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Particularities of the therapeutic procedures and success in treatment of combat-related lower extremities injuries

Osobenosti terapeutskih postupaka i uspešnog lečenja povreda donjih ekstremiteta nastalih u borbi

Budimir Šegrt

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Abstract

Background/Aim. In a combat environment the extremities continue to be the most common sites of injury with associated high rates of infectious complications due to initial contamination. The aim of this observational study was to determine therapeutic procedures effective in a combat environment and to assess functional outcomes of definitive care. **Methods.** A total of 44 casualties with combat-related lower extremities fractures sustained during combat operations in former Yugoslavia in a 2-year period (1993–1994) were enrolled. Initial management of these injuries was performed at battlefield (echelon I), surgical treatment was provided in the hospital in Trebinje (echelon II) and definitive care was provided in the Orthopedic Ward of General Hospital in Nikšić (echelon III). **Results.** All combat casualties received surgical treatment within 6–48 hours. Antibiotics were administered during hospitalization in 37 (84%) of all the patients. In all the cases fractures healed, while 15 (38.59%) of them developed complications (most notably osteomyelitis in 3 of the cases, dysfunction in adjacent joints in 3 of the cases and infection of the soft tissue around pins in 3 of the cases). Follow-up period was a little bit over 2 years and reliable conclusions regarding the therapy and the outcomes could be made. Good functional outcomes were prevalent (63.63%), satisfactory were present in one fifth and inadequate in 13.63% of all the cases. There were no amputations or fatalities. Internal fixation was shown to be the method of definitive surgical care of combat-related lower extremity fractures. **Conclusion.** The management of combat-related lower extremity fractures is complex, multidisciplinary approach through echelons is necessary and internal fixation as the method of definitive surgical care is essential.

Key words:
wounds, penetrating; war; tibial fractures; fractures comminuted; surgicenters; survival; montenegro.

Apstrakt

Uvod/Cilj. Ekstremiteti i dalje predstavljaju najčešće mesto povreda u borbenim uslovima i to sa visokim stopama komplikacija zbog infekcija usled početne kontaminacije. Cilj ove opservativne studije bio je da se utvrde delotvorni terapeutski postupci u borbenom okruženju i procene funkcionalni ishodi završnog lečenja. **Metode.** U ovu studiju bile su uključene ukupno 44 osobe sa prelomima donjih ekstremiteta nastalim u borbi tokom ratnih sukoba u bivšoj Jugoslaviji u 2-godišnjem periodu (1993–1994). Početno zbrinjavanje povreda izvršeno je na terenu (ešelon I), hirurško lečenje u bolnici u Trebinju (ešelon II), dok je završno lečenje sprovedeno u Odeljenju za ortopediju, Opšte bolnice u Nikšiću (ešelon III). **Rezultati.** Svi povređeni u borbi lečeni su hirurški tokom prvih 6–48 sati. Tokom hospitalizacije dati su antibiotici kod 37 (84%) od ukupnog broja povređenih. Prelomi su zarasli kod svih povređenih, kod 15 (38,59%) došlo je do komplikacija (najčešće do osteomijelitisa, kod 3 povređena, disfunkcije okolnih zglobova, takođe kod 3 povređena, i infekcije mekog tkiva oko igala, kod 3 povređena). Period praćenja trajao je nešto duže od 2 godine, te je bilo moguće napraviti pouzdane zaključke o terapiji i ishodima. Dobri funkcionalni ishodi postignuti su kod 63,63% povređenih, zadovoljavajući kod 20%, a neodgovarajući kod 13,63% povređenih. Nije bilo ni amputiranja, niti smrtnih ishoda. Prema našem iskustvu, interno fiksiranje predstavlja metodu potpunog hirurškog zbrinjavanja preloma donjih ekstremiteta nastalih u borbenom okruženju. **Zaključak.** Zbrinjavanje preloma donjih ekstremiteta nastalih u borbenim uslovima veoma je složeno, zahteva multidisciplinarni pristup u ešelonima, dok je metoda internog fiksiranja suštinska za potpuno hirurško izlečenje.

Ključne reči:
rana, penetrantna; rat; potkolenica, prelomi; prelomi, kominutivni; bolnice, hirurške, pokretne; preživljavanje, crna gora.

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Introduction

Modern attitudes in treatment of combat-related lower extremities injuries are not oriented only towards life saving, saving of extremities, avoiding infections and allowing fracture recovery, but also towards the idea to achieve a total recovery of all functions of the injured extremity. It is well-know that the treatment of combat-related injuries differs from the treatment applied in peaceful conditions [1]. Also, it is well-known that combat-related injuries are initially contaminated [2, 3] and that missiles can cause mass destruction of soft tissue, bones and other structures [4].

Methods

A total of 44 injured with combat-related lower extremities fractures sustained during combat operations in former Yugoslavia in a 2-year period (1993–1994) were enrolled, and treated in the Orthopedic Ward of General Hospital in Nikšić. The treatment and care of the injured was managed through echelons. Initial management of these injuries was performed at battlefield, surgical treatment was provided in a hospital in Trebinje and definite surgical care of the injured was provided in a hospital in Nikšić.

Results

Demographic characteristics of the injured are presented in Table 1.

Table 2 shows the percentage of fractures localizations according to the anatomic level of the lower extremities and distribution of fractures depending on the level of comminution.

Table 1

Distribution of the injured according to gender and age

Age (years)	Male		Female		Total	
	n	%	n	%	n	%
21–30	12	27.27	1	2.27	13	29.54
31–40	15	34.09	1	2.27	16	36.36
41–50	10	22.72	0		10	22.72
51–60	4	9.09	0		4	9.09
61–70	0	0	0		0	0
Over 70	1	2.27	0		1	2.27
Total	42	95.45	2	4.54	44	100

Table 2

Fractures localization according to lower extremities anatomic level and fractures distribution regarding the level of comminution

Anatomic level of fracture	n	%	Type of fracture	n	%
Upper third	3	6.81	Without or with small comminution	16	36.36
Middle third	32	72.72	Medium comminution	18	40.90
Lower third	9	20.45	Big comminution	10	22.72
Total	44	100	Total	44	100.00

Complications present in combat-related injuries are a current problem in military medicine, while in the literature there is a very small amount of dates and facts about the treatment of combat-related injuries. The aim of this study was to contribute through a detailed retrospective analysis of injured patients in the period from 1993 to 1994, to success in treatment of this category of injuries and to compare the treatment that was once used with the modern doctrine of military medicine.

In spite of the fact that 20 years passed from that period, our aim was to compare our experience gathered in the treatment of combat-related injuries in that period, and to determine if our experience was different from modern doctrine used in treatment of combat-related injured patients, in order to contribute to the whole consideration of this matter.

In the study, shrapnel caused injuries in 27 (61.36%) and bullet in 17 (38.63%) of the cases. There were statistically significant differences in the instruments that caused injuries ($\chi^2 = 23.24$; $p < 0.01$). In 7 (15.90%) injured were also registered joined injuries as follows: 3 of them had other fractures, and other 4 cases had injuries of the head, chests, urinary tract and blood vessels (*arteria tibialis anterior*).

All the injured received surgical treatment within 6–48 hours. Most of them, 19 (43.18%) injured, received surgical treatment in the first 24 hours. Up to 12 hours were necessary for 17 (38.63%) injured to be surgically treated, and 48 hours for the rest (11.38%). Only 6.81% of the injured were surgically treated in the first 6 hours from wounding.

Antibiotics were administrated during hospitalization in 37 (84.09%) of all the patients. In the first 6 hours following wounding, antibiotics were administrated only to one (2.27%) patient. In 18 (40.90%) cases of all the patients, 24 hours passed from wounding to administration of antibiotics. Twelve hours after wounding, 13 (29.54%) of the injured received antibiotics, while 5 (11.36 %) of the injured received antibiotics after 48 hours.

Sixteen (36.36%) of the injured that received antibiotic therapy (n = 37) during hospitalization had moderately comminuted fractures, 11 (25%) had small comminuted fractures and 10 (22.72%) had big comminuted fracture. The relation between the level of fracture and the antibiotic treatment is showed in the Table 3.

3 (6.81%) had small comminution. Duration of hospitalization in relation to the type of fracture is shown in Table 5. There was a highly statistically significant difference in a relation between the duration of hospitalization and the type of fracture ($\chi^2 = 23.56$; $p < 0.01$).

Table 3

Administration of anitbiotics during the treatment regarding the level of comminution

Type of fracture	Antibioticscs				Total	
	yes		no			
	n	(%)	n	(%)	n	(%)
Small comminution	11	(25.00)	5	(11.36)	16	(36.36)
Medium	16	(36.36)	2	(4.54)	18	(40.90)
Big	10	(22.72)	0		10	(22.72)
Total	37	(84.09)	7	(15.90)	44	(100)

Intraoperatively, during hospitalization, smear was taken from all the injured. Bacterial analysis showed the positive results in half of the cases. The positive results were found in 23 (52.25%) of the patients, while the negative one were present in 21 (47.72%) of the cases. In the group of patients with the positive results different bacteria were found, (Table 4).

Table 4

Bacteria isolated at the injury site

Isolated bacteria	Microbiologic result, n (%)	
	positive	negative
Staphilococcus aureus	9 (20.45)	21 (47.72)
Pseudomonas aeruginosa	7 (15.90)	
Proteus species	4 (9.09)	
Acinetobacter baumannii	3 (6.81)	

In all the cases fracures healed, while 15 (38.59%) of them developed complications. The highest number of complications was present in fractures with big comminution (8; 18.16%). Osteomyelitis developed in 3 (6.81%) of the patients. It is also important to mention other complications like 2 (4.54%) cases of dysfunction in adjacent joints. There was soft tissue infection around pins in 3 (6.81%) cases and in one case unequality was bigger than 3%. The level of comminution was highly statistically significant for the appearance of complications ($\chi^2 = 14.32$; $p < 0.01$).

Regarding functional therapeutic results, the period of monitoring of the patients lasted 8.3– 38.4 months, so the average period was 25.7 months long. The mentioned period provided good and reliable conclusions related to the results of the treatment. Good results of the treatment were noticed in 23 (63.63%) of all the injured, satisfactory results of the treatment in 10 (22.72%), and inadequate in 6 (13.63%) of the cases.

Table 5

Lenght of hospitalization in relation to the type of fractures

Type of fracture	Lenght of hospitalization										Average lenght of hospitalization (days)
	15 days		up to 20 days		up to 30 days		over 30 days		total		
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
Small	6	(13.63)	8	(18.18)	2	(4.54)	0		16	(36.36)	19.3
Medium	1	(2.27)	4	(9.09)	10	(22.72)	3	(6.81)	18	(40.90)	28.6
Big	0		0		3	(6.81)	7	(15.90)	10	(22.72)	36.00
Total	7	(15.90)	12	(27.27)	15	(34.09)	10	(22.72)	44	(100)	27.96

Injured patients were treated in hospital from 15 to 30 and more days. The average period spent in hospital for all the injured was 27.96 days. The average period of hospitalization for the injured with small comminution was 19.3 days, with moderate comminution 28.6 days, and with big comminution 36 days. Most of the injured (15; 34.09%) were hospitalized up to 30 days. From that number, 10 (22.72%) injured had moderate comminuton, and 3 (6.81%) patients had big comminution. For 12 (27.27%) injured the period of hospitalization took up to 20 days, where 8 (18.18%) of them had small comminution and 4 of them (9.09%) had big comminution. Ten injured (22.72%) were hospitalized more than 30 days, 7 (15.90%) of them had big comminution, and

Discussion

It is well-know that the treatment of combat-related injuries differs from the treatment applied in peaceful conditions [1]. Also, it is well-known that combat-related injuries are initially contaminated [2, 3] and that missiles can cause mass destruction of the soft tissue, bones and other structures [4, 5]. These facts imply different approachs than those the surgeons meet in everyday procedures. Instruments that cause combat-related injuries are different, therefore injuries differ, too. Missiles often move very fast, and they are fragmented in the moment of crash. Surgeons sometimes do not know the weapon that causes injury. Therefore, it is very important

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	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
Small	6	(13.63)	8	(18.18)	2	(4.54)	0		16	(36.36)	19.3
Medium	1	(2.27)	4	(9.09)	10	(22.72)	3	(6.81)	18	(40.90)	28.6
Big	0		0		3	(6.81)	7	(15.90)	10	(22.72)	36.00
Total	7	(15.90)	12	(27.27)	15	(34.09)	10	(22.72)	44	(100)	27.96

Injured patients were treated in hospital from 15 to 30 and more days. The average period spent in hospital for all the injured was 27.96 days. The average period of hospitalization for the injured with small comminution was 19.3 days, with moderate comminution 28.6 days, and with big comminution 36 days. Most of the injured (15; 34.09%) were hospitalized up to 30 days. From that number, 10 (22.72%) injured had moderate comminuton, and 3 (6.81%) patients had big comminution. For 12 (27.27%) injured the period of hospitalization took up to 20 days, where 8 (18.18%) of them had small comminution and 4 of them (9.09%) had big comminution. Ten injured (22.72%) were hospitalized more than 30 days, 7 (15.90%) of them had big comminution, and

Discussion

It is well-know that the treatment of combat-related injuries differs from the treatment applied in peaceful conditions [1]. Also, it is well-known that combat-related injuries are initially contaminated [2, 3] and that missiles can cause mass destruction of the soft tissue, bones and other structures [4, 5]. These facts imply different approachs than those the surgeons meet in everyday procedures. Instruments that cause combat-related injuries are different, therefore injuries differ, too. Missiles often move very fast, and they are fragmented in the moment of crash. Surgeons sometimes do not know the weapon that causes injury. Therefore, it is very important

for a surgeon to know the mechanisms that can cause injuries and possible types of damages in order to make an appropriate evaluation of each patient's condition and to apply optimal methods in management of injuries. There are principles of surgical treatment of tibia fractures that are common for combat-related injuries and for injures in peaceful conditions.

Our experience shown in this study is related to the elements of definitive operative management of lower extremities fractures applied as it was imposed by medical doctrine 20 years ago. In the echelons of combat-related injuries management, internal fixation was in the last place of the treatment procedure. Meanwhile, new studies show that there is a trend of temporal and spatial approaching of external and internal fixation to the war environment, so it starts from the hypothesis that the performance of these surgical procedures is possible even at battlefield. Possley et al. [6] made a study based on the analysis of 55 consecutive tibia fractures inflicted in war environment, that were initially managed by external fixation. They especially paid attention to complications related to the procedure. They concluded that important complications as neurovascular damages, mechanical dysfunctions and osteomyelitis were not present. External fixation was successful in 77% of the cases, so they concluded that this procedure was safe and efficient in war environment. Rigid external fixation allows aggressive and simultaneous treatment of bones and soft tissues. Bandaging of injuries is easier, and it is possible to put a skin graft on injury, to install irrigation without any fear that bone fragments will be moved. External fixation is very suitable in the treatment of infections.

Stinner et al. [7] analyzed the results in fractures treatment in patients with injuries managed by internal fixation at battlefield. The authors point out that internal fixation at battlefield is rarely performed because there is a limited availability of instruments and radiological support, as well as impossibility to confirm the sterility in the first line at battlefield. Because of the lack of facts, the authors made analysis of 47 injured with internal fixation on 50 fractures in the operating room in the zone of battlefield. The most common were hip fractures forearm and ankle joint and open fractures. The average value of the Injury Severity Score (ISS) was 11.4. Thirty nine of all fractures healed without any complications. There was one case of infection and one case of acute surgical complications. In 10 cases of fractures, including the one with infection, it was necessary to perform additional procedures. Internal fixation at battlefield was managed efficiently, therefore the level of complications did not exceed the usual number.

All the injured in our study received surgical treatment in 6–48 hours. Surgical treatment was provided for the most of the injured in the first 24 hours. In the first 12 hours, the surgical treatment was necessary for 17 of the injured, and in the 48 hours for the 8 of the injured. The treatment was provided in the first 6 hours only for 6.81% of the injured. The percentage is that low because of the conditions at battlefield, the lack of adequate equipment and trained staff .

In our study, fractures healed in all the cases, and 15 of them developed complications. The most of complications were developed in the cases of big comminution. Osteomyelitis was developed in 3 of the cases and it is important to mention other complications like dysfunction in adjacent joints in 2 of the cases. There was soft tissue infection around pins in 3 of the cases, and one patient presented inequality more than 3 cm. The level of fractures had important statistical significance for the presence of complications. Comminution cannot be easily estimated by simple clinical examination, even after radiography. Comminuted fractures are at a high risk for the aspect of osteogenesis, because it is slow and uncertain. And if there is a case of initial contamination, osteogenesis is even more endangered. From the above-written, it can be concluded that it is better when fixation is made earlier during the echelons in the treatment of patients, but we did not have any conditions for it.

As far as the functional results of therapeutic procedures are concerned, the period of monitoring of the injured patients was in the range 8.3–38.4 months, so the average period was 25.7 months. The quoted period gave the possibility to reliably conclude on the results of treatment. Good results of the treatment were achieved in 23 of the cases, satisfactory results in 10 of the cases, while inadequate ones were present in 6 of the cases. In the majority of cases (86%), good or satisfactory results of definitive reconstruction were accomplished. We think that it is a direct result of the fact that we, as far as we could, followed the principles and aims of good clinical practice, like covering and closing of injuries, prevention of infection, reestablishment of the length, alignment, rotation and stability, injury healing and functions regaining [8, 9].

Soft tissues defects of different intensities often follow fractures of other bones, especially in the combat-related injuries. Therefore, infected injury can be present in the moment of wounding, and it can be connected to the longer period of hospitalization that can expose the patients to nosocomial pathogens. All this can contribute to infective complications in the patients. Historically, etiology of infection of combat-related injuries has changed from the clostridium that provoked infections, registered before World War I, to polimicrob infections registered in the Vietnam War, when an increase in the frequency of pathogens resistant to antibiotics was also noticed. New experiences from battlefields indicate gram-negative pathogens that are resistant to more antibiotics, like *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Klebsiella pneumonia* that provoke infections of combat-related injuries. Johnson et al. [10] in their research focused on infectious complications present in tibia fractures. Meanwhile, there were registered recurrent infections provoked by staphylococcus. New studies show that infectious complications and injuries of soft tissues are risk factors that contribute to late amputation after severe lower extremities trauma [11].

Within combat processes, extremities are most commonly the location of injuries connected to the high risk of infectious complications. In about 15% of the injured patients with injuries of extremities, osteomyelitis was pres-

ent, while 17% of present infections were recurrent which in addition makes more complicated the procedure of definitive management of injuries. Bacterial spectrum that provokes these infections involves, apart from the mentioned ones (*Acinetobacter baumannii, Pseudomonas aeruginosa* and *Klebsiella species* that produces ß-laktamase), *Escherichia coli*, as well as methicillin – resistant *Staphylococcus aureus* – MRSA. Surgical debridement [12] and early use of proper antibiotics [13] are the key elements in prevention of infections together with combat-related extremity injuries.

In our study, antibiotic therapy was applied during hospitalization in 37 of all the patients. In the first 6 hours after wounding, only one injured received antibiotic therapy, in 18 of the cases 24 hours passed from the moment of wounding to the moment of antibiotics administration. Twelve hours after wounding, 13 patients received antibiotics, and 5 received them after 48 hours. At first glance it seems that the percentage of those who received appropriate antibiotic therapy in 6–12 hours is not satisfying, however, it should be taken into consideration that new studies on the appropriate use of antibiotic therapy in cases of difficult sepsis and septic shock for example, show that only 50% of them got appropriate antibiotic in the first 6 hours, in the elite units of intensive therapy in peaceful conditions in America and Canada [14, 15]. Even in circumstances of appropriate antibiotics use on time, the rate of mortality in cases of difficult sepsis and septic shock is unacceptably high [16].

Intraoperatively, during surgical hospitalization, smear was taken from injuries of any patients. Bacterial analysis showed the positive result in half of the cases. In the group of the patients with the positive results different bacteria were found, and the results, in part, match with the similar studies [12, 13]. (*Staphylococcus aureus, Pseudomonas aeruginosa, Acinetobacter baumannii*).

The outcomes of combat-related injury depends on the type and character of the instrument that caused injury. The bigger amount of kinetic energy is used, the bigger will be the destruction of tissues, and fractures will be multifragmented with bigger bone destruction. Injury contamination is also significant. Different wounding factors influence specific processes present in an injury. The loss of blood causes the beginning of pathophysiological reactions that lead to ischemic-reperfusion damages. In injury of arterial blood vessels that feed muscle mass, damages of soft tissue are even more expressed.

The injured patients were monitored during 25 months following the treatment, which allowed us to make reliable conclusions on the methods and quality of treatment. Good functional results were confirmed in most of the cases, satisfactory results in one fifth of the patients, while inadequate results in 13.63%. The key element in the analysis of the functional capacity of the injured, meaning the restoration of the functions of the bone and joint system of the lower extremities is the fact that there was no need for amputation in any of the cases. A big study on 569 injured in peaceful conditions, was focused on the results of severe trauma of the lower extremities. The two results were present – reconstruction or amputation, and the functional capacity of the injured was evaluated after two years [17, 18]. The period of monitoring was almost identical to our period, our sample, indeed, was smaller, but there were involved primary infected combat-related injuries and there was no amputation of any height. One of the new studies that analyzed the return to active military service of 395 American injured patients who had their extremities amputated, showed that from the quoted number 65 patients returned to active military service [19]. The authors concluded that compared to the period 1980–1990 when out of 469 injured with amputation, 11 returned to active military service, this percentage increased by over 16% as a direct consequence of improvement in the management of the injured. Lately, there are lots of analysis of risk factors for delayed amputation [20]. In our study, none of our patients, among those with the inadequate functional results, was at risk of amputation. Today, it is considered that the functional result between those who had primary amputation and those who had their lower extremities saved is not very different [21] and that the quality of life depends more on the height of amputation in cases of the lower extremities (below knees and thighs) [22]. Of course, there are complications directly related to the trauma and amputation in cases of combat-related injuries, for example heterotopic ossification [23].

Regarding complications of difficult lower extremities injures, in our study osteomyelitis developed in 3 of the patients. It is important to mention other complications, like 2 patients with dysfunction in adjacent joints. In 3 of the cases there was soft tissues infection around pins, and in one case unequality was higher than 3 cm. These percentages are visibly lower than the ones mentioned by other authors. Harris et al. [24] reported the following complications in the injured that had their extremities saved after severe injuries in peaceful conditions: infections (23.2%), osteomyelitis (8.6%) and dysfunctions (31%) of the cases.

During the 25-month monitoring period of the injured in our study, there were no cases of fatalities. Numerous studies have ascertained that 10% of soldiers killed in battle bleed to death from extremity wounds. In the study of Dorlac et al. [25] authors examined the treatment course and outcomes of civilian patients who exsanguinated from isolated penetrating extremity injuries. In this study all the patients died (n = 14), and 93% succumbing within 12 hours.

Conclusion

The treatment of lower extremities combat-related injuries presents a very complex therapeutic problem that requires management in echelons and team work of different fields. Stabilization of bone elements has special importance in the treatment of lower extremities combat-related injuries and presents the key element that substantially influences the success of treatment.

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