

An Overview of Recent Developments in the Management and Research of Trauma

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Abstract

Trauma is one of the devastating problems of modern society. Each year, more than one million people die of trauma worldwide. In this paper, some of the recent developments in the management and research of trauma are presented: (1) Traumatology and injury epidemiology; (2) Trauma scoring and multiple injuries; (3) Blast injury and impact injury; (4) Mine injuries and firearm injury; (5) Classification of war wounds; and (6) Basic science research on trauma.

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Introduction

With the development of socio-economy and medicine, many diseases such as fulminating infectious diseases, have been effectively controlled or obliterated, but trauma, the “twin brother of modern civilization”, is on the rise. Each year, more than one million people die of trauma and several millions are injured worldwide.¹ In the past 40 years in China, trauma is the fifth cause of death in urban districts, following malignant tumour, cerebral vascular diseases, respiratory diseases and cardiovascular diseases and the fourth cause of death in the countryside, following respiratory diseases, cerebral vascular diseases and malignant tumours.^{2,3} In the same time period, the number of yearly road traffic accidents (RTAS) and road traffic trauma (RTT) increased 30 to 50 times.⁴ Annually, road traffic accidents alone killed more than 50 000 people in China. In 1995 it went up to 271 843.”

Traumatology

With the development of trauma medicine, an independent and comprehensive subject-traumatology has been formed. In the aspect of clinical and preventive medicine, it deals with injury epidemiology, trauma scoring system, emergency technique and equipment, diagnosis, treatment and prevention of various regions of trauma, multiple injuries and their complications. In the aspect of basic sciences, it includes pathomorphology, pathophysiology, biochemistry, bacteriology, immunology and bioengineering mechanics on trauma and wound ballistics. In addition, a new branch of

traumatology, molecular traumatology, is being formed. At present, the research focuses on various cell factors, for instance, platelet-derived growth factor (PDGF), interferon, fibroblast growth factor (FGF), insulin-like growth factor (IGF), transferring growth factor β (TGF- β), epithelial growth factor (EGF), nervous growth factor (NGF), interleukin (IL), tumour necrosis factor (TNF), and their role in trauma, especially in wound healing or tissue repair after injury.⁵

Injury Epidemiology

This is a new branch of traumatology, which deals with the causes, influential factors and epidemiological roles of trauma and its prevention.^{6,7} Many scientists are interested in the study on the epidemiology of road traffic trauma. An analysis of the causes of traffic accidents showed that more than 95% of road traffic accidents were due to “the man factor”, including lack of sense of traffic safety and non law-abiding for all road users, and the driver’s fault accounted for about 70%.⁴ Recently, the emphasis of the study has been put on the psychological tests for driver’s occupation, aptitude and accidental proneness, showing that 0.1% to 1.0% of professional drivers should be eliminated and 8% to 10% of drivers were considered defective.⁴ In comparison with other diseases, road traffic accident was the first in Work Year of Potential Life Lost (WYPLL) and the second in Years of Potential Life Lost (YPLL).⁸ This shows that road traffic accident is indeed “the main public hazard” and should be given more attention.

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Trauma Scoring and Multiple Injuries

Since the publication of AIS (Abbreviated Injury Scale) in the United States, many new trauma scoring methods have been put forward. At present, Trauma Index and CRAMS (Circulation, Respiration, Abdomen and Thorax, Motor, Speech) are often used in the prehospital stage, while AIS-ISS (Injury Severity Scale) is widely used in hospitals. In cases of multiple abdominal organ injuries, the maximal AIS score should be squared and the AIS scores of other injured organs added i.e. $(A_1)^2 + A_2 + A_3$. Here A_1 stands for the score of the abdominal organ with the most severe injury, while A_2 and A_3 stand for the scores of other injured abdominal organs." In addition, TRISS (Trauma Score and Injury Severity Score) may reflect both physiological (RIS) and anatomical (ISS) parameters. Age and injury type are weighted and included.¹⁰ The probability of survival (PS) may be estimated through a mathematical model. In this way the physician will be able to diagnose the severity of the injury quantitatively and in a standardized manner. A retrospective analysis of 1238 trauma cases showed that a case with I'S close to 0 has more severe injury and higher mortality." ASCOT (A Severity Characterization of Trauma) was reported to be more accurate in prediction of I'S than TRISS.⁹

Champion et al¹¹ reported recently that "the widely-used scoring systems that we have (AIS, RTS, TRISS and ASCOT) are a fairly primitive focus on mortality, and are certainly not robust enough for many important applications". They advocated that "substantial refinement is required to link injury severity with the many outcomes other than death". Obviously, it is a long-term task to define a simple, robust and effective way to compare the complexities of injury in a manner that accurately represents the possible multitude of organs injured with all grades of severity.

Blast Injury and Impact Injury

With shock tubes and TNT explosions, some experimental results were accepted as follows: 1) The underpressure of blast wave may produce various degrees of lung injury similar to those by overpressure. The peak underpressure values are proportional to the severity of the lungs. A decreasing ratio would be better than a peak pressure level to reflect the relationship between blast strength and its biological effects. 2) The mechanism of being injured by blast wave is due to overstretching caused by sharp extension. 3) Based on an experiment on 145 sheep, a reference formula was established to express the safety limit of muzzle blast wave for nonauditory injuries of the human body as follows:

$$P_s = 37 - 3 \ln \frac{TC \cdot N}{4} \quad (\text{kPa})$$

Here P_s stands for peak overpressure at the gunner's position. N for times of gun firing and TC for the duration of gun firing. $\ln$ is the natural logarithm.¹²

In an experimental study with sheep exposed to complex blast waves in enclosures, Axelsson and Yelverton¹³ reported that there was a good linear relationship between the severity injury index (which includes injury to the lungs, upper respiratory tract, gastrointestinal tract and solid intra-abdominal organs) and the calculated chest wall velocity. The maximum chest wall velocity was nearly constant for the same degree of injury: 4 m/s for threshold injury, 8 m/s for 1% of lethal dose (LD_{01}) and 12 m/s for 50% of lethal dose (LD_{50}).

Studies of personal protection from primary blast lung injury by Cooper and Cripps^{14,15} showed that acoustic decoupling achieved by foamed polymer backing on glass-reinforced plastic (GRP) or resin-bonded Kevlar plates to the thorax, significantly reduced the severity of primary blast lung injury in the pig's model. The blast protection designed to protect the lungs from coupled stress waves is also effective in preventing small bowel injury. However, enhanced coupling achieved by a foam layer alone applied to the thorax increased the severity of lung injuries.

Research on impact injury of the chest showed that the physical parameters of impact (impact velocity, energy and force) correlated with the responsible parameters (compressed volume, deformation velocity and viscous response) in an exponential or logarithmic function. There was a more significant relationship between viscous criterion and injury score among many tested parameters. A "blast" type injury would occur when the compression response is small enough and the impact velocity is high. On the contrary, a "crushing" type injury would occur when the impact velocity is low and the compression response is large. In addition, the severity of bronchial injury is greater than alveolar injury when the impact velocity is low. However, alveolar injury is much more severe than bronchial injury when the impact velocity is high. The severity of cardiac injury is closely related to the product of impact velocity and compression criterion.^{16,17}

Mine Injuries

Coupland and Molde¹⁸ reported that over the last 12 years, about 12 000 of the 45 000 war-injured patients treated by the International Committee of the Red Cross Society were victims of anti-personnel mines. An analysis of the ICRC database in Geneva showed that in five hospitals, 17 414 patients (24%) were injured by anti-personnel mines. There was a very high percentage of mine injuries in hospitals near to the Cambodian border where sometimes more than 60% of the patients were injured by mines. Of the 4140 patients injured by mines,

31% (1284 cases) required surgical amputation of the lower limbs and almost 3% (110 cases) required amputation of both lower limbs. Death rates were around 3% (4.5% for patients arriving within 6 hours after injury and 1.5% for patients arriving after 72 hours). Netchaev and Gritsanov¹⁹ said that mine-explosion injuries were the result of impulse action of numerous afflicting factors of an explosion. Mine explosions cause not only severe and extensive tissue destruction, mainly of the lower extremities, but also a general contusion-commotion syndrome (CCS), syndromes of capillary-trophic insufficiency (micro-circulatory crisis) and neurodystrophic disturbances. Treatment should concentrate on prompt evacuation of the wounded and high quality of emergency treatment at the prehospital stage.

Classification of the War Wound

Coupland²⁰ put forward "The Red Cross Wound Classification" in 1991. The main contents are shown in Tables I and II.^{20,21}

Bowyer and others^{22,23} used this classification to categorise the wounds of 123 victims in Afghanistan and quite a few wounds during the Gulf War. The results showed that this wound classification system is quick and simple to apply. Fragments produce a higher proportion of simple soft tissue wounds than bullets; bullet wounds are fewer but tend to be more severe, often

involving fracture or damage to vital structures. Mines produce a mixed pattern of soft tissue wounds (from fragments) and extensive limb injuries (from direct contact with the exploding device).

Sippo²⁴ applied this classification to the NATO medical forces. He felt that the Coupland classification provides a simple, informative and quick method of classifying wounds so that the management of injuries can be compared. But this classification does not accumulate all information needed by the military surgeons. It would be better to add the following information, that is, the source of injury, protective equipment performance, associated injuries, time table of evacuation, management and resuscitation.

Firearm Wounds

Savic et al²⁵ indicated that plasma glucose concentration is positively related to ISS over the whole severity range, and post-traumatic hyperglycaemia is a good indicator of both the magnitude and duration of general response of the organism to injury. Also, measurement of blood glucose concentrations can be repeatedly obtained in the field in a few minutes. Therefore, they believe that measurement of blood glucose might be a good adjunct triage tool to the Red Cross Wound Classification in the battlefield.

Mattox et al²⁶ put forward a new concept in ballistic resuscitation. More than 1000 penetrating trauma patients were randomised to immediate versus delayed fluid resuscitation. The results showed that mortality was 33.2% for the immediate (traditional) fluid resuscitation group and 23.6% for the delayed or limited fluid resuscitation group. Complications including adult respiratory distress syndrome (ARDS) and renal failure were greater in the immediate fluid resuscitation group as was ICU stay plus blood replacement requirements. They advocated restriction of crystalloid fluid resusci-

TABLE I: RED CROSS WOUND SCORES

E = Entry	Estimate maximum diameter of entry wound (cm)	
X = Exit	Estimate maximum diameter of exit (cm)	Score X = 0 if no exit
C = Cavity	Assess if wound cavity will admit two fingers before surgery	For chest and abdominal wounds, this refers to the wound of the wall
	C = 0, no	
	C = 1, yes	
F = Fracture	F = 0, no fracture	Some wounds will fall between these categories; guidance is given in the ICRC Red Cross Wound Classification booklet
	F = 2, fracture with clinically significant comminution	
V = Vital structure	Assess for breach of dura, pleura, peritoneum, or major vessel	Vascular damage as far distal as the brachial or popliteal vessel is considered major in this classification
M = Metallic body	Bullets or fragments on radiograph	
	M = 0, none	
	M = 1, one	
	M = 2, more than one	

TABLE II: DEFINITION OF WOUND GRADE AND TYPE

Grade (the extent of tissue damage)	Definition
	E plus X scores < 10, with C = 0 and F = 0 or 1 (low energy transfer inferred)
2	E plus X < 10, but with C = 1 or F = 2 (high-energy transfer inferred)
	E plus X > 10, with C = 1, or F = 2 (high-energy transfer inferred)
	Wounds from explosive blast, such as from mines, with massive tissue injury are graded 3, despite the absence of a true entry or exit wound
Type (the structures involved)	
ST (Soft Tissue only)	Wounds with F = 0 and V = 0
F (Fracture)	Wounds with F = 1 or 2 and V = 0
V (Vital structure)	Wounds with F = 0 and V = 1
VF (Fracture + Vital structure)	Wounds with F = 1 or 2 and V = 1

tation until there was operative control of haemorrhage for patients with penetrating missile injuries and post-traumatic hypotension.

An experimental study on pigs²⁷ showed that infection may be prevented in penetrating soft tissue missile wounds for up to three days after injury, provided antibiotic treatment is instituted as soon as possible after injury, ideally within 1 hour. A delay in administration of 6 hours after injury significantly reduces the effectiveness of the antibiotic (benzpenicillin).

Bowyer²⁸ presented his experience in the management of small fragment wounds from the Afghan conflict. The majority of the more than 2000 fragment wounds affected the limbs. Many of the wounds affecting only the skin and muscle were managed with antibiotics and dressings alone. There were complications in only 2 of the 65 casualties who had their wounds managed non operatively. He believes that careful assessment of the wounds and treating selected wounds conservatively is a worthwhile recommendation.

Basic Science Research

Trauma is the result of an instant transfer of exogenous energy to the body. Research on the mechanical process that resulted in trauma is a necessity to clarify this mechanism. A few authors have made some progress in the study of the mechanical response and tolerance of biological tissues and of the relationship between the quantity of the energy transferred and the injury severity ("dose-response relationship").²⁹

Infection or endotoxic shock has been the focus of research because the mortality rate of endotoxic shock is as high as 30% to 50%. Animal experiments have confirmed that lipopolysaccharide (LPS) antibodies, TNF antibodies, thyrotropin-releasing hormone (TRH), prostaglandin inhibitor and calcium channel blocker are promising agents for the treatment of endotoxic shock.⁵

Since 1980, endogenous infection, instead of the exogenous one after severe trauma or thermal injury, has become one of the frontier subjects to study. The significance of the translocation of intestinal flora or intestinogenic infection was assessed.³⁰

In addition, some new concepts or definitions on infection are put forward to replace the old ones.³¹

Sepsis syndrome, recently named the systemic inflammatory response syndrome (SIRS), which is a more exact term to describe the systemic inflammatory response in the absence of infection, should be suspected in critical trauma patients with evidence of tachypnoea (>20 breaths/min) or hyperventilation ($\text{PaCO}_2 < 4.27$ kPa or 32 mmHg), tachycardia (heart rate >90 beats/min), hypothermia (<36°C) or hyperthermia (>38°C) and a white blood cell (WBC) of less than $4.0 \times 10^9/\text{L}$ or more than $12 \times 10^9/\text{L}$.

Sepsis is defined as SIRS in the presence of infection, and septic shock is sepsis plus hypotension (systolic blood pressure <12 kPa or 90 mmHg).

There is a significant alteration in cells of the immune response when severe injury has occurred.³²

Immune dysfunction, secondary to trauma or burns, is the main cause of post-injury infection. At present, the discovery of immuno-inhibitory factor and the intensification of inhibitory cellular activity are the two topics being investigated. Monoclonal antibodies against immuno-inhibitory factor have been developed and used clinically.

The study on the changes of immunoactive factors such as IL, TNF and interferon after trauma or burns and the changes of surface antigen of the inhibitory cellular membrane and its receptor, is a trend today in order to further clarify the mechanism of immune inhibition.³³

The study on the metabolism of endocrine hormones after trauma or burns is now concentrated on their receptors such as the changes in the number and sensitivity of insulin receptors.^{34,35} The changes of glucocorticoid receptors and the regulatory effects of glucocorticoid on the receptor mRNA. The study on hormones after trauma has deepened into the investigations of the responses of peptide hormones including the gene chemical synthesis of IL-1, IL-2 and others, and the nitrogen balance and protein metabolism after trauma. The study on fibronectin is now focused on the analysis of genes and molecular submicrostructure and the studies on enzymes such as angiotension converting enzyme, superoxide dismutase, β -decarboxylizing enzyme, elastinase, and phospholipidase A_2 are still concentrated on their activities.

In recent years, the study of tissue repair has progressed from the traditional histological and cytological level to the molecular level.³⁶ The activity of growth factors in wound healing has been studied by many authors.^{37,38} The macrophage is considered central to the normal wound healing process and serves as a source of growth factors (such as EGF, FGF, TGF- β , PDGF, TNF and IL-1) that have activity for fibroblastic and epithelial cells and matrix in the wound. Wounds treated with cytokines showed increase in epidermal and dermal thickness, organisation and maturation.³⁷ At present, the factors promoting tissue repair can be obtained through gene engineering. Another hot spot of the study on tissue repair is the employment of artificial skin, which is composed of cultured human epithelium conjugated with synthetic dermas. It is believed that artificial skin is very useful in the field of traumatology, especially for the treatment of burns.

The syndrome known as multiple-organ failure (MOF) was first recognised by Tilney et al³⁹ in 1973 after

abdominal aortic aneurysm surgery. MOF accounts for more than 50% of late deaths in trauma patients.³¹ Knaus et al⁴⁰ pointed out that "the duration of MOF is also important". They reported no survivors if three or four organ system failures lasted for more than 4 days.

Multiple-organ failure may be caused by two categories of factors: the first includes those that lead to regional blood flow distribution abnormalities, such as hypotension or fluid overload, and the second includes those that incite inflammation, such as sepsis or pancreatitis. Major trauma and burns can produce both regional perfusion deficits and a systemic inflammatory response.³¹ Goris et al⁴¹ reported that 44% of trauma patients with MOF had no positive blood cultures or definite foci of infection. The severity of organ failure was similar to that seen in patients with documented infection.

In the presence of major injury or bacterial challenge, the uncontrolled release of many mediators, called cytokines (polypeptides with hormone-like activity) occur,³¹ and they play an important role in the overstimulation or excessive response of the immune inflammatory system which may, cause MOF syndrome, the physiologic end point of late death in severely injured patients.⁴² Now there is a suggestion that the term multiple organ failure (MOF) be replaced by multiple organ dysfunction syndrome (MODS).⁴³

In China, several laboratories studying trauma biomechanics have been established. The Research Institute of Surgery of the Third Military Medical University is building a specialised laboratory on impact injury which is able to simulate various injuries such as traffic accidents and other impact injuries.⁴⁴ In addition, the workers of the institute have made considerable achievement in the establishment of mathematical and physical models of the blast injury of the lungs and in the determination of certain mechanical response parameters. The study of biomechanics in the field of orthopaedics goes much deeper and a reference book has already been published.⁴⁵ The research on wound ballistics has attracted the attention of researchers from other countries.⁴⁶

A lot of work has been done on the clarification of the relationship between the cellular factors, such as TNF, PAF, and IL, and the pathogenesis of infection and/or endotoxic shock. It has been confirmed that TNF is closely related to the outbreak of infection and/or endotoxic shock. General immune suppression and marked changes of phospholipidase A, were found in patients with shock.⁴

Li et al⁴⁷ reported that the sera from rabbits with close comminuted fracture could reduce immune response. In the serum there is a substance with a molecular weight of about 9000. They feel that it might be the main

factor involved in the pathogenesis of immune suppression in animals with mechanical injuries.

Bacteriological, immunohistochemical and ultra-structural studies have been carried out on the translocation of intestinal flora or intestinogenic infections. The changes in the morphology of the intestinal mucosa and its barrier function were observed in the onset and development of intestinogenic infections. The efficacy of Chinese herbal immunomodulators such as *Astragalus membranaceus*, *Coriolus versicolor*, *Paeonia lactiflora* Pall, and *Lonicera japonica* Thumb was assessed.⁴

Quite a lot of work has been done on the receptors of insulin and glucocorticoid, the response of peptide hormones to injury and its mechanism and the role of fibronectin in tissue repair. The gene expression of EGF, FGF and BMP (bone morphogenetic protein) has been completed and that of TGF, IGF and PDGF are being studied. It is confirmed that bFGF plays an important role in tissue repair. An animal model of multiple system organ failure (MSOF) has been established and the study on the pathogenesis, prevention and treatment of MSOF has started.⁴

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