Chinese Journal of Traumatology 22 (2019) 129–133

Contents lists available at ScienceDirect

Chinese Journal of Traumatology

journal homepage: http://www.elsevier.com/locate/CJTEE

Original Article

Analysis of early treatment of multiple injuries combined with severe pelvic fracture

Guang-Bin Huang, Ping Hu*, Jin-Mou Gao, Xi Lin

Chongqing Emergency Medical Center, Chongqing 400014, China

ARTICLE INFO

Article history:
Received 13 January 2019
Received in revised form
19 March 2019
Accepted 27 March 2019
Available online 11 April 2019

Keywords:
Multiple trauma
Pelvic fractures
Internal iliac artery
Consumptive coagulopathy
Hemostasis

ABSTRACT

Purpose: To summarize and analyze the early treatment of multiple injuries combined with severe pelvic fractures, especially focus on the hemostasis methods for severe pelvic fractures, so as to improve the successful rate of rescue for the fatal hemorrhagic shock caused by pelvic fractures.

Methods: A retrospective analysis was conducted in 68 cases of multiple trauma combined with severe pelvic fractures in recent 10 years (from Jan. 2006 to Dec. 2015). There were 57 males and 11 females. Their age ranged from 19 to 75 years, averaging 42 years. Causes of injury included traffic accidents in 34 cases (2 cases of truck rolling), high falling injuries in 17 cases, crashing injuries in 15 cases, steel cable wound in 1 case, and seat belt traction injury in 1 case. There were 31 cases of head injury, 11 cases of chest injury, 56 cases of abdominal and pelvic injuries, and 37 cases of spinal and limb injuries. Therapeutic methods included early anti-shock measures, surgical hemostasis based on internal iliac artery devasculization for pelvic hemorrhage, and early treatment for combined organ damage and complications included embolization and repair of the liver, spleen and kidney, splenectomy, nephrectomy, intestinal resection, colostomy, bladder ostomy, and urethral repair, etc. Patients in this series received blood transfusion volume of 1200–10,000 mL, with an average volume of 2850 mL. Postoperative follow-up ranged from 6 months to 1.5 years.

Results: The average score of ISS in this series was 38.6 points. 49 cases were successfully treated and the total survival rate was 72.1%. Totally 19 patients died (average ISS score 42.4), including 6 cases of hemorrhagic shock, 8 cases of brain injury, 1 case of cardiac injury, 2 cases of pulmonary infection, 1 case of pulmonary embolism, and 1 case of multiple organ failure. Postoperative complications included 1 case of urethral stricture (after secondary repair), 1 case of sexual dysfunction (combined with urethral rupture), 1 case of lower limb amputation (femoral artery thrombosis), and 18 cases of consumptive coagulopathy.

Conclusion: The early treatment of multiple injuries combined with severe pelvic fractures should focus on pelvic hemostasis. Massive bleeding-induced hemorrhagic shock is one of the main causes of poor prognosis. The technique of internal iliac artery devasculization including ligation and embolization can be used as an effective measure to stop or reduce bleeding. Consumptive coagulopathy is difficult to deal with, which should be detected and treated as soon as possible after surgical measures have been performed. The effect of using recombinant factor VII in treating consumptive coagulopathy is satisfactory.

Introduction

Management of multiple injuries with severe pelvic fracture is difficult, and the early focus is on hemostasis. However, due to the complex source of bleeding, there is no definitive method suitable for all patients with pelvic fractures. The incidence of pelvic fractures in all fractures is about 5%, and the mortality rate is less than 20%.[1] However, pelvic fractures caused by high-energy injuries such as traffic accidents, high falling, and heavy objects are often accompanied by adjacent organs or vascular injuries. And the degree of fracture is severe, which seriously affects hemodynamic stability and greatly increases the difficulty of treatment. The mortality rate of the severe pelvic fracture combined with multiple injuries is as high as

* Corresponding author.
E-mail address: hupin988506@aliyun.com.cn (P. Hu).
Peer review under responsibility of Chinese Medical Association.

https://doi.org/10.1016/j.cjtee.2019.03.001

30%–70%,[2,3] and the prognosis is poor. The reason may be related to the following factors: complicated source of bleeding in severe pelvic fractures, rapid bleeding, lacking timely and effective hemostasis measures, consumptive coagulopathy caused by severe blood loss and complicated treatment of combined damage. From Jan. 2006 to Jan. 2015, 68 multiple injury patients with severe pelvic fractures and hemodynamic instability were surgically treated in our department. The treatment methods are reported in this study, especially hemostasis methods for the severe pelvic fracture, so as to improve the successful rate of fatal hemorrhagic shock caused by the pelvic fracture (Tables 1 and 2).

Methods

General data

This study included 68 patients. The inclusion criteria were as follows: pelvic fracture (confirmed by X-ray or CT examination) combined with adjacent organ injury, hemodynamic instability, systolic blood pressure <90 mmHg, having received surgical hemostasis. The exclusion criteria were as follows: stable hemodynamic state and no need to cease bleeding by surgical procedure. There were 57 males and 11 females. Their age ranged from 19 to 75 years with the mean age of 42 years. Causes of injury included traffic accidents in 34 cases (2 cases of truck rolling), high falling injuries in 17 cases, crashing injuries in 15 cases, steel cable wound in 1 case, and safety belt traction injury in 1 case. According to Young-Bergess classification, there were 21 cases of anterior and posterior compression type (APC), 30 cases of lateral compression type (LC), 15 cases of vertical shear type (VS), and 2 cases of composite stress type (CM). The combined adjacent organ injuries included liver contusion in 4 cases, liver rupture in 7 cases, spleen rupture in 20 cases, renal contusion in 5 cases, kidney rupture in 3 cases, renal pedicle rupture in 2 cases, adrenal hematoma in 1 case, pancreatic contusion in 1 case, intestinal contusion in 6 cases, intestinal rupture in 3 cases, bladder contusion in 14 cases, bladder rupture in 9 cases, diaphragmatic hernia in 2 cases, uterine contusion in 1 case, rectal anal canal rupture in 2 cases, urethral rupture in 7 cases, vaginal rupture in 1 case, vascular injury in 12 cases (2 cases of iliac vein, 4 cases of superior gluteal artery, 1 case of inferior gluteal artery, 2 cases of obturator artery, 2 cases of femoral artery, and 1 case of superficial femoral artery), nerve injury in 3 cases (2 cases of sciatic nerve injury and 1 case of sacral nerve injury), and hip soft tissue degloving injury (Morel-Lavallee injury) in 2 cases. Thirty-one patients were combined with brain injury, 11 cases with chest injury and 37 cases with spinal injury. The injury severity was scored according to the AIS 2005 version. The AIS score was 2–5 points, and the ISS score was 28–41 points, with an average of 38.6 points. The admission time ranged from 20 min to 7 h after injury, with an average of 2.2 h. The study was approved by the Ethics Committee of Chongqing Emergency Medical Center (Fourth People's Hospital of Chongqing).

Treatment methods

Immediately after admission, establish two or more infusion channels through the upper limbs, or establish a central venous channel, and immediately infuse 1500–2000 mL of crystalloid solution to maintain the systolic blood pressure at 90 mmHg and heart rate at 100 beats/min. However, it should be noted that for patients with high blood pressure previously or combined with craniocerebral injury, lower blood pressure may not be able to meet tissue perfusion and hence properly increase systolic blood pressure is needed. All patients should transfuse blood as soon as possible based on laboratory tests. Internal iliac artery embolization or ligation was applied for surgical hemostasis. Steel ring and gelatin granules were used for internal iliac artery trunk embolization. Internal iliac artery ligation begins at 1 cm away from the initiation site of the internal iliac artery, and surgeons should not injure the accompanying vein and the adjacent ureter while separating the artery. Before the ligation, an assistant in the operating table assists in touching the dorsal artery pulsation or using portable Doppler to determine the arterial blood flow so as to avoid ligation of external iliac artery. If the pelvic hematoma continues to increase after the internal iliac artery devasculization, or the pelvic peritoneum ruptured and cannot inhibit bleeding, the pelvic tamponade should be performed. In addition to comminuted fracture of the iliac crest, external fixation of the pelvis was used. If sacroiliac joint is vertically unstable, then the lower limb traction was applied. Other adjacent damaged regions and organs were treated by repair, packing, and resection according to the characteristics of the injured organ and severity. Then definitive surgery was performed in late stage if necessary.

All patients were admitted to the trauma intensive care unit for adequate fluid resuscitation, including blood transfusion to correct shock, and close observation. Attention should be focused on: whether it is effective to stop bleeding, whether there is consumptive coagulopathy caused by a large amount of blood loss. Once a common and intractable consumptive coagulopathy was confirmed, recombinant activated factor VII should be applied as soon as possible in addition to blood products infusion.

Functional evaluation

At the early stage, heart rate, blood pressure, blood routine, and coagulation function should closely be observed; attention should be paid to determine whether it is effective to stop bleeding and correct shock, whether there is consumptive coagulopathy caused by a large amount of blood loss, whether there is ischemic complication caused by internal iliac artery devasculization including gluteal muscle necrosis, difficult defecation and dysuria, male sexual dysfunction. In addition, whether there is pelvic fracture combined with vascular injury or lower limb ischemia caused by iatrogenic external iliac artery injury also needs to be observed. Postoperative follow-up ranged from 6 months to 1.5 years.

Table 1
Clinical data of patients with internal iliac artery hemorrhage ($\bar{x}\pm s$).

Group	Age (years)	ISS	Systolic blood pressure (mmHg)	Heart rate (beats/min)	Hemoglobin (g/L)	Blood transfusion (mL)	Hemorrhagic shock death (n)	Factors VII used (n)
Internal iliac artery embolization (14 cases)	45 ± 8	28 ± 5	78 ± 12	112 ± 11	71 ± 13	1620 ± 576	2	2
Internal iliac artery ligation (49 cases)	42 ± 6	37 ± 7	72 ± 13	121 ± 9	65 ± 22	2350 ± 446	4	16
t value/χ^2 value	1.53	4.48	1.55	3.14	1.28	2.37	15.89[a]	1.72[a]
p value	>0.05	<0.05	>0.05	<0.05	>0.05	<0.05	>0.05	<0.05

[a] Represents χ^2 value.

Table 2
Comparison of laboratory test before and after using factor VII in patients with pelvic fracture combined with consuming coagulopathy ($\bar{x}\pm s$).

Time of application	Prothrombin time (s)	Activated partial thromboplastin time (s)	Fibrinogen (g/L)	Platelets ($\times 10^9$/L)	Hemoglobin (g/L)
Before application	21.4 ± 7.5	65.2 ± 26.8	5.8[c]	5.8[c]	65.7 ± 21.4
4 h after application	13.9 ± 1.5	43.5 ± 21.4	7.2[c]	6.7[c]	55.8 ± 28.5
t value/*T* value	3.82	2.71	87.00[d]	91.00[d]	1.17
p value	<0.05	<0.05	>0.05	>0.05	>0.05

Note: c means average rank sum; d means *t* value.

Statistical analysis

The data were expressed as $\bar{x}\pm s$, SPSS 16.0 statistical software was applied, and the count data was analyzed by χ^2 test. The normal distribution of measurement data was compared by *t*-test, and the non-normal distribution was tested by rank sum test. $p < 0.05$ is considered statistical difference.

Results

Patients in this study received blood transfusion with an average blood transfusion volume of 2850 mL ranging from 1200 to 10,000 mL. Totally 14 cases received internal iliac artery embolization, 49 cases received internal iliac artery ligation, 5 cases received internal iliac artery branch embolization plus internal iliac artery ligation, and 2 cases received internal iliac artery ligation plus pelvic packing. External fixation of the anterior pelvic ring was performed in 53 cases and traction of the lower limbs in 7 cases. Other adjacent sites and organ surgeries included liver embolism in 4 cases, liver repair in 16 cases (2 cases received hepatic artery ligation simultaneously), splenic embolization in 1 case, splenic resection in 19 cases, renal embolism in 5 cases, renal repair in 2 cases, renal resection in 3 cases, intestine repair in 5 cases, intestinal resection and anastomosis in 2 cases, colostomy in 2 cases, diaphragmatic repair in 2 cases, bladder repair in 13 cases, removal of bladder blood clot in 1 case (kidney blood clot accumulated without urine), cystotomy in 14 cases, primary-stage urethral injury in 2 cases, secondary-stage reconstruction in 2 cases, vaginal repair in 1 case, lower extremity vascular embolization in 7 cases, lower extremity vascular repair in 2 cases, incision for thrombus removal and reconstruction in 3 cases, sciatic nerve exploration and release in 1 case, and sacral canal decompression in 1 case. One case of Morel-Lavallee injury was treated with debridement and hemostasis and negative pressure closure. One patient underwent small incision to remove blood clots and apply pressure dressing at 3 weeks after injury. Consumable coagulopathy was treated with recombinant activated factor VII in 18 patients. In this series, 49 cases were successfully treated, and the total survival rate was 72.1%. If only the failure of early treatment of severe pelvic fractures was considered, the survival rate of the group was 89.1%. Nineteen patients died (ISS score 42.4 on average), including 6 cases of hemorrhagic shock, 8 cases of brain injury, 1 case of heart injury, 2 cases of pulmonary infection, 1 case of pulmonary embolism, and 1 case of multiple organ failure. The ISS was 42.4 points on average. Postoperative complications included urethral stricture (postoperative repair) in 1 case, sexual dysfunction in 1 case, and lower extremity amputation in 1 case (delayed treatment after femoral artery thrombosis). All patients were followed up for 1–8 years.

Discussion

It is difficult to treat multiple injuries with severe pelvic fractures in clinical practice. The key points lie in early diagnosis, early correct treatment, treatment priority, and prevention of complications.

Early diagnosis

While maintaining basic vital signs, patients' states should be assessed, simple physical examination and abdominal multiple quadrant puncture should be initiated. Urethral or anorectal injury is confirmed by routine catheterization, rectal examination, obstruction of the urinary catheter and the color of the fingertips. In addition, the amount and color of urine can be used to roughly determine the degree of shock, whether there is bladder and kidney damage. In the subsequent contrast embolization treatment, contrast agents can also be injected through the catheter to determine whether the bladder is ruptured. For female patients, attention should be paid to observe whether there is vaginal bleeding. In the emergency department, focused assessment sonograph for trauma (FAST) is simple to use and does not add extra exertion on patients who are not suitable for moving.[4] For shock patients, we prefer to choose spiral CT examination under certain conditions. More importantly, organs evaluation such as the head, chest, abdomen, and pelvis should be completed quickly. An anteroposterior pelvic plain film and CT three-dimensional reconstruction are more conducive to determine conditions of the fracture. Although the incidence of large blood vessels in pelvic fractures is not high, it is often missed and hence brings out serious consequences. Especially, thrombosis after vascular contusion is more easily overlooked. Repeated ultrasound and CTA examinations are simple and convenient to perform. In addition to observing the trunk vessel, it is important to evaluate the collateral circulation, which is an important basis for formulating treatment plans.[5] Neurological soft tissue injury can be found by further examination after the patient is awake and blood flow is stable.

Early anti-shock

Restricted fluid resuscitation is conducted at admission, and systolic blood pressure should be maintained at 90 mmHg, heart rate at about 100 times/minute.[6] If patients having severe shock and estimated blood loss is great, consumptive coagulopathy is considered, which needs urgent blood check to ensure a venous channel for blood transfusion during further examination or treatment. This is particularly important for open pelvic fracture patients with large blood loss or elderly patients with poor blood loss tolerance. As elderly patients often have poor heart and lung function and may previously be inflicted with some diseases, once the breathing and cardiac arrest occurred due to hemorrhagic shock, the successful rate of resuscitation is very low.

Surgical hemostasis

The bleeding source of pelvic fractures is complex, including pelvic vein plexus, internal and external iliac arteriovenous system. Fracture end bleeding in severe pelvic injuries is often not from a single source except in the case of large vascular injuries, which is difficult to precisely find and manage, so pelvic bleeding often requires a combination of various treatment measures. Surgical

techniques are still the main means of hemostasis, and its use has always been debated in terms of indications and effects.

Internal iliac artery embolization and ligation is the most commonly used hemostatic method in the author's hospital. The selection of surgical methods should be based on patient's vital signs state, combined injuries, medical settings and professional levels. Generally, internal iliac artery angiography as a minimally invasive surgical method, is in line with the principle of severe traumatic injury control, and is suitable for elderly patients, patients with a variety of combined diseases, mild shock patients with stable blood pressure after fluid infusion or patients who are negative or only a small amount of incoagulable blood for abdominal puncture examination or have mild organ injury (except viscus organ rupture) confirmed by imaging examination. The ligation of internal iliac artery is suitable for patients with abdominal pelvic organ injury, vascular injury, pelvic floor structure injury, open pelvic fractures, or severe pelvic fractures needing laparotomy.[7] In this series, the ISS scores of internal iliac artery embolization patients were lower than those of internal iliac artery ligation ($p < 0.05$), suggesting that patients who underwent internal iliac artery ligation were more severe, but there was no statistically significant difference in blood pressure and hemoglobin examination, which may be related to early body compensation, blood concentration or infusion dilution. The difference in heart rate was statistically significant ($p < 0.05$), suggesting that a close focus on heart rate changes could make it easier to evaluate injuries and choose treatment measures. There was also difference in blood transfusion volume and consumptive coagulopathy between the two groups ($p < 0.05$). However, death resulting from large blood loss was not statistically different between the two groups ($p > 0.05$). This may be due to the fact that the main cause of blood loss in this group is pelvic fractures. In our experience, low blood pressure can be improved within 5–10 min of anti-shock after bilateral embolism, and the branch embolism often has poor effect. After the trunk embolism, ischemic complications are rare because of collateral circulation. In this series, bleeding was successfully stopped in 14 cases by direct arterial embolization, and 5 cases who were treated by selective iliac artery branch embolism previously, were improved after trunk embolism because of decreased blood pressure.

In this series, no lower limb blood supply disorder, gluteal ischemia necrosis, dysuria and dysfunction were found. One patient with decreased sexual function also had urethral rupture. It has been reported that partial sexual dysfunction may occur in some urethral ruptured patients. It is not clear whether this sexual dysfunction is related to ischemia after hemorrhage. Scholars also reported no exact ischemic complication after using this technique.[8]

Pelvic tamponade is an effective means of hemostasis and is used more frequently in trauma centers in Europe. However, pelvic tamponade may increase infection rate, and bleeding may reoccur after removing tamponade.[9] Pelvic tamponade is not used as the first choice in Chongqing Emergency Medical Center, which is generally used in combined with other measures. In this series, 2 patients had continuous blood pressure decline and early consumptive coagulopathy during operation. Immediately after bilateral internal iliac artery ligation, intraperitoneal pelvic tamponade was added to stop bleeding. For these patients, performing standard extraperitoneal tamponade may be time consuming and may increase the amount of bleeding.

The fixation for severe pelvic fractures is conducive to stabilize fracture ends and reduce bleeding, and reduce secondary adjacent organ damage. It is simple and effective to use external fixation. In this study, 53 patients underwent external fixation. The external fixator is mostly used for APC type pelvic fracture. The Front ring external fixator is used if the front ring is unstable, and C-type clamp is used if the rear ring is unstable. However, as external fixation facilitates mobility and nursing care, some LC-type and VS-type fractures in this series also used external fixation to stabilize the pelvis. For VS-type fractures, its combination with traction can achieve partial reduction and maintain vertical stability.

Since pelvic hemorrhage is complicated, surgical method can only partly reduce bleeding. When blood pressure rises, bleeding may continue. Finally, an intact peritoneal pressure and normal coagulation function are essential to achieve hemostasis, which requires repeated and large dose of blood transfusion. In this series, some patients received tens of thousands of milliliters of blood transfusion.

Treatment for other combined injuries

Severe pelvic fractures often combines other organ injuries, especially adjacent organs in the abdomen, which is one of the important reasons for a high mortality of pelvic fractures. Early diagnosis is essential to perform laparotomy as soon as possible. Although the incidence of abdominal organ injury is high in these patients, the most serious injury leading to death is severe craniocerebral injury.

Attention should be paid to the treatment of adjacent vascular injuries caused by pelvic fractures. This includes vascular injury directly caused by the fracture end (e.g. the ankle joint bone fragment pokes the common iliac vein, pubic fracture pokes the femoral vein) and the nearby vascular injury which is not directly caused by the fracture. Surgeons should perform timely angiography once find a special-site fracture, and peritoneal exploration is performed as soon as possible if blood pressure is continuously decreased and fails to return after transfusion. In this series, one patient with thrombosis after femoral artery injury received amputation due to delayed treatment.

Treatment of consumptive coagulopathy

Severe pelvic fracture is associated with blood loss, and coagulation dysfunction occurs early. In our experience, coagulation dysfunction is particularly obvious if blood loss is more than 3000 mL in pelvic fracture patients with liver rupture. Extensive bleeding can be observed on the wound site during surgery, which needs early prevention and timely treatment. Surgical intervention should be conducted within 3 h of admission. After operation, patients need to be sent to ICU for resuscitation. Concentrated red blood cells, fresh frozen plasma and platelets are necessary to transfused as the ratio of 1:1:1, but platelets are often difficult to be guaranteed in practical application. Fresh whole blood seems to have a better clinical effect for the treatment of traumatic hemorrhagic shock and consumptive coagulopathy.[10,11] When patients still have significant bleeding and abnormal blood coagulation after conventional hemostasis, early use of activated recombinant factor VII is effective and safe.[12] In this series, 18 patients with consumptive coagulopathy were given VII factors, and the prothrombin time and activated partial thromboplastin time were significantly improved ($p < 0.05$). Ultimately, the mortality rate caused by hemorrhagic shock was only 8.8%.

In short, the treatment of multiple injuries combined with severe pelvic fracture is a great challenge to surgeons and the mortality is high. The internal iliac artery rupture technique for early hemostasis is effective and safe, and a variety of surgical methods need to be flexibly conducted. Consumptive coagulopathy should be treated as soon as possible. Great importance should be attached to the treatment of combined injuries following pelvic fractures so as to reduce mortality and disability.

Funding

This work was supported by the Chongqing Commission of Science and Technology Social Undertakings and Livelihood Security Science and Technology Innovation Special Project, China (cstc 2016 shms-ztzx 10001).

Acknowledgements

Thanks to the trauma team of Chongqing Emergency Medical Center for providing clinical cases.

Ethical statement

This study was approved by the Medical Ethics Committee of Chongqing Emergency Medical Center (approval certificate No. 2015–19).

Conflicts of interest

All the authors have declared no conflicts of interest.

References

1. Oliphant BW, Tignanelli CJ, Napolitano LM, et al. American College of Surgeons Committee on Trauma verification level affects trauma center management of pelvic ring injuries and patient mortality. *J Trauma Acute Care Surg*. 2019;86:1–10. https://doi.org/10.1097/TA.0000000000002062.
2. Burlew CC, Moore EE, Stahel PF, et al. Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures. *J Trauma Acute Care Surg*. 2017;82:233–242. https://doi.org/10.1097/TA.0000000000001324.
3. Dente CJ, Feliciano DV, Rozycki GS, et al. The outcome of open pelvic fractures in the modern era. *Am J Surg*. 2005;190:830–833. https://doi.org/10.1016/j.amjsurg.2005.05.050.
4. Coccolini F, Stahel PF, Montori G, et al. Pelvic trauma: WSES classification and guidelines. *World J Emerg Surg*. 2017;12:5. https://doi.org/10.1186/s13017-017-0117-6.
5. Hussami M, Grabherr S, Meuli RA, et al. Severe pelvic injury: vascular lesions detected by ante- and post-mortem contrast medium-enhanced CT and associations with pelvic fractures. *Int J Leg Med*. 2016;131:731–738. https://doi.org/10.1007/s00414-016-1503-4.
6. Carrick MM, Leonard J, Slone DS, et al. Hypotensive resuscitation among trauma patients. *BioMed Res Int*. 2016;2016:8901938. https://doi.org/10.1155/2016/8901938.
7. Eckroth-Bernard K, Davis JW. Management of pelvic fractures. *Curr Opin Crit Care*. 2010;16:582–586. https://doi.org/10.1097/MCC.0b013e3283402869.
8. DuBose J, Inaba K, Barmparas G, et al. Bilateral intemal iliae artery ligation as a damage control approach in massive retroperitoneal bleeding after pelvic fracture. *J Trauma*. 2010;69:1507–1514. https://doi.org/10.1097/TA.0b013e3181d74c2f.
9. Ron G, Epstein D, Ben-Galim P, et al. Extra-peritoneal pressure packing without external pelvic fixation: a life-saving stand-alone surgical treatment. *J Emergencies, Trauma, Shock*. 2015;8:181–187. https://doi.org/10.4103/0974-2700.166586.
10. Holcomb JB, Wade CE, Michalek JE, et al. Increased plasma and platelet to red blood rations improves outcome in 446 massively transfused civilian trauma patients. *Ann Surg*. 2008;248:447–458. https://doi.org/10.1097/SLA.0b013e318185a9ad.
11. Spinella PC. Warm fresh whole blood transfusion for severe hemorrhage: U. S. military and potential civilian application. *Crit Care Med*. 2008;36:S340–S345. https://doi.org/10.1097/CCM.0b013e31817e2ef9.
12. Noda M, Morozumi J, Mishima S, et al. Visualization of efficacy of recombinant factor FVIIa in a pelvic fracture patient. *J Trauma*. 2008;64:E86–E88. https://doi.org/10.1097/TA.0b013e318175d700.