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Posteromedial Approach in Fracture Fixation of Malleoli and Posterior Edge of Tibia

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Background. Surgical treatment of malleoli injuries is performed according to the principles of articular fractures management. It is particularly true for ankle injuries involving fractures of posterior edge of the tibia. The posteromedial approach enables to improve the results of surgical treatment of patients due to the direct reduction of tibia fragments.
Aim of the study — to evaluate the efficacy and advisability of the modified posteromedial approach in patients with unstable fractures of malleoli and posterior edge of the tibia.
Methods. Twenty two patients with unstable fractures of malleoli and posterior edge of the tibia underwent surgical treatment via the posteromedial approach. The X-ray control was performed the next day after the surgery as well as 6, 12, 24 and 48 weeks from the osteosynthesis. The functional results were evaluated in 12, 24 and 48 weeks after the surgery with the use of AOFAS and Neer scales.
Results. The average duration of postoperative period (9.3±3.8 days) was mainly determined by the state of the soft tissues. 91% of patients had anatomical reduction of posterior edge fragment of the tibia, 17 (77%) from 22 patients demonstrated fracture consolidation in X-rays 12 weeks after the surgery and all 22 patients (100%) 24 weeks after surgery. There were no cases of postoperative complications in patients 24 weeks after the surgery. While managing patients the range of motion in the ankle joint increased from 41.1±6.9° 12 weeks after the surgery to 57.3±4.6° 48 weeks after the surgery, that was statistically significant ($p<0.01$). The functional results improved as well according to both AOFAS and Neer scales and this improvement was also statistically significant ($p<0.01$).
Conclusion. The is rather effective in Patients with unstable fractures of malleoli and posterior edge of the tibia had a statistically significant improvement in function after posteromedial approach.

Keywords: fracture fixation, articular fracture, malleoli fracture, posteromedial approach.

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Использование заднемедиального хирургического доступа для остеосинтеза при переломах лодыжек и заднего края большеберцовой кости

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Актуальность. Хирургическое лечение повреждений лодыжечного сегмента осуществляется в соответствии с принципами лечения внутрисуставных переломов. Применение заднемедиального доступа за счет прямой репозиции фрагментов большеберцовой кости позволяет улучшить результаты хирургического лечения пострадавших.

Цель исследования — оценить эффективность и целесообразность применения модифицированного заднемедиального доступа у пациентов с нестабильными переломами лодыжек и заднего края большеберцовой кости.

Материал и методы. Двадцать два пациента с нестабильными переломами лодыжек и заднего края большеберцовой кости прооперированы с применением заднемедиального хирургического доступа. Рентгенологический контроль осуществляли на следующий день после операции и через 6, 12, 24 и 48 нед. после остеосинтеза. Функциональные результаты лечения оценивали через 12, 24 и 48 нед. после операции по шкалам AOFAS и Neer.

Результаты. Медиана (Me) длительности предоперационного периода составила 9 дней (min = 6, max = 24 дней, Q1-Q3 = 7–10 дней) и во многом определялась состоянием мягких тканей. У 91% пациентов была достигнута анатомичная репозиция фрагмента заднего края большеберцовой кости. Рентгенологические признаки сращения отмечены у 17 (77%) пациентов через 12 нед. после операции и у 22 (100%) пациентов через 24 нед. Случаев развития осложнений не выявлено. За время наблюдения объем движений в голеностопном суставе статистически значимо (p<0,01) увеличивался: Me через 12 нед. после операции составила 40° (min = 30°, max = 55°, Q1–Q3 = 35–45°), через 48 нед. — 55° (min = 50°, max = 65°, Q1–Q3 = 55–60°). Отмечалось статистически значимое (p<0,01) улучшение показателей с течением времени при оценке функциональных исходов по шкалам AOFAS и Neer.

Заключение. Заднемедиальный доступ эффективен при нестабильных переломах лодыжек и заднего края большеберцовой кости и позволяет добиться высоких функциональных результатов лечения.

Ключевые слова: остеосинтез, внутрисуставной перелом, перелом лодыжек, заднемедиальный доступ.

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BACKGROUND

Malleolar fractures are rather severe injuries with high complication rate [1]. Failure in achieving good fracture fragments reduction leads to pronounced functional impairment of the ankle joint [2]. This is more typical for unstable fractures of the ankle joint, associated with the fracture of the posterior edge of tibia. That is why modern trauma surgery pays great attention to such type of injuries. The paradigm of treatment of patients with these complex injuries have changed significantly over the recent years. Earlier on these fractures supposed close reduction of the posterior edge of tibia fragment and its fixation with front to back screws was preferable. Nowadays more and more specialists emphasize that only precise restoration of the anatomy of all injured bone structures can ensure optimal functional recovery of the ankle joint and reduce the risk of clinically significant posttraumatic arthritis [3, 4]. In accordance with this concept, an open and precise reduction of the posterior edge of tibia and its back to front fixation are required, that can be performed via posterior surgical approaches only [5].

Posterolateral approach is widely applied in the surgical treatment of patients with unstable malleolar fractures associated with posterior tibia edge fracture [6, 7]. Despite the fact that this approach allows open and precise (anatomical) reduction of the posterior edge of tibia with simultaneous osteosynthesis of the lateral malleolus and fixation of distal tibiofibular syndesmosis, it may have disadvantages and cannot be used in all clinical situations. In addition, most surgeons perform it in prone position of patient, which complicates the reduction and fixation of the medial malleolus fragment significantly, as well as the reduction of the anterior part of the distal tibiofibular syndesmosis and fixation of the tibia anterolateral fragment (Tillaux-Chaput fragment) and the fibula anterolateral fragment (LeFort fragment) [6]. Therefore, the injuries discussed suppose intraoperative rotation of the patient in case of performing posterolateral approach, which increases the surgery time and the risk of infectious complications.

In addition, the use of posterolateral approach is also inconvenient with type 3 fracture of the posterior edge of tibia according to J. Bartoníček et al. [8], which suggests the presence of posterior fragment of the medial malleolus. The reason is that a direct access to the specified bone fragment via this approach is impossible. In such cases, a number of authors recommend to use alternative posteromedial approach justified in many clinical situations, since it allows to restore the anatomy of the injured ankle and achieve stable fixation of the posterior edge of tibia and medial malleolus fractures [9, 10].

At the same time, the surgical technique of posteromedial approach, its advantages, disadvantages and indications for clinical use for osteosynthesis in unstable malleolar fractures and posterior edge of tibia have not been definitively determined, and we have not discovered scientific publications in Russian on this relevant problem of modern traumatology. These reasons laid significant groundwork for the preliminary clinical trial, and its results are presented and discussed in this article.

The *aim of the study was* to evaluate the features of the modified posteromedial surgical approach technique and its effectiveness for osteosynthesis in patients with unstable malleolar fractures and the posterior edge of tibia, as well as to clarify the indications for its clinical use.

METHODS

Research design

A prospective multicenter cohort study was conducted on the basis of the traumatology departments of two hospitals in the Leningrad region: Vsevolozhsk Region Hospital and Tosnenskaya Region Hospital, as well as the I.I. Dzhanelidze St. Petersburg Institute of Emergency Medicine in the period from 2020 to 2021.

Patients

The study group included 22 patients (5 men and 17 women) with unstable malleolar fractures associated with posterior edge of tibia fracture, who underwent surgery performed via posteromedial surgical approach. An important inclusion criterion was the ability to evaluate the dynamics of the functional results of treatment 12, 24 and 48 weeks after surgery. The age of patients ranged from 31 to 80 years: median (Me) — 50.5 years, interquartile range (IQR) — from 44 to 61 years.

As for the mechanism, most patients got injured by twisting the ankle when falling from their own height, i.e., the injury had an indirect low-energy character. High-energy injury was di-

agnosed in two patients who fell from a bicycle, and two – from small height.

Preoperative examination

The type of fracture and injury of the ankle joint structures was assessed based on the analysis of two views of X-rays with using the classification of the Association of Osteosynthesis (AO) [11]. 12 (55%) patients had the comminuted trans-syndesmotic fracture with involvement of the posterior edge of tibia type 44B3, 3 (14%) patients had simple supra-syndesmotic fracture type 44C1.3, 5 (23%) patients - comminuted fracture type 44C2.3. 2 more patients (9%) had fibula fracture localized in its upper third type 44C3.3. The majority of patients (64%) suffered pronounced ankle valgus deformation, lateral and posterior subluxation of the foot.

During the treatment 19 (86%) patients got primary reduction of fragments and cast immobilization upon admission under local anesthesia. However, three patients (14%) were put on skeletal traction through the calcaneal bone due to significant soft tissue edema and irreducible foot subluxation. For high-quality preoperative planning and determination of surgical tactics (selection of approaches), all patients underwent preoperative CT scanning of the ankle joint area with an assessment of the fracture pattern and the existing injury components based on 3D reconstruction, analysis of sagittal, frontal and axial scans.

The degree of distal tibial syndesmosis disruption was determined by assessing the contours of fibula and tibia in the distal fibular notch area by axial CT scans. Separately the size of the fragment of the posterior edge of tibia was estimated using common method involving measuring the proportion of the articular surface of fragment from the entire tibial articular surface on a lateral X-ray [7]. The configuration of the posterior edge of tibia was determined from CT data, mainly axial sections, using the methodology and classification of J. Bartoniček et al. [8]. Analyzing axial CT scans, it was possible to determine the localization and dimensions of the identified fragments of the tibial articular surface interposing the fracture line (Fig. 1).

Bone fragments were measured on lateral radiographs of the ankle joint in Radiant Dicom Viewer X-ray image viewer. In particular, the proportion of the articular surface of the posterior edge of tibia fragment was determined, and the results were presented in the form of decimal fractions, where the entire articular surface of the distal tibia was taken as 1.

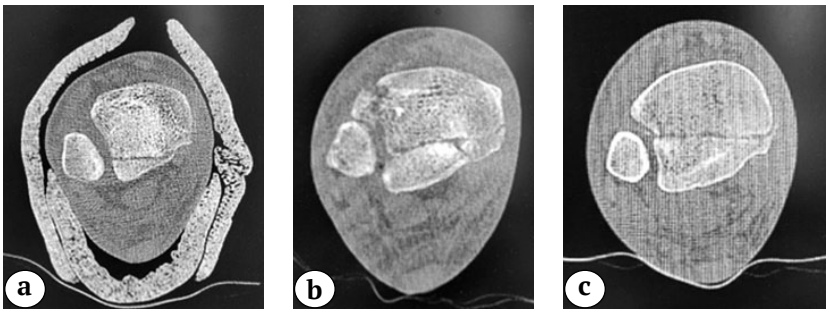

Fig. 1. Differences in the size of the tibia posterior edge fragment on axial CT sections of different patients: a — intra-incisural posterolateral fragment involving 1/3–1/4 fibular incisura (type 2 according to J. Bartoniček et al.);
b — intra-incisural posteromedial two-fragmental fracture, including the posterior part of the fibular incisura laterally and the posterior part of the medial ankle medially (type 3 according to J. Bartoniček et al.);
c — large posterolateral fragment of triangular shape, including the posterior half of the fibular incisura (type 4 according to J. Bartoniček et al.)

Surgical technique

The surgical technique generally corresponded to the method of extended posteromedial approach described by Y. Wang et al. [12]. The surgery was performed in supine position of the patient with the lower limb bent at the knee joint and rotated laterally. The skin incision started 10 cm from the level of the apex of the medial malleolus and was extended longitudinally in the middle of the distance between the medial edge of the Achilles tendon and the malleolus, starting vertically at the level of the proximal and middle thirds of the incision, followed by anterior bend in its lower third and extension just below apex of medial malleolus. The fascia propria of the lower third of the leg and the flexor tendon retinaculum were dissected longitudinally, obtaining two possible "surgical windows": between the tendons of the posterior tibial muscle and the flexor digitorum longus, as well as between the tendons of the latter and the flexor hallucis longus. Dissection of tissues was performed carefully due to the risk of injury to the posterior tibial vessels and the tibial nerve. At the same time, the indicated neurovascular bundle was diverted posteriorly without its mobilization in contrast to the generally accepted technique described in the literature [4].

Bone fragments were reduced by manipulating the fragment of the tibia posterior edge, focusing on the upper fracture line — directly in the wound — and the tibia articular surface, visualized using C-arm in lateral and AP views. K-wires were used to temporarily fix the fragment of the posterior edge of tibia. In 3 cases (14%) it was necessary to remove a small fragment of the articular surface interposing between the main fragment of the posterior edge and its bed to achieve anatomical reduction of the posterior edge of tibia fragment. In 1 case (4%) it was possible to perform reimpaction of the fragment of articular surface of the tibia posterior edge, since the impact zone was localized on the posteromedial side of the latter, which was the reason for choosing posteromedial approach in this patient.

In number of cases a "pointed" bone clamp was used for the reduction of posterior edge of tibia fragment, placing it under visual control. If there was a tendency to vertical displacement the method of sequential compression on an anti-glide plate under C-arm control was applied, i.e., due to the pressing of the plate to the tibia diaphyseal part above the fracture of the posterior edge, its correct positioning occurs (pressing to the bed) followed by interfragmentary compression [7, 13].

Fixation of the fragment of the posterior edge of tibia was performed using cancellous screws 4.0 mm with partial thread in 6 cases and plates in 16 cases. Short 1/3-tubular plates with 3-5 holes, T-shaped plates from a set for fixing small bone fragments were used, introducing 3.5 mm cortical screws and 4.0 mm cancellous screws with partial thread (Fig. 2). The reduction of the medial malleolus was performed via the anterior window of the posteromedial surgical approach with its fixation with two cancellous screws 4.0 mm with partial thread in 15 cases, one screw and a K-wire — in 3 cases of comminuted fractures, and 1/3-tubular plate with 3.5 mm screws — in 1 case with a vertical fracture line. In 2 patients without bone injury to the medial structures of the ankle joint, the suture of the deltoid ligament was not performed, since foot subluxation could

Fig. 2. Intraoperative image of the posteromedial approach at the stage of fixation of the posterior edge of the tibia with a 1/3-tubular plate:
1 — 1/3-tubular plate fixation the posterior fragment of the tibia;
2 — posterior tibial muscle, flexor digitorum longus, retracted by the Farabeuf hook;
3 — the flexor hallucis longus and the posterior neurovascular bundle, retracted by the Farabeuf hook

be reduced after osteosynthesis of the tibia posterior edge, lateral malleolus and splinting of distal tibiofibular syndesmosis.

Reduction and fixation of lateral malleolus were performed via standard lateral approach in supine position of the patient. In most cases, fibula osteosynthesis was performed using 1/3-tubular plates, 3.5 mm cortical screws and 4.0 mm cancellous screws with partial thread. In 2 cases of type 44 C3.3 fractures osteosynthesis of fibula was not performed, since the fracture zone was in its upper third. However, in both cases fixation of the distal tibiofibular syndesmosis was performed with a positional screw. The reconstruction of the ankle joint was concluded by examining the stability of distal tibiofibular syndesmosis by lateral stability stress tests [14]. In 10 cases (46%) of the revealed lateral instability, one 3.5 mm cortical positional screw was used to fix distal tibiofibular syndesmosis.

All stages of osteosynthesis were accompanied by intraoperative fluoroscopy in standard AP, AP with internal rotation at 15° and lateral views. The time of each surgery was recorded and their average duration in minutes was calculated. The surgery ended with active drainage and wound suturing. Only skin sutures were applied using the Allgower or Donati suture in case of excessive tension of the wound edges.

Active movements in the ankle joint were permitted the day after the surgery. The axial load was restricted until the appearance of radiological signs of bone union. As a rule, this period ranged between 10 and 12 weeks after the surgery.

Results assessment

The quality of the reduction of posterior edge of tibia fragments was determined by the presence or absence of residual displacement along the line of articular cartilage and/or diastasis in the fracture zone on the lateral radiograph. The result of the reduction with a complete restoration of the anatomy of the articular surface, the absence of diastasis between fragments and subluxation in the ankle joint was considered excellent. A satisfactory result suggested the presence of a step of the articular surface and/or diastasis in the fracture zone up to 2 mm; the displacement of bone fragments along the line of the articular surface and/or diastasis in the fracture zone of more than 2 mm and/or subluxation in the ankle joint was considered unsatisfactory.

X-ray was performed the day after the surgery and within 6, 12, 24 and 48 weeks after osteosynthesis. All radiographs were evaluated in order to identify possible signs of osteosynthesis failure, implant migration, loss of reduction and increase in deformation, as well as the appearance of radiological signs of bone union of the tibia posterior edge, fibula and medial malleolus. These signs included a distinct “darkening” or disappearance of the fracture line in the case of simple fractures, as well as the appearance of a visible callus in the area of a comminuted fracture. In addition, standard X-rays were evaluated 24 and 48 weeks after the injury to identify the signs of post-traumatic arthritis, especially if its symptoms (persistent pain syndrome, edema and pronounced restriction of movements in ankle joint) were present.

During the patients’ follow-up, attention was paid to the maintenance of the correct relationship of articular surfaces of the ankle joint, the increase of deformation, secondary displacement and migration of implants. The functional results of treatment were evaluated 12, 24 and 48 weeks after surgery according to the AOFAS and Neer scales. The ankle joint range of motions was measured within the time specified according to standard technology using an orthopedic goniometer. The ankle joint range of motions was determined as the sum of deviations from the zero position of the foot (90° relative to the axis of the lower leg) with its plantar and dorsal flexion. The data obtained were used to evaluate the functional results of treatment according to the AOFAS and Neer scales.

Cases of deep and superficial infection in the area of surgical intervention, failure of osteosynthesis manifested by migration of implants, delayed union of fractures, secondary displacement of fragments, post-traumatic arthritis were taken into account analyzing early and delayed complications of surgical treatment. At the same time, the relative values characterizing the frequency of occurrence or proportion were expressed as a percentage.

Statistical analysis

Statistical analysis of the obtained quantitative data was performed using Excel, as well as Statistica 8 for Windows (StatSoft) program. The median (Me) and interquartile range (IQR) were calculated using the programs mentioned above (the values of the first and third quartiles are presented). The type of distribution of the obtained digital values was evaluated using the Shapiro–Wilk test. Non-parametric Friedman test was used to determine the statistical significance of the differences between the analyzed samples due to non-normal type of data distribution. The statistical significance of changes during the observation period in the parameters of the ankle joint range of motion and scores reflecting the functional results of treatment according to the AOFAS and Neer scales was determined.

RESULTS

CT scan of all patients before surgery allowed us to analyze the structure of the ankle joint injury, identify all its components and evaluate the individual architectonics of fractures, which facilitated preoperative planning greatly, allowing us to determine the sequence of fixation of all injury components via rational surgical approaches.

After analysis the CT scans fractures of 3 classical components were detected in 14 patients: fractures of the lower third of fibula above syndesmosis, medial malleolus with a fragment of its anterior tubercle or both tubercles, as well as the posterior edge of tibia. Four patients had only a fracture of the posterior tubercle of the medial malleolus adjacent to the fragment of the posterior edge of tibia. In these 4 patients and in 3 more with a medial malleolus fracture, the presence and fracture pattern of its posterior tubercle were revealed only by analyzing CT scans. Three patients had no bone injury to the ankle joint medial complex, but deltoid ligament injuries were present. Two of our patients did not have fibula fractures in the ankle joint area or in the lower third of the lower leg. Two patients suffered a fracture with the presence of tibia anterolateral fragment (Tillaux-Chaput fragment), and 2 more patients had a displacement of a similar fibula anterolateral fragment (LeFort fragment). In 3 patients, according to preoperative CT scans, impacted fractures of the articular surface of the posterior edge of tibia were found.

Division of patients depending on the type of fracture of the posterior edge of tibia according to the classification of J. Bartoniček et al. was performed only after evaluation of CT data. In 13 (59%) patients the 3rd type of fracture of the posterior edge of tibia was identified, in 3 (14%) patients — the 2nd type, in 6 (27%) patients — the 4th type. The Me of the fragment size of the posterior edge of tibia was 0.28 (from 0.1 to 0.5 of the tibia articular surface), the interquartile range was from 0.2 to 0.4.

Thus, the use of spiral CT at the stage of preoperative planning revealed a wide variety of injuries that occurred in patients with unstable malleolar fractures and the posterior edge of tibia, and also made it possible to make a reasoned choice of tactic for fixing bone fragments.

Normalization of the soft tissues condition was a crucial moment determining the timing of surgery. The optimal time for the surgery was determined by the appearance of clinical signs of normalization of microcirculation in the injury area, manifested by regression of soft tissue edema and epithelization of skin blisters, if they were present. The Me duration of the preoperative period was 9 days (from 6 to 24 days), IQR — from 7 to 10 days.

Open osteosynthesis of the posterior edge of tibia via posteromedial surgical approach allowed to achieve its anatomical reduction in the absolute majority (20 out of 22 or 91%) of patients.

An example of using the technique is shown in Figure 3.

Results of reduction of only 2 (9%) patients were recognized as satisfactory due to the presence of intraarticular step with a size of up to 2 mm between the posterior tibial fragment and the rest part of articular surface, which was revealed on the lateral view x-rays of ankle joint. At the same time, no residual subluxation in the injured joints was detected in any of the patients.

There were no local complications in the early postoperative period. All wounds healed by primary tension without inflammation and infectious complications. There was no migration of implants and secondary displacement of fragments in the early postoperative period.

The studied stage radiographs during the follow-up did not reveal the failure of fixation, secondary displacement of fragments, migration of implants in any patient. Bone union of the posterior edge of tibia, lateral and medial malleolus

was noted on X-rays in 17 (77%) of 22 patients examined 12 weeks after surgery, and in all patients after 24 weeks.

The increase over time in ankle joint range of motions in patients was statistically significant ($p<0.01$) (Table 1).

The increment of scores over time according to both evaluation scales was statistically significant ($p<0.01$). Only 3 (14%) patients examined 48 weeks after osteosynthesis had complaints of moderate pain and swelling in the ankle joint area after physical activity.

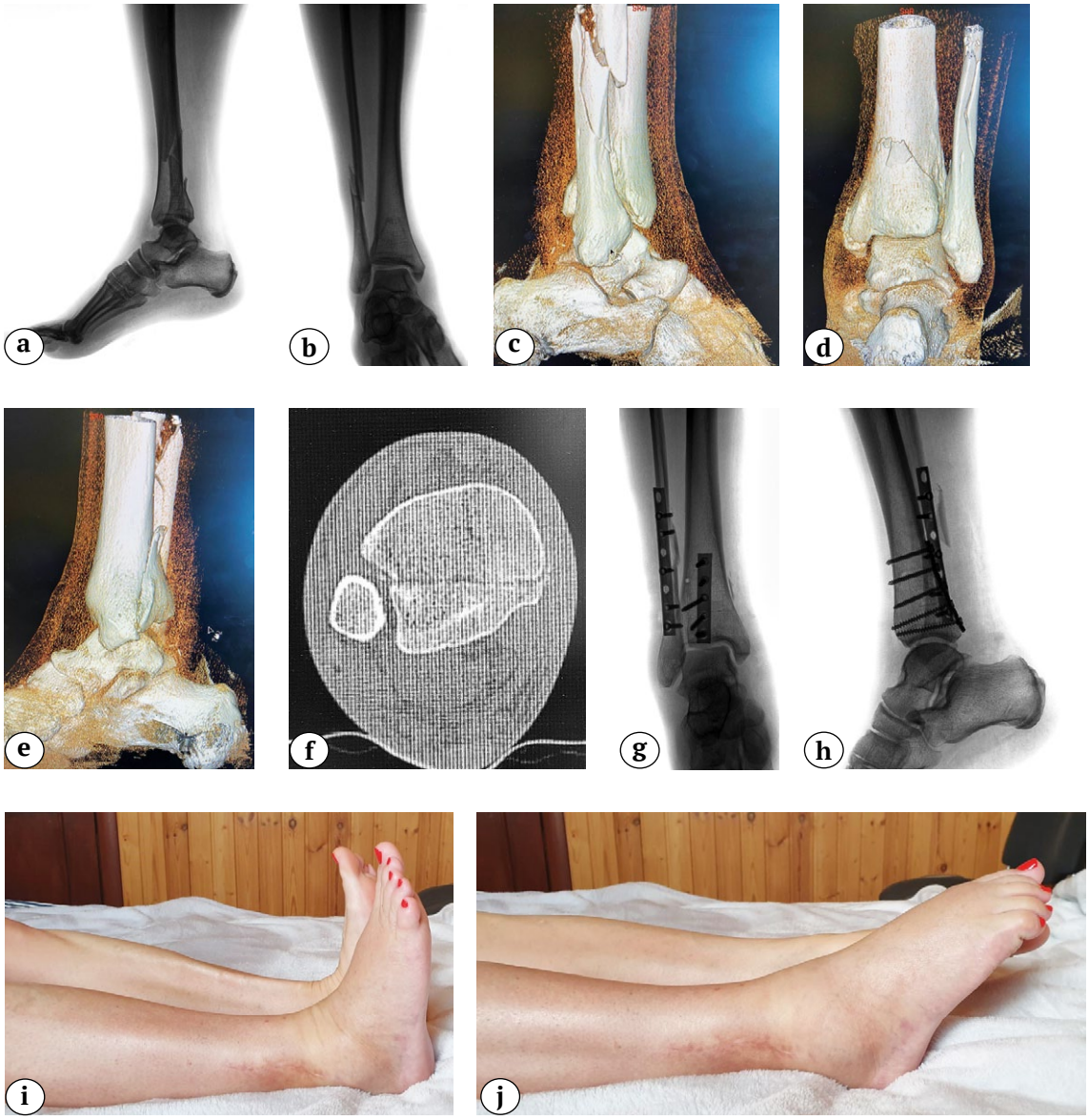

Fig. 3. Surgical treatment of a patient with a fracture 44C2.3:
a, b — primary X-rays in AP and lateral projections;
c, d, e, f — CT data showing the size of the posterior edge of the tibia;
g, h — postoperative X-rays in AP and lateral projections — anatomical reposition of bone fragments in the ankle joint;
i, j — functional result of treatment 48 weeks after injury

Table 1

Parameters of the range of motions in the ankle in dynamics

Parameter		Observation period		
		12 weeks.	24 weeks.	48 weeks.
The range of motions in the ankle, deg.	Median	40	55	55
	Min/Max	30/55	45/65	50/65
	IQR	35–45	55–60	55–60
AOFAS, points	Median	67,5	88	90
	Min/Max	61/72	78/95	85/97
	IQR	64–70	82–90	90–95
Neer, points	Median	67,5	90	94
	Min/Max	62/74	82/96	86/96
	IQR	64–70	85–93	94–96

$p<0,01$.

DISCUSSION

Fractures of the posterior edge of tibia are typical intraarticular fractures. Therefore, standard principles of treatment of such injuries should be applied, among which accurate (anatomical) reduction and interfragmentary compression of the articular surface fragments are especially important. Nevertheless, until recently, it was believed that these principles for fractures in question can be applied with certain limitations. Thus, many authors reported that only fragments of the posterior edge of tibia containing at least 1/3 of the articular surface require fixation [4, 5, 15]. In addition, a number of authors recommend close reduction of the posterior edge of tibia fragments with minimally invasive fixation with screws introduced from front to back [4, 16]. However, this technique often does not allow anatomical reduction and reliable fixation of fragments of the fractures discussed. Moreover, for adequate interfragmentary compression, it is necessary that the entire threaded part of the screw is located in the fragment of the posterior edge of tibia, but in case of fragment of small size, it is technically impossible to create an interfragmentary compression. It must be taken into account that in cases of impaction of tibia articular surface, it is impossible to achieve precise reduction. Therefore, open reduction of bone fragments seems to be more adequate.

It should be noted that nowadays, the choice of surgical approaches for osteosynthesis of unstable malleolar fractures and the posterior edge of tibia is largely determined by the dread of trauma surgeons to excessively injure soft tissues in the ankle joint area, which can lead to serious complications that negate even the impeccable anatomical result of the surgery. As a matter of fact, for anatomical reduction of the posterior edge of tibia, it is necessary to perform one of posterior approaches to the ankle joint, which increases surgical trauma. At the same time, in order to lessen it, it is logical to couple the fixation of the posterior edge of tibia with osteosynthesis of one of the malleoli via the same surgical approach. This is exactly what surgeons do performing posterolateral approach to the posterior edge of tibia with subsequent fixation of the lateral malleolus via the same approach [17, 18]. However, this approach does not allow adequate visualization of the posteromedial fragment of the posterior edge of tibia in case of type 3 fracture according to J. Bartoniček et al. Therefore, in such cases, in our opinion, it is logical to use posteromedial surgical approach with simultaneous fixation of fragments of the posterior edge of tibia and medial malleolus.

Surgical technique of posteromedial approach described in the literature may somewhat differ. So, in the manual of Ch.M. Court-Brown et al., it is proposed to perform a longitudinal incision of the skin in the middle of the distance between the medial malleolus and the Achilles tendon. After dissection of the fascia, the tendons of the

posterior tibial muscle, flexor digitorum longus and flexor hallucis longus muscles are identified, and the approach to the posterior edge of tibia is provided between the last two tendons. In this case, the posterior tibial vessels and the tibial nerve are situated anteriorly from the tendon of the flexor hallucis longus. Approach to the posterior part of the medial malleolus opens by bypassing these vessels and nerve from the front. At the same time, it is recommended to be careful to avoid injury to the posterior tibial vessels and the tibial nerve [4].

Although such approach is not used very often, it gives better visualization of the posterior edge of tibia compared to the posterolateral approach according to M. Philpott et al. [19]. M. Assal et al. consider that the approach between the tendon of the flexor hallucis longus from behind and the neurovascular bundle with the tendon of the flexor digitorum longus from the front gives the widest (up to 91%) field of view of the posterior edge of tibia with the least tension of soft tissues, vessels and nerves [20]. In addition, posteromedial approach can be performed in supine position of the patient and combined with traditional lateral approach to the lateral malleolus, thereby simplifying ankle joint space orientation, including when performing intraoperative control radiographs [21].

Y. Wang et al. proposed a modified posteromedial approach, which was used in our study. According to this technique, the approach to the posterior edge of tibia fragment is performed between the tendon of the flexor hallucis longus and the neurovascular bundle, which is carefully withdrawn anteriorly together with the tendon of the flexor digitorum longus. The approach to the posteromedial part of the medial malleolus is made between the tendon of the flexor digitorum longus, which is diverted posteriorly together with the neurovascular bundle and the tendon of the posterior tibial muscle, which is shifted anteriorly, exposing the posterior surface of the medial malleolus. Surgeon passing anteriorly of the tendon of the posterior tibial muscle can get a full view on the anterior medial malleolus via the same approach. Thus, the authors achieved direct visualization of both the tibia posterior fragment and all parts of the medial malleolus and performed an open anatomical reduction and osteosynthesis of all fracture fragments [12].

Separate lateral approach was used with patient in the same supine position for osteosynthesis of the lateral malleolus and fixation of distal tibiofibular syndesmosis. Notably authors obtained an anatomical reduction of the posterior fragment of tibia in all 16 operated patients, and the average functional result graded on the AOFAS scale was 85.6 points [12].

Z.B. Lai et al. compared two groups of patients in which they used two modifications of the posteromedial approach for osteosynthesis of the posterior edge of tibia, first passing behind the tendon of the flexor digitorum longus, and second anteriorly from the latter. In both groups authors achieved anatomical reduction of the posterior edge of tibia fragment in more than 80% of patients and good functional recovery of ankle joint — in average more than 84 points on the AOFAS scale. At the same time, the authors noted even slightly better outcomes in the group with posteromedial approach passing posteriorly from the tendon of the flexor digitorum longus, due to less duration of surgery. In addition, the proportion of patients with anatomical reduction of the posterior edge of tibia was 90.5%, and the average functional outcome on the AOFAS scale was 88.2 ± 7.8 points. However, the advantages identified by the authors were not statistically significant [22].

Currently, it is obvious that CT scan is necessary for adequate preoperative planning and the choice of surgical approaches for fractures of the posterior edge of tibia and malleoli [23]. In case of such complex fractures G.M. Arrondo and G. Joannas recommend to evaluate preoperative axial CT scans first and then choose between three types of posterior approaches depending on the involvement of the fracture components: posterolateral, posteromedial and modified posteromedial [21].

S. Donohoe et al. state that ideas about the pattern of fractures in discussion change in 52% of cases after studying the CT scans, and in 44% of cases adjustments are made to the surgery plan and patient positioning [24]. The results of our study confirm the data of these authors. We decided on the optimal approaches for performing osteosynthesis in each case individually depending on the fracture patterns acquired using CT scans. For example, posteromedial surgical approach for reduction and fixation of the fracture

was chosen in case of identifying by CT scan impacted articular surface of the posterior edge of tibia, since this approach is most convenient for osteosynthesis and provides a better view. This is exactly what seems essential when it is necessary to eliminate the impaction, which requires adequate visualization of the fracture zone of the tibia articular surface.

It should be noted that our study included patients with fractures of the posterior edge of tibia of the 2nd, 3rd and 4th types according to J. Bartoniček et al. requiring surgical treatment. Thus, it was shown that the use of posteromedial approach is possible for all the variants of fractures of the posterior edge of tibia that we studied associated with malleolar fractures. At the same time, out of several options for posteromedial approach, we chose modified technique [12], since in our opinion it provides the best view with the least traction of soft tissues and neurovascular bundle [20].

It is known that many authors perform posteromedial approach with patient in prone position [21, 25]. However, we prefer to perform it in a supine position and consider this possibility one of the advantages in some clinical situations. These include, for example, the need for direct anterolateral approach in combined Tillaux-Chaput, LeFort injuries or the necessity of visualization of the anterior portion of distal tibiofibular syndesmosis. At the same time, supine position ща the patient does not complicate the surgery and allows performing all its stages without changing it.

In general, our accumulated clinical experience has shown that the described technique of posteromedial surgical approach allows achieving a good anatomical result of osteosynthesis in the vast majority of cases (91%) of unstable malleolar fractures and the posterior edge of tibia due to good visualization of the posterior edge of tibia and intraoperative control of bone fragments reduction using C-arm. This creates, in our opinion, the necessary conditions for achieving good functional results of surgical treatment of patients and reduces risk of complications.

Limitations of the study

A small number of patients were included in the study, and a comparative analysis of the results of osteosynthesis of the studied fractures using alternative surgical approaches on our own clinical material was not performed.

CONCLUSION

Despite the fact that the present clinical study of usage of posteromedial approach for osteosynthesis of fractures of the posterior edge of tibia and malleoli was preliminary, it can already be stated that the approach we used has shown its convenience and clinical effectiveness, as well as the possibility of application for osteosynthesis in unstable ankle fractures in many clinical situations. These, in our opinion, include first of all cases in which the use of posterolateral approach is impossible or excessively traumatic (the presence of a fracture of the tibia anterolateral edge, the need for its reduction and fixation, the need for revision of the anterior portion of the tibiofibular syndesmosis), as well as fracture of the posterior edge of tibia in combination with fracture of the medial malleolus of the 3rd type by J. Bartoniček et al. In addition, we have shown the possibility of successful application of posteromedial approach in other clinical situations: in fractures of the 2nd and 4th types according to J. Bartoniček et al. In our opinion, that indicates that when trauma surgeons master the rational technique of posteromedial surgical approach, the indications for its use can be expanded.

DISCLAIMERS

Author contribution

Belen'kii I.G. — research concept and design, data statistical processing, manuscript writing and editing.

Maiorov B.A. — research concept and design, data statistical processing, manuscript writing and editing.

Kochish A.Yu. — research concept and design, data statistical processing, manuscript writing and editing.

Sergeev G.D. — data collection and analysis, manuscript writing.

Refitskii Yu.V.— research concept and design, data statistical processing, manuscript writing and editing.

Savello V.E. — research concept and design, data statistical processing, manuscript writing and editing.

Smirnov S.S. — data collection and analysis, manuscript writing.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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REFERENCES

1. Solod E.I., Zagorodny N.V., Lazarev A.F., Abdulhabirov M.A., Ermolayev E.G., Akraa M. [The Possibility of surgical treatment of ankle fractures in the problems of the skin of the ankle joint]. *Ural'skiy meditsinskiy zhurnal* [Ural Medical Journal]. 2019;12(180):96-101. (In Russian). doi: 10.25694/URMJ.2019.12.38.
2. Mikhailov S.V., Khominets V.V., Shakun D.A., Shchukin A.V., Foos I.V., Komarov A.V. [Surgical treatment of the leak of distal tibiofi bular syndesmosis after ankle fracture: clinical case]. *Vestnik sovremennoy klinicheskoy meditsiny* [The Bulletin of Contemporary Clinical Medicine]. 2019;(3):78-82. (In Russian). doi: 10.20969/VSKM.2019.
3. Goost H., Wimmer M.D., Barg A., Kabir K., Valderrabano V., Burger C. Fractures of the ankle joint: investigation and treatment options. *Dtsch Arztebl Int.* 2014;111(21):377-388. doi: 10.3238/arztebl.2014.0377.
4. Court-Brown Ch.M., Heckman J.D., McQueen M.M., Ricci W.M., Tornetta P. (III), McKee M.D. Rockwood and Green's fractures in adults. 8th ed. Wolters Kluwer Health; 2015. Ch. 59, p. 2541-2592.
5. Belen'kii I.G., Maiorov B.A., Kochish A.Yu., Tul'chinskii A.E., Grigoryan F.S., Nikolaev I.K. [The current aproaches to the osteosynthesis of the posterior rim of the distal tibia in cases of unstable ankle fractures]. *Sovremennye problemy nauki i obrazovaniya* [Modern problems of science and education]. 2021;(2). (In Russian). Available from: https://science-education.ru/ru/article/view?id=30751. doi: 10.17513/spno.30751.
6. von Rüden C., Hackl S., Woltmann A., Friederichs J., Bühren V., Hierholzer C. [The Postero-Lateral Approach - An Alternative to Closed Anterior-Posterior Screw Fixation of a Dislocated Postero-Lateral Fragment of the Distal Tibia in Complex Ankle Fractures]. *Z Orthop Unfall*. 2015;153(3):289-295. (In German). doi: 10.1055/s-0035-1545706.
7. Belenkiy I.G., Maiorov B.A., Kochish A.Yu., Sergeev G.D., Savello V.E., Tul'chinskii A.E. et al. [Unstable Fractures Osteosynthesis of Malleoli and Posterior Edge of the Tibia Using Posterolateral Surgical Approach]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2021;27(3):29-42. (In Russian). doi: 10.21823/2311-2905-2021-27-3-29-42.
8. Bartoníček J., Rammelt S., Kostlivý K., Vaněček V., Klika D., Trešl I. Anatomy and classification of the posterior tibial fragment in ankle fractures. *Arch Orthop Trauma Surg.* 2015;135(4):505-516. doi: 10.1007/s00402-015-2171-4.
9. Toth M.J., Yoon R.S., Liporace F.A., Koval K.J. What's new in ankle fractures. *Injury.* 2017;48(10):2035-2041. doi: 10.1016/j.injury.2017.08.016.
10. Zhong S., Shen L., Zhao J.G., Chen J., Xie J.F., Shi Q. et al. Comparison of posteromedial versus posterolateral approach for posterior malleolus fixation in trimalleolar ankle fractures. *Orthop Surg.* 2017;9(1):69-76. doi: 10.1111/os.12308.
11. Meinberg E.G., Agel J., Roberts C.S., Karam M.D., Kellam J.F. Fracture and Dislocation Classification Compendium-2018. *J Orthop Trauma.* 2018;32 Suppl 1S1-S170. doi: 10.1097/BOT.0000000000001063.
12. Wang Y., Wang J., Luo C.F. Modified posteromedial approach for treatment of posterior pilon variant fracture. *BMC Musculoskelet Disord.* 2016;17(1):328. doi: 10.1186/s12891-016-1182-9.
13. Nasrallah K., Einal B., Shtarker H. Trimalleolar fracture: The endless posterior malleolus fracture debate, to repair or not to repair? *Orthop Rev (Pavia).* 2021;13(1):8784. doi: 10.4081/or.2021.8784.
14. Mayorov B.A., Belenkiy I.G., Kochish A.Yu., Grigoryan F.S. [To the issue of the fibula fixation in cases of pilon fractures in association with fibula fractures]. *Sovremennye problemy nauki i obrazovaniya* [Modern problems of science and education]. 2020;(6). (In Russian). Available from: https://science-education.ru/ru/article/view?id=30311. doi: 10.17513/spno.30311.
15. Drijfhout van Hooff C.C., Verhage S.M., Hoogendoorn J.M. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. *Foot Ankle Int.* 2015;36(6):673-678. doi: 10.1177/1071100715570895.
16. Odak S., Ahluwalia R., Unnikrishnan P., Hennessy M., Platt S. Management of Posterior Malleolar Fractures: A Systematic Review. *J Foot Ankle Surg.* 2016;55(1):140-145. doi: 10.1053/j.jfas.2015.04.001.
17. Voronkevich I.A., Kulik V.I., Lavrentyev A.V. [Ergonomics of osteosynthesis of "trimalleolar" fracture]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2002;(1): 44-46. (In Russian).
18. Forberger J., Sabandal P.V., Dietrich M., Gralla J., Lattmann T., Platz A. Posterolateral approach to the displaced posterior malleolus: functional outcome and local morbidity. *Foot Ankle Int.* 2009;30(4):309-314. doi: 10.3113/FAI.2009.0309.
19. Philpott M.D.G., Jayatilaka M.L.T., Millward G., Molloy A., Mason L. Posterior approaches to the ankle - an analysis of 3 approaches for access to the posterior malleolar fracture. *Foot (Edinb).* 2020;45:101725. doi: 10.1016/j.foot.2020.101725.

20. Assal M., Dalmau-Pastor M., Ray A., Stern R. How to Get to the Distal Posterior Tibial Malleolus? A Cadaveric Anatomic Study Defining the Access Corridors Through 3 Different Approaches. *J Orthop Trauma.* 2017;31(4):e127-e129. doi: 10.1097/BOT.0000000000000774.
21. Arrondo G.M., Joannas G. Complex ankle fractures: practical approach for surgical treatment. *Foot Ankle Clin.* 2020;25(4):587-595. doi: 10.1016/j.fcl.2020.08.002.
22. Lai Z.B., Zhu Y.Z., Zou Y.X., Zhang H.N., Li X., Zhong D.G. et al. [Modified posteromedial approach via lateral side of flexor hallucis longus for the treatment of posterior Pilon fracture]. *Zhonghua Yi Xue Za Zhi.* 2021;101(15):1077-1082. (In Chinese). doi: 10.3760/cma.j.cn112137-20200828-02484.
23. Palmanovich E., Brin Y.S., Laver L., Kish B., Nyska M., Hetsroni I. The effect of minimally displaced posterior malleolar fractures on decision making in minimally displaced lateral malleolus fractures. *Int Orthop.* 2014;38(5):1051-1056. doi: 10.1007/s00264-013-2224-7.
24. Donohoe S., Alluri R.K., Hill J.R., Fleming M., Tan E., Marecek G. Impact of Computed Tomography on Operative Planning for Ankle Fractures Involving the Posterior Malleolus. *Foot Ankle Int.* 2017;38(12):1337-1342. doi: 10.1177/1071100717731568.
25. Chen J., Wang Y., Kong L., Li B., Zhao Z. [Posterolateral and posteromedial approaches for treatment of posterior pilon fractures in elderly patients]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi.* 2016;30(9):1089-1093. (In Chinese). doi: 10.7507/1002-1892.20160222.

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