Advanced Trauma and Surgery

Xiaobing Fu
Liangming Liu
Editors

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Xiaobing Fu
Key Laboratory of Wound Repair and Regenerative Medicine of PLA
The First Affiliated Hospital of PLA General Hospital
Beijing
China

Liangming Liu
State Key Laboratory of Trauma, Burns and Combined Injury,
Daping Hospital, Research Institute of Surgery
Third Military Medical University
Chongqing
China

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Preface

As we know that trauma and accident injury are one among the main causes of death in human, and they are the first cause of death in youth below 45 years. Effective and precise prevention and management of serve damage in tissues and organs will benefit not only in reducing the early mortality, but also in improving the quality of life after survival in later. Advances in basic research and clinical management in trauma and surgery have confirmed these conceptions.

In this monograph titled Advanced Trauma and Surgery, recently advanced knowledge and skills in early wound care, traumatic or burn shock, pathogenesis in sepsis and tissue repair and regenerative medicine are offered. The authors pay much attention to the cellular, molecular, and gene research and their relationship with the pathogenesis in trauma and injury. Also, how to translate application of these advanced theories and skills in management of trauma patients is highlighted.

We would like to say that this book is not served as the sophisticated instruction manual to guide those who have less experience through difficult experiences in the management of trauma and surgery. It is our hope that this book can be served as the advanced textbook to help the young scientists and clinicians to know the new knowledge and technology in these fields, which will benefit their work in research and clinic through multidisciplinary collaboration.

We would like to express our gratitude to all authors who contribute his knowledge and time for this book. We thank Prof. Zengang Wang and Prof. Zhiyong Sheng in particular, for their continued support and guide in the fields of trauma and burn. Both of them are very famous experts in trauma, burn, field surgery, and traffic medicine. Their professional contribution is not only in China, but also in the world. Their ideas have been responsible for influencing the ideas in young generation, and we appreciate them very much for the great contribution.

Beijing, China Xiaobing Fu
Chongqing, China Liangming Liu

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Editors and Contributors

About the Editors

Prof. Xiaobing Fu, M.D., Ph.D., He is an academician (Chinese Academy of Engineering, Division of Health and Medicine); president of the College of Life Science, the General Hospital of PLA; director of the Key Laboratory of Wound Repair and Regeneration of PLA, Trauma Center of Postgraduate Medical College.

He has made great contributions on trauma, especially in tissue repair and regeneration. His works were supported in part by the National Basic Science and Development Program (973 Program), National High-Technique Program (863 Program), Grant for National Distinguished Young Scientists, and Grant for National Natural Science Foundation of China. He has published more than 500 scientific papers, including papers published in the *Lancet* (1998, 2001), and 20 books as the editor in chief, and won the 25 international and national prizes of Sci-Tech Progress from 1989 to 2015.

He was the member of the Scientific Committee of the Third Joint Meeting of the European Tissue Repair Society and the Wound Healing Society held in Boudreaux in 1999; he was also a member of the Scientific Committee, advisor or member of the International Faculty from the First World Union of Wound Healing Societies (WUWHS) Congress to 5th WUWHS Congress, held in Melbourne in 2000, Toronto in Canada in 2008, Yokohama in Japan in 2012, and Florence in Italy in 2016. He was the vice chairman of Trauma and Burn Section of the International Conference on Life Science and Clinical Medicine in 2000.

Now, he is the chairman of the Asian Wound Healing Association (AWHA), the president of the Chinese Tissue Repair Society (CTRS), the president of the

Chinese Tissue Repair and Regeneration Society (CTRRS), and the member of National Natural Science Foundation of China.

Professor Fu was awarded the International Lifetime Achievement Award in Wound Repair and Regeneration in 2008. He was selected as the academician (Chinese Academy of Engineering, Division of Health and Medicine) in 2009.

Liangming Liu, M.D., He is a research professor, doctoral supervisor, director of Shock Research Lab, Research Institute of Surgery, Third Military Medical University. He is also a shock research specialist; a distinguished young scholar of national science foundation of China; the committee member of International Federation of Shock Society and Chinese Trauma Society; the vice chairman of Shock Society of China and War Wound and Trauma Committee of PLA; the standing member of Cardiovascular Committee of Chinese Pharmacology Society; the editorial board member of Annals of Cardiology and Cardiovascular Diseases, Frontier of Medicine, Chin J Traumatology, and Military Medical Research; the invited reviewer of Intl J Cardiology, Cell Biol Intl, J Endocrinology, Exp and Ther Med, Pharmacol Reports, and so on; and the evaluation expert of National Natural Science Foundation of China and Yangtse River Scholars of Education Ministry in China.

He has long been undertaking the studies of pathogenesis, prevention, and care of traumatic shock. His main grants comprise the state and military key and major projects such as the key project of the national natural science foundation of China, the national major new drug development plan, and the national major research program of basic science (973 plan). In the flied of shock research, he raised the calcium desensitization mechanism of vascular hyporeactivity in critical illness such as severe trauma and shock and raised the effective prevention and treatment measures; he raised the new concept that permissive hypotensive resuscitation is all needed for uncontrolled hemorrhagic shock before and after bleeding controlled; and he developed a series of emergent care devices for war wound and trauma, which play important roles in combat casualty care, disaster rescue, and military training. These studies published over 350 papers including in Ann Surg, Cardiovasc Res, Crit Care Med, Crit Care, and Anesthesiology and Shock and obtained 12 national and provisional science and technology progress awards.

Contributors

Monowar Aziz Center for Immunology and Inflammation, The Feinstein Institute for Medical Research, Manhasset, NY, USA

Xiangjun Bai Department of Trauma Surgery, Tongji Hospital, Hua Zhong University of Science and Technology, Wuhan, People's Republic of China

Sa Cai The First Affiliated Hospital, Chinese PLA General Hospital, Beijing, People's Republic of China

Cindy Cen Department of Surgery, Hofstra Northwell School of Medicine, Manhasset, NY, USA

Zelin Chen State Key Laboratory of Trauma, Burns and Combined Injury, Chongqing Engineering Research Center for Nanomedicine, Institute of Combined Injury, College of Preventive Medicine, Third Military Medical University, Chongqing, China

Biao Cheng The General Hospital of PLA, College of Life Sciences, Medical College of PLA, Beijing, People's Republic of China; The Key Laboratory of Trauma Treatment & Tissue Repair of Tropical Area, PLA, Guangzhou, People's Republic of China

Tingyu Dai State Key Laboratory of Trauma, Burns and Combined Injury, Chongqing Engineering Research Center for Nanomedicine, Institute of Combined Injury, College of Preventive Medicine, Third Military Medical University, Chongqing, China

JiaoYun Dong Medical School, Rui Jin Hospital, Shanghai Jiao Tong University, Shanghai, People's Republic of China

Dingyuan Du Chongqing Institute of Accident and Emergency Medicine, Chongqing Emergency Medical Center, Chongqing, People's Republic of China

Chenyang Duan State Key Laboratory of Trauma, Burns and Combined Injury, Second Department of Research Institute of Surgery, Daping Hospital, Third Military Medical University, Chongqing, People's Republic of China

Jie Fan School of Medicine and Veterans Affairs Pittsburgh Healthcare System, University of Pittsburgh, Pittsburgh, PA, USA

Liyan Fan School of Medicine, Case Western Reserve University, Cleveland, OH, USA

Xiaobing Fu The College of Life Sciences, Chinese PLA General Hospital, Chinese PLA Medical College, Beijing, People's Republic of China; The First Affiliated Hospital, Chinese PLA General Hospital, Beijing, People's Republic of China

Wei Gu State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Xiaosong Gu Nantong University, Nantong, Jiangsu, People's Republic of China

Sha Huang The College of Life Sciences, Chinese PLA General Hospital, Chinese PLA Medical College, Beijing, People's Republic of China

Jianxin Jiang State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Baiqiang Li Jinling Hospital, Research Institute of General Surgery, Nanjing University Medical School, Nanjing, China

Bingcang Li State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Lei Li State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Tao Li State Key Laboratory of Trauma, Burns and Combined Injury, Second Department of Research Institute of Surgery, Daping Hospital, Third Military Medical University, Chongqing, People's Republic of China

Weiqin Li Jinling Hospital, Medical School of Nanjing University, Nanjing, Jiangsu Province, China

Huaping Liang State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, China

Baiyun Liu Department of Neurosurgery, Beijing Tantan Hospital, Capital Medical University, Beijing, China; Neurotrauma Laboratory, Beijing Neurosurgical Institute, Capital Medical University, Beijing, China; Nerve Injury and Repair Center of Beijing Institute for Brain Disorder, Beijing, China; China National Clinical Research Center of Neurological Diseases, Beijing, China; Department of Neurotrauma, General Hospital of Armed Police Forces, Beijing, China

Chaozhi Liu State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Institute of Surgery Research, Third Military Medical University, Chongqing, China

Guie Liu State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Liangming Liu State Key Laboratory of Trauma, Burns and Combined Injury, Second Department of Research Institute of Surgery, Daping Hospital, Third Military Medical University, Chongqing, People's Republic of China

Xiao Liu State Key Laboratory of Trauma, Burns and Combined Injury, Institute of Burn Research, Southwest Hospital, Third Military Medical University, Chongqing, People's Republic of China

Shuliang Lu Ruijin Hospital, Shanghai Jiaotong University, Shanghai, People's Republic of China

Xiaoyuan Ma State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, China

Xiang Mao Department of Neurosurgery, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, China

Qing Ouyang State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Daizhi Peng State Key Laboratory of Trauma, Burns and Combined Injury, Institute of Burn Research, Southwest Hospital, Third Military Medical University, Chongqing, People's Republic of China

Xi Peng State Key Laboratory of Trauma, Burns and Combined Injury, Research Institute of Burn Injury, Southwest Hospital, Third Military Medical University, Chongqing, People's Republic of China

Chun Qing Medical School, Rui Jin Hospital, Shanghai Jiao Tong University, Shanghai, People's Republic of China

Jun Qiu State Key Laboratory of Trauma, Burns and Combined Injury, Institute for Traffic Medicine, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Xiao Shen Jinling Hospital, Medical School of Nanjing University, Nanjing, Jiangsu Province, China

Zhiyong Sheng The First Affiliated Hospital, Chinese PLA General Hospital, Beijing, People's Republic of China

Chunmeng Shi State Key Laboratory of Trauma, Burns and Combined Injury, Chongqing Engineering Research Center for Nanomedicine, Institute of Combined Injury, College of Preventive Medicine, Third Military Medical University, Chongqing, China

Haichen Sun Jinling Hospital, Research Institute of Neurosurgery, Nanjing University Medical School, Nanjing, China

Xiaoyan Sun The College of Life Sciences, Chinese PLA General Hospital, Chinese PLA Medical College, Beijing, People's Republic of China

Lixing Tian State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, China

Ming Tian Medical School, Rui Jin Hospital, Shanghai Jiao Tong University, Shanghai, People's Republic of China

Jianmin Wang State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Ping Wang Department of Surgery, Hofstra Northwell School of Medicine, Manhasset, NY, USA; Center for Immunology and Inflammation, The Feinstein Institute for Medical Research, Manhasset, NY, USA

Liao Wu State Key Laboratory of Trauma, Burns and Combined Injury, Chongqing Engineering Research Center for Nanomedicine, Institute of Combined Injury, College of Preventive Medicine, Third Military Medical University, Chongqing, China

Yamin Wu State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Institute of Surgery Research, Third Military Medical University, Chongqing, China

Guangming Yang State Key Laboratory of Trauma, Burns and Combined Injury, Second Department of Research Institute of Surgery, Daping Hospital, Third Military Medical University, Chongqing, People's Republic of China

Cuiping Zhang The First Affiliated Hospital, Chinese PLA General Hospital, Beijing, People's Republic of China

Lianyang Zhang Trauma Center, State Key Laboratory of Trauma, Burns and Combined Injury, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Jihong Zhou State Key Laboratory of Trauma, Burns and Combined Injury, Institute for Traffic Medicine, Daping Hospital, Research Institute of Surgery, Third Military Medical University, Chongqing, People's Republic of China

Damage Control Theory in Treatment of Multiple Injuries

Xiangjun Bai

Abstract Lethal triad of death is the most serious complication of multiple injuries, which often manifests as metabolic acidosis, hypothermia and coagulation disorder, and all lead to multiple organ dysfunction syndrome (MODS). During the treatment process, early effective control of all kinds of primary injuries and bleeding could maintain the stability of the internal environment for avoiding exhausting of patients' physiological potential, then making it possible for patients to get definitive surgeries after resuscitation, which depends on the damage control theory (DCT).

Keywords Trauma · Lethal triad · Multiple injury · Damage control

As modernization of nowadays society progresses, trauma has become the primary cause of death in patients under 40 years old, therefore a major public enemy of society. High energy severe multiple injuries can easily cause serious physiological disorders in patients, which often manifests as metabolic acidosis, hypothermia and coagulation disorder [1], known as the lethal triad of death, followed by secondary strike such as severe infection, systemic inflammatory response syndrome (SIRS) and sepsis, which can all lead to multiple organ dysfunction syndrome (MODS). During the treatment process, because of multiple injury sites and complex associated injuries, early stage inappropriate treatment and definitive surgery could result in aggravating the injury and patients often die of late stage exhaustion of physiological storage. Therefore, how to effectively control the primary injury in early stage of treatment and to actively prevent secondary injury have become an urgent problem for emergency and trauma surgeons. The main purpose of damage control treatment of multiple injuries is: early effective control of all kinds of primary injuries and bleeding, maintaining the stability of the internal environment, as well as avoiding exhausting of patients' physiological potential, so that patients,

X. Bai (✉)
Department of Trauma Surgery, Tongji Hospital, Hua Zhong University of Science and Technology, Wuhan, People's Republic of China
e-mail: baixiangjun@hotmail.com

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especially those suffering from severe multiple injury, can get through the acute stress period safely and stably, making it possible for patients to get definitive surgeries after resuscitation. The time gap between the onset of the injury and the occurrence of lethal triad is critical to improve the success rate of severe multiple trauma treatment and improve the prognosis of patients. Therefore, this period is also defined as the new gold hour (NGH).

1 Damage Control Theory and Relative Concepts

Damage control theory (DCT) is the core of damage control. DCT is an emergency surgical staging principle, which emphasizes on temporary control of bleeding and further contamination instead of taking definitive surgery for anatomical repair, contemporaneously conducting resuscitation to ensure minimal tissue perfusion, avoiding excessive, low temperature, ineffective liquid infusion. DCT contains two primary concepts: damage control surgery (DCS) and damage control resuscitation (DCR) [2].

1.1 Damage Control Surgery

As a surgical strategy for periodic recovery of severe trauma patients, DCS aims to avoid the irreversible physiological damage caused by "lethal triad" [3]. Stone first raised the concept of DC on the Ann-Surg in 1983. In 1993 Rotondo established a standardized procedure regarding DCS, namely the three stage principle of DCS: early simplified surgery, resuscitation in ICU and late definitive surgery. The reasonable application of DC surgery can effectively reduce the mortality of patients with complicated trauma. DCS was first applied in abdominal trauma patients. In recent years, DCS has been gradually applied to the department of orthopedics, the department of Neurosurgery, the vascular surgery, especially the treatment of multiple injuries, and has made certain progress.

1.2 Damage Control Resuscitation

Derived from DCS, DCR was first pointed out by the American military trauma surgical consultant colonel HoLcomb in 2006 [4]. The basic principle of damage control resuscitation is to quickly identify patients with high risk of abnormal coagulation mechanism, and to reverse the abnormal coagulation, hyperthermia and metabolic acidosis by fluid resuscitation. It has provided people with insights into certain clinical medical problems. DCR is now becoming more and more important in the treatment of severe multiple trauma [5].

1.3 Secondary Strike

Patients with Severe multiple injuries often die from secondary strike such as MODS and MOF. This theory suggests that as a direct result of trauma, the first strike develops early. Secondary strike is a series of inflammatory reactions from SIRS, sepsis to MODS and MOF, resulting from inappropriate treatment and definitive surgery of the first strike. The purpose of DCT is to minimize the impact of secondary strike on patients.

1.4 New Golden Hour

With the systematic establishment of trauma organizations, development of trauma center, application of standard resuscitation method and improvement of modern blood bank technology, the ability to resuscitate trauma patients with extreme trauma has improved. The concept of “Gold hour” is understood to be the fastest speed and the effectiveness of resuscitation, and its ultimate goal is to reduce injury-to-incision time. This change does not simply indicate the transportation of the severe injured patients from the scene of the accident to the emergency room, rather than applying resuscitation in the operation room and eventually the ICU. The most appropriate meaning of “the new golden hour” is the critical time period before patients develop lethal triad in the operation room. ICU nurses must understand the importance of this triad, because it indicates the establishment of the concept of DC or DCS, as well as the medical team’s emphasis on damage control in trauma patients.

1.5 The Dual Meaning of DCT

The proposal and clinical practice of DCT has played an important role in the development of medicine [6, 7]. It is a milestone in the development of multiple injuries treatment. In recent years, DCT continues to improve and ripen. DCT consider surgeries to be a part of resuscitation, rather than an end in itself [8], and that the prognosis depends much on patients’ physiological limit, rather than surgeon’s efforts to restore anatomical structure. Therefore, there is a secondary meaning of DCT [9]: (1) to control, decelerate or prevent blood loss and infection caused by original trauma; (2) to reduce the damage brought by surgery and invasive procedure in order to stabilize patients, creating opportunities for following treatment.

2 Pathophysiological Basis of DCT

2.1 Metabolic Acidosis

When blood pH is below 7.25, the body is in a continuous hypoperfusion state. Normal pathway of glycometabolism changes, anaerobic glycolysis will replace aerobic metabolism under normal physiological state, resulting in the accumulation of lactic acid in the body. Therefore, the level of blood lactic acid can reflect the severity of acidosis in patients with multiple injuries. Previous studies show that there is a clear correlation between blood lactic acid level and mortality [10]. The survival rate is 100 % in patients who can clear lactic within 24 h, and the survival rate in patients who can clear lactic within 48 h is only 14 %. If the duration of surgery is too long, the patient will develop continuously and repeatedly low perfusion and hypoxia, resulting in excessive accumulation of lactic acid in the body, which leads to increased mortality.

2.2 Hypothermia

Blood loss, large number of cryogenic liquid perfusion and exposure of body cavity all lead to acceleration of heat loss. Thermogenesis dysfunction and loss of peripheral vasoconstriction during anesthesia can cause patients' core temperature to drop under 35 °C. If the continuous hypothermia reaches patients' body limit (below 32 °C for more than 90 min), the damage become irreversible [11], and death is inevitable.

2.3 Coagulation Disorder

Acidosis and hypothermia can cause reduction in thrombin, platelet count and synthesis of clotting factor V, VIII, as well as activation of fibrinolytic. Blood dilution caused by fluid resuscitation can further aggravate coagulation disorders, which can develop into uncontrollable DIC, seriously endangering patients' lives. Therefore, patients can die of physiological exhaustion during or after invasive definitive surgery or procedures, which leads to application of DCT. Surgeons should not only tend to control the blood loss and infection, but also control damage caused by emergency surgeries and invasive procedures, keeping patients stable enough for follow-up treatment [12].

3 Indications of DCT

Grasping indications is very important in DCT application. Studies show that pH level, hypothermia and blood transfusion are sensitive index of patients' prognosis, therefore important index of choosing DCS [13]: (1) patient status: severe multiple injuries, ISS ≥ 25, associated severe hemorrhagic shock, diastolic pressure <70 mmHg on admission, in need of emergency operation; (2) lethal factors: severe acidosis, hypothermia, non-mechanical coagulation disorder, pH <7.25, BE ≤ -8 mmol/L, T <35 °C, PT >16 s, APTT >50 s or 50 % of normal value; (3) surgery: estimated resuscitation and operation time is more than 90 min, in need of large amount of blood transfusion (>10 u); (4) conflicts in treatment: hard to make priorities in case of severe and complicated injuries; (5) medical condition: in low level hospitals or when restricted by technical conditions, or dealing with large number of patients, definitive surgery can not be performed, precious time need to be saved for transportation. When meet the first requirement and any of the rest 4 requirements, DCS should be applied.

4 Three-Phases Principle of DCT

The physiological potential of severe multiple injury patients is often on the verge of exhaustion. Even if surgeons can perform complex surgery despite of technicality, patient would eventually die of exhaustion of physiological potential. Therefore, surgery ought to be considered part of the whole resuscitation progress. The outcome of treatment does not depend on surgically restoring anatomic relations, but on timely correction of severe internal environment disorder [14]. Inappropriate, unbearable operation will accelerate patients' death. DCT reduces secondary strike to patients. Blood loss is reduced by methods of ligation and packing hemostasis. In the mean time reducing blood transfusion can lower the possibility for transmitted inflammatory factors and toxic substances [15]. Providing a better foundation for rapid resuscitation can significantly reduce patient mortality.

The three-phases principle of DCT includes [16, 17]: (1) simple surgery: during the initial operation, the surgeon carries out only the absolute minimum necessary to rapidly control blood loss and infection. Close the wound immediately to avoid further damage, keeping operation time within 90 min. (2) Secondary resuscitation in traumatic intensive care unit [18, 19]: this phase includes correction of coagulation and acidosis, rewarming, ventilatory support and full body examination. Improve tissue perfusion and microcirculation in order to reduce lactic production; avoid heat loss and blood loss by shortening operating time; avoid excessive infusion of low temperature liquid, and take measures to keep patients' body temperature to reduce the possibility of developing DIC or Coagulation disorder [20]. (3) Elective surgery (definitive surgery): further surgery to remove package and to repair injuries organs after fully surgical exploration.

4.1 Bleeding and Contamination Control

Wadding and pressure hemostasis are most simple and effective methods for superficial bleeding, and also one of the most applied methods for treating trauma patients. For deep hemorrhage with deep plugging part, temporary vascular ligation or interventional therapy can be applied. Catheter drainage can be used to prevent the spillage of intestinal contents and urine into the peritoneal cavity. After keeping bleeding and contamination under control, vacuum sealing drainage can be used for thoracic or abdominal cavity closure.

4.2 Rewarming and Resuscitation in TICU

Measures should be taken to rewarm the patient at the beginning of treatment, such as keep the patient away from the cold environment, raise room temperature, preserve body temperature, etc. Infusion and peritoneal lavage of warm liquid is also effective. Patient's body temperature should be monitored during rewarming process. We've discovered in practice that the key to bleeding control and to avoid coagulation disorders is to stop the bleeding, rather than fluid infusion. Blood perfusion of vital organs can be maintained while the systolic pressure is over 70 mmHg. Aggressive and rapid fluid resuscitation on post operation patient can cause diluted coagulation disorder, which aggravates patient's critical condition [21]. Damage control fluid resuscitation doesn't request fully blood pressure recovery. With less fluid infusion, preoperative preparation and TICU resuscitation can be completed much sooner: (1) maintain systolic blood pressure around 90 mmHg in case of rebleeding caused by high blood pressure; (2) use colloid solution as resuscitation fluid. Component blood transfusion is better than concentrated red blood cells transfusion. Platelets and cryoprecipitation transfusion to improve coagulation should also be considered when necessary. For patients in critical conditions, whole blood transfusion can also be used. The amount of crystal liquid infusion should be minimized. Crystal liquid should be used only for preparation of necessary first aid drugs or to maintain smooth flow of the catheter after blood transfusion.

4.3 Definitive Surgery

The purpose of reoperation is to remove the stuffing in body cavity, to stop active bleeding, and to treat secondary injury and explore oversighted injury, including the repair, resection and partial resection of parenchyma organs, repair or resection of cavity organ damage, repair of vascular injury, permanent fixation of fracture, and closure of the thoracic abdominal incision, etc. Definitive surgery is generally performed within 48–72 h after initial surgery. Fixation of bone fracture is usually performed two weeks after injury, when patient's condition is suitable for further surgery and invasive treatment.

5 DCT in Multiple Injury

5.1 Preparation

Patient prognosis improves as time from injury to DCT shortens. So the decision of whether to perform DCT should be made before or soon after surgery begins. The decision is based on patient's initial physiological conditions and traumatic conditions. Do not wait until after the appearance of metabolic disorder. Prehospital emergency medical care time and preparation time should be minimized. After initial patient estimation, procedure of diagnosis and treatment should be made and all non-necessary examination should be avoided. For example, if diagnostic abdominocentesis is positive and patient presents symptom of hemorrhagic shock, immediate exploratory laparotomy should be performed. Under this circumstance, radiographic examination is not necessary. Consent forms for examination, treatment and surgery should be prepared in advance for time saving. Standard procedures of diagnose and treatment for critical patients should be established by paramedics, surgeons and the operation room, and should be followed. Volumetric resuscitation can aggravate hypothermia and coagulation disorders, therefore is not recommended.

5.2 Primary Estimation of Trauma Injury

Whether to apply DCT should depend on type of trauma. Patient's physiological function parameters only serve as a reference. The type of trauma is the decisive factor: (1) the mechanism of injury: high energy blunt trauma, multiple penetrating injury; (2) the nature of injury: major vessel injury with multiple organ damage and fatal bleeding. (3) major organ damage: major thoracic vascular injuries and heart injury, severe liver and peripancreatic vascular injury, severe pancreatic duodenal injury, pelvic hematoma and open pelvic fracture.

6 DCT Principle in Multiple Injury

6.1 Brain Injury

The main principle is to actively treat primary brain injury and prevent secondary brain damage and other complications, such as cerebral edema, brain swelling, hypoperfusion of brain tissue and ischemia reperfusion damage. The initial estimation of brain damage patients is based on trauma history and GCS. In the early stage, any unnecessary definitive surgeries can aggravate patients CPP, therefore aggravate secondary strike. For patients with unstable hemodynamics, especially those in need of emergency craniocerebral operations, diastolic pressure during surgery need to be maintained around 90 mmHg to ensure organ hemoperfusion. In summary, primary surgeries are aimed to stop intracranial hemorrhage, to evacuate intracranial hematoma and to prevent infection. Treatment at this stage emphasizes on quick diagnosis and immediate surgeries, while treatment at later stage emphasizes on preventing cerebral edema and intracranial infection: (1) Large amount of scalp avulsion: treatment focuses on controlling bleeding and contamination. (2) Skull fracture: restoration of open fracture and depressed fracture should be performed after early debridement and suture, when risk of infection decreases. (3) Basilar fracture with active bleeding: first apply intubation to ensure airway potency. Meanwhile, use gauze packing, hemostasis injection or interventional therapy to control bleeding, as well as blood transfusion to correct hypovolemia. (4) Intracranial hemorrhage: conservative treatment should be applied for patients in critical condition. For patients with intracranial mass lesion resulting from epidural, subdural or intracranial hematoma who can not tolerant major surgery while in need of intracranial decompression, surgeons should consider trepanation and drainage. After improvement, patient should be treated with decompressive craniotomy. (5) When suffering from brain stem damage, patient is in risk of coma and cardiac arrest and should be treated with tracheotomy.

6.2 Thoracic Injury

The main principle is to immediately treat life-threatening tension pneumothorax, hemathroax and cardiac vessel injury to ensure patient's respiratory function and control bleeding. Precautions should be taken to prevent pulmonary edema, ARDS and infection. Analgesic therapy should be applied to relief active breathing reduction due to fear of chest pain. Thoracic close drainage and chest fixation can be used for most thoracic injuries. Disturbance of circulation due to mediastinal flutter and late-presenting diaphragmatic hernia should not be ignored. Patients with cardiac tamponade and bleeding caused by thoracic vessel injury should be operated immediately. Severe lung and bronchus injury can be treated with emergency pneumonectomy. In case of diaphragm injury, diaphragmatic repair should be performed. Resuscitation and life support are necessary after surgery. Definitive surgeries such as internal fixation of rib fracture, esophagus repair, vessel damage restoration should be performed after patient's improved. (1) Chest wall injury: chest wall injuries mainly consists of rib fracture, sternum fracture and paradoxical respiration due to flail chest. Treatments include external fiction of chest wall and external tractive fixation. Treating lethal associated injury and shock before internal fixation can significantly improve patient's prognosis and reduce complications. (2) Lung and bronchus injury: lung injuries include contusion of lung, laceration of lung, traumatic wet lung, atelectasis and hydropneumothorax, all of which can further develop into ALI and ARDS. Excessive infusion of crystalloid and rapid reexpansion should be avoided. Patients with trachea injury and complex injury should be treated with intubation, distal inflation or bronchial fistula. Definitive surgery should be performed after the patient is stabilized. (3) Major cardiac vessel injury: cardiac vessel injury mainly include cardigan tamponade, aortic arch injury and traumatic aortic arch dissection. Treatment should focus on early diagnosis and immediate emergency surgery.

6.3 Abdominal Injury

Main principle is to contain contamination, to temporarily close the abdominal cavity, and to apply resuscitation and life support within 48 h after initial surgery. Definitive surgery should be performed after resuscitation to repair damage discovered during the initial surgery. (1) Parenchymal organs: use packing and vascular ligation method to control bleeding and contamination (bile, etc.). Packing can be used for all the abdominal organs and retroperitoneal tissues, such as liver, pancreas, kidney, spleen, pelvis, retroperitoneal vascular and other organs. Bleeding caused by tissue damage, including arterial, venous bleeding and wound errhysis. Simple, safe and effective measures can be adopted for complex vascular damage, such as repair of rupture, ligation, temporary cavity shunt. (2) Hollow organs: Once the bleeding is under control, surgeons should focus on containing contamination. Simple intestine perforation can be closed using one-layer suture. Complex intestine damage such as colon damage or extensive small bowel injury should be treated with resection and secondary anastomotic. Ileostomy or colostomy is not recommended, neither is conventional resection and anastomosis. Duodenal, biliary, pancreatic injury can be treated with drainage and packing. Gallbladder stoma drainage can be performed for biliary injury. Pancreaticoduodenectomy can be performed for duodenal papilla injury, but restoration is not recommended. Apply intubation and drainage for ureteral injury instead of direct suture. Urethral drainage and suprapubic drainage can be applied in bladder injury. Distal pancreatic injury with extensive tissue damage, including pancreatic duct damage, can be treated with distal pancreatic resection. Severe pancreatic and duodenal injury should only be treated with debridement and drainage, because of patient's intolerance of complex surgery such as pancreatic and duodenal resection. Small duodenal injury can be fixed by single layer suture, while debridement and secondary surgery are required for major duodenal injury.

6.4 Bone Fracture

The main principle is to stabilize fracture ends by temporary external fixation. Vascular shunt can ensure the blood supply of the distal end of the limb. Close open fracture to prevent infection and bone necrosis. Definitive surgery should be performed after stabilization. (1) Limb fracture: For elderly patients or patients with primary cardiac or pulmonary diseases and who can not tolerant major surgery, bone traction and external fixation should be considered. Precautions should be taken to prevent thrombosis and thrombosis associated complications. Anatomical reduction is not required. Patients with intra-articular fracture or bone defect should be treated with second operation such as internal fixation and bone grafting. (2) Pelvic fracture: Using pelvic external fixator and sacral iliac screw technology to stabilize the pelvic ring. Packing and intervention can be used to reduce pelvic bleeding, as well as internal iliac artery ligation. Damage control in orthopedics department is mainly used in 2 occasions, one of which is the joint injury associated with head, chest or abdominal injury, the other is when patient can't tolerant complex surgery. (3) Spinal fractures: Spinal fractures often combines with nerve injury, resulting in paraplegia or high paraplegic. Prone position is often used during surgery. Therefore, the priority is to guarantee respiratory and circulatory function. Fixation of bone fracture should wait until secondary surgery.

6.5 Vessel

The main principle is to use temporary intravascular shunt technology instead of vascular transplantation and repair. The procedure can be performed safely by medical instruments, with no rely on vascular surgeons. Definitive surgery of restoration must be completed within 24 h. For patients under unstable condition who can not tolerant surgery, amputation is necessary to prevent necrosis induced sepsis, which can develop into life threatening MODS.

6.6 Skin and Soft Tissue

The main principle is to deride damaged tissue as much as possible. Using VSD technology to contain contamination and to promote wound healing, eventually to improve wound condition for the secondary suture and skin grafting. (1) Soft-tissue defection; (2) burn: Using VSD can prevent patient from further deterioration. Fixation of skin graft and skin substitute is necessary. topical application of antibiotics. The physiological advantages and the same point of other indications are: to remove the wound edema, infection and inflammatory substances, and to increase the perfusion of the wound. Especially in the prevention of further burns in the skin layer depth. Partial administration of antibiotics to prevent infection. Taking cautions to prevent wound swelling, infection and inflammation benefits tissue recovery. (3) Skin graft: The survival of skin graft depends on sufficient fixation during the critical period of 2–5 days after transplantation. The graft is likely to shift and exude on the irregular surface, which results in separation and eventually graft failure. VSD technique can be applied to reduce the defect, to increase granulation tissue formation, to control infection and to clear exudate, therefore to keep the graft and recipient bed laminated. VSD can also stimulate neovascularization, increasing the successful rate for skin graft.

6.7 Resuscitation

Damage control resuscitation (DCR) is an integrated recovery measures. It starts immediately after the initial rapid assessment of patients in the emergency room, and carries out during following surgeries and ICU monitoring. The main principles are: (1) Systolic blood pressure should be maintained under 90 Hg mm (1 Hg = 0.133 kPa mm), in case of rebleeding due to high blood pressure. (2) Use blood products as resuscitation fluid. The amount of crystal liquid infusion should be minimized. Crystal liquid should be used only to maintain smooth flow of the catheter after blood transfusion. (3) Restoration of blood volume mainly relies on fresh frozen plasma (FFP). FFP should be infused together with concentrated red blood cells at the ratio of 1:1. (4) For severe critical patients, whole blood transfusion can be used for resuscitation. (5) Other blood products such as platelet and recombinant activated factor VIIa. (6) When to terminate resuscitation: (1) Blood level and duration time of lactic are closely related with patient's prognosis, so the lactic acid level could be used as a parameter for ending DCR treatment. (2) Lack of alkali can reflect the degree of systemic tissue acidosis and is closely related with prognosis. The level of alkali lack should be monitored during DCR process, as well as be used as a parameter for ending DCR treatment.

Patients with multiple injuries are often in critical conditions. Therefore, indications of DCT on severe multiple injury patients should be extended. In addition, there are conflicts when dealing with severe multiple injury. Surgeons should establish priorities. Severe injuries such as intracranial hematoma with intracranial hypertension, severe lung and bronchus injury, thoracic-abdominal injury, parenchyma organ injury such as liver and spleen combined with hemorrhage etc. should be treated immediately. Surgeons can divide into different groups and deal with each injured site simultaneously if necessary. The less lethal injuries can be treated with secondary definitive surgeries after resuscitation. Operation plan is also necessary for definitive surgery. Restoration of each tissues and organs can be settled one by one. Therefore, in future treatment of multiple injuries, it is important to pay attention to every step of treatment. Application of DCT can effectively sustain first strike during early time of trauma, and actively prevent secondary strike. Applying customized and integrative treatment according to each patient's individual injuries and conditions is an important developing direction of multiple injury treatment [22].

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