DIAGNOSTIC ERRORS AND MANAGEMENT OF FOOT FRACTURES IN PATIENTS WITH MULTIPLE OR CONCOMITANT INJURIES

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Delayed or missed diagnosis of foot fractures in patients with multiple or concomitant injuries often leads to the inadequate choice of treatment and causes serious long-term effects. This article reports the most common mistakes accompanying diagnostic procedures and therapy of this injury type. The study conducted in 2007–2015 enrolled 67 patients. Patients were divided into two groups: a prospective experimental group (n = 31) and a retrospective control group (n = 36). For both groups, diagnostic procedures and the range of therapeutic interventions applied were the same, but with the experimental group we used a stepped care approach, followed a specific sequence of activities and adjusted therapy considering the limb condition and the patient's overall state. In total, we identified 40 and 69 foot fractures in the prospective and retrospective groups, respectively. In the prospective group there were 5 delayed and 3 missed fracture diagnoses; in the second group those numbers were 7 and 9, respectively. The most common factors contributing to diagnostic errors were: excluding radiographic evaluation, severity of patient's overall condition, poor medical history. Missed fractures were often due to a combination of various factors. A one-step approach was prevalent in the controls (41 fractures); the experimental group underwent a multistep treatment (30 fractures). Therapy outcomes were assessed by Visual Analogue Scale. The results were statistically higher in the prospective group (Mann–Whitney U was 347), which indicates a better treatment applied in this group. The study also showed that using minimally invasive fixation for foot fractures improves treatment outcome.

Keywords: foot fractures, diagnostic error, concomitant injury, multiple injury

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Received: 30.03.2016 **Accepted: 22.04.2016**

ОШИБКИ ДИАГНОСТИКИ И ОСОБЕННОСТИ ЛЕЧЕНИЯ ПЕРЕЛОМОВ КОСТЕЙ СТОПЫ ПРИ СОЧЕТАННОЙ И МНОЖЕСТВЕННОЙ ТРАВМЕ

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Переломы костей стопы при множественной и сочетанной травме часто диагностируются поздно или не диагностируются вовсе, что обусловливает ненадлежащее лечение и его неудовлетворительный отдаленный результат. В статье сообщается о наиболее распространенных ошибках диагностики и лечения этой группы переломов. В исследовании, проведенном в 2007–2015 гг., участвовали 67 пациентов. Их разделили на группу проспективного наблюдения (n = 31) — опытную и группу ретроспективного наблюдения (n = 36) — контрольную. Для обеих групп диагностические и лечебные мероприятия были одинаковыми, но для опытной группы соблюдали некоторые принципы лечения: этапность, последовательность всех действий, зависимость от состояния конечности и общего состояния пациента. Выявили 40 и 69 переломов костей стоп для группы проспективного и группы ретроспективного наблюдения соответственно, при этом в первой были поздно диагностированы или не диагностированы 5 и 3 переломов, а во второй — 7 и 9. Наиболее частыми ошибками диагностики стали: невыполнение рентгенологического исследования, тяжесть общего состояния пациента, скудный анамнез. Часто пропуск перелома был обусловлен влиянием сразу нескольких факторов. В контрольной группе преобладало одноэтапное лечение повреждений (41 перелом), а в опытной — многоэтапное (30 переломов). Оценка результатов лечения по шкале Visual Analogue Scale достоверно выше (критерий Манна–Уитни равен 347) в группе проспективного наблюдения, что свидетельствует о более высоком качестве лечения пациентов группы. Исследование также показало, что применение малоинвазивных способов фиксации переломов костей стопы улучшает результат лечения.

Ключевые слова: переломы костей стопы, ошибки диагностики, сочетанная травма, множественная травма

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Статья поступила: 30.03.2016 **Статья принята в печать:** 22.04.2016

According to some estimates, 17–20 % of all bone fractures are foot fractures. [1]. Foot fractures are more frequent in patients with multiple and concomitant injuries. We have analyzed statistical data provided by the Trauma Unit of Pirogov City Clinical Hospital no.1, Moscow. In 2007– 2015 the hospital admitted 923 patients with multiple and concomitant injuries. We have found that 15 % of them were diagnosed with foot fractures; still, foot fractures accounted for only 7 % of all

fractures registered in the Unit during that period. It is probably because a large number of multiple and concomitant injuries are caused by car accidents, and the latter are often damaging for extremities [2–4].

Another important detail is a high rate of delayed diagnosis of foot fractures [5].Thus, in Guly's study fractures accounted for 79.7 % of delayed diagnoses of injuries; 11 % of them were injuries to the foot [6]. Delayed diagnosis affects the effectiveness and the duration of treatment [5, 7], patients develop persisting pain [8], and the quality of their life deteriorates [9]. Considering that, diagnostic and therapeutic approaches to this type of fractures should be improved.

At the first stage of providing medical service to the patient, the medical personnel should eliminate a life threatening condition, which is normally not caused by foot fractures, although the latter can negatively affect the treatment outcome [5]. After the patient has been resuscitated, urgently operated on and stabilized, the trauma specialist can perform a secondary survey to detect occult injuries to bones and soft tissues [10]. Rizoli et al. emphasize the importance of secondary physical examinations, since in their study about 30 % of injuries were diagnosed only because patients had repeatedly voiced their concerns [11].

Imaging is an important diagnostic tool. It includes ultrasonography (US), radiography, computed tomography (CT), and magnetic resonance imaging (MRI). Atilla et al. suggest performing US on the patients with injuries to the foot and ankle; they see it as helpful for diagnosing malleolar and fifth metatarsal fractures, but do not recommend it for other foot bone injuries [12]. Some researchers consider radiography ineffective [13], and many insist on a CT scan [14–17], the reason being its high accuracy and convenience. A CT scan is often ordered for patients with severe traumas. Given the indications, the foot can be scanned along with other body parts [17]. Magnetic resonance imaging is highly effective in detecting both soft tissue injuries, such as ruptured ligaments, tendons or muscles, and transchondrial foot fractures not visible on radiography [18].

Arthroscopy is a promising diagnostic and therapeutic technique. It is normally used to treat the talus due to the size of the talocrural joint and its relative accessibility [19], but there are reports on performing arthroscopy on other foot bones [20–22].

Poor diagnosis and/or treatment can result in a medical malpractice lawsuit. In 2010, 125 such lawsuits were filed in Moscow [23], while in 2013 their number increased to 325; in 58.5 % of cases the patient's claim was satisfied [24]. When treating foot fractures, orthopedic traumatologists face significant legal risks, because there are still no clinical guidelines for this type of fractures in Russia. There are guidelines for treating similar pathologies of different localization, but therapeutic methods they suggest cannot justify the doctor in case a lawsuit is filed.

Thus, diagnosis and treatment of foot fractures in patients with multiple injuries are a medical and a legal issue. The aim of our study was to analyze the most common errors in the diagnosis and treatment of foot fractures in patients with multiple and concomitant injuries and to elaborate guidelines for reducing the risk of missed fractures and improving their management.

METHODS

The study was conducted in 2007–2015 in the Trauma Unit of Pirogov City Clinical Hospital no.1 in Moscow. The study enrolled 67 patients with multiple and concomitant injuries, including foot bone fractures. The following exclusion criteria were applied: patient's early death, foot bone dislocations, or patient's refusal to participate. Two groups were formed: a group of prospective observation (n = 31; 22 men and 9 women, mean age of 38 years) and a control group of retrospective observation (n = 26; 29 men and 7 women, mean age of 41 years). In both groups injuries were caused by car accidents (81.2 % and 74.7 %, respectively), falls from height (8.3 % and 12.0 %, respectively) and other factors (11.5 % and 13.3 %, respectively).

Diagnostic and therapeutic procedures were the same for both groups; however, with the prospective observation group we were able to make adjustments in the course of treatment and adhere to some important principles of treatment tactics, such as using a stepped-care approach, following a specific sequence of diagnostic and therapeutic procedures, and considering how foot condition affected patient's geenral health. Diagnostic and therapeutic interventions in the retrospective observation group were assessed using medical histories, phone surveys and medical examinations in person.

During clinical examinations, the presence and the severity of edema, deformities and pain were assessed; foot mobility was tested with extra care. To detect acute neurocirculation disorders, dorsalis pedis pulse was palpated. Sensitivity was tested using external stimuli; local skin temperature was compared to body temperature. Biplanar radiography was performed in all cases; with the talus and calcaneus, a special projection was performed, when necessary. CT was performed to clarify the type of the fracture, to understand the need for therapeutic adjustments and to decide on postoperative procedures. In cases of capsular ligaments or damaged cartilages, MRI was ordered.

A diagnosis was classified as early if a fracture had been detected during the primary clinical examination or no later than within half of the time to bony union. A diagnosis was classified as delayed if a fracture had been detected at a different time prior to patient's discharge. A fracture was classified as missed if it had been detected in the course of outpatient treatment at a first aid facility.

A primary criterion for deciding on the surgical treatment of foot fractures in patients with multiple and concomitant injuries was patients' general condition. The surgery was under no circumstances to interfere with resuscitation and elimination of life-threatening conditions. It was also ruled out if the risk of anaesthetic complications was high.

Undisplaced closed foot bone fractures were fixed with plaster splints and bandages. If redisplacement of bone fragments was likely to occur, which is often the case with metatarsal and toe fractures, we used minimally invasive techniques, such as closed reduction and pin, screw or plate fixation.

Open foot fractures were an absolute indication for surgery. The extent of surgery was inversely proportional to the severity of patient's condition.

Displaced hindfoot fractures (involving the calcaneus or the talus) were treated surgically by open reduction or plate and/or screw osteosynthesis. If time elapsed after the injury exceeded 14 days, calcaneal and talar fractures were treated by open reduction and subsequent osteosynthesis; if time elapsed after the injury was less than 14 days, closed reduction with subsequent osteosynthesis was performed.

A one-step care approach implied only one type of treatment, while a multiple-step care approach implied primary atraumatic stabilization of the fracture (by casting, external fixation or adhesive tape fixation) followed by the introduction

of more complex and stable fixators (plates, screws and nails).

Treatment outcome was assessed using the following scales: SF-36 (Short Form 36), AOFAS (American Orthopaedic Foot and Ankle Society Score), FFI (Five-Factor Inventory), VAS (Visual Analogue Scale), MFTS (Moscow Foot Trauma Scale) and AQSA (Abbreviated Questionnaire of Subjective Assessment). The latter 2 scales had been developed at the department of Traumatology and Orthopedics of Pirogov Russian National Research Medical University [26]. The assessment was performed 1, 3, 6 and 12 months after the treatment had been completed, and once a year afterwards.

For all parameters the mean value and standard deviation were computed. To evaluate the significance of differences between the means and their correlations, Spearman's rank correlation coefficient (r) and Pearson's chi square were computed (considering Yates' correction, Tschuprow's T and Cramer's V). Since many samples were asymmetrical and distribution in those samples differed from normal, we used Mann-Whitney U test instead of Student's t-test.

The study was approved by the Ethics Committee of Piragov Russian National Research Medical University (Protocol no. 139 dated November 10, 2014). All patients gave written informed consent to participate.

RESULTS

Mean observation period was 4 years for each patient. In total, 109 foot fractures in 71 feet were detected; 40 of them, including 6 open, were detected in the prospective observation group; 69 fractures, including 7 open, were detected in the retrospective observation group (see table 1). In the control group, 53 fractures were diagnosed early, 7 diagnoses were delayed, and 9 were missed. For the prospective observation group, those numbers were 32, 5 and 3, respectively.

In both groups the majority of the fractures were diagnosed during the primary survey by the trauma surgeon, that is, 27 and 36 in the experimental and control groups, respectively, which accounted for 67.5 % and 52.1 % of the total number of fractures in both groups (see table 2). During the secondary survey in the resuscitation and intensive care unit, 8 fractures were detected in the experimental group, and 7 — in the controls (20.0 % and 10.1 %, respectively). After patients were transferred to the trauma unit, 3 fractures were diagnosed in the experimental group, and 11 — in the controls (7.5 % and 15.9 %, respectively). Of 16 delayed and missed diagnoses in the retrospective observation group, only 3 were radiographed (18.8 %); bipolar radiography was performed for 2 such fractures out of 8 in the prospective observation group (25.0 %). CT scans were performed on 6 patients in the experimental group and 3 controls, but in both groups patients with missed fractures did not have a CT scan. We should note that out of 67 patients 34 received a CT scan of other body regions, and 12 patients received multiple follow-up CT scans.

The most common reasons for missed foot fractures were as follows: no rfailure to perform radiography, severity of the patient's condition, scant medical records, and other (see table 3).

In the prospective observation group, 30 foot fractures were treated using a stepped-care approach; only 16 patients of the retrospective observation group were managed similarly. Plaster splints and bandages prevailed over surgical interventions: in the experimental group they were used for 10 fractures to which a one-step care approach was applied, and in 17 fractures to which a multiple-step care approach was applied. With the controls, those numbers were 41 and 4, respectively. In both groups, the most common surgical interventions were pin fixation and external fixation. Emergency osteosynthesis was not performed on any patient in both groups.

Arithmetic means of scores obtained from different scales indicate a better therapy outcome in the prospective observation group compared to the controls (see table 4). In the experimental group, standard deviations were lower than in the controls, which indicates a more stable treatment outcome. However, statistically significant differences were observed for VAS scale only, because Mann-Whitney U was 347, i.e., within the significance interval. For FFI scale, Mann-Whitney U was 420 and fell within the uncertainty range; it was insignificant for other scales. For all scales except VAS and FFI, Spearman's coefficient proves wrong the null hypothesis that early diagnosis does not affect the treatment outcome. For missed fractures, Pearson's coefficient was computed. Its value (2.517) shows a moderate association, which implies a possible correlation between the scores and indicates a need for earlier diagnosis and a therapy different from the one applied in the retrospective

Table 1. General description of the experimental and control groups

Criterion		Prospective observation group (n = 31)		Retrospective observation group (n = 36)	
		number	percentage, %	number	percentage, %
Number of patients with concomitant injuries (Injury Severity Score)	less than 16 points	5	16	2	5
	16 to 40 points	8	25	13	36
	over 40 points	0	0	0	0
Number of patients with multiple injuries	up to 2 fractures	4	12	5	13
	up to 3 fractures	5	16	8	22
	more than 3 fractures	9	29	8	22
Number of patients with foot fractures of various localization	on the right foot	15	48	16	44
	on the left foot	9	29	14	38
	bilateral	7	22	6	16
Number of foot fractures grouped according to the time to diagnosis	early diagnosis	32	80	53	74
	delayed diagnosis	5	12	7	11
	missed	3	8	9	15

observation group. Contingency coefficient, Tschuprow's T and Cramer's V indicate a weak association.

DISCUSSON

The most common reasons for delayed or missed diagnosis in our study were: failure to perform radiography, severity of patient's general condition and scant medical history. It is important to note that in many cases a fracture was not diagnosed early due to the combination of the factors mentioned above. Guly et al. mention poor analysis of radiological reports and poor radiography as the most common errors in foot fracture diagnosis [6]. Houshian et al. believe errors are due to the insufficient attention to detail exhibited by traumatologists and misinterpreted radiological data [27]. Brooks et al. report seven injuries visible on radiography (all images were good quality), but missed by trauma specialists [28]. Sharma et al. rank errors differently putting the severity of the patient's condition first, followed by the inaccurate assessment of his condition, misinterpretation of medical imaging data, and poor screening [29]. Alternative results provided by other authors are probably due to the fact that only lethal cases were studied.

We believe that severity of patient's general condition should not be seen as an obstacle to diagnosis of foot fractures. If a thorough medical examination is impossible in the resuscitation ward, it should be performed later by the trauma surgeon. With severe injuries, medical history is often scant, but signs of damage to the extremity are easy to discern, since it is usually characterized by conspicuous edema, deformities or pain. To improve radiographic image quality and thus reduce the number of missed fractures, digital equipment must be used; or data from an X-ray machine must be transmitted to a computer for better radiographic contrast control and stable image quality while scanning larger body regions. Unfortunately, not all hospitals in Russia are properly equipped.

Computed tomography is an important imaging tool; it is especially effective in identifying talar fractures [30–32]. The medical community is currently discussing a whole-body CT (WBCT) performed on patients with multiple injuries. Davies et al. report that WBCT helped them to diagnose a concomitant injury in 16 % of cases and some injury-related conditions in 42 % of cases; in the rest 42 % of cases it did not detect any injuries [17]. Based on the obtained results, the researchers recommend performing WBCT on patients with major trauma only after indications for this type of screening have been thoroughly considered. During WBCT a patient is exposed to a high dose of radiation (about 20 mSv), which can cause tissue malignization.

We also studied the effectiveness of various approaches to foot fracture management. Which is better: a one-step or a multiple-step approach? Minimally invasive or standard fracture fixation? Urgent or delayed intervention?

There are two main approaches to managing multiple traumas. The first is called Early Total Care (ETC) and implies urgent fixation of all fractures regardless of the patient's condition [33]. Pakhomov et al. believe that fixation of multiple fractures must be performed immediately and in one step. It is important, though, that their patients' condition was stable [14]. The second concept called Damage control orthopedics (DCO) implies that traumatologists must focus on the severe injuries first, while minor fractures can be treated later when patient's general condition improves [34]. This approach has some drawbacks. Nicola writes that DCO reduces the risk of complications caused by early medical intervention, but increases the need for a secondary surgery that can be less

Table 2. How foot fractures were diagnosed

How foot fractures were diagnosed	Group	Number of fractures	Percentage, %
On receiving a radiological report	R	33	47.8
	P	19	47.5
On receiving a CT report	R	3	4.3
	P	6	15.0
On receiving an MRI report	R	0	0.0
	P	2	5.0
During secondary examinations in the Resuscitation and Intensive Care Unit	R	7	10.1
	P	8	20.0
After patient's transfer to the Trauma Unit	R	11	15.9
	P	3	7.5
After radiographs were analyzed by the surgeon	R	2	2.9
	P	0	0.0
After radiographs were analyzed by the general practitioner	R	0	0.0
	P	0	0.0
After the first series of patient's complaints	R	3	4.3
	P	0	0.0
After the second series of patient's complaints	R	1	1.4
	P	0	0.0
After patient's transfer to the Surgical Unit	R	2	2.9
	P	0	0.0
After patient's transfer to the Medical Unit	R	0	0.0
	P	0	0.0
In a follow-up clinic	R	1	1.4
	P	0	0.0
Undocumented cases	R	6	8.7
	P	2	5.0
Total	R	69	100.0
	P	40	100.0

Note: R represents the retrospective observation group, P represents the prospective observation group.

Table 3. Reasons for delayed or missed foot fracture diagnosis

Reason for diagnostic error	Prospective observation group	Retrospective observation group
Failure to perform radiography	7	11
Severity of patient's general condition	7	10
Scant medical history	6	5
Absence of clinical signs of a fracture	2	6
Inaccurate assessment of trauma by the doctor	2	5
Poor quality of radiographs	2	4
Fractures detected on the other foot	1	3
Short stay in hospital	3	1
Other fractures detected on the same foot	0	3
Other	2	0

Note: in some cases there were several reasons contributing to the missed or delayed diagnosis of a foot fracture. Because of that, the absolute number of delayed or missed fractures does not coincide with the totals shown in table 1.

Table 4. Assessment of treatment outcome using standard scales and questionnaires

Parameter		SF-36		VAS	AOFAS	FFI	MFTS	AQSA
		PCS	MCS					
M	retrospective observation group	42.027	45.777	2.02	45.888	46.027	43.08	8.44
	prospective observation group	43.032	48.032	1.03	51.225	34.61	45.93	6.9
SD	retrospective observation group	9.78	8.45	1.66	18.89	21.88	19.54	8.23
	prospective observation group	9.63	8.31	1.04	19.121	17.45	19.98	7.06
Mann-Whitney U		526	461	347	459	420	514	488
Spearman's rank correlation coefficient		0.623	0.535	-0.05	0.494	0.138	0.641	0.698
Statistical analysis of missed fractures								
Pearson's chi square		2.517						
	Yates' correction	1.771						
	Contingency coefficient	0.19						
	Tschuprow's T	0.194						
	Cramer's V	0.194						

Note: M represents arithmetic mean, SD represents standard deviation.

effective, which, in turn, results in a longer hospital stay [35]. Our study convincingly demonstrates that surgical treatment of foot fractures should be postponed until the patient is stable, if possible.

There are many ways to fix a foot fracture: plaster splints, adhesive tape, pins, screws, plates and nails. Our study shows that patient's condition should be considered first when deciding on the fixation method. If a patient is stable, comminuted fractures of the calcaneus and metatarsal bones with displaced fragments should be fixed with plates, as plates ensure bone immobility. Phalanx fractures can be fixed with adhesive tapes, pins or miniplates. However, if a patient is hemodynamically unstable, hyperthermic or hypocoagulable, has a conspicuous edema, or the wound in the fracture area is contaminated, it is reasonable to use temporary fixation first, such as plaster splinting, skeletal extension or external fixation, and then proceed to surgery.

Some authors suggest using Ilizarov apparatus and external pin fixators, especially for calcaneal and talar fractures with displaced fragments [36–39]. Ilizarov apparatus was not used in this study, and there may be several reasons for that. First, some trauma surgeons in the emergency room had no experience using it. Second, there were no indications for its use. It is a complex and somewhat unwieldy system difficult to care for. We did use external pin fixators, though, mainly as a temporary solution. Those were later replaced by internal fixators.

Other authors report a beneficial effect of plates on fracture healing [14, 40]. We believe that plates are the most reliable fixation technique. They also allow the patient to manage almost on his own, given that the postoperative wound heals well and the patient gradually restores his physical activity. An alternative to plate fixation is minimally invasive screw fixation [41, 42].

CONCLUSIONS

In most cases, physical examination inadequacy and severity of patient's general condition are main reasons for delayed or missed diagnosis of foot fracture in patients with concomitant or multiple injuries. To improve diagnosis accuracy, a minimum of two projections should be performed during radiographic screening, digital equipment being a considerable advantage here.

If a trauma patient receives a CT scan of other body parts, and his medical history, nature of trauma and clinical symptoms indicate a foot injury, it is advisable to CT-scan the foot (or both feet) along with other body parts. When treating a patient with multiple or concomitant injuries, we recommend a stepped-care approach and minimally invasive fixation techniques, as those can improve treatment outcome, reduce the length of hospital stay and prevent complications.

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