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Surgical correction of the pelvis after malunited pelvic fracture

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Mal-union and non-union of the pelvic bones is a complication of the treatment of its injuries, which mostly occur with 61C fractures according to the AO/OTA classification. Objective. To analyze the results of surgical treatment of a female patient with a pelvic fracture that has healed with residual deformity (shortening, posterior displacement, internal rotation to the right and external rotation to the left) and to demonstrate the importance of careful planning with the involvement of 3D modeling in cases of reconstructive surgery after a pelvic fracture. Methods. The study has the form of a clinical case description. The results of the treatment were evaluated according to the IPS score. During the examination, multiple fractures of the pelvic bones and dislocations corresponding to type 61 C3 according to the AO/OTA classification were revealed. After a CT scan of the pelvis with 3D reconstruction, a 3-stage surgical intervention was planned and performed. The first stage: 2 K-wires were percutaneously inserted through the left sacroiliac joint at the S_I-S_{II} level to the area of the planned osteotomy of the sacrum; through a paramedian access, a longitudinal osteotomy of the sacrum was performed on the right through the area of the previous fracture with mobilization of the lateral fragment. The second: transection of the symphysis, osteotomy of the pubic bone at the site of improper fusion, repositioning, fixation with a simulated reconstructive plate and standard screws; reposition of the right pelvic semiring. The third: adequate closure of the posterior wound. For control, a CT scan of the pelvis and a comparative evaluation of the main projections and images on 3D reconstruction and frontal sections were performed. 4 months after the operation, the patient carries out a full axial load with no pain syndrome and continues rehabilitation aimed at returning the correct stereotype of gait. The functional result was estimated at 90 points on the IPS scale. Conclusions. Late surgical correction is difficult to perform and is associated with a large number of possible severe complications. Careful preoperative planning is the key for the pelvic fractures treatment and their consequences. The best method of prevention of late reconstructions is the correct initial definitive treatment. This requires the presence of specialized medical centers with experts specializing in the treatment of pelvic fractures, the necessary equipment and a defined protocol.

Неправильне зрощення та незрощення кісток таза є ускладненням лікування його ушкоджень, які переважно виникають за переломів 61С за класифікацією AO/OTA. Мета. Проаналізувати результати хірургічного лікування перелому таза, що зрісся зі залишковою деформацією, та довести важливість ретельного планування реконструктивних операцій зі застосуванням 3D-моделювання. Методи. Описано клінічний випадок лікування хворої, яку прооперовано з використанням трьохетапної корекції на пізніх термінах. Ефект лікування оцінено за шкалою IPS. Результати. Під час обстеження виявлено множинні переломи кісток таза та вивихи (тип 61 С3 за AO/OTA). Виконано хірургічне втручання в три етапи. Перший: перкутанно проведено 2 спиці через ліве крижово-клубове зчленування на рівні S_I–S_{II} до зони запланованої остеотомії крижової кістки; через парамедіанний доступ справа виконано повздовжню остеотомію крижової кістки через зону попереднього перелому, мобілізація латерального фрагмента. Другий: перетин симфізу, остеотомія лобкової кістки по місцю неправильного зрощення, репозиція, фіксація модельованою реконструктивною пластиною та стандартними гвинтами; репозиція правого тазового напівкільця. Третій: адекватне закриття задньої рани. Для контролю здійснено КТ таза та порівняльне оцінювання основних проєкцій і зображень на 3D-реконструкції та фронтальних зрізах. Через 4 міс. після операції пацієнтка здійснює повне осьове навантаження, продовжує реабілітацію. Больовий синдром відсутній. Функціональний результат — 90 балів за шкалою IPS. Висновки. Пізня хірургічна корекція ускладнень після переломів таза складна під час виконання та пов'язана з великою кількістю важких ускладнень. Ключем до лікування переломів таза та їхніх наслідків є ретельне передопераційне планування. Найкращою профілактикою пізніх реконструкцій є правильне первинне лікування. Це потребує наявності спеціалізованих медичних центрів з експертами-фахівцями, необхідним обладнанням і визначеним протоколом. Ключові слова. Перелом таза, неправильне зрощення, незрощення, пізня реконструкція, 3-D моделювання.

Key word. Pelvic fracture, malunion, nonunion, late reconstruction, 3-D modeling

Introduction

Malunion and non-union of pelvic bones most often occur after conservative treatment (bed rest with a specific position, use of skeletal traction, bandages), use of various types of external fixation devices (EFD), postponement of final surgical treatment due to complex concomitant injuries [1–3]. However, some cases are sometimes observed even after surgery. These complications usually occur in the case of 61C fractures according to the AO/OTA classification and injuries of the «vertical shear» type according to the Young-Burgess classification secondary to rotational and vertical instability of the pelvis.

There is not much essential information about malunion and non-union of pelvic fractures in the literature. This is primarily due to the special approach in developed countries to the treatment of acute injuries with the fastest possible identification and referral of patients to specialized medical centers with experts in the treatment of pelvic fractures, necessary equipment and a defined protocol. No information was found on the existence of such centers in Ukraine; accordingly, there is no data in the country on the frequency and results of treatment of malunion and non-union of pelvic fractures.

N. K. Kanakaris et al. [4] noted that these complications cause disability and have serious socio-economic consequences. The authors analyzed 437 cases of malunion/non-union of pelvic fractures from 25 clinical studies and determined the factors leading to complications, presentation, and the effectiveness of known protocols. Treatment of these severe sequelae was largely effective, with an average overall union rate of 86.1 %, pain relief of 93 %, patient satisfaction of 79 %, and return to pre-injury activity of 50 %. However, regardless of the treatment method, about 5 % of patients with pelvic fractures had an unsatisfactory location of the fragments [5]. In addition, the patient should be informed about the frequency of perioperative complications, namely: neurological injury (5.3 %), symptomatic venous thrombosis (5.0 %), pulmonary embolism (1.9 %), and deep wound infection (1, 6 %).

The key to a successful outcome is careful preoperative planning and methodical surgical intervention, creating a network of specialized centers for the treatment of pelvic injuries.

Purpose. To analyze the results of surgical treatment of a pelvic fracture with residual deformity (shortening, posterior displacement, right internal rotation, and left external rotation) and to demonstrate the importance of careful planning of reconstructive operations with the involvement of 3D modeling.

Material and methods

The study has the form of a clinical case description. The work is based on the treatment outcomes in a patient who was injured as a result of a traffic accident on 02.11.2021 and was operated on using a three-stage correction at a later date (30.12.2021) in Rivne City Hospital. Treatment outcomes were evaluated according to the IPS scale [15].

Results and their discussion

An 18-year-old girl was injured in a traffic accident 2 months before hospitalization in the medical institution where pelvic correction was performed. The patient's main presenting symptoms were pain in the front and back of the pelvis, which worsened when changing the position of the body in bed, pain on the back surface of the foot, which was combined with limitation of its extension and increased during passive extension attempts in the supracalcaneal joint and lack of sensitivity. The patient noted that these symptoms had appeared in the last few weeks and had a tendency to increase. She was especially concerned about the shortening of the right limb by 4 cm with adductor and flexor contractures in the right hip joint and a pronounced visual change in the shape of the pelvis.

Examination showed multiple fractures of the pelvic bones and 61 C3 dislocations according to the AO/OTA classification: a rupture of the left sacroiliac joint, a fracture of the pubic and ischial bones on the left, a rupture of the symphysis, a Denis II transformative fracture of the sacrum on the right, which were combined with an incomplete transverse fracture of the right hip socket (Fig. 1).

It is obvious that the mechanism of such an injury is a combination of multi-vector forces with high energy and different points of application. Reduction of the pelvic cavity, medial width displacement and internal rotation of the right pelvic semiring with an impacted fracture of the sacrum on the right, pubic and ischial bone on the left could have been caused by lateral compression through the wings of the iliac bones. It likely absorbed the energy and reduced the force of lateral compression applied to the ipsilateral greater acetabulum, resulting in an incomplete, nondisplaced transverse fracture of the right acetabulum. Rupture of the left iliac-sacral joint and symphysis with displacement of the left semiring of the pelvis backward with detachment of the right transverse process of the lumbar V vertebra together with the turned back

upper branch of the right pubic bone indicated the effect of anteroposterior compression. Signs of vertical cutting were visualized as an upward displacement of the right pelvic semiring, which in digital measurement on the frontal sections at the level of both hip joints was 3 cm. All displacements were visualized on the 3D reconstruction of the pelvis (Fig. 2).

The patient was scheduled for two-stage surgical intervention. At the first stage, a stress test was performed on the stability of the left sacroiliac joint in the prone position under the electronic optical transducer (EOT) and confirmed due to the absence of displacement to lateral traction of the hip. Guide pins were inserted percutaneously from the left side through the sacroiliac joint at the S_I–S_{II} level for further fixation with cannulated sacral screws to the area of the planned sacral osteotomy using a standard method under the control of the EOT (Fig. 3). Next, paramedian access was performed on the right to the area of the impacted fracture of the sacrum. Because of the fused fracture, an osteotomy was applied along the entire contact vertical under the control of EOT with mobilization of the lateral fragment and lateral crossing of the iliolumbar ligaments holding the ilium with L_{IV}–L_V transverse processes.

The second stage was carried out in the supine position. Stoppa approach was used to visualize the symphysis and the site of malunion of the left pubic bone. Its distal segment was mobilized by crossing the symphysis and osteotomy of the pubic bone at the site of improper fusion. The fragment was repositioned in an anatomical position and fixed with a premodeled reconstructive plate inserted into the supraacetabular zone and standard screws (Fig. 4).

The next step was to reposition the right pelvic hemiring forward using an arsenal of repositioning tools (Fig. 5).

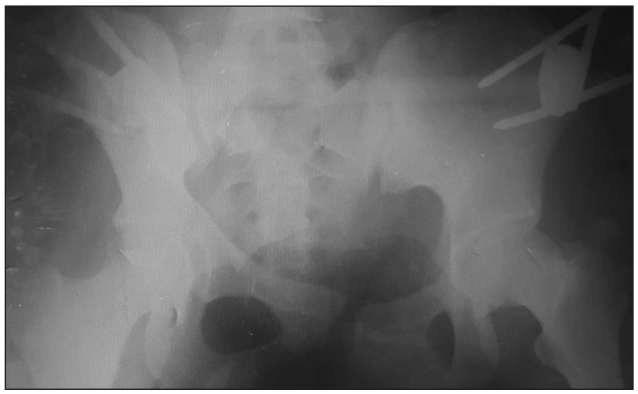

Fig. 1. Direct radiography image of the patient's pelvis at the time of admission

With the help of a large femoral distractor, the right half of the pelvis was brought into an anatomical position (Fig. 6).

To maintain the restored position, the guide pins, placed in the sacrum at the SI–SII level, were passed through the osteotomy zone, crossing the right sacroiliac joint (Fig. 7) to exit percutaneously to the right for further insertion of sacral cannulated screws from right to left to fix the posterior departments of the pelvis.

The correct position of all parts of the pelvis was controlled and its front part was finally fixed by inserting screws through the plate into the right pubic bone (Fig. 8).

The second stage was completed by inserting sacral cannulated screws from right to left to fix the posterior parts of the pelvis (Fig. 9).

At the third stage, the patient was placed in the prone position for adequate wound closure. In the postoperative period, a direct X-ray of the pelvis was performed (Fig. 10), which showed satisfactory repositioning and stable fixation of the reconstruction.

In order to control the quality of the intervention, a CT scan of the pelvis was performed after the operation and a comparative evaluation of the main projections and images on 3D reconstruction before and after surgical treatment (Fig. 11) and on frontal sections for the analysis of vertical displacement recovery (Fig. 12) was carried out.

After surgery, an increase in neuropathy due to manipulation and stretching in the area of the L_V root was noted, which positively regressed during the postoperative period.

Four months after surgery, the patient carried out full axial load with no pain syndrome and continued rehabilitation aimed at returning the correct stereotype of gait. The functional result was estimated at 90 points on the IPS scale.

Discussion

The correct approach to providing medical care to patients with pelvic fractures not only saves lives, but also prevents the development of further complications. Malunion and non-union are often combined. Because the pelvis is ring-shaped, unstable fractures imply at least a combination of one posterior and one anterior injury.

Inadequate position of fragments with bone contact can be the cause of malunion, while the presence of diastasis between fragments is a resource for non-union.

Displacement of half of the pelvis by more than 1 cm and rotation by more than 15°–20° may be signs of malunion, although the latter is not always symptomatic [6]. Non-union in the absence of final surgical treatment and typical clinical symptoms, taking into

Fig. 2. 3D reconstruction of the pelvis: projection of the inlet (a) and outlet (b), posterior view (c)

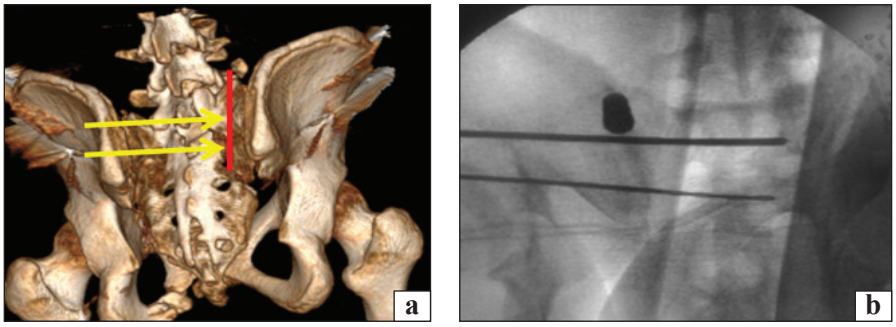

Fig. 3. 3D planning of the osteotomy zone (red line) and the insertion of needles (yellow arrows) at the S_I–S_{II} level (a) from the opposite side to the osteotomy zone, EOT image of the inserted spokes (b)

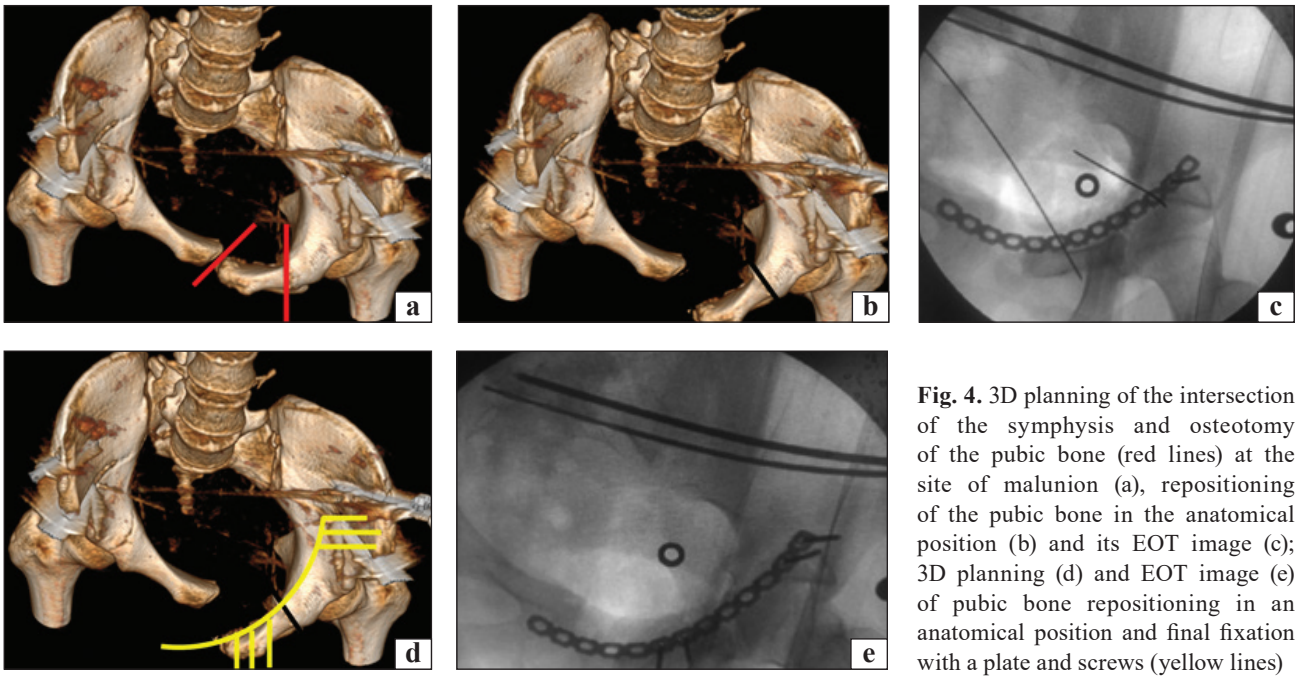

Fig. 4. 3D planning of the intersection of the symphysis and osteotomy of the pubic bone (red lines) at the site of malunion (a), repositioning of the pubic bone in the anatomical position (b) and its EOT image (c); 3D planning (d) and EOT image (e) of pubic bone repositioning in an anatomical position and final fixation with a plate and screws (yellow lines)

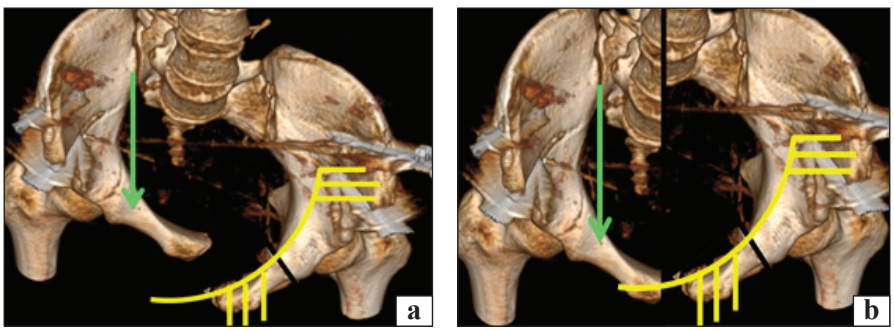

Fig. 5. 3D-planning: a) direction of the repositioning maneuver (green arrow) of the right pelvic semiring forward; b) repositions after it

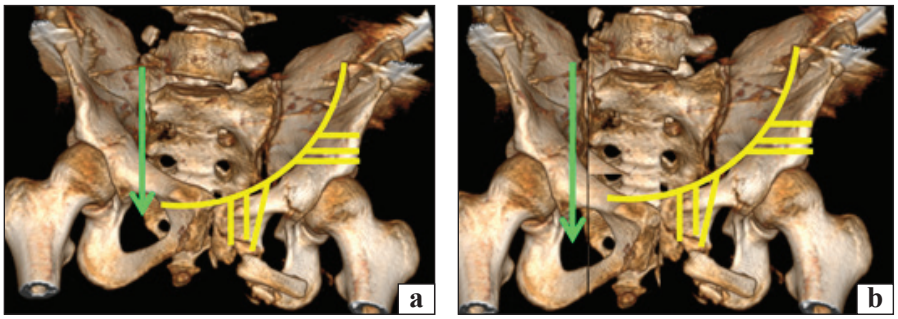

Fig. 6. 3D-planning: a) direction of the repositioning maneuver (green arrow) of the right pelvic semiring downwards; b) repositions after it

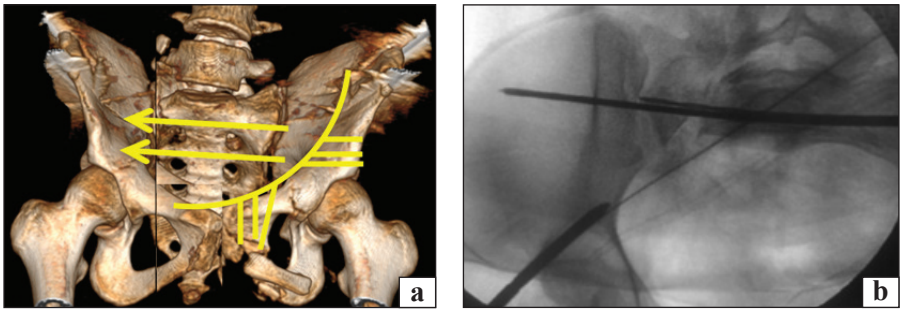

Fig. 7. 3D planning (a) and EOT image (b) of spoke insertion (yellow arrows) at the SI–SII level through the osteotomy zone

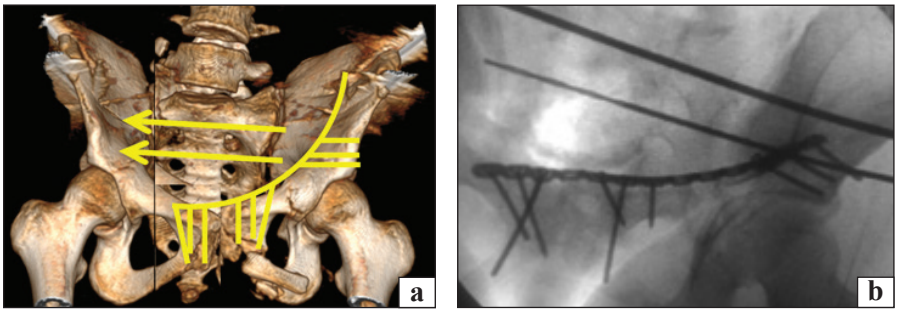

Fig. 8. 3D planning (a) and EOT image (b) of fixation of the anterior segment by driving screws (yellow lines) through the plate into the right pubic bone

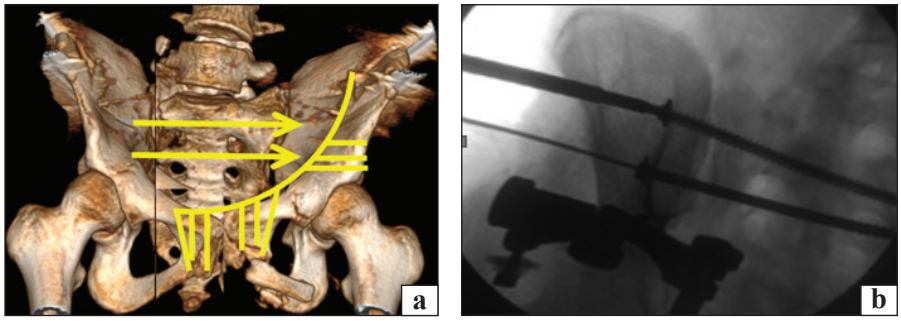

Fig. 9. 3D planning (a) and EOT image (b) insertion of sacral cannulated screws (yellow arrows) from right to left for fixation of the posterior parts of the pelvis

Fig. 10. Radiogram. Postoperative direct projection

account radiological examination, does not cause difficulties in diagnosis.

Uncorrected pelvic deformities after vertically unstable injuries can lead to leg length discrepancies, gait abnormalities, sitting problems, and low back pain [7, 8].

However, it is important to determine whether the symptoms are related to pelvic non-union/deformity rather than other clinical conditions [4].

Pain was clearly the main symptom reported in all the studies reviewed with a frequency of 97 % [4]. If the source of pain is non-union, it is more often localized in the back, although frontal pain or its combination in both areas is also possible, which is associated with limitation of motor activity of the hip joints depending on the intensity of the pain syndrome [9] and discomfort while sitting, dyspareunia and sexual problems of mechanical origin [10]. Finally, there may be bed rest for patients with persistent debilitating pain [11]. Pain has been attributed to the site of non-union, which is caused by pelvic instability, deformity, and altered biomechanics in patients with malunion, or a combination of all of these. Pain associated with neurologic injury at the initial accident is differentiated as a symptom and is

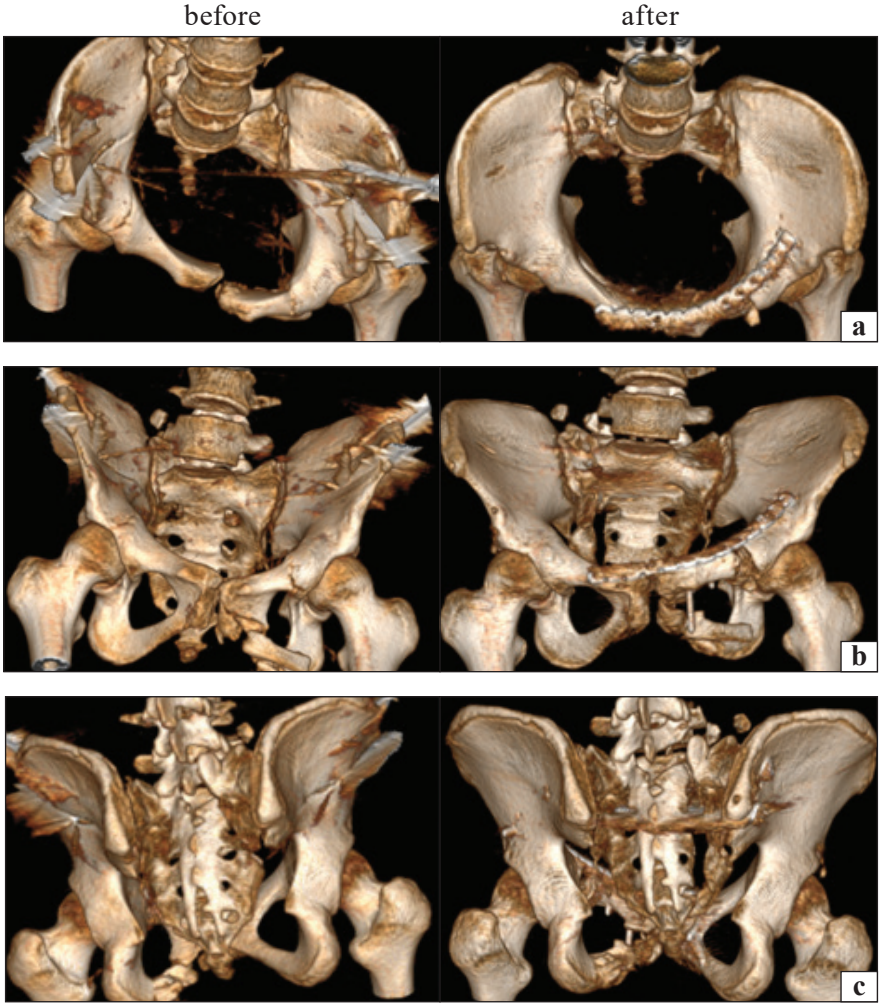

Fig. 11. 3D reconstruction of the comparison before and after the operation: a) projection of the pelvic inlet; b) projections of the pelvic outlet; c) posterior view

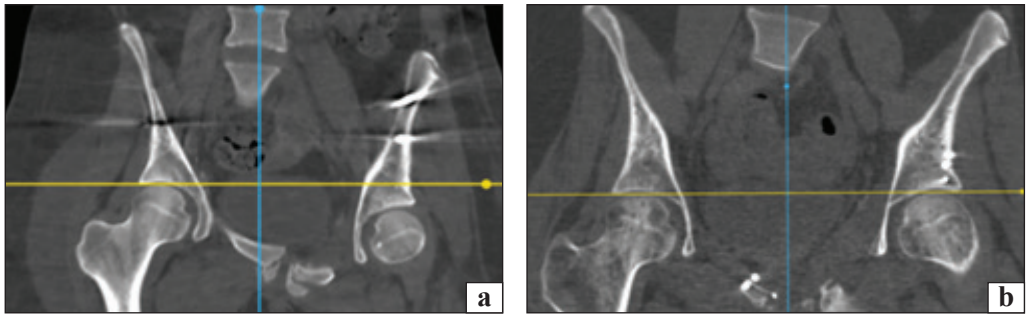

Fig. 12. Frontal sections at the level of the middle of the hip joints on CT before (a) and after (b) surgery for analysis of recovery of vertical displacement

not expected to resolve after revision surgery for pelvic non-union or malunion [12].

Walking disorders (antalgic walking, Trendelenburg) and the use of aids were found in 67.4 % of patients, clinically important leg length discrepancy in 24.8 %. However, the latter measure has been defined differently in studies (e. g., a length difference of more than 1 cm [12] and more than 2 cm [13]), which compromises the compatibility of reported percentages [5].

To detect pelvic instability, an additional X-ray examination is usually necessary, comparing images with weight on both and one leg or dynamic fluoroscopy [1]. Deformation of the pelvis, described as an aesthetic problem, which is especially noted by young women: uneven location of the buttock tubercles, especially with discomfort while sitting, change in the symmetry of the pelvis with uneven location of the buttock and inguinal folds, the shape of the buttocks.

Not all patients with malunion or non-union require surgery. A decision on surgical intervention should be made only after a thorough assessment of the patient's condition and injury. In addition, patients should be informed that reconstruction is associated with complications in 20 % of cases and surgical results are imperfect. Indications for surgical intervention are pain, instability of the pelvis and clinical problems associated with its deformation — difficulty sitting, shortening of limbs, dyspareunia, and dysuria [1–3, 14].

The multi-stage reconstruction, the example of which we have given, is a typical method of treating malunion or non-union of the pelvis. Although there is only a rotational deformity with displacement of the hemipelvis medially or laterally, without vertical shearing, it can be successfully corrected during one stage [2, 12].

Multistage reconstruction involves an individual choice based on the type of deformity and localization of non-union or malunion of one of two approaches — anterior-posterior-anterior or posterior-anterior-posterior. An anterior Stoppa approach is typical, although an ileoinguinal approach can be used if necessary. Anterior access makes it possible to open the zone of non-union or improper union of the pubic bones with mobilization by removing scar intermediate tissues or osteotomy at the top of the deformity with mandatory consideration and analysis of the need for additional manipulations on the ischium depending on the location and degree of fusion. Through this access, it is possible to reposition rotational displacements (external or internal rotation of the hemipelvis), anterior-posterior displacements, provided the posterior part is mobilized, and lateral lateral displacement. Maximum attention during the anterior approach should be focused on preserving the soft tissues in the non-union mobilization zone and during the osteotomy. It is necessary to prevent damage to the bladder (especially in lateral compression with a close location of the fracture to the symphysis) in case of presenting symptoms that may indicate it. The front parts of the pelvis are mostly fixed with a 3.5 reconstructive plate and screws, and cannulated screws are also used. Posterior access is performed from the side of the lesion and makes it possible to carry out mobilization in the zone of non-union or osteotomy of improper fusion of the sacrum or sacroiliac joint. Osteotomy increases the risk and volume of intraoperative bleeding and neurological complications. Through the posterior access, repositioning maneuvers are possible to eliminate the lateral displacement in width, anterior-posterior, as well as rotational displacement around the frontal axis. The dissection of the iliolumbar ligaments, which hold the ilium with the L_{IV}–L_V transverse processes, is of great importance for repositioning. In certain cases, it is necessary to consider the dissection of *lig. sacrotuberisum* and *lig. sacrospinosum*. The posterior sections are fixed with sacral or sacroiliac cannulated screws, a plate, or their combination.

Surgical treatment of pelvic malunion and non-union is technically challenging and has potential serious complications. The average duration of the operation is more than 6 hours, with significant blood loss predicted. Despite the use of SSAP monitoring and standard thromboprophylaxis, neurologic injury and venous thromboembolism are the most frequently reported postoperative complications. Additional risks (vascular and visceral injuries, infections, implant fracture, persistent nonunion, incomplete union, and residual disruption of the connection) dictate the need for careful preoperative planning and treatment of patients with pelvic trauma in specialized centers by expert surgeons. A clear description of realistic goals and risks of serious complications and patient compliance with the postoperative rehabilitation scheme is necessary [4].

Conclusions

Late surgical correction of complications after pelvic fractures is difficult to perform and is associated with a large number of possible severe complications. Careful preoperative planning is a key to the management of pelvic fractures and their sequelae. The best method of prevention of late reconstructions is the correct initial definitive treatment. This requires the presence of specialized medical centers with expert specialists in the treatment of pelvic fractures, the necessary equipment and a defined protocol.

Conflict of interest. The author declare no conflict of interest.

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SURGICAL CORRECTION OF THE PELVIS AFTER MALUNITED PELVIC FRACTURE

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