trauma Acute Care Surg. 2017. Vol. 82, N 2. P. 233–242. doi: 10.1097/ta.0000000000001324
23. Kleweno C., Bellabarba C. Lumbopelvic fixation for pelvic fractures // Oper Tech Orthop. 2016. Vol. 25, N 4. P. 270–281. doi: 10.1053/j.oto.2015.09.001
24. Shetty A.P., Bosco A., Perumal R., et al. Midterm radiologic and functional outcomes of minimally-invasive fixation of unstable pelvic fractures using anterior internal fixator (INFIX) and percutaneous iliosacral screws // J Clin Orthop Trauma. 2017. Vol. 8, N 3. P. 241–248. doi: 10.1016/j.jcot.2017.05.009
25. Cavalcanti Kußmaul A., Greiner A., Kammerlander C., et al. Biomechanical comparison of minimally invasive treatment options for Type C unstable fractures of the pelvic ring // Orthop Traumatol Surg Res. 2020. Vol. 106, N 1. P. 127–133. doi: 10.1016/j.otsr.2019.09.032
26. Breuil V., Roux C.H., Carle G.F. Pelvic fractures: epidemiology, consequences, and medical management // Curr Opin Rheumatol. 2016 Vol. 28, N 4, P.442–447. doi: 10.1097/BOR.0000000000000293
27. Li S., Meng X., Li W., et al. Effects of minimally invasive plate-screw internal fixation in the treatment of posterior pelvic ring fracture // Exp Ther Med. 2018. Vol. 16, N 5. P. 4150–4154. doi: 10.3892/etm.2018.6670
28. Bo Q.I.A.O., Weidong N.I., Zhiqiang G.A.O., et al. Lumbopelvic fixation of vertically unstable Tile type C pelvic fractures combined with complex sacral fractures // Chinese Journal of Trauma. 2017. N 12. P. 510–515.
29. Tempelaerea C., Vincentab C., Courta C. Percutaneous posterior fixation for unstable pelvic ring fractures // Orthop Traumatol Surg Res. 2017. Vol. 103, N 8. P. 1169–1171. doi: 10.1016/j.otsr.2017.07.024
30. Wong J.M.L., Bucknill A. Fractures of the pelvic ring // Injury. 2017. Vol. 48, N 4. P. 795–802. doi: 10.1016/j.injury.2013.11.021
31. Vigdorchik J.M., Jin X., Sethi A., et al. A biomechanical study of standard posterior pelvic ring fixation versus a posterior pedicle screw construct // Injury. 2016. Vol. 46, N 8. P. 1491–1496. doi: 10.1016/j.injury.2015.04.038
32. Koshimune K., Ito Y., Sugimoto Y., et al. Minimally invasive spinopelvic fixation for unstable bilateral sacral fractures // Clin Spine Surg. 2016. Vol. 29, N 3. P. 124–127. doi: 10.1097/bsd.0000000000000090
33. Giannoudis P.V., Pape H.C. Principles of damage control for pelvic ring injuries. In: Pape H.C., Peitzman A., Rotondo M., Giannoudis P., editors. Damage control management in the polytrauma patient. Cham: Springer, 2017. doi: 10.1007/978-3-319-52429-0_21
34. El-Desouky I.I., Mohamed M.M., Kandil A.E. Percutaneous iliosacral screw fixation in vertically unstable pelvic injuries, a refined conventional method // Acta Orthop Belg. 2016. Vol. 82, N 1. P. 52–59.
35. Лазарев А.Ф., Гудушаури Я.Г., Костив Е.П., и др. Клинические аспекты осложнений повреждений таза // Тихоокеанский медицинский журнал. 2017. № 1. С. 17–23. doi: 10.17238/PmJ1609-1175.2017.1.17-23

AUTHOR INFO

***Ruslan I. Zakirov,** postgraduate student,
traumatologist-orthopedist;
address: 49 Butlerova str., Kazan, 420012, Russia;
ORCID: https://orcid.org/0000-0002-5747-2573;
eLibrary SPIN 1414-9290;
e-mail: 1980zri@gmail.com

Ildar F. Ahtyamov, MD, professor, traumatologist-orthopedist;
ORCID: https://orcid.org/0000-0002-4910-8835;
e-mail: yalta60@mail.ru

ОБ АВТОРАХ

***Руслан Ильгизарович Закиров,** аспирант,
врач травматолог-ортопед;
адрес: Россия, 420012, Казань, ул. Бутлерова, д. 49;
ORCID: https://orcid.org/0000-0002-5747-2573;
eLibrary SPIN 1414-9290;
e-mail: 1980zri@gmail.com

Ильдар Фуатович Ахтямов, профессор, врач травматолог-ортопед; ORCID: https://orcid.org/0000-0002-4910-8835;
e-mail: yalta60@mail.ru

* Автор, ответственный за переписку / Corresponding author