

PRINCIPI LEČENJA PRELOMA KARLICE KOD POLITRAUMATIZOVANIH PACIJENATA

PREGLEDNI RAD

REVIEW ARTICLE

PRINCIPLES OF PELVIC FRACTURE TREATMENT IN POLYTRAUMA PATIENTS

Uroš Dabetić¹, Danilo Golubović², Jovana Grupković¹, Marko Ilić^{1,3}, Dejan Aleksandrić⁴, Goran Tulić^{1,3}

¹ Univerzitetski klinički centar Srbije, Klinika za ortopedsku hirurgiju i traumatologiju, Beograd, Srbija

² Gradski zavod za hitnu medicinsku pomoć Beograd, Beograd, Srbija

³ Univerzitet u Beogradu, Medicinski fakultet, Beograd, Srbija

⁴ Institut za ortopediju „Banjica“, Beograd, Srbija

¹ University Clinical Center of Serbia, Clinic for Orthopedic Surgery and Traumatology, Belgrade, Serbia

² City Medical Emergency Department, Belgrade, Serbia

³ University of Belgrade, Faculty of Medicine, Belgrade, Serbia

⁴ Institute for Orthopedic Surgery "Banjica", Belgrade, Serbia

SAŽETAK

Uvod: Lečenje preloma karlice predstavlja jedan od najvećih izazova u ortopedskoj hirurgiji i traumatologiji. Radi se o povredama čiji mortalitet dostiže i do 21%, te je od velike važnosti prepoznavanje i adekvatno lečenje. Najčešći uzrok smrtnog ishoda u prva 24 sata od povrede je krvarenje. Prelomi karlice variraju od jednostavnih preloma do kompleksnih fraktura sa posledičnom hemodinamskom nestabilnošću. Cilj ove studije je da proceni trenutne standarde zbrinjavanja preloma karlice, kao i da ukaže na moguću strategiju poboljšanja krajnjeg ishoda lečenja.

Rezultati: Kada protokol ne postoji, dežurni tim se vodi smernicama koje su im dostupne. U novije vreme DCR se smatra vodećim principom u zbrinjavanju politraumatizovanih pacijenata. Primarno je uspostaviti kontrolu krvarenja – primenom PPP-a, angiografskom embolizacijom ili REBOA metodom. U literaturi se primena karličnih povski preporučuje kao primarni vid zbrinjavanja povreda karlice od strane službe hitne pomoći ili obučenog lica u predbolničkim uslovima. Spoljašnja fiksacija nestabilnih preloma karlice je jedan od ključnih koraka u sklopu DCR protokola. ORIF preloma karlice je definitivni tip fiksacije preloma, ali je indikovana kod hemodinamski stabilnog pacijenta.

Zaključak: S obzirom na anatomske karakteristike karlične duplje, povrede karličnog prstena predstavljaju samo deo spektra politraume, tako da se lečenje u početku bazira na hemodinamskoj stabilizaciji pacijenta (DCR protokol). Lečenje ovakvih pacijenata zahteva multidisciplinarni pristup. Plasiranje spoljašnjeg fiksatora u sklopu DCO protokola ima ulogu u kontroli krvarenja, te je to metoda izbora kod hemodinamski nestabilnih pacijenata. Definitivna fiksacija preloma karlice (ORIF) se sprovodi kod stabilnih pacijenata, koji nisu životno ugroženi.

Ključne reči: prelom karlice, politrauma, krvarenje, DCO

ABSTRACT

Introduction: The treatment of pelvic fractures is one of the biggest challenges in orthopedic surgery and traumatology. Mortality from these injuries can be as high as 21%, which is why recognizing them and providing adequate treatment is of great importance. The most common cause of death in the first 24 hours following injury is bleeding. Pelvic fractures range from simple to complex fractures with consequent hemodynamic instability. The aim of this study is to assess current standards of pelvic fracture care, as well as to indicate a possible strategy to improve the final outcome of treatment.

Results: When there is no established protocol, the on-duty team of doctors is guided by the guidelines available to them. More recently, DCR has been considered a guiding principle in the care of polytraumatized patients. It is of primary importance to establish bleeding control – using PPP, angiographic embolization or the REBOA method. The use of pelvic bandages is recommended in literature as the primary form of care for pelvic injuries by the emergency service or by a trained person in pre-hospital conditions. External fixation of unstable pelvic fractures is one of the key steps in the DCR protocol. ORIF of pelvic fracture is a definite type of fracture fixation, but it is performed only in hemodynamically stable patients.

Conclusion: Due to the anatomical characteristics of the pelvic cavity, pelvic ring injuries represent only a part of the spectrum of polytrauma, therefore the treatment is initially based on the hemodynamic stabilization of the patient (DCR protocol). The treatment of such patients requires a multidisciplinary approach. Placement of an external fixator as part of the DCO protocol has a role in bleeding control and is the method of choice in hemodynamically unstable patients. Definitive pelvic fracture fixation (ORIF) is performed in hemodynamically stable patients, who are not in life-threatening condition.

Key words: pelvic fracture, polytrauma, bleeding, DCO

Autor za korespondenciju:

Uroš Dabetić

Klinika za ortopedsku hirurgiju i traumatologiju, Univerzitetski klinički centar Srbije

Pasterova 2, 11000 Beograd, Srbija

Elektronska adresa: urosdabetic1983@gmail.com

Corresponding author:

Uroš Dabetić

Clinic for Orthopedic Surgery and Traumatology, University Clinical Center of Serbia

2 Pasterova Street, 11000 Belgrade, Serbia

E-mail: urosdabetic1983@gmail.com

Primljeno • Received: January 25, 2022; **Revidirano • Revised:** February 14, 2022; **Prihvaćeno • Accepted:** February 15, 2022; **Online first:** June 25, 2022

DOI: 10.5937/smcl3-36072

UVOD

Lečenje preloma karlice predstavlja jedan od najvećih izazova u ortopedskoj hirurgiji i traumatologiji. Ovi prelomi nastaju usled dejstva jake sile, i to u saobraćajnim udesima (60%), prilikom pada sa visine (30%), kao i pri ustrelnim i industrijskim nezgodama [1]. Kod manjeg broja starijih pacijenata, mogu nastati usled pada sa sopstvene visine, a usled osteodistrofičnih promena koštano-zglobnog sistema. S obzirom da se radi o povredama čiji mortalitet dostiže i 21% [2], od velike važnosti su, kako prepoznavanje, tako i pravovremeno i adekvatno lečenje. Krvarenje je najčešći uzrok smrtnog ishoda u prva 24 sata od povrede.

Prelomi karlice variraju od jednostavnih preloma do kompleksnih višestrukih fraktura sa posledičnom hemodinamskom nestabilnošću. Kod politraumatizovanih pacijenata, prelomi karlice su zastupljeni u čak 20% slučajeva [3]. Kod zbrinjavanja ovakvih pacijenata, neophodan je multidisciplinarni pristup lečenju – tim sastavljen od iskusnih ortopedskih i opštih hirurga, kao i interventnog radiologa i anesteziologa.

U nekoliko objavljenih studija je zapaženo da je u centrima u kojima je napravljen i primenjen algoritam za zbrinjavanje preloma karlice kod hemodinamski nestabilnih pacijenata došlo da značajnog opadanja mortaliteta [4–7].

Cilj ove studije je da proceni trenutne standarde zbrinjavanja preloma karlice, kao i da ukaže na moguću strategiju poboljšanja krajnjeg ishoda lečenja.

POLITRAUMA

Politrauma, prema novoj Berlinskoj definiciji, podrazumeva slučajeve sa skorom na skali povreda (engl. *Abbreviated Injury Scale – AIS*) ≥ 3 , za najmanje dva anatomska regiona tela, i sa jednim od sledećih pet fizioloških parametara, odnosno sa kombinacijom dva ili više navedena parametra:

1. Hipotenzija (sistolni pritisak ≤ 90 mmHg)
2. Gubitak svesti (Glazgovska skala kome - *Glasgow Coma Scale* ≤ 8)
3. Acidoza
4. Koagulopatija (parcijalno tromboplastinsko vreme ≥ 40 s)
5. Starost pacijenta (≥ 70 godina) [8].

Kod politraumatizovanog pacijenta, barem jedna, od dve ili više povreda, ugrožava njegov život.

PRVI KORAK U ZBRINJAVANJU PRELOMA KARLICE

Protokol za zbrinjavanje preloma karlice varira od ustanove do ustanove. Kada protokol ne postoji, dežurni tim se vodi smernicama koje su im dostupne. U novije

INTRODUCTION

Treating pelvic fracture is one of the greatest challenges in orthopedic surgery and traumatology. Pelvic fractures occur as the result of powerful force, primarily in traffic accidents (60%), in falls from height (30%), as well as in shooting and industrial accidents [1]. In a small number of elderly patients, pelvic fracture may occur as the result of the patient falling from standing height, due to osteodystrophic changes in the bone joint system. Bearing in mind that mortality in these injuries can be as high as 21% [2], it is of great importance that they should be recognized and treated adequately and on time. Bleeding is the most common cause of death in the first 24 hours following injury.

Pelvic fractures vary from simple fractures to complex multiple fractures with consequent hemodynamic instability. In polytraumatized patients, pelvic fractures are present in as many as 20% of cases [3]. In treating these patients, a multidisciplinary approach is necessary – a team made up of experienced orthopedic and general surgeons, including also an interventional radiologist and anesthesiologist.

In several studies published so far, it has been noted that, in those centers where an algorithm for treating pelvic fracture in hemodynamically unstable patients has been designed and put into use, a significant drop in mortality has occurred [4–7].

The aim of this study is to assess the current standards of pelvic fracture treatment, as well as to indicate the possible strategy for improving the final outcome of treatment.

POLYTRAUMA

According to the new Berlin Definition, polytrauma indicates cases with an Abbreviated Injury Scale (AIS) score ≥ 3 , for at least two anatomical regions of the body, and with one of the following five physiological parameters, or with a combination of two or more of these parameters:

1. Hypotension (systolic blood pressure ≤ 90 mmHg)
2. Loss of consciousness (Glasgow Coma Scale ≤ 8)
3. Acidosis
4. Coagulopathy (partial thromboplastin time ≥ 40 s)
5. Patient age (≥ 70 years) [8].

In a polytraumatized patient, at least one of two or more injuries is life-threatening.

FIRST STEP IN TREATING PELVIC FRACTURE

The protocol for treating pelvic fracture varies from hospital to hospital. When there is no established protocol, the on-duty team of doctors are guided by available guidelines. As of late, damage control resuscitation

vreme, DCR (engl. *damage control resuscitation*) se smatra vodećim principom u zbrinjavanju politraumatizovanih pacijenata. DCR je strategija koja za cilj ima da zaustavi krvarenje, kao i da spreči ili preokrene razvoj komponenti letalnog traumatskog trijasa - hipotermije, acidoze i kogaulopatije, kroz niz kombinovanih terapijskih protokola [9].

Međutim, primena ove strategije zavisi od mnoštva faktora – kapaciteta same bolnice, opremljenosti, osposobljenosti hirurškog tima za *damage control* hirurgiju, kao i mogućnosti izvođenja hitne angiografije (embolizacije krvnih sudova).

Nezavisno od izbora strategije, neophodno je uraditi dijagnostiku (klinički pregled, laboratorijske analize, RTG, EHO, MSCT), napraviti procenu težine povreda, procenu potrebe za neinvazivnom/invazivnom stabilizacijom karlice, procenu eventualnih povreda abdomena, te doneti odluku o potrebi za hirurškim lečenjem i angiografijom [10].

IZVORI KRVARENJA

Mogući izvori krvarenja su arterije, vene i spongiozne kosti [11]. Neophodno je utvrditi izvor i uspostaviti kontrolu krvarenja. Veffs i saradnici su u svojoj studiji naveli da je, kod hemodinamski nestabilnih pacijenata sa povredom karlice i hipotenzijom otpornom na reanimaciju, u 70% slučajeva bilo prisutno arterijsko krvarenje [12].

Takođe, određeni tipovi preloma su u korelaciji sa povredom određenih krvnih sudova – prelomi pubičnih kostiju koreliraju sa povredom obturatornih krvnih sudova; dislokacija sakroilijačnog zgloba (povreda po tipu smicanja) korelira sa venskim krvarenjem, i to iz glutealnih i hipogastričnih grana.

KARLIČNE POVESKE

Primena karličnih poveski se u literaturi preporučuje kao primarni vid zbrinjavanja povreda karlice od strane službe hitne pomoći ili obučenog lica u predbolničkim uslovima. Karlične poveske predstavljaju neinvazivni vid spoljašnje kompresije, koji se pokazao koristan u kontroli krvarenja i privremenoj stabilizaciji karličnog prstena [10].

Karlične poveske treba pozicionirati oko velikih trohantera i pubične simfize, kako bi primenjeni pritisak doveo do privremene stabilizacije preloma karlice, addukcije nogu i smanjenja unutrašnje zapremine karlične duplje.

SPOLJAŠNJA FIKSACIJA PRELOMA KARLICE

Spoljašnja perkutana fiksacija mehanički nestabilne karlice predstavlja jedan od ključnih koraka u sklopu DCR protokola politraumatizovanih pacijenata sa

(DCR) has been considered the leading principle in treating polytraumatized patients. DCR is a strategy whose aim is to stop bleeding, as well as to prevent or reverse the development of the components of the trauma triad of death – hypothermia, acidosis, and coagulopathy, through a series of combined therapeutic protocols [9].

However, the implementation of this strategy depends on a number of factors – the capacities of the hospital, equipment, the capability of the surgical team to perform damage control surgery, as well as the possibility of performing urgent angiography (blood vessel embolization).

Regardless of the choice of strategy, it is necessary to perform the following: requisite diagnostics (clinical examination, laboratory analyses, X-ray, ECHO, MSCT), assessment of the severity of the injuries, assessment of the need for noninvasive/invasive pelvic stabilization, assessment of possible abdominal injuries, and then reach a decision on the need for surgical treatment and angiography [10].

SOURCES OF BLEEDING

The possible sources of bleeding are arteries, veins, and cancellous bones [11]. It is necessary to determine the source and establish control of the bleeding. In their study, Wijffels et al. stated that in 70 % of cases of hemodynamically unstable patients with pelvic injury and hypotension resistant to resuscitation, arterial bleeding was present [12].

Also, certain types of fractures correlate with injury of certain blood vessels – pubic bone fractures correlate with injury to obturator blood vessels; dislocation of the sacroiliac joint (shear injury) correlates with venous bleeding, primarily from gluteal and hypogastric branches.

ABDOMINAL-PELVIC TOURNIQUETS

The application of abdominal-pelvic tourniquets is recommended in literature as the primary method of taking care of pelvic injuries by the emergency services or by a trained person, in prehospital care. Abdominal-pelvic tourniquets are a noninvasive form of external compression, which has proven useful in the control of bleeding and for temporarily stabilizing the pelvic ring [10].

Abdominal-pelvic tourniquets should be positioned around the great trochanters and the pubic symphysis, so that the pressure applied would lead to temporary stabilization of pelvic fracture, leg adduction, and a decrease of the internal volume of the pelvic cavity.

EXTERNAL PELVIC FRACTURE FIXATION

External percutaneous fixation of a mechanically unstable pelvis is one of the key steps in the DCR protocol

prelomom karlice. Osim što se stabilizuje karlični prsten, cilj primene ove metode je i smanjenje volumena karlične duplje, kako bi došlo do tamponade venskog krvarenja [13].

U literaturi su opisana dva glavna principa spoljašnje fiksacije, u zavisnosti od vrste preloma karlice. Za rotaciono nestabilne, antero-posteriorne kompresivne i lateralne kompresivne prelome, metoda izbora je prednja spoljašnja fiksacija. Zadnja spoljašnja fiksacija (*C clamp*) je pristup koji se preporučuje kod vertikalno nestabilnih preloma karlice, kako bi se postigla stabilnost posteriornih segmenata karlice [10,14].

Spoljašnja fiksacija se u najvećem broju slučajeva sprovodi u sklopu DCR protokola i predstavlja privremenu metodu stabilizacije preloma i kontrole krvarenja, koja, međutim, u određenom broju slučajeva, može biti i definitivna metoda fiksacije [15]. Tada imobilizacija preloma spoljašnjim fiksatorom traje 6 – 12 nedelja, sve dok se ne pojave klinički i radiografski znaci zarastanja preloma.

Kod primene ove metode, neophodno je da hirur bude iskusan i upoznat sa principima spoljašnje fiksacije karlice, s obzirom na moguće komplikacije, u smislu povreda neurovaskularnih struktura neadekvatnim pozicioniranjem klinova, potom popuštanja fiksacije i pojave ponovne nestabilnosti, kao i u smislu razvoja infekcija na mestu plasiranih šrafova.

PREPERITONEALNO TAMPONIRANJE KARLICE (PPP)

Glavni izvor akutnog retroperitonealnog krvarenja kod hemodinamski nestabilnih pacijenata sa povredama karličnog prstena pripisuje se venskom krvarenju, u 80% – 90% svih slučajeva, a potiču iz presakralnog i paravezikularnog venskog plexusa, kao i od krvarenja spongioznih kostiju, usled ilijačnih i sakralnih fraktura i prekida sakroilijačnog zglobova, dok je 10% – 20% arterijskog porijekla [16].

Koncept „direktnog” preperitonealnog karličnog tamponiranja (engl. *preperitoneal pelvic packing – PPP*), opisanog u Denveru, predstavlja posebnu hiruršku metodu, prilikom koje se pravi suprapubična incizija, koja omogućava direktni retroperitonealni pristup, nakon čega se vrši tamponiranje [17].

Modifikovana PPP metoda omogućava efikasnije tamponiranje unutar skrivenog retroperitonealnog prostora, pri čemu se tri jastučića za laparotomiju postavljaju sa svake strane mokraćne bešike, tako da budu upakovani ispod oboda karlice a prema ilijačnim krvnim sudovima, bez potrebe ekspaniranja retroperitonealnog prostora [10]. Ovom tehnikom, laparotomija na srednjoj liniji se može izvesti kroz odvojeni rez, proksimalno od suprapubičnog pristupa, ako postoje

for polytraumatized patients with pelvic fracture. In addition to stabilizing the pelvic ring, the goal in applying this method is also to decrease the volume of the pelvic cavity, in order to bring about the tamponade of venous hemorrhage [13].

Two main principles of external fixation, depending on the type of pelvic fracture, have been described in literature. For rotationally unstable, anteroposterior compression fractures and lateral compression fractures, the method of choice is anterior external fixation. Posterior external fixation (*C clamp*) is the approach recommended in vertically unstable pelvic fractures, in order to achieve stability of posterior pelvic segments [10,14].

In most cases, external fixation is carried out within the DCR protocol and represents a temporary method for stabilizing the fracture and establishing control of the bleeding, which, however, in a certain number of cases, may be the definitive method of fixation [15]. In such cases, immobilization of the fracture with an external fixator lasts 6 – 12 weeks, until clinical and radiographic signs of fracture healing are registered.

In the application of this method, it is necessary that the surgeon is experienced and familiar with the principles of external pelvic fixation, due to the possibility of the development of complications, such as injury to the neurovascular structures caused by inappropriate positioning of the pins, loosening of the fixation and renewed instability, as well as the development of infection at the placement site of the pins.

PREPERITONEAL PELVIC PACKING (PPP)

The primary source of acute retroperitoneal bleeding in hemodynamically unstable patients with pelvic ring injury is attributed to venous bleeding, in 80% – 90% of all cases, and it originates from the presacral and paravesical venous plexus, as well as from bleeding from the cancellous bones, due to iliac and sacral fractures and the disruption of the sacroiliac joint, while in 10% – 20% of cases the bleeding is of arterial origin [16].

The concept of ‘direct’ preperitoneal pelvic packing (PPP), as described in Denver, is a special surgical method, wherein a suprapubic incision is made, enabling direct retroperitoneal access, upon which packing is performed [17].

The modified PPP method enables more efficient packing within the hidden retroperitoneal space, wherein three laparotomy pads are placed on each side of the urinary bladder, in such a way as to be packed below the rim of the pelvis and towards the iliac blood vessels, without there being any need to expose the retroperitoneal space [10]. Using this technique, mid-line laparotomy can be executed through a separate incision, proximally to the suprapubic access, if there are

pridružene intraabdominalne povrede [18]. Ova metoda se preporučuje zajedno sa spoljašnjom fiksacijom kod hemodinamski i mehanički nestabilnih pacijenata. Nedostaci ove tehnike ogledaju se u tome što ona zahteva dodatnu operaciju radi uklanjanja obloga - jastučića, neefikasna je za arterijsko krvarenje i može kompromitovati buduće hirurške intervencije [11].

ANGIOGRAFSKA EMBOLIZACIJA

Angiografska embolizacija je tehnika kojom se u arterijski krvni sud kateterom plasiraju sintetički materijali, koji se nazivaju embolički agensi, i na taj način se blokira tok krvi u datom području tela. Arterijsko krvarenje se javlja u oko 10% – 15% svih krvarenja kod hemodinamski nestabilnih karličnih povreda, što je obično praćeno hipotenzijom, koja je otporna na reanimaciju i mehaničku stabilizaciju [19]. Arterijske povrede imaju lošu prognozu, posebno kada su zahvaćeni veći krvni sudovi. Unutrašnja ilijačna arterija predstavlja glavni izvor arterijskog krvarenja u karlici (86%), sa najvećim brojem lezija na njenoj glavnoj grani [11]. Indikacije za angiografiju su sledeće: hemodinamska nestabilnost otporna na reanimaciju, delimično responzivni pacijenti sa kontrastnom ekstrasvazacijom na CT-u, kao i progresivni pad nivoa hemoglobina, koji zahteva četiri ili više jedinica krvi [11].

REANIMACIJSKA ENDOVASKULARNA BALONSKA OKLUZIJA AORTE (REBOA)

Reanimacijska endovaskularna balonska okluzija aorte (engl. *resuscitative endovascular balloon occlusion of the aorta* – REBOA) predstavlja perkutanu transfemoralnu proceduru, koja uključuje postavljanje endovaskularnog balona u aortu, u cilju kontrole arterijskog krvarenja i privremenog održavanja krvnog pritiska kod traumatskog hemoragičnog šoka [11,20]. Visoko je zavisna od funkcionalnog pristupa femoralnoj arteriji, a rano formiranje ovog pristupa je od velikog značaja. Ova metoda je poslednjih godina postala alternativa za urgentnu torakotomiju kod hemodinamski nestabilnih politraumatizovanih pacijenata.

REBOA se može sprovesti u Zoni 1 (supracelijačna aorta ili descendentna aorta), Zoni 2 (pararenalna aorta) ili Zoni 3 (infrarenalna aorta). Zona 2 se uglavnom izbegava, zbog moguće ishemije visceralnih organa. Zona 3 je optimalna kod krvarenja u karlici, zato što se prevenira ishemija visceralnih organa a istovremeno omogućava dugo vreme okluzije (4 – 6 h) [21].

REBOA je samo privremeno rešenje, a definitivna kontrola krvarenja se mora postići. Jedan od glavnih nedostataka ove tehnike je pojava ishemijskih oštećenja organa i tkiva koja mogu dovesti i do višestrukog otkazivanja organa (engl. *multiple organ dysfunction*

associated intraabdominal injuries [18]. This method is recommended along with external fixation in hemodynamically and mechanically unstable patients. The drawbacks of this method are reflected in the following: it requires additional surgery, which is necessary to remove the pads; it is inefficient for arterial bleeding; it may compromise future surgical procedures [11].

ANGIOGRAPHIC EMBOLIZATION

Angiographic embolization is a technique whereby synthetic materials, called embolic agents, are injected into an artery via catheter, which results in blood flow blocking in the given region of the body. Arterial bleeding occurs in approximately 10% – 15% of all hemorrhages in hemodynamically unstable pelvic injuries, which is usually accompanied by hypotension, resistant to resuscitation or mechanical stabilization [19]. Arterial injuries have an unfavorable prognosis, especially when larger blood vessels are involved. The internal iliac artery is the main source of arterial bleeding in the pelvis (86%), with the greatest number of lesions occurring on its main branch [11]. Indications for angiography are as follows: hemodynamic instability resistant to reanimation, partially responsive patients with CT contrast extravasation, as well as a progressive fall of the hemoglobin level, requiring the transfusion of four or more units of blood [11].

RESUSCITATIVE ENDOVASCULAR BALLOON OCCLUSION OF THE AORTA (REBOA)

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a percutaneous transfemoral procedure, which includes the placement of an endovascular balloon into the aorta, for the purpose of controlling arterial bleeding and temporarily maintaining blood pressure in traumatic hemorrhagic shock [11,20]. This procedure is highly dependent on a functional approach to the femoral artery, and early implementation of this approach is of the utmost importance. This method has become the alternative for emergency thoracotomy in hemodynamically unstable polytraumatized patients.

REBOA can be performed in Zone 1 (supraceliac aorta or descendant aorta), Zone 2 (pararenal aorta), or Zone 3 (infrarenal aorta). Zone 2 is usually avoided, due to possible visceral organ ischemia. Zone 3 is the optimal approach in pelvic hemorrhage, as it prevents visceral organ ischemia, at the same time enabling a long occlusion time (4 – 6 h) [21].

REBOA is just a temporary solution, while definitive hemorrhage control still needs to be achieved. One of the main limitations of this technique is the occurrence of ischemic organ and tissue damage, which may lead to multiple organ dysfunction syndrome (MODS), due

syndrome – MODS) usled ishemijsko – reperfuzijske reakcije. Ovaj problem se prevenira kratkotrajnom REBOA procedurom, intermitentnom REBOA procedurom (iREBOA), Zona 3 REBOA procedurom i parcijalnom REBOA procedurom [22,23].

DCO U SKLOPU DCR-A

Nakon teške traume, razvoj kliničke slike određuju tri glavna faktora:

1. Inicijalni stepen povrede („*first hit*” – opterećenje traumom)
2. Individualni biološki odgovor organizma povređenog
3. Vrsta lečenja („*second hit*” – opterećenje operacijom) [24].

U sklopu DCR protokola, svoje mesto ima i *damage control orthopedics – DCO*.

DCO je hirurška strategija koja se fokusira na:

1. postizanje kontrole krvarenja – *ABCDE* pristup (engl. *airway, breathing, circulation, disability, exposure – ABCDE approach*), osim u uslovima katastrofalnog krvarenja kada se primarno zbrinjava komponenta C;
2. sprečavanje kontaminacije mekog tkiva – debridman rane;
3. ranu privremenu stabilizaciju preloma – uglavnom spoljašnjom fiksacijom, što je metoda izbora jer je ekspeditivna i minimalno invazivna, ali i jednostavnijim procedurama, kao što su trakcija i gips;
4. stabilizaciju pacijenta – zahteva dobru komunikaciju hirurškog tima sa anesteziologom, s obzirom da anesteziolog ima najbolju sliku o opštem stanju pacijenta; sve terapijske procedure su usmerene na dostizanje željenih vrednosti – srednji arterijski pritisak > 60 mmHg, puls < 100, diureza = 0,5 – 1,0 ml/kg/h, serumski laktati < 2,5 i normalan bazni deficit (-2 do +2);
5. izbegavanje „*second hit*” i letalne trijade [9].

Ovakav pristup minimalizuje operativno vreme i gubitak krvi, a istovremeno olakšava negu bolesnika i omogućava raniju i bolju pokretljivost pacijenta [25]. Smatra se da je to najkorisniji pristup za pacijente sa udruženom traumom glave i grudnog koša, visokim skorom ozbiljnosti povrede (engl. *injury severity score – ISS*), predispozicijama za razvoj postoperativnih komplikacija, kao i za „*borderline*” pacijente [16]. Kod ovakvih politraumatizovanih pacijenata, izlaganje hirurškoj intervenciji povećava rizik od postoperativnih komplikacija [26]. Ovaj pristup je proizašao iz primera zbrinjavanja pacijenata sa abdominalnom i karličnom traumom, gde se pokazalo da primarno zaustavljanje krvarenja i sekundarna revizija, u cilju definitivnog zbrinjavanja pacijenta, poboljšava postoperativni tok i oporavak [27].

to ischemia-reperfusion injury. This problem is prevented by applying short REBOA, intermittent REBOA (iREBOA), Zone 3 REBOA, and partial REBOA [22,23].

DCO AS A PART OF DCR

After severe trauma, the following three major factors determine the development of clinical presentation:

1. Initial degree of injury ("first hit" – burden of trauma)
2. Individual biological response of the injured patient's body
3. Type of treatment ("second hit" – burden of surgery) [24].

Within the DCR protocol, damage control orthopedics (DCO) also has its place.

DCO is a surgical strategy focused on the following:

1. establishing control of the bleeding – the *ABCDE* (airway, breathing, circulation, disability, exposure) approach, except in conditions of catastrophic bleeding, when component C is primarily focused on;
2. prevention of soft tissue contamination – wound debridement;
3. early temporary stabilization of the fracture – primarily with external fixation, which is the method of choice as it is expedient and minimally invasive, but also with simpler procedures, such as traction and plaster;
4. stabilization of the patient – requires good communication between the surgical team and the anesthesiologist, as it is the anesthesiologist who has the best understanding of the general status of the patient; all treatment procedures are aimed at achieving the desired values – median arterial pressure > 60 mmHg, pulse < 100, urine output = 0.5 – 1.0 ml/kg/h, serum lactates < 2.5, and normal base deficit (-2 to +2);
5. avoiding 'second hit' and the trauma triad of death [9].

Such an approach minimalizes the duration of the procedure and blood loss; at the same time, it makes patient care easier and provides earlier and better mobility of the patient [25]. It is believed to be the most useful approach for patients with associated head and chest trauma, patients with a high injury severity score (ISS), patients with a predisposition for the development of postoperative complications, as well as for 'borderline' patients [16]. In such polytraumatized patients, undergoing surgery increases the risk of postoperative complications [26]. This approach stems from examples of patient care in cases with abdominal and pelvic trauma, where it has transpired that the strategy of primary bleeding control and secondary revision surgery, with the aim of definitive patient treatment, improves the course of postoperative recovery [27].

Kod primene DCO-a, umesto rane potpune fiksacije (< 24 – 36 časova posle povrede), ortoped privremeno stabilizuje prelom pomoću trakcije ili eksterne fiksacije, kod „borderline“ visokorizičnih pacijenata [28]. Za pacijente sa teškim povredama, koagulopatijom, hipotermijom, kao i pacijente koji su u šoku, ovo je metoda prvog izbora.

Kada se lečenje sprovodi po principima DCO-a, važno pitanje jeste u kom je trenutku optimalno izvesti sekundarnu hiruršku intervenciju.

Smatra se da period od 2 – 4 dana nakon povrede nije pogodan za sekundarnu intervenciju. U ovo vreme, imunološke promene su još uvek u toku [29], a generalizovani edem tkiva se još nije povukao [30]. Rezultati velikog istraživanja, kojim je obuhvaćeno 4.314 pacijenata, pokazali su da tajming sekundarne operacije, koja traje duže od tri sata, može biti povezan sa razvojem organske disfunkcije. Pacijenti su podeljeni u odnosu na prisustvo ili odsustvo sindroma disfunkcije više organa – MODS. Kod pacijenata koji su operisani 2 – 4 dana nakon traume, došlo je do otkazivanja organa, dok kod pacijenata koji su sekundarno operisani između 6. i 8. dana, nije došlo do razvoja disfunkcije organa ($p < 0,0001$) [31]. Takođe, istraživanje je pokazalo da je, kod pacijenata koji su ranije operisani, došlo do razvoja jače inflamacije, u odnosu na pacijente koji su operisani kasnije. Stoga, nakon DCO-a, trebalo bi da postoji period čekanja od nekoliko dana pre sekundarne definitivne operacije.

OTVORENA REPOZICIJA I UNUTRAŠNJA FIKSACIJA (ORIF)

Otvorena repozicija i unutrašnja fiksacija (engl. *open reduction and internal fixation* – ORIF) preloma karlice jeste jedna od najkompleksnijih ortopedskih operacija i predstavlja definitivan tip fiksacije preloma. Kod politraumatizovanih pacijenata, otvorena repozicija i unutrašnja fiksacija preloma realizuje se najčešće u drugom aktu, nakon potpune stabilizacije pacijenta, a u cilju omogućavanja najboljeg funkcionalnog oporavka i minimalizovanja poremećaja kvaliteta života i potencijalne stope invaliditeta, u slučaju nelečenog preloma karlice [32,33]. Za vreme stabilizacije pacijenta od strane intenzivista, prelom karlice ostaje stabilizovan spoljašnjim fiksatorom.

U odnosu na vrstu preloma, adekvatnim pristupom se dolazi do mesta preloma, te se učini otvorena repozicija prelomnih fragmenata, koji se potom fiksiraju odgovarajućim implantacionim materijalom – u najvećem broju slučajeva, kompresivnim zavrtnjima, anatomsom pločicom i pripadajućim zavrtnjima. U poređenju sa spoljašnjom fiksacijom, ORIF obezbeđuje anatomsku repoziciju prelomnih fragmenata i superiorniju biomehaničku stabilnost, kao i brži oporavak.

In DCO, instead of early complete fixation (< 24 – 36 hours after injury), the orthopedic surgeon temporarily stabilizes the fracture by means of traction or external fixation, in 'borderline' high-risk patients [28]. For patients with severe injuries, coagulopathy, hypothermia, as well as patients in a state of shock, this is the method of first choice.

When treatment is carried out according to the principles of DCO, an important issue to consider is the optimal moment for carrying out the secondary procedure.

It is believed that the period of 2 – 4 days following injury is not favorable for the second procedure. In this period, immunological changes are still ongoing [29] and generalized edema has as yet not subsided [30]. The results of a large study, which included 4,314 patients, showed that the timing of the secondary operation, which normally lasts more than three hours, may be associated with the development of organ dysfunction. Patients were divided according to the presence or absence of MODS. In patients surgically treated 2 – 4 days following trauma, organ failure did occur, while in patients which had a secondary operation between day 6 and day 8, organ dysfunction did not develop ($p < 0,0001$) [31]. Also, the study showed that, in patients who were operated on earlier, more severe inflammation developed, as compared to patients who were operated on later. Therefore, after DCO, there should be a waiting period of several days before secondary definitive surgery.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF)

Open reduction and internal fixation (ORIF) of pelvic fracture is one of the most complex orthopedic surgical procedures and represents a definitive type of fracture fixation. In polytraumatized patients, open reduction and internal fracture fixation is most often carried out as a second step, after the patient has been completely stabilized, with the aim of providing the best possible functional recovery and minimizing the disruption in the quality of life, as well as minimizing potential invalidity, in case of untreated pelvic fracture [32,33]. While the patient is being stabilized in intensive care, the pelvic fracture remains stabilized with an external fixator.

Depending on the type of fracture, the site of the fracture is accessed using the appropriate approach, open reduction of the fractured fragments is performed, and the fractures are then fixed with the appropriate implantation material – in most cases, with lag screws and with plates. As compared to external fixation, ORIF provides anatomical reduction of fractured fragments and more superior biomechanical stability, as well as faster recovery.

ZAKLJUČAK

Povrede karličnog prstena uglavnom nastaju dejstvom jakih sila, usled čega dolazi do oštećenja, kako skeletnog, tako i drugih organskih sistema. To su retko izolovane povrede (kod starijih pacijenata, nisko energetske povrede), te u najvećem broju slučajeva postoje udružene povrede koštano-zglobnog sistema, grudnog koša, abdomena i/ili glave. To znači da je pravovremeno i adekvatno zbrinjavanje ovih povreda od ključnog značaja, kako na mestu pružanja prve pomoći, tako i u trauma centrima. S obzirom na anatomske karakteristike karlične duplje, povrede karličnog prstena predstavljaju samo deo spektra politraume, tako da se lečenje u početku fokusira na hemodinamsku stabilizaciju pacijenta (DCR protokol). Lečenje ovakvih pacijenata zahteva multidisciplinarni pristup (hemodinamska stabilizacija, PPP, REBOA). Tek kada se osiguraju vitalne funkcije, može se pristupiti lečenju drugih poremećaja, koji primarno ne ugrožavaju život pacijenta.

Plasiranje spoljašnjeg fiksatora, u sklopu DCO protokola, ima ulogu u kontroli krvarenja, te je to metoda izbora kod hemodinamski nestabilnih pacijenata.

Definitivna fiksacija preloma karlice (ORIF) se inicijalno sprovodi kod stabilnih pacijenata, koji nisu životno ugroženi, ili po stabilizaciji politraumatizovanih pacijenata. Predstavlja nezamenjiv način lečenja, u pogledu funkcionalnog oporavka pacijenta i smanjenja stope invaliditeta.

Iako je stopa mortaliteta kod ovih pacijenata i dalje visoka, pravovremenim pružanjem pomoći i ispravnim odabirom i primenom terapijskih metoda, pomenuta stopa se uspešno smanjuje.

SPISAK SKRAĆENICA KORIŠĆENIH U TEKSTU

- ABCDE – pristup koji se koristi za kontrolu krvarenja (engl. *airway, breathing, circulation, disability, exposure – ABCDE approach*)
DCO – engl. *damage control orthopedics*
DCR – protokol za hemodinamsku stabilizaciju pacijenta (engl. *damage control resuscitation*)
ISS – skor ozbiljnosti povrede (engl. *injury severity score*)
MODS – sindrom disfunkcije više organa (engl. *multiple organ dysfunction syndrome*)
ORIF - otvorena repozicija i unutrašnja fiksacija (engl. *open reduction and internal fixation*)
PPP – preperitonealno karlično tamponiranje (engl. *preperitoneal pelvic packing*)
REBOA – reanimacijska endovaskularna balonska okluzija aorte (engl. *resuscitative endovascular balloon occlusion of the aorta*)

Sukob interesa: Nije prijavljen.

CONCLUSION

Pelvic ring injuries mainly occur as the result of powerful force, resulting in injury, not only to the skeletal, but to other body systems as well. These are rarely isolated injuries (in elderly patients, low-energy injuries), and, in most cases, associated injuries of the bone joint system, thorax, abdomen, and/or head are also present. This means that timely and appropriate treatment of these injuries is of vital importance, both at the site of first aid and at trauma centers. Bearing in mind the anatomical features of the pelvic cavity, injuries to the pelvic ring are only one segment of polytrauma, which is why treatment is initially focused on hemodynamic stabilization of the patient (DCR protocol). The treatment of such patients requires a multidisciplinary approach (hemodynamic stabilization, PPP, REBOA). Only when vital functions are stabilized, can doctors proceed to treat other medical issues, which do not primarily threaten the life of the patient.

Placement of an external fixator, within the DCO protocol, has a role in bleeding control, which makes it the method of choice in hemodynamically unstable patients.

Definitive fixation of pelvic fracture (ORIF) is carried out initially in stable patients, whose life is not in danger, or in polytraumatized patients, upon their stabilization. It is an indispensable method of treatment with respect to functional recovery and decreasing the rate of invalidity.

Although the mortality rate in these patients is still high, timely medical assistance and the correct choice and application of treatment methods, reduce the said rate effectively.

LIST OF ABBREVIATIONS AND ACRONYMS

- ABCDE –airway, breathing, circulation, disability, exposure – ABCDE approach; approach used in bleeding control
DCO – damage control orthopedics
DCR – damage control resuscitation; protocol used for hemodynamic stabilization of the patient
ISS – injury severity score
MODS – multiple organ dysfunction syndrome
ORIF – open reduction and internal fixation
PPP – preperitoneal pelvic packing
REBOA – resuscitative endovascular balloon occlusion of the aorta

Conflict of interest: None declared.

LITERATURA / REFERENCES

- Schmal H, Markmiller M, Mehlhorn AT, Sudkamp NP. Epidemiology and outcome of complex pelvic injury. *Acta Orthop Belg.* 2005 Feb;71(1):41-7. PMID: 15792206.
- Tseng IC, Chen IJ, Chou YC, Hsu YH, Yu YH. Predictors of Acute Mortality After Open Pelvic Fracture: Experience From 37 Patients From A Level I Trauma Center. *World J Surg.* 2020 Nov;44(11):3737-42. doi: 10.1007/s00268-020-05675-z.
- Incagnoli P, Puidupin A, Ausset S, Beregi JP, Bessereau J, Bobbia X, et al. Early management of severe pelvic injury (first 24 hours). *Anaesth Crit Care Pain Med.* 2019 Apr;38(2):199-207. doi: 10.1016/j.accpm.2018.12.003.
- Cheng M, Cheung MT, Lee KY, Lee KB, Chan SC, Wu AC, et al. Improvement in institutional protocols leads to decreased mortality in patients with haemodynamically unstable pelvic fractures. *Emerg Med J.* 2015 Mar;32(3):214-20. doi: 10.1136/emered-2012-202009.
- Giannoudis PV, Pape HC. Damage control orthopaedics in unstable pelvic ring injuries. *Injury.* 2004 Jul;35(7):671-7. doi: 10.1016/j.injury.2004.03.003.
- Balogh Z, Caldwell E, Heetveld M, D'Amons S, Schlaphoff G, Harris I, et al. Institutional practice guidelines on management of pelvic fracture-related hemodynamic instability: do they make a difference? *J Trauma.* 2005 Apr;58(4):778-82. doi: 10.1097/01.ta.0000158251.40760.b2.
- Heetveld MJ, Harris I, Schlaphoff G, Sugrue M. Guidelines for the management of haemodynamically unstable pelvic fracture patients. *ANZ J Surg.* 2004 Jul;74(7):520-9. doi: 10.1111/j.1445-2197.2004.03074.x.
- Rau CS, Wu SC, Kuo PJ, Chen YC, Chien PC, Hsieh HY, et al. Polytrauma Defined by the New Berlin Definition: A Validation Test Based on Propensity-Score Matching Approach. *Int J Environ Res Public Health.* 2017 Sep 11;14(9):1045. doi: 10.3390/ijerph14091045.
- Wood D, Bruce A. Damage control orthopaedics. *Surgery.* 2015;33(6):248-50.
- Coccolini F, Stahel PF, Montori G, Biffl W, Horer TM, Catena F, et al. Pelvic trauma: WSES classification and guidelines. *World J Emerg Surg [Internet].* 2017;12(1):1-18. doi:10.1186/s13017-017-0117-6
- Halawi MJ. Pelvic ring injuries: Emergency assessment and management. *Journal of clinical orthopaedics and trauma.* [Internet]. 2015 Dec 1;6(4):252-8. Dostupno na: <http://dx.doi.org/10.1016/j.jcot.2015.08.002>
- Wijffels DJ, Verbeek DO, Ponsen KJ, Carel Goslings J, van Delden OM. Imaging and Endovascular Treatment of Bleeding Pelvic Fractures: Review Article. *Cardiovasc Intervent Radiol.* 2019 Jan;42(1):10-8. doi: 10.1007/s00270-018-2071-4.
- Mejia D, Parra MW, Ordoñez CA, Padilla N, Caicedo Y, Pereira Warr S, et al. Hemodynamically unstable pelvic fracture: A damage control surgical algorithm that fits your reality. *Colomb Med (Cali).* 2020 Dec 30;51(4):e4214510. doi: 10.25100/cm.v51i4.4510.
- Halawi MJ. ScienceDirect Pelvic ring injuries: Surgical management and long-term outcomes. *J Clin Orthop Trauma [Internet].* 2015;7(1):1-6. doi: 10.1016/j.jcot.2015.08.001
- Tosounidis TH, Sheikh HQ, Kanakaris NK, Giannoudis PV. The use of external fixators in the definitive stabilisation of the pelvis in polytrauma patients: Safety, efficacy and clinical outcomes. *Injury.* 2017 Jun;48(6):1139-46. doi: 10.1016/j.injury.2017.03.033.
- Gänsslen A, Hildebrand F, Pohlemann T. Management of hemodynamic unstable patients "in extremis" with pelvic ring fractures. *Acta Chir Orthop Traumatol Cech.* 2012;79(3):193-202. PMID: 22840950.
- Smith WR, Moore EE, Osborn P, Agudelo JF, Morgan SJ, Parekh AA, et al. Retroperitoneal packing as a resuscitation technique for hemodynamically unstable patients with pelvic fractures: report of two representative cases and a description of technique. *J Trauma.* 2005 Dec;59(6):1510-4. doi: 10.1097/01.ta.0000197330.81352.94.
- Burlew CC, Moore EE, Smith WR, Johnson JL, Biffl WL, Barnett CC, et al. Preperitoneal pelvic packing/external fixation with secondary angioembolization: optimal care for life-threatening hemorrhage from unstable pelvic fractures. *J Am Coll Surg.* 2011 Apr;212(4):628-35; discussion 635-7. doi: 10.1016/j.jamcollsurg.2010.12.020.
- Wong JM, Bucknill A. Fractures of the pelvic ring. *Injury.* 2017 Apr 1;48(4):795-802.
- Moore LJ, Martin CD, Harvin JA, Wade CE, Holcomb JB. Resuscitative endovascular balloon occlusion of the aorta for control of noncompressible truncal hemorrhage in the abdomen and pelvis. *Am J Surg.* 2016 Dec;212(6):1222-30. doi: 10.1016/j.amjsurg.2016.09.027.
- Elias K, Engelhardt M. „Resuscitative endovascular balloon occlusion of the aorta“ : Überbrückende Maßnahme bis zur operativen Versorgung [Resuscitative endovascular balloon occlusion of the aorta : Bridge to surgery]. *Unfallchirurg.* 2018 Jul;121(7):537-43. German. doi: 10.1007/s00113-018-0503-x.
- Ribeiro Junior MAF, Feng CYD, Nguyen ATM, Rodrigues VC, Bechara GEK, de-Moura RR, et al. The complications associated with Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA). *World J Emerg Surg.* 2018 May 11;13:20. doi: 10.1186/s13017-018-0181-6.
- Johnson NL, Wade CE, Fox EE, Meyer DE, Fox CJ, Moore EE, et al.; Emergent Truncal Hemorrhage Control Study Group. Determination of optimal deployment strategy for REBOA in patients with non-compressible hemorrhage below the diaphragm. *Trauma Surg Acute Care Open.* 2021 Feb 23;6(1):e000660. doi: 10.1136/tsaco-2020-000660.
- Pape HC, Giannoudis P, Krettek C. The timing of fracture treatment in polytrauma patients: relevance of damage control orthopedic surgery. *Am J Surg.* 2002 Jun;183(6):622-9. doi: 10.1016/s0002-9610(02)00865-6.
- Behrman SW, Fabian TC, Kudsk KA, Taylor JC. Improved outcome with femur fractures: early vs. delayed fixation. *J Trauma.* 1990 Jul;30(7):792-7; discussion 797-8. doi: 10.1097/00005373-199007000-00005.
- Giannoudis PV, Smith RM, Bellamy MC, Morrison JF, Dickson RA, Guillou PJ. Stimulation of the inflammatory system by reamed and unreamed nailing of femoral fractures. An analysis of the second hit. *J Bone Joint Surg Br.* 1999 Mar;81(2):356-61. doi: 10.1302/0301-620x.81b2.8988.
- Henry SM, Tornetta P 3rd, Scalea TM. Damage control for devastating pelvic and extremity injuries. *Surg Clin North Am.* 1997 Aug;77(4):879-95. doi: 10.1016/s0039-6109(05)70591-0.
- Tuttle MS, Smith WR, Williams AE, Agudelo JF, Hartshorn CJ, Moore EE, et al. Safety and efficacy of damage control external fixation versus early definitive stabilization for femoral shaft fractures in the multiple-injured patient. *J Trauma.* 2009 Sep;67(3):602-5. doi: 10.1097/TA.0b013e3181aa21c0.
- Waydhas C, Nast-Kolb D, Trupka A, Zettl R, Kick M, Wiesholler J, et al. Posttraumatic inflammatory response, secondary operations, and late multiple organ failure. *J Trauma.* 1996 Apr;40(4):624-30; discussion 630-1. doi: 10.1097/00005373-199604000-00018.
- Staub NC. Pulmonary edema. *Physiol Rev.* 1974 Jul;54(3):678-811. doi: 10.1152/physrev.1974.54.3.678.
- Pape H, Stalp M, v Griensven M, Weinberg A, Dahlweit M, Tschern H. Optimaler Zeitpunkt der Sekundäroperation bei Polytrauma. Eine Evaluation an 4,314 Schwerverletzten [Optimal timing for secondary surgery in polytrauma patients: an evaluation of 4,314 serious-injury cases]. *Chirurg.* 1999 Nov;70(11):1287-93. German. doi: 10.1007/s001040050781.
- Gordon WT, Fleming ME, Johnson AE, Gurney J, Shackelford S, Stockinger ZT. Pelvic Fracture Care. *Mil Med.* 2018 Sep 1;183(suppl_2):115-7. doi: 10.1093/milmed/usy111.
- Devaney GL, Bulman J, King KL, Balogh ZJ. Time to definitive fixation of pelvic and acetabular fractures. *J Trauma Acute Care Surg.* 2020 Oct;89(4):730-5. doi: 10.1097/TA.0000000000002860.