1 Introduction to the Repair and Regeneration of War Wound Tissue

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1.1 A Brief History of the Development of War Wound Tissue Repair and Regenerative Medicine

Trauma is the oldest medical problem. Because since the birth of mankind, there has been a history of people fighting against nature. In order to survive, human beings will experience falls and various injuries during activities such as hunting and fruit picking. Trauma has become one of the earliest forms of human disease, and it has been used in the continuous exploration of such things as clay and charcoal. The hemostasis of wound, sputum wounds, chewing plants applied to the wound surface to accelerate healing and complete the most primitive wound healing prototype of human beings. With the development of mankind, wars began to emerge due to the emergence of classes and religions. Ambulance and healing wounded and sick became the origin of war trauma medicine. War became one of the important factors in promoting the theory and technology development of trauma treatment. The development and upgrading of war further promote the theoretical and clinical improvement of posttraumatic tissue repair and regeneration. Therefore, war wound and trauma are actually two areas under the big concept that are both interconnected and have certain connotations. Trauma is the general concept of injury, while war wound is a special form of trauma. Fourth century BC, war wounds were cold weapon wounds, and the treatment was very simple. From the fourteenth century, firearms gradually replaced cold weapons, and a large number of armed forces completely changed the nature of war wounds. In the sixteenth century, French surgeon Ambroise Paré (1510–1590) suggested that due to the large amount of peripheral tissue damage caused by firearm injuries, the wound should be incision when the wound is severe. The word "debridement" appeared in the seventeenth century. In the eighteenth century, the initial treatment of firearm injuries included incision, resection, and drainage. During the Napoleonic Wars, Dominique-Jean Larrey (1766–1842) set a precedent for regular and certain system of battlefield ambulances, transporting the wounded to safe areas for further treatment, and establishing aid station. The foundation for modern trauma repair medicine has been laid. During the First World War, the number of people killed on the battlefield was about 10 million, and the number of injured reached more than 20 million. During the Second World War, the belligerents lost a total of about 50 million people. The number of casualties far exceeded that of the First World War. This fully shows that the weapons are more and more advanced, and the killing power is getting bigger and bigger. In addition to the early field ambulance to save the lives of the wounded, millions of wounded in the later stage in order to reduce disability need to obtain ideal and fine repair and reconstruction treatment. Surgeons face a large number of tissues and organs that need to be repaired and reconstructed, such as cracked skulls, severe facial burns, crushed jaw bones, nose and lip gunshot wounds, etc. The type and severity of trauma is unprecedented. Past war statistics show that during the Second World War (1939–1945), the total number of US casualties reached 963,403, of which 291,557 (30%) died in combat. In the Vietnam War (1955–1975), the total number of casualties in the US military was 200,727, and the number of deaths in combat was 47,424 (24%). With the further improvement of transportation tools, communication means, medical and health equipment, as well as the improvement in the quality and technology of the rescue personnel, the fatality rate of war wounds has gradually declined. According to the statistics of the US Department of Defense on November 17, 2004, the number of casualties of the US military in the wars in Afghanistan and Iraq reached 10,726, of which 1004 were killed in combat, accounting for only 10%. Therefore, a lot of work is repair and functional reconstruction. In the era of peace, the number of deaths from traffic injuries caused

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by the rapid development of transportation has greatly increased, which has become one of the important causes of injury in modern society. In addition to the casualties caused by other factors, trauma has become the main cause of death in modern society. In 1966, the American Academy of Sciences published a programmatic document entitled *Injury Caused by Accidental Injuries, a Disease Neglected by Modern Society*, which changed people's perceptions of trauma, from "trauma is an accident" to "trauma is a disease that can be prevented and controlled," effectively promoting the development of modern trauma first-aid systems, basic research, technology research, and clinical treatment. The establishment of a trauma emergency center and a first-aid system is the basis for standardized treatment of trauma, and each state has established its own regional trauma emergency center. Since then, the developed countries, such as Britain, France, Germany, and Japan, have also established their own trauma emergency systems. After more than 30 years of development, developed countries have formed a relatively complete network of trauma emergency and formulated various corresponding normative documents. It significantly improved the success rate of trauma treatment. In Canada, for example, the ever-improving trauma emergency system has reduced the severe trauma mortality rate from 51.8% in 1992 to 8.6% in 2002. At present, the concept of war wound treatment has changed a lot. In addition to the wounded directly caused by the war, the treatment of wounded people in nonwar military operations (including major natural disasters, counterterrorism, and stability) is also included in the scope of war wound treatment. At the same time, war wound treatment is no longer a patent for army surgeon, and many nonmilitary hospitals have directly or indirectly participated in the treatment of war wounds. With the increase in the number of noncombatants injured in modern conflicts, the equipment and technology for traumatic treatment in peacetime cannot meet the requirements for treatment. Therefore, it is imperative to establish a complete war wound treatment system, linking the site, transshipment, hospital treatment, and later rehabilitation and regeneration to form a complete chain of treatment. In addition, due to changes in social development and disease spectrum, various tissue damages caused by diseases, such as the treatment of diabetic foot (the important complication of diabetes), have also been included in the scope of trauma treatment, which deserves everyone's attention.

1.1.1 A Brief Review of the Development of Traumatic Repair Medicine in the World War

As early as 3500 BC, the Mesopotamia region, one of the birthplaces of the four major civilizations, had records of doctors participating in war wounds. In ancient Egypt, there were 48 examples of how wounds were treated in 1600 BC, and they were similar to today's surgical treatment principles; there was also a mixture of gum, goat's milk, and human milk to treat burns. In 600 BC, Chinese people used tinctures or tea extracts rich in tannin to converge on the wounds, while the Romans used honey and exposed treatments for burns. In the decree of the Babylonian dynasty, there is also a record of "if the free man dies due to surgery, the surgeon's right hand must be cut off." There is still no systematic understanding of anatomy in this period, and there is still limited progress in surgical medicine to the Middle Ages (sixth–fifteenth century). In the era of the Roman Empire, from 30 BC to 38 AD, the highly educated Roman aristocrat Celsus had reconstructed the surgical repairs of the glans, face, lips, nose, and ears of the Roman soldiers. In Egypt, according to historical records, ancient Egyptians did not perform reconstructive surgery using living tissue transplantation as a means. In ancient India, there was a nose-cutting wind. The winner of the war could cut off the nose of his prisoners of war. The government could impose a cut-off sentence on the criminals to show punishment. Therefore, the lack of nose in this period is no shortage of people. Since the position of the nose is most prominent on the face, its deformity is very significant, so most people who lack the nose are eager to get a new nose. In order to meet this need, the Indian society invented the forehead midline flap for nasal reconstruction.

In the ninth century BC, the ancient Greek epics Iliad and Odyssey recorded some treatments for orthopedic diseases such as trauma. In the sixth century BC, the Indian Sushruta Samhita described a technique in detail in his related medical monograph *The Collection*, which is a reconstructive surgery for the repair of organ defects. At the same time, the book also describes the surgical suture and suture line in detail. From the fifth century BC to the fourth century BC, the ancient Greek famous doctor Hippocrates (460 BC–370 BC), regarded as the "father of medicine," explained the importance of hemostasis, bandaging, and providing cleaned equipment and the concept of "War is the only proper school of the surgeon" was presented. The school's principle of dealing with wounds is to keep the wounds quiet and minimize external stimuli. The careful docking can heal the broken tissues and bones. This is the prototype of the theory of surgical sutures and fracture repair. *The Hippocrates Collection* records manual reduction, external fixation of the splint can treat limb fractures, and dislocation of the joints. The Hippocratic Reduction for shoulder dislocation is still used in clinical practice. Later, Rome's most famous surgeon, Galen (130—200? AD), sutured the sword cut for the gladiator and tried the repair of muscles and nerves, laying the anatomical basis for the traumatic surgery of Western medicine. His work has influenced people's perceptions of soft tissue repair for centuries.

In the first century, the Celsus people mentioned the use of alcohol and myrrh (myrrh is a tropical resin, which can be used as a medicinal material) to make an antibacterial detergent to treat burns. Galen uses vinegar and wound exposure technique to treat burns.

In the seventh century (around 695), the nose of the Byzantine Emperor Justinian II was cut off in a mess. Because the forehead skin was used to repair the reconstructed nose to form a distinct scar, which did not meet the rules that the emperor could not have obvious physical defects at the time, he could not return to the throne of the emperor. In the thirteenth century, Theodoric had a new and deeper understanding of wound healing, especially delayed healing, and he made a significant contribution to the formation of modern concepts in military surgical wound healing. From 1337 to 1453, the Hundred Years' War between Britain and France was intermittently carried out for 116 years. In the war, a lot of new weapons emerged. Especially in the later period, the large-scale use of gunpowder and artillery by the French army not only rewrote the war process, but also brought a large number of wounded people with serious injuries or burns, which accelerated the development of trauma repair surgery. While saving the lives of soldiers, we should minimize the disability of injured soldiers, so that they can return to society. This becomes an important job in trauma repair surgery. In the fourteenth century, the surgeon of the Bavarian army, Pfolspreundt, described rhinoplasty, and the surgeon of the Alsatian army, Brunschwig, contributed to the gunshot wound. By the fifteenth century, Brancas used Italian-style nasal reconstruction to avoid facial scarring. In the sixteenth century, Copernicus's *On the Revolutions of the Heavenly Spheres* was published. Since then, the development of the natural science has dealt a heavy blow to religious theology. This is not only a revolution in the history of science, but also an ideological emancipation movement. Subsequently, the publication of Vesalius's *Structure of the Human Body* freed medicine from the idealistic theology and laid the foundation for modern anatomy. Ambroise Paré (1510–1590) was hailed as one of the founders of modern surgery for his great contribution to surgery. He first proposed the use of ointment burns. During the Renaissance, Gaspare Tagliacozzi (1546–1599), a well-known anatomist and surgical professor at the University of Bologna in Italy, used a single-armed flap to create a new nose for patients with nasal defects. This technique is described in great detail in his surgical monograph. In the seventeenth century, the rapid development of physics and mechanics quickly penetrated into the medical field, bringing unprecedented prosperity to medicine and laying the foundation for the rise of trauma surgery. In 1610s, the British anatomist Harvey reported "blood circulation and its structure of bone tissue," pioneered the anatomical physiology of bone tissue, and made human understanding of bone from macro to micro. In 1741, based on the development of anatomy and anatomical physiology, Nicholas Andre first proposed the scientific name of orthopedics at the University of Paris and was widely accepted, marking the rise of modern orthopedics. Because traumatic orthopedics is the essence of the initial orthopedics (because humans have a relatively shallow understanding of orthopedic infections, tumors, etc., traumatic orthopedics have not yet differentiated from the big family of orthopedics), so the rise of modern orthopedics also reflects the rise of trauma repair science. In 1812, Dominique-Jean Larrey first reported the trench foot. In the early nineteenth century, Dupuytren studied on 50 burn patient treated with bandage therapy and proposed a classification of burn depth. The Englishman Joseph Lister (1827–1912), the founder of the surgical disinfection method, contributed a lot to the treatment of trauma. He first proposed lacking disinfection is the main cause of infection after surgery. Since his publication in 1867, the postoperative mortality rate reduced from 45% to 15% in less than 10 years, saving hundreds of millions of lives. Later, the German surgical specialist Friedrich von Esmarch (1823–1908) invented the first-aid kit and the tourniquet in 1876.

During the American Civil War, Jones suggested a one-stage repair of damaged facial wounds and advocated retaining the skin as much as possible. The necessary trimming of the edges of the irregular wounds should be carried out. Plastic surgeons began to recreate eyelids, nose, cheeks, lips, moles, and chin. Buck completed the first major reconstruction of the total damage, nasal reconstruction with forehead flap. In 1832, the French army's gunner, Louis, in the Siege of Antwerp, was almost killed by the pieces of artillery shells. The left cheek and most of the upper lip were missing, and the right side involved a 1.25-cm earlobe. The soft palate was extensively torn to the upper esophagus, the tongue was extensively avulsed, the lower jaw was almost completely defected, and the four molars were broken. Only a small right side part of the mandible is still intact. His right forearm was a composite fracture with an extensive soft tissue damage caused by shrapnel. M. Louis was immediately taken to the Hoboken Battlefield Hospital, and some thought his death was inevitable. Dr. Forjet, as a surgeon in the Northern Army, completed a preliminary maxillofacial hemostasis and debridement surgery and bandaged him. After the wound healed, the entire mandibular bone defect caused the craniofacial deformity made him almost unable to eat and talk. At that time, no relevant doctors had the knowledge to solve the problem of reconstructing the chin. A silversmith used a mask to cover the missing face. The first to describe this incident was Ballingall, a professor of military surgery at Edinburgh. For almost a century, British and French soldiers masked their face deformities if they had severe facial damage.

In 1863, Gibson completed a complex orthopedic surgery during military service to repair the loss of the lower jaw and lower lip due to gunshot wounds. In the same year, Gouley completed a mandibular reconstruction with two rotating flaps. In 1868, the US military surgeon Prince pointed out that plastic surgery had a lot of uses in military surgery. As a medical inspector of the US military, Hamilton made an outstanding contribution to plastic surgery. That is the application of the transfer flap increased the local blood supply. On the 14th day, the cross-leg flap successfully broken ensured the flap survival rate.

The war has a significant role in promoting the development of modern trauma repair surgery. This can be seen from the incidence of bone trauma in war. In the Franco-Prussian War of 1870–1871, the incidence of limb injuries was 72.5%. In a short period of time, the emergence of a large number of casualties is not only a promotion for the development of traumatic orthopedics, but also provides a lot of practical opportunities and lessons worth summing up, so that the trauma orthopedics can be quickly promoted and developed. The plaster-fixing technique was invented by the Belgian military doctor Antonius Mathijsen during the war and quickly promoted.

In the middle of the nineteenth century, the Russian military doctor Pirogov made a major contribution to the treatment of war injuries. He focused on the systemic reaction of the wounded and fixed it with ether and plaster bandages. In the field of trauma care, an outstanding figure, Nightingale, who reduced the death rate of British soldiers from 50% to 2.2% in the Crimean War, is recognized as the founder and pioneer of modern nursing and nursing education.

In the twentieth century, the outbreak of the two world wars made the trauma repair surgery develop rapidly and was continuously subdivided and improved.

During the First World War, many new weapons, such as tanks and airplanes, were invented, which caused a large number of serious wound-burning patients. On the other hand, although the use of trenches and steel helmets had saved the lives of many warriors, it also brought a lot of facial and neck injuries, especially bone and soft tissue defects of the maxillofacial region. Nonfatal jaw and facial trauma accounted for 10% of the total body trauma, and these wounded were urgently required for advanced repair surgery. Take the German army as an example, the percentage of limb injuries was 63.3%. Therefore, doctors from the United Kingdom, France, Germany, and Russia faced such serious and numerous patients, and established teams of surgeons. The plastic surgery, trauma orthopedics (including hand surgery), and reconstructive surgery developed rapidly, and at the same time a large number of well-known trauma repair surgeons appeared, like Varaztad Kazanjian, Blair, Maliniac, and Gustave in the United States, Veau and Dufourmentel in France, Trueta in Spain, Lexer in Germany, Gillies and Rainsford Mowlem in the United Kingdom, Hâlit Ziyâ Konuralp and Cihat Borçbakan in Turkey, Risdon and Waldron in Canada, Henry Pickerill in New Zealand, Newland in Australia, etc. Blair of the United States and Kazanjian, a French dentist, returned to the United States to create plastic surgery and craniofacial surgery there. Kazanjian, who is revered as the "Western Line Legend," became the first professor of plastic surgery at Harvard University. In the 15th volume of the book *The Medical Department of the United States Army in the World War*, there are three chapters in the 11th volume that cover the craniofacial surgery. In 1917, surgeon Gorgas formed plastic surgery and oral surgery and assigned Blair to manage it. A dentist from Philadelphia, Ivy, was his assistant. Their primary task was to train general surgeons and dentists to work together on craniomaxillofacial wounds. In 1917, the initiative revised Blair's textbook *Surgery and Diseases of the Mouth and Jaws* in 1913. Some new information about gunshot wound treatment was compiled, and the plastic and oral parts were distributed to every hospital in the United States overseas. A summary of the latest articles on craniomaxillofacial surgery was published in the *Review of War Surgery and Medicine* and *Survey of Head Surgery*.

Captain Gillies, a New Zealand-born surgeon in the United Kingdom (later a major), made a significant contribution to the development of trauma repair surgery. His book, *Plastic Surgery of the Face*, described gunshot wounds, shell fragments, and some craniofacial damage that occurs in a car accident. Although Tagliacozzi had described the use of pedicle grafts to reconstruct the nose as early as in the sixteenth century, Gillies was not familiar with Tagliacozzi's classic surgery. He borrowed a book written by the German surgeon Lindemann, invited Morestin, the most famous French plastic surgeon at the time, to persuade medical authorities to form a special treatment center for craniofacial injuries. In less than a year, the Cambridge Hospital in Aldershot began work, and patients with facial injuries were sent to the new medical facility. Gillies took the £10 label written "the Faciomaxillary injury-cambridge hospital, Aldershot," to the hospital in France and pasted it on the injured person's chest. A total of nearly 2000 wounded people were sent there for treatment. He used the flap technique to reconstruct the nose, mouth, eyelids, and auricles, and filled the mandibular defects with ribs. Many complicated operations were original. For example, Gillies and his colleague the Royal dental specialist Valadier first attempted to reconstruct the anatomy and repair the mandibular defect with bone and other tissues, which is called the enlightenment of craniomaxillofacial surgery. The imagery of orthopedics is very important. Gillies asked Tonks to paint all the damage and surgery in picture. It still looks very rare today. Due to his contribution, Gillies was crowned by the British Empire after the war. After returning to the United Kingdom, he continued to work on plastic surgery. In his later book, *Principles and Art of Plastic Surgery*, Gillies left a large space for Millard to write the part of craniomaxillofacial surgery. There were many principles of emergency treatment for craniomaxillofacial surgery that occurred during the First World War, but perfected in the Second World War, combining dental expertise such as oral infections, injuries, and mandibular fractures, with the experience of ordinary surgeons. The treatment of patients with craniofacial and maxillofacial defects was completed by the designated hospital. He emphasized the need to initiate early treatment and make postrepair systematic. When there is a defect in the internal tissues of the mouth, the mandible, and the skin, it is desirable to immediately perform a good aesthetic substitution and restore normal function as soon as possible. The musculocutaneous flap and the free flap become the basic means of replacing the tissue, and many operations during this period have opened up a history. Filatov published a design on the tubular flap in 1917 to address chronic osteomyelitis. In addition to the skin tube, other important contributions of the First World War include: free cartilage graft reconstruction of the nose, double pedicle flap reconstruction of the lips, and repair of intraoral defects with cervical flap.

In the European theater of war during the Second World War, the 298th General Hospital in December 1942 established the first plastic surgery center, from then to Normandy landing on June 6, 1944, in just 18 months, the United Kingdom alone has 10 functionalities. The plastic surgery centers were located in Basingstoke, Gloucester, Birmingham, and Edinburgh. The African theater was located in Algiers and the Italian theater was in Naples. This allowed all the wounded to be effectively treated within a few hours of the injury. After the United States declared war on Japan and Germany, it sent troops from New York to England in October 1942. After landing in Liverpool, a burns hospital was established in November. The plastic surgery had a ward with 25 beds, and in May 1945, at the end of the European battlefield, there were three wards. Due to the use of aircraft and tanks, a large number of patients with burns and facial injuries appeared. In order to share the experience of treatment, the first plastic surgery magazine *The Brenthurst Papers* appeared in the United Kingdom, and it was also the first English plastic surgery journal. In the latter part of the war, nearly 11,572 craniofacial operations were performed at Queen's Hospital in Kent, England. The 4th Maxillofacial Surgery Unit in North Africa and Italy also handled nearly 5000 seriously wounded, including 3000 maxillofacial injuries and 1000 burn patients.

In the 1930s, there were only two plastic surgeons in the United Kingdom. At the beginning of the Second World War, there were four plastic surgeons in the United Kingdom, but by the end of the war, there were about 25 plastic surgeons. There were more than 150 plastic surgeons in the United States at this time. Davis even said that the development of plastic surgery in the United States was a gift from the Second World War to the United States. At the beginning of the Second World War, there were four plastic surgeons in Canada, of which Tilley handled hundreds of allied pilots who needed organ reconstruction for serious damage in the war. Some even joked that the wounded were like laboratory "guinea pigs," which brought Tilley and others back to Canada with a lot of experience in traumatic tissue repair. Even if the war was over, the war wound repair work had not stopped, and these "guinea pigs" continued to play their role.

If the First World War was only the initial establishment of craniofacial surgery, after the Second World War, the French plastic surgeon Tessier really created and developed the craniofacial surgery, with the help of neurosurgery colleague Guiot. A series of plastic surgeries were reformed according to the situation and used to correct facial deformities to bring them closer to normal facial contours. The Germans used mafenide acetate to treat open wounds during the Second World War. In addition, the true skin transplantation technology (first reported by German Bunger in 1823) was widely used and made breakthroughs by means of the treatment experience in the Second World War, and related tissue transplantations such as cartilage, fascia, fat, nerves, etc. appeared at this stage. Bunnel's professional training base for hand surgery has greatly improved the treatment of plastic surgery. At the same time, the psychological work of plastic surgery has also received great attention.

Before the Second World War, hand surgery was basically a blank field. In the 1930s, hand surgery was established in the United Kingdom, the United States, Germany, and Japan. With the advancement of human infection and control technology, hand surgery gradually progressed from the fingers/limbs/toes amputation to the fingers/limbs/toes salvage and put emphasis on functional recovery. In 1944, Sterling Bunnell published the first-hand surgery monograph *Surgery of the Hand*.

In the 1970s, debridement and other advances had significantly reduced mortality, and Andrew M. Munster began to focus on the quality of life of patients with severe burns. In 1979, the first published *Burn-Specific Health Scale* by him became an important work in modern burns research.

During the Korean War, Vietnam War, and Iran-Iraq War, with the development of microsurgery, vascular surgery had made tremendous progress, and the proportion of amputation had dropped to a very low level. At the same time, advances in vascular surgery have provided a strong guarantee for craniomaxillofacial surgery. Due to the impact of high-speed bullets, the damage to soldiers is often from outside to inside, accompanied by various tissue injuries such as skin, bones, and muscles, making the damage more serious and complicated, thus requiring higher repair. The iliac crests and fibulas have reliable vascular pedicles, and secondary deformities are few, often used as donor sites to repair composite tissue defects.

In short, the modern trauma repair surgery has evolved to the present, largely influenced by the two world wars of the first half of the twentieth century. Modern war weapons are rapidly updated. High-speed, high-killing weapons cause a high incidence of bone and soft tissue trauma, and the injury is more complicated. In addition, nerve and blood vessel damage, multiple injuries, and combined injuries are more and more. In the Malvinas War, the rate of limb injury was 67.5% and severe trauma accounted for 90%. How to reduce the health reduction, ensure the combat effectiveness of the troops, and adapt the trauma orthopedics to the needs of military medical support in modern warfare is an important research topic for trauma orthopedics.

After the Second World War, more than 200 local wars or armed conflicts occurred in the world, and new research topics were constantly raised in the tissue repair surgery of the wounds. Russia has conducted an in-depth research on the injury condition, category of wound, injury characteristics, and the organization and management of surgical treatment in local wars or armed conflicts, and introduced the concept of early specialist treatment.

The characteristics of the treatment on the wounded in local wars or armed conflicts are: the war is carried out in a limited area, the human and material resources are limited, and the number of casualties arriving at the rescue ladder is significantly less; due to the effective helicopter air transport, the time for the injured to reach the ladder rescue unit is obviously short; medical conditions improved, early specialist treatment is feasible; not many combat personnel, however, medical ambulance personnel have sufficient reserves, can continuously use to gather strength, and can widely use efficient battlefield surgical techniques. Accordingly, the Russian field surgery focused on the issue of the organization of the wounded in local wars. In the Afghan War and the Chechnya War, due to the widespread use of helicopter evacuation, reducing the level of stairs, shortening the time of specialist treatment, the death rate of the Afghan War was reduced to 4.7%, and the return rate reached 82%. In combination with the actual situation of the war, the study on a large number of mine blast injuries during the war in Afghanistan proposed measures to reduce the complications and casualties. In the treatment of firearm long bone fractures, they first used external fixation devices, first used temporary blood vessels during aortic injury. At the same time, in the treatment of the wounded, a two-step treatment mode was implemented, that is, after the first medical treatment, the wounded were directly sent to the first-step multispecialty hospital for specialist treatment, and new treatment techniques, such as external fixation, endoscopic, injury control techniques, and comprehensive treatment techniques for infection complications, were used in actual combat. In addition, with the development of science and technology and the application of telemedicine technology, it may have an important impact on the application of organization, service, and technology for trauma treatment.

In addition to the above brief historical review, since the beginning of the twentieth century, international scholars have made rapid progress in the basic research, product development, clinical treatment, and discipline construction of war wound tissue repair and regeneration, which has significantly promoted the discipline to a certain extent. It is mainly manifested in: the understanding of tissue repair and regeneration process is further deepened, from the traditional general, tissue, and cellular levels to the molecular and genetic levels. The representative event is the research of growth factors involved in tissue regulation and regeneration in the 1990s and the development of a genetic engineering drug represented by the basic fibroblast growth factor (bFGF) for wound burn wound treatment; the description of the connotation of the repair and regenerative treatment process from the past using three "Rs" (Resection, Repair, and Replacement) to summarize the disposal concept, and later added the fourth "R," that is, regeneration. Later, Xiaobing Fu and other experts recognized the important role of rehabilitation theory, techniques, and methods in tissue repair and regeneration, and proposed rehabilitation as the fifth "R" for perfect repair and regeneration, thereby damaged tissue repair and regeneration forming an organized whole [1, 2] in the treatment technology, the method of debridement of damaged tissue has been developed from the simple use of scalpel debridement to the use of protease debridement, ultrasonic debridement, and other methods to make debridement more precise and beneficial to post-tissue repair and regeneration; breakthroughs in the theory of wound wet healing have enabled many advanced dressings (revolutionary dressings) to be developed, produced, and used in clinical applications. Since then, the theory and technology of using dressings to promote wound healing have been initiated. It has played a major role in shortening the wound healing time, reducing the intensity of nursing, and improving the quality of patients. The technology of tissue engineering has enabled people to construct related tissue repair materials in vitro, thus changing or repairing the damaged tissue; with the breakthrough in genetic engineering technology, people can produce large quantities of proteins or peptides for tissue repair and regeneration to regulate the proliferation and differentiation of repair cells at the molecular and genetic levels; in addition, the establishment and development of negative pressure drainage techniques, physical or chemical methods, and tissue repair of sound, light, electricity, magnetism, oxygen, etc. The elaboration of the regenerative relationship has made many techniques and methods have been applied to the treatment of tissue repair and regeneration, and has become an important means of modern wound repair and tissue regeneration. In the discipline construction, it is proposed to treat wounds (especially various complicated and refractory wounds) as a large class of complex diseases caused by various reasons [3, 4]. In view of the characteristics of wounds, especially the rising incidence of various chronic refractory wounds, the more and more complicated pathogenesis, and the increasing difficulty of treatment, the authors put forward the idea of establishing a specialist for wound healing (center) and carrying out special treatment for wounds. At the same time, in order to shorten the hospitalization time of patients with chronic refractory wounds, a new model of two-way linkage between the wound treatment specialists of large hospitals and the wound treatment points of community health institutions was developed. Through advanced technologies such as "4G" and Wi-Fi, the hospital's wound treatment specialists are linked to the community to ensure the treatment of patients at the grassroots level. These theories have been validated in later clinical practice and have played an important role in improving wound healing speed and improving healing quality. Theories, techniques, and methods for these innovations will be described in detail in later relevant chapters.

1.1.2 A Brief History of the Development of Trauma Repair in Ancient China

Among the various diseases, the earliest and most experienced is surgery. It can be said that from the Stone Age, there has been a certain knowledge of healing damage. Traditional Chinese medicine surgery was initially formed in the Shang, Zhou, Qin, and Han Dynasties. In the Jin and Song Dynasties, relatively systematic surgery was performed, especially the theory of traumatology. At that time, the famous Gao Boji, Liu Juanzi, and others had worked for a great development of the principle, diagnosis, and treatment methods for carbuncle-abscess of the back, compared with what the *Lingshu* had said. At that time, the treatment methods such as trauma anastomosis and suture were different, but most of them have a great scientific value. For example, mulberry bark is used as suture for suturing wounds, bamboo curtains, splints, etc. can be used in fixed reduction, etc., and all these have achieved the desired therapeutic effect. In short, although the subject originated from the Hua Tuo in the second century AD, it was much later.

In the case of Jinchuang, there were two famous books, but unfortunately both of them were lost. Gan's hereditary family had a profound medical history and many writings, and left a glorious historical record in the history of traumatic science in China.

As for the masterpieces in surgery, there are endless streams. For example, "*Lingshu,*" "*Liu Juanzi Guiyi Fang,*" "*Yongjubu Dang zabing Jiyuan,*" "*Ge's Fang,*" "*Xiaopin Fang,*" "*Waike Zhengzong,*" "*Treatment of phlegm and blood stasis*," etc., all provide a wealth of practical and theoretical guidance for future. Among them, the "*Liu Juanzi Guiyi Fang*" written by Gong Qingxuan in Nanqi is the earliest surviving surgical book in China with great practical value.

For a long time in the past, the Chinese have always believed that "the body is affected by the parents and does not dare to damage." In the oracle bones of the Shang Dynasty in the fourteenth century BC, there were records of the words "jie" and "sore." In the Zhou Dynasty (1046 BC–256 BC), surgery became an independent procedure, and surgeons called it the "drug medicine." The "drug medicine" recorded in "*Zhou Li*" is responsible for the treatment of "tumor, ulcer, golden ulcer, and ulcer." The term "golden ulcer" as used herein, that is, "Jinchuang" refers to the wound caused by the metal blade to damage the limb; "Folding and ulceration" summarizes the diseases such as bone fracture and bone injury caused by hitting, smashing, falling, and fluttering. The treatment methods are also relatively rich. In addition to oral administration of traditional Chinese medicine, there are also treatments such as dressing (giving medicine) and surgery (scrapping). At that time, although there was no monograph on traumatology, it was recorded in several of the oldest medical literatures in the same period. For example, in the "*Huangdi Neijing*," there is a discussion of the symptoms, diagnosis, and treatment of bruises. There are dozens of drugs in the "*Shennong Bencaojing*" collected by the "Master Jin Chuang continued bones and bones." The "*Jingui Yaolüe*" contains the prescriptions for the treatment of "golden sores," Wangbuliuxing San, and the treatment of horses and some bone and bone injuries. It can be seen that traumatology had achieved certain development at that time. "*Lingshu·Jingshui*" pointed out: "If the husband of the eight-footer, the flesh is here, the outside can be measured, and it can be obtained by cutting it. The death can be dissected and viewed." "*Lingshu·Boneness*" through the measures of the length, size, and width of human skeleton, and divides the standard deviation according to the head, torso, and limbs. "*Lingshu·Jingjin*" discusses the muscle system attached to the first and second meridians. The development of anatomy and physiology has significantly promoted the development of traumatology. In the ninth century, the first traumatic orthopedics monograph "*Xianshou Lishang Xuduan Mifang*" came out, forming a treatment of fractures with the principle of "reconstruction, fixation, activity and internal and external medication," marking a human understanding of trauma orthopedics. Gradually deepened, the formation of the traumatic orthopedics.

During the Spring and Autumn Period and the Warring States Period, traditional Chinese medicine Surgery began to take shape. Ma Wangdui Han Tomb's book "*Mai Fa*" has long been used to treat sputum and purulent sputum, and the pus deep sputum shallow, pus shallow sputum deep, pus large sputum small, four kinds of situation and the size of the meteorite does not match "Four evils." "*Shan Hai Jing*" said: "The Mountain of Gao there are many meteorites." Guo Pu note: "Acupuncture needles, cure sputum." At that time, the needle was the tool to cut the pus and the earliest surgical instrument. The "*52 Bing Fang*" is another early medical literature that records various surgical diseases such as trauma and frostbite. The "*Lingshu·YongJu*" in the theoretical work "*Nei Jing*" records 17 kinds of surgical diseases and has a considerable understanding of the etiology and pathology of sputum. It must be soft, but the stone is born. "Stone" is the meaning of cutting stone, also known as phlegm or phlegm. Some chapters propose the use of toe surgery to treat gangrene, indicating that surgery has greatly improved from theory to practice.

The Han Dynasty (206 BC–220 AD) was the prosperous era of the traditional Chinese medicine. Hua Tuo, a well-known traumatic medical scientist in history, could treat diseases with prescriptions and acupuncture, and was better at surgery. Extremely high surgical skills have prompted him to use surgery for wound healing, elimination of purulent infections, and treatment of visceral diseases. Moreover, he used the "powder for anesthesia" anesthesia to perform surgery on patients, which is the earliest record of the use of general anesthesia for surgical treatment in the history of medical science in the world.

In the Jin Dynasty, Chen Yanzhi wrote "*Xiaopin Fang*" to record the earliest use of "fire needles" for surgical diseases, such as "attached bones, if not lost when the time is lost, use fire needles, cream, scattered." The book "*Liu Juanzi Guiyi Fang*" written in 499 AD is the earliest existing surgery monograph in China.

The main content is the differential diagnosis of sputum. It summerized many in the treatment of cold sore, phlegm, and skin diseases. Among them, Volume 4, "*Xiang Yongju Zhi Younong Ke Po Fa*," the use of the sputum needle to smash the "pum up the pus." The method of breaking the sputum "should be broken from the bottom, so that the pus easily." It is the pioneer of today's "low-level drainage" and "Where there is sepsis, all kinds of medicines are not broken, it is better to use a cooked copper needle on the oil fire, first use the ink pen to point to the head, then use the copper needle shallow needle, and the needle out of the pus, Shun also. If you do not pus with the needle, when using white paper for fine sputum, smash into the pinhole, lead to its sepsis, then swollen a few points will be good," this is the ancestor of the posterior sputum medicine line drainage method. Ge Hong's use of alpaca (e.g., wildflowers) and aconite as an anesthetic drug is an early stage in the development of surgical anesthetics, which is of great significance. At the same time, there are records of treatment of water and fire.

In the Sui Dynasty (581–618), Chao Yuanfang's "*Zhu Bing Yuan Hou Lun*" explored the source of various diseases, and the nine waiting items listed more than 1700 diseases, which was the first pathological monograph in China. The book "*Jinchuang Shangjing Duangu Hou*" states that after a tendon injury, it can cause circulatory disorders (the camp is impassable). Although the wound is healed, the symptoms of nerve palsy and dyskinesia can still be left behind, and the wound must be treated immediately after the injury. It introduced the correct point of stitching. Even the "8" suture method and continuous suture method are introduced in detail, and it is pointed out that if the suture is improper, it will cause infection. Once the infection occurs, the suture should be removed. For those with serious pollution, it is recommended to avoid suturing for drainage. The previous related treatment theories are more complete.

In the Tang Dynasty (618–907), Sun Simiao recorded the reduction method of temporomandibular joint dislocation in "*Qian Jin Fang*." "A person takes a finger and pulls it to gradually push it, then he re-enters the cockroach, pushes it out, and fears that the person is also hurting." And pointed out that after the restoration, wax therapy and hot compress can be used to help the recovery of joint function. This is the world's first method of treatment for the dislocation of the temporomandibular joint, which is still widely used until now. Sun Simiao also used cannabis as an anesthetic drug and studied the depth of anesthesia, the amount of use, and the rescue of poisoning. Wang Tao wrote "*Waitai Miyao*" and advocated using the felt as a moist heat to relieve the pain of the injured limb. Wang Tao's "*Waitai Miyao*" is treated with a bamboo tube. "Repeatedly boiled. And the hot out of the tube, the place where the cage ink is pressed for a long time. The knife is used to break the corner. Bring to a boil and repeat heavy angle. When the yellow and white waters are out, there are pus outs, and there are also insects. Counting such a horn, the evils are exhausted, that is, they are removed. The day is light and light." This is the most detailed drainage of the bamboo tube at that time. Lin Daoren wrote "*Xianshou Lishang Xuduan Mifang*," which is the first traumatic monograph in China. It describes the treatment principles of fractures for correct reduction, splinting, functional exercise, drug treatment, and fracture healing.

In the Song Dynasty (960–1279), surgery developed rapidly, and the incision and drainage technique was further developed. In the pathology, we pay attention to the relationship between the whole and the local. The treatment focuses on the combination of righting and stagnation, and internal and external treatment. The "*Sheng Ji Zonglu*" proposed "five good and seven evils," of which chapter 145 detailed the method of drainage. "*Taiping Shenghui Fang*" pointed out that the "five good and seven evils" should be identified, and the internal treatment methods such as internal elimination and Tori are summarized. The idea that the drainage should be cut in the treatment of pus is more positive than in the previous period. Chen Ziming's "*Waike Jingyao*" records multiple prescriptions of Tori's pus, which is still in clinical use.

In the Yuan Dynasty (1271–1368), the Mongolian people were good at riding and shooting, and they had considerable expertise in the traumatology department. Among the 13 subjects in the medical system, there were orthopedics. Wei Yilin's "*Shiyi Dexiao Fang*" has great achievements in the traumatology department. He believed that "the invading injury, the pain of the flesh and blood, the rectification is not allowed, first use the anesthetic clothes, until they do not know the pain, before they can start." The amount of anesthetic is determined according to the patient's age, physical condition, and bleeding, and then gradually increases or decreases according to the patient's anesthesia. "There is no need to take too much medicine." Wei Yilin is the first person in the world to treat spinal fractures by suspension reduction.

In the Ming Dynasty (1368–1644), there were 13 departments of large hospitals, among which there were orthopedics. Xue Ji wrote "*Zhengti Neiyao*," in which he pointed out: "If the limb is damaged, the qi and blood will be injured, the camp will be inconsistent, and the viscera will be disharmonious." The dialectical relationship between the local and the overall disease is clarified. This period is also an important stage in the development of TCM surgery, and the debridement and suturing has been further improved. In the Ming Dynasty, Chen Shigong, who is good at surgical treatment, clearly stated in the "*Waike Zhengzong*," "The person who has been necrotic cannot be resurrected, but only those who have not been necrotic in the future. But those who are not rotted, cut one by one." The understanding and elucidation of this issue is more thorough. Shen Douyuan in his book "*Waike Qi Xuan*" also said: "There is a necrosis, if the pain is difficult, get more rotten when it is considered to be urgent, the size of the necrosis or the method of cutting with a needle knife cannot be cured." Zhao Yizhen of the Ming Dynasty also pointed out, "If the pus is exhausted, use the cockroach to pick out the carrion and pus," in the "*Michuan Waike Fang*." Both have new supplements to the understanding on the removal of necrotic tissue and the severity of its problems, as well as treatment measures.

In the Qing Dynasty (1636–1911), the traumatology department had a new development. Wu Qian collected the great achievements of the traumatology department in the past and wrote "*Yizong Jinjian·zhenggu Xinfa Yaozhi*." This book systematically summarizes the experience of orthopedics before the Qing Dynasty. It described the bones, techniques, binding devices, and internal and external prescriptions of various parts of the human body. It is the most detailed book, both from theoretical and practical points of view, and has a picture and text. A more complete orthopedic book. In the late Qing Dynasty, Gao Wenjin wrote the "*Waike Tushuo*" (1856), which was an exegesis-based Chinese medicine surgery.

After the Opium War in 1840, China became a semicolonial and semifeudal country. With the cultural aggression of imperialism, Western medicine was introduced to China, and traditional Chinese medicine orthopedics was greatly devastated. During this period, there were very few books on orthopedics, and the extremely rich experience of traumatology was scattered among the older doctors and the public. It lacked finishing and improvement, and even almost lost.

In the 1920s and 1930s, some Chinese Western medicine orthopedic pioneers who received orthopedic training in Europe and the United States returned to China, and successively carried out orthopedic surgery in Shanghai, Beijing, Tianjin, and other big cities, opened Western medical orthopedic wards and orthopedic hospitals. The predecessors worthy of people's memory include Meng Jimao, Hu Lansheng, Niu Huisheng, Fang Xianzhi, Zhu Lvzhong, Ren Tinggui, Ye Yanqing, and others. In 1937, the orthopedic group was organized under the auspices of the Chinese Medical Association in Shanghai, which laid the foundation for the beginning of modern orthopedics in China.

After the founding of the People's Republic of China, the trauma department of traditional Chinese medicine has renewed its vitality. At the same time, Western medicine orthopedics has also developed rapidly in China. In the 1960s, Professor Fang Xianzhi and Shang Tianyu from Tianjin Hospital absorbed the advantages of traditional Chinese medicine orthopedics theory and Western medicine orthopedics. They proposed a new principle of fracture treatment including the combination of dynamic and static, both jin and bones, internal and external treatment, and doctor-patient cooperation, and published *Chinese and Western Medicine for the Treatment of Fractures* in 1966 to promote treatment experience in the country. In the 1950s, Beijing Jishuitan Hospital established a hand surgery specialty and opened a hand surgery ward. In 1960, Shanghai Huashan Hospital also established hand surgery. In 1978, China published the first classic of hand surgery *Hand Surgery*. In 1980, the Chinese Medical Association Orthopedics Society was established. After 1984, a number of professional groups were established. For example, in 1984, the Chinese Medical Association orthopedics branch established the Hand Surgery Group. In 1994, it was renamed the Chinese Medical Association Hand Surgery Society. In 1985, *the Journal of Hand Surgery* was officially launched. In 1993, it was renamed as *Chinese Hand Surgery Magazine*. In clinical work, the survival rate of replanted limbs (finger) was continuously improved, and famous surgeries, such as forearm flap (Yang Guofan), hand reconstruction (Yu Zhongjia), and replacement of C7 cervical nerve in the healthy side (Gu Yudong), were performed. In 1999, Professor Pei Guoxian of the Southern Hospital successfully carried out limb allograft (the third and fourth cases in the world). These achievements have made China's hand surgery a success.

Since the early 1960s, microsurgery in China has generally experienced three stages of initiation, development, and improvement/gradual maturity. From the early 1960s to the early 1970s, it was the initial stage of microsurgery in China. Design and improve microsurgical instruments, explore small vessel anastomosis, improve the patency rate of small blood vessel anastomosis, and carry out limb and finger replantation was the main progress at this stage. Professor Yang Dongyue explored boldly, pioneered, and innovated. In 1966 and 1973, he pioneered the second toe and free flap transplantation. In 1970, Gu Yudong first created a radial nerve transposition for the treatment of brachial plexus root avulsion, which made Chinese hand surgery rank first in the world of hand surgery. From the early 1970s to the mid-1980s, it was the development stage of microsurgery in China. Further improvement in the patency rate of small vessel anastomosis, extensive replantation of severed fingers, and expansion of the application field of microsurgical techniques are major advances in this phase. From the late 1980s to the present, it is in the improvement and gradual maturity stage of microsurgery in China. Microsurgical technology has matured and achieved fruitful results in basic and application fields. At the same time, it has gradually improved the theoretical aspect of the system and developed into an emerging clinical discipline. Chinese scholars have made important milestone contributions to the development of microsurgery [5, 6].

The real surgical treatment of burns in wound repair started in the 1950s in the War to Resist U.S. Aggression and Aid Korea, and a large number of burns of napalm and other burning weapons, which quickly cultivated professional rescue talents for early treatment and postplastic surgery in China. In the Great Leap Forward era, the whole country has set off a wave of treatment for burns. Medical universities, provincial/municipal/regional hospitals, and even grassroots hospitals have established burn departments or burn treatment groups. With the establishment of professional burn teams, burn surgery in China has flourished. The successful case of Qiu Caikang with 80% of the burn area, who was rescued in Ruijin Hospital affiliated to Shanghai Second Medical University, marked a breakthrough in the treatment of large-area burns in China. From the end of the 1960s to the end of the 1970s, it was the stage of burn treatment popularization, stable and further improvement in China. Due to the progress made in anti-shock and anti-infection, especially on the basis of the successful experience of cutting III degree eschar and intensive skin grafting to eliminate wounds as early as possible, the first large-scale staged batch removal of III degree eschar was carried out. The allogeneic skin opening was embedded in a small piece of autologous skin graft after full coverage of the wound method (German burn medical doctors call the Chinese method), in one fell swoop in the country and the world to break through the cure for the III degree burn area of 70% of the mark. This breakthrough is a great leap in the treatment of burns in China, and then it has further cured a large number of severely burned patients with.

III degrees of 90% or more than 95% in the country, making China's burn treatment level a world leader. It has been the basic theoretical research stage of burns since the end of the 1970s. The clinical treatment level of burns in China has been consistently ranked first in the world or is in the leading position. However, from the perspective of basic theoretical research, there is still a gap compared with the advanced countries in the world. How to use theoretical research results to guide clinical practice and improve the level of treatment and rehabilitation has become the key to the present [7].

The development of plastic surgery in trauma in China began around the first half of the twentieth century.

Ni Baochun (1899–1997) received his doctorate in medicine from Johns Hopkins University in 1925. In 1926, he studied under the famous plastic surgery expert John Davis. He returned to China in 1927. He served as the Acting President of St. John's University and the Dean of St. John's University School of Medicine. In 1952, he served as the Associate Dean of Shanghai Second Medical College. In 1929, Ni Baochun opened a plastic clinic at the Tongren Hospital of St. John's University School of Medicine (St. Luke's Hospital), where he served as the director of plastic surgery and is concurrently in the teaching faculty of anatomy and plastic surgery at the Shanghai Medical College. In the *Shen Kefei Surgery* published in the early 1950s, he wrote the chapter on "Plastic Surgery." According to the information that can be accessed now, Ni Baochun should be called the earliest pioneer of modern Chinese plastic surgery, and the first person to establish a modern Chinese plastic surgery discipline in medical colleges. During the same period, in the 1930s and 1940s, Shi Guanghai opened a cosmetic clinic with Yang Shuyin and others in Shanghai and Beijing before the founding of the People's Republic of China. After Ni Baochun established plastic surgery in Chinese medical colleges for 19 years, from September to December in 1948, J. Webster, a famous American professor of plastic surgery, held a plastic surgery class at Shanghai Zhongshan Hospital. Zhu Hongyin, Zhang Disheng, Song Ruyao, Wang Liangneng, Li Wenren, and other students took part in the class. They were predecessors of the later development of plastic surgery in China.

At the beginning of the founding of the People's Republic of China, especially after the War to Resist US Aggression and Aid Korea, the trauma repair surgery entered a stage of stable development. Taking maxillofacial surgery as an example, before the 1950s, China's oral and maxillofacial trauma and repair surgery had not been established. After 1949, with the treatment of war wounds and work injuries, traffic accidents and other accidental injuries increasing, the oral and maxillofacial trauma and repair surgery are constantly evolving. For example, during the Korean War, the volunteer medical teams in Shanghai and Tianjin, the Southwest Plastic Surgery Team, and later the Nanjing Medical Team participated in the rescue of maxillofacial trauma, and created the oral and maxillofacial trauma and repair surgery in China. Subsequently, a specialist ward was established in higher medical colleges and various types of specialist classes were held to train a large number of professionals. In 1955, the Ministry of Education of China hired Professor Kosh-he of the Soviet Union Molotov School of Stomatology to hold a national high-level teacher course in oral and maxillofacial surgery at Beijing Medical University, systematically introducing the Soviet Union in the rescue of oral and maxillofacial injuries in the Second World War. In the anti-self-defense counterattack against Vietnam in the late 1970s, in the process of treating maxillofacial wounds, the development of oral and maxillofacial trauma and repair surgery in China was further promoted.

Plastic surgery has also developed rapidly during this period:

(a) Song Ruyao, a student at the University of Pennsylvania School of Medicine in Philadelphia, is a student of Professor Avi, the founder of American Plastic Surgery. After returning from the United States in 1948, he became a professor of maxillofacial surgery and plastic surgery at Huaxi University. In the War to Resist U.S. Aggression and Aid Korea, the US military used a variety of modern weapons other than atomic bombs, causing injuries to the wounded among the volunteers, and these injuries were far more complicated and serious than those caused during the War of Resistance Against Japan and the War of Liberation. In 1951, when major medical colleges and universities across the country organized the medical team, Song Ruyao, a professor of plastic surgery at West China University, also organized a team of medical and surgical aids with the teachers and assistants of the medical school and the dentistry school to treat the wounded with plastic surgery and maxillofacial surgery. This time, the plastic surgery and maxillofacial surgery for the wounded are of great significance. First of all, it is the first large-scale official plastic surgery work in China. Secondly, it has made the people of the People's Republic of China fully aware of the importance of plastic surgery in war trauma. If there is no plastic surgery, many face and hand wounded or burned people will not be able to get the best treatment and will not be able to return to society. In the War to Resist U.S. Aggression and Aid Korea, the US air force used a large number of napalm bombs for low-altitude bombing. The volunteers had a large number of burns by napalm bombs. These wounded people were seriously injured and numerous. If routine treatment was used consistently, the treatment of a large number of casualties could not be completed. Therefore, they invented innovative treatments such as continuous getting skin, one operation to complete full face burn skin grafting and full hand burn skin grafting, which became an important stage in the enlightenment and development of burn surgery in China. In 1952, Song Ruyao became a professor of plastic surgery at Peking Union Medical College. In 1954, the "Chinese People's Liberation Army Plastic Surgery Hospital" was born, and Song Ruyao was appointed as Dean. In 1957, the General Logistics Department of the Chinese People's Liberation Army decided to merge the General Logistics Department Peace Hospital with the Peking Union Medical College Hospital. The Commander-in-Chief Zhu De autographed the hospital's title "Chinese People's Liberation Army Plastic Surgery Hospital." In 1958, the State Council decided to transfer seven military academies such as the "Chinese People's Liberation Army Plastic Surgery Hospital" to the Central Ministry of Health, belonging to the local leadership, and affiliated to the Chinese Academy of Medical Sciences.
(b) Professor Zhu Hongyin, graduated from the Department of Biology, Yanjing University in 1939, and received his doctorate in medicine from Union Medical College in 1943. He established a plastic surgery department at Beijing Medical College in September 1949. He has served as a professor at Beijing Medical College, Director of Plastic Department and Associate Dean of the Fourth Affiliated Hospital of Beijing Medical College, Director of Plastic Department and Associate Dean of the Third Affiliated Hospital of Beijing Medical College, Professor of Beijing Medical University, and Member of the Medical Science Committee of the Ministry of Health. After the founding of the People's Republic of China, he led the first plastic surgery delegation to the Czech Republic to participate in the International Plastic Surgery Academic Exchange Conference.
(c) Zhang Disheng and Song Ruyao had successively studied under the American plastic surgeon Ivy, and returned to China to carry out plastic surgery, and participated in the War Resist U.S. Aggression and Aid Korea.
(d) Chen Shaozhou after returning from the United States in 1948 was hired as a professor of oral and maxillofacial plastic surgery by Aurora University (Shanghai) and

concurrently at Shanghai Guangci Hospital (now Shanghai Jiaotong University Ruijin Hospital) as the director of the department. In 1951, he established plastic surgery at the Renji Hospital (now Renji Hospital affiliated to Jiaotong University).

(e) Wang Liangneng, who graduated from the National Central University School of Medicine in 1942, went to the United States to study in 1949. In September 1951, Professor Wang Liangneng, who was full of patriotism and enthusiasm, embarked on a journey back to the motherland, but was severely obstructed by the US government. When passing through Honolulu, the US Customs prevented him from leaving the country on the grounds that "wartime scientific and technical personnel were not allowed to leave the United States," causing his return to fail. In 1954, he took the opportunity to go to Hong Kong to take over his family and left the United States alone. With the help of the underground party organization of the Chinese travel agency in Hong Kong, he finally returned to the embrace of the motherland and created the first burn and plastic surgery department at the Fourth Military Medical University in the northwest.

(f) In the early years, Zhang Guangyan was first admitted to the Qilu University School of Medicine and then transferred to the West China Medical College. In 1938, he graduated from the medical school and was a school doctor. He graduated from the School of Dentistry of West China Medical College in 1941 and was recommended to study in the United States. He studied at Northwestern University in Chicago and majored in dentistry and plastic surgery. After the victory of the War of Resistance Against Japan in 1945, Professor Zhang Guangyan returned to China. He has developed and established plastic surgery at Beijing Medical College and Henan Medical College. In 1963, he established the first department of plastic surgery in Henan in the First Affiliated Hospital of Henan Medical College.

(g) Dong Shufen, graduated from Harbin Medical University in 1941, worked as a dentist in Changchun and Tianjin, worked in the Tianjin Medical Team of the War to Resist U.S. Aggression and Aid Korea in 1950, and went to the Institute of Stomatology of the Moscow University in 1954. After returning to China, he established the maxillofacial surgery in Xi'an in 1957 [8].

Hospitals with plastic surgery in the 1950s were mainly distributed in Beijing, Shanghai, and Xi'an, followed by Zhengzhou, Nanjing, Shenyang, Taiyuan, Dalian, Nanchang, Gansu, Urumqi, Fuzhou, Guangzhou, and Zhanjiang. In the 1970s, the Beijing Plastic Surgery Hospital compiled a total of seven lectures on "*Plastic surgery training*," which played an important role in cultivating the plastic surgery personnel in China. From 1949 to 1978, a variety of plastic surgery monographs were published, including Professor Zhang Disheng's *The Reconstruction of Cleft Lips and Splits* (1957), *Summary of Formal Surgery* by Zhu Hongyin, Wang Damei, Kong Fanhu, et al. (1959), Professor Song Ruyao's *Organic Surgery of Hand Trauma* (1962), Professor Kong Fanhu's *Practical Plastic Surgery* (1964), and Song Ruiyao's *Repair of Cleft Lips and Cleft Palate* (1965), which are important for the popularization and development of plastic surgery in China. Since 1966, due to the influence of the "Cultural Revolution," the development of plastic surgery in China had suffered setbacks. In 1978, according to statistics before the reconstruction of Beijing Plastic Surgery Hospital, there were only 170 doctors engaged in plastic surgery in China at that time.

In the Sino-Indian border, the Chen-pao Island, the Xisha Islands' self-defense counterattack, and the counterattack against Vietnam, the plastic surgery in China has made advances and explored some good experiences. In recent years, through the earthquake relief, the military health work has been further exercised, which is conducive to further improvement in the field of plastic surgery.

After the mid-1980s, the Chinese Medical Association Trauma Branch (including the tissue prosthetics group), the Chinese Medical Association Plastic Surgery Society, the Chinese Medical Aesthetic Surgery Society, the Chinese Reconstructive Surgery Society, the Chinese Hand Surgery Society, and the Chinese Microsurgery Society, academic organizations related to wound healing, tissue repair, and regeneration, have been established. At the same time, the corresponding professional academic journals have also been born. The military also established various professional committees. In 1962, the Army Burning Professional Team of the People's Liberation Army was formally established, and a military conference was held every 2 years, which played an important role in promoting the development of plastic surgery and trauma repair surgery in the new era. During this period, China's plastic reconstructive surgery and microscopic reconstruction surgery have entered the world's advanced ranks. In 2007, the Army Plastic Surgery Committee became independent from the Burn Professional Committee and became a separate academic organization. In addition, military traumatic academic organizations such as the Army Trauma Professional Committee have also been established.

In the new era, China's tissue repair and regenerative development benefited from the advancement of modern science and technology, the transformation of related therapeutic concepts, multidisciplinary collaboration, and the rapid transformation and application of new theories and new technologies.

Systematic and in-depth research and development of wound tissue repair and regeneration began in the 1980s, represented by the development and application of growth factors (cytokines), stem cells, and new dressings.

In 1986, with the Nobel Prize in Physiology or Medicine for growth factor research represented by nerve growth factor and epidermal growth factor, it was gradually recognized that various growth factors (cytokines) are important in regulating tissue repair and regeneration. Thus, traditional tissue repair begins with pathological descriptions and shifts to research at the cellular, molecular, and genetic levels. At that time, because the genetic engineering recombinant protein technology was not mature enough, many growth factors applied to tissue repair and regeneration could only be extracted from the organs of cattle and rats. This method took time, effort, and expense, and the amount of growth factors obtained was also very few, and could not meet the needs of basic research, let alone clinical applications. At the same time, a large number of scientific and technological workers had little understanding of the growth factor, and the treatment in this area was very limited. In the early 1990s, the People's Military Medical Press published a comprehensive monograph on growth factors and tissue repair and regeneration, published by Xiaobing Fu, *Growth Factor and Wound Repair*. This is the first international monograph devoted to growth factors and tissue repair and regeneration. The publication of this book helped domestic experts to comprehensively and systematically understand the basic knowledge of growth factor biology and growth factors involved in wound repair and tissue regeneration regulation. This book played a positive role in promoting basic research, new drug development, and clinical application in related fields on a large scale in China. Later, the publication of the first international *Molecular Trauma* led by Academician Wang Zhengguo further refined and improved the cellular, molecular, and genetic basis of trauma and wound treatment. China is in an advanced position in the fields of trauma and wound treatment in the world [4, 9].

At the same time, Professor Lin Jian from Jinan University of China began research on genetic engineering technology to recombine bovine basic fibroblast growth factor. The Zhuhai Bioengineering Co. Ltd., which was established at that time, quickly developed the first generation of recombinant bovine basic fibroblast growth factor (bFGF). Through close cooperation with researchers and clinical experts in many large hospitals, in 1998, the company obtained the new drug certificate of the State Food and Drug Administration and began clinical application. It became the first new drug in the country of genetic engineering for wound healing. The relevant research results were published in the internationally renowned medical journals *Lancet and Wound Rep Reg* [10, 11], which attracted the attention and positive evaluation of international peers, such as the Health Column of the British BBC: Bovine protein promotes wound healing. The Lancet commented in the Highlights: This is a time to promote wound healing. Later, recombinant human basic fibroblast growth factor (rhbFGF), recombinant human acidic fibroblast growth factor (rhaFGF), recombinant human epidermal growth factor (rhEGF), and platelet-derived growth factor (PDGF) were developed at home and abroad. These products have been used as a conventional drug for the treatment of wound burns and have achieved remarkable results.

The idea of traditional treatment is that in a relatively large open wound, in order to prevent bacterial infection, a dry method should be used for treatment. In the 1960s, British scientist Winter confirmed through animal experiments that if the wounds kept moist, not only did the bacterial infection rate not increase significantly, but the wound healing was also significantly faster than the control. This discovery has changed the basic understanding of the wound healing environment. According to this principle, various advanced dressings (revolutionary dressings) represented by moisturizing dressings were produced in the 1980s. A significant feature of this large class of dressings is the ability to provide a relatively moisturizing and slightly acidic healing environment for the wound, which facilitates the dissolution of necrotic tissue and the release of various growth factors associated with wound healing, while not significantly increasing the infection rate of bacteria. In addition, due to the translucent membrane, it is beneficial to the gas exchange between the wound surface and the external environment. At the same time, after using the dressing the patient's wound surface does not affect the daily work, labor, even bath and can be replaced weekly saving a lot of manpower and financial resources. Clinical applications have proven that these dressings significantly reduce patient suffering and, in general, save medical costs and labor costs. So far, various advanced dressings for moisturizing, antibacterial, dissolving necrotic tissue and damage tissue repair and regeneration have been widely used in the treatment of various acute and chronic wounds [12]. The dressing for wound treatment covers the wound from mere gauze, "insulates" the contact between the wound and the outside world, avoids the traditional concept that the wound is contaminated again, and promotes the "active" repair and healing of the wound with advanced dressing, which is completely benefited from wound treatment. The discovery of theory and the breakthrough of traditional concepts are a successful example of translational medicine. Although it is not an original work in the field of advanced dressings, it has significantly promoted the application of this technology and products in China through the introduction, digestion, and integrated innovation.

The basic research of stem cell and tissue engineering and related clinical application are important advances and development directions in the field of wound tissue repair and regeneration. At present, preliminary effects on chronic wound treatment, wound angiogenesis, and sweat gland regeneration have been observed by adult stem cell induction techniques. In particular, the innovative theory and key technologies for the induction of autologous bone marrow mesenchymal stem cells to regenerate sweat glands by the team led by Xiaobing Fu and Sheng Zhiyong of the General Hospital of the People's Liberation Army have broken through the international problem of sweat gland regeneration, and first realized the function in human wounds in the world. The sweat glands regenerated, and some cases followed up for 10 years proved to have a stable sweating function, and no adverse reactions were observed. The result was evaluated by international peers as a "milestone study." [13] At present, some tissue engineering skin, nerves, tendons, cartilage, etc. have begun preliminary clinical application, which proves that it has a good effect on warfare tissue repair and regeneration [14, 15].

In the 1990s, the main academic works related to tissue repair and regeneration were published in China: *Basic for Wound Repair* (Edited by Xiaobing Fu, Wang Dewen, People's Military Medical Press, 1997), *Wound Healing and Tissue Restoration* (Edited by Wang Zhengguo, Shandong Science and Technology Press, 1998), and *Modern Trauma Restoration* (Edited by Xiaobing Fu, Wang Dewen, People's Military Medical Press, 1999) have played a positive role in further expanding the academic influence and communication of tissue repair and regeneration.

Since the beginning of the twenty-first century, the epidemiology of trauma and wounds has undergone great changes. Related research by Xiaobing Fu et al. showed that in 1998, the main etiology of inpatients in China due to chronic refractory wounds was traumatic burns and infections, accounting for about 67%, while the chronic refractory wounds caused by diabetic foot accounted for only 4.9%. However, new research in 2008 after 10 years shows that after only 10 years, the main etiology of chronic refractory wounds in China has undergone a fundamental change, and diabetic foot has become the main cause of chronic refractory wounds accounting for about 36%, and chronic wounds caused by traumatic burns fell to about 20%. This result suggests that with the rapid development of China's economy and the continuous improvement of people's living standards, chronic refractory wounds have become one of the important chronic diseases affecting the Chinese people's physical and mental health and quality of life. The epidemiological characteristics are the same with developed countries in the West. The social economic burdens and consumption of medical resources that it caused should be highly valued by the whole society. During this period, the country began systematic research on the mechanism, treatment, and prevention of chronic refractory wounds. In terms of treatment, in addition to traditional surgical treatment, new techniques and drugs such as new dressings (also known as revolutionary dressings), growth factors, optical therapy, and vacuum suction have played a positive role in accelerating the healing rate of chronic refractory wounds and improving the quality of healing. In the field of academic publishing, he has edited *Modern High-tech and Trauma Repair* (Xiaobing Fu, Wang Zhengguo, People's Military Medical Press, 2002), *Modern Wound Dressing: Theory and Practice* (Xiaobing Fu, Wu Zhigu, Chemical Industry Press, 2007), and *Theory and Practice of Prevention and Treatment of Chronic Wounds* (edited by Xiaobing Fu, People's Medical Publishing House, 2008). Especially in medical undergraduate and postgraduate education, he has edited many textbooks, such as *Stem Cell and Regenerative Medicine* (Pang Xining, Xiaobing Fu, People's Medical Publishing House, 2014) and *Study on Stem Cell and Regenerative Medicine* (Pang Xining, Xiaobing Fu, People's Medical Publishing House, 2016). The textbook introduces stem cells and regeneration medical overview, clarifies the concept and research content of stem cells and regenerative medicine, the status of stem cells and regenerative medicine in life sciences, and the relationship between regenerative medicine and normal growth and development, and on this basis, introduces a brief history of stem cells and development of regenerative medicine. The textbook runs through the relationship between stem cells as a regenerative seed cell and regenerative medicine, and introduces the mechanism of regeneration, tissue level regeneration, new regeneration and deformation regeneration, physiological regeneration and pathological regeneration and its significance, and methods of regenerative medicine, including cell transplantation and biological artificial tissue and in situ regeneration induction. The key chapters describe the regeneration and regenerative medicine of skin, eye and cornea, nerves, cardiovascular, digestion, respiration, bone, cartilage, muscle, tendon and ligament, reproductive system, dental tissue, and appendage. In 2014, Academician Xiaobing Fu also edited the postgraduate textbook of the National Twelfth Five-Year Plan of the National Health and Family Planning Commission, *Wound, Burn and Regenerative Medicine* (published by People's Medical Publishing House). The book brings together more than 80 experts and scholars in the field of trauma, burns, and tissue repair and regenerative medicine.

In the publicity education and training of prevention and control of chronic refractory wounds, the hospital has established treatment specialists for complex chronic refractory wounds in Shanghai, Hangzhou, Xi'an, and Beijing (new or expanding previously established burn and trauma surgery), a new model for the treatment of complex chronic refractory wounds as a disease has been created. Its representative experts include Professor Lu Shuliang, Professor Han Chunmao, and Professor Xie Ting. At the same time, the Chinese Medical Association Trauma Branch Professional Reconstruction Committee (CTRS) and the World Diabetes Foundation (WDF) and the Access to Healthcare (Ath) work closely together to use the international fund to conduct propaganda and education of prevention and control of chronic refractory wounds in China for more than 3 years. By organizing high-level expert teams, writing different levels of training materials, and establishing training bases, at the completion of the project, training bases were established in nearly 60 hospitals in more than 20 provinces, municipalities, and autonomous regions across the country, a total of more than 10,000 doctors, nurses, and other related personnel were trained. This project achieved remarkable results.

In 2011, in order to promote the specification of diagnosis and treatment of chronic wounds, under the guidance of Xiaobing Fu, according to the relevant literature on chronic wounds at home and abroad, the first guide book on chronic wounds was edited and published in China——2011 edition of *Chronic Wound Diagnosis and Treatment Guide*, which has been welcomed by everyone. At the end of 2013, in order to further promote the standard of diagnosis and treatment of acute wounds in China, and in order to make the guidelines more in line with the characteristics of Chinese people, Academician Xiaobing Fu guided the establishment of a Chinese-based wound treatment guide based on relevant domestic literature and foreign-related guidelines. In the beginning of 2014, the guideline development team was established and the guideline development plan was officially launched. The guideline was developed based on the contents of clinical research papers published in China. The main purpose of the guideline is to develop guidelines that are consistent with China's national conditions, and it has practical guidance. This work was basically completed by consulting domestic literature and eight seminars. This document retrieval searches all papers about wound from January 1, 2004 to May 1, 2014, from the China National Knowledge Infrastructure (CNKI) and CNKI dissertation databases. After many researches and conference discussions by various experts for more than a year, the guide to China's wounds was finally born!

Perfect tissue repair and regeneration is the highest goal of war wound tissue treatment, and it has always been the main content and goal of research on science and technology workers in China. At the national level, relevant departments attach great importance to research in this field. In addition to the Chinese Academy of Sciences and the Chinese Academy of Engineering planning the organization of restoration and regeneration as the main research direction in relevant science and technology planning, since 1999, three National Basic Research Planning Projects ("973" Project) have been invested to study key scientific and technical problems in tissue repair and regeneration after trauma. The chief scientists are Academician Wang Zhengguo, Professor Jiang Jianxin, and Academician Xiaobing Fu. At the academic level, Academician Wang Zhengguo, Academician Wu Zuze, and Academician Xiaobing Fu successively organized and held three "Regenerative Medicine" Xiangshan Science Conferences on the theme of regenerative medicine. The major recommendations were launched that played an active role in further consolidating key scientific issues and organizing academics to tackle key problems and treating tissue repair and regeneration as a national strategic initiative. During this period, three large-scale academic monographs were published in succession *Regenerative Medicine: From Basic to Clinical Research, Regenerative Medicine: Basic and Clinical Research,* and *Regenerative Medicine: Transformation and Application*. These books have had a good influence on academia. The first one is *Regenerative Medicine: From Basic to Clinical Research*, published by Shanghai Science and Technology Press in 2008. The second one is *Regenerative Medicine: Basic and Clinical Research*, published by People's Medical Publishing House in 2013. The third one is *Regenerative Medicine: Transformation and Application*, published by People's Medical Publishing House in 2016. The three books can be called the trilogy of academic monographs on regenerative medicine in China [16–18]. In 2012, the internationally renowned academic journal *Science* also invited Prof. Xiaobing Fu to organize Chinese scientists to publish a series of *Regenerative Medicine in China* in the form of a supplement. After the publication, there was a good international response, in addition to the highly praised publications in the *Science* and its supplement, other international journals also commented, which has significantly expanded the international impact in the field.

1.1.3 The Promotion of Science and Technology Development in the Development of Trauma Repair and Tissue Regeneration

1.1.3.1 Disinfection, Anesthesia, Hemostasis, and Blood Transfusion Provide a Good Foundation for the Establishment of Modern Trauma Repair Surgery

In the old days, infection, bleeding, and pain limited the development of surgery. Since the 1940s, the scope of surgery has been expanded and the safety of surgery has been greatly increased due to the problems of wound infection, surgical pain, hemostasis, and blood transfusion solved [19].

Infection

Wound "suppression" is one of the biggest problems faced by surgeons more than 100 years ago. The biggest achievement in war trauma surgery is the treatment of wound infections. At that time, the mortality rate after amputation was as high as 40–50%. Before the First World War, people cultivated and fertilized (animal feces) year after year, causing every soldier injured in the trenches to carry a different number of pathogens. At the time of the war front, sepsis was very common. Although many measures have been taken, these attempts have been in vain, and disinfection of infected wounds has proven to be an effective measure. Surgeons have tried countless disinfectant solutions as well as surgical dressings. Ultimately, trimming necrotic tissue and repeated rinsing stand out in the principles of wound management. Henry Dakin (1880–1952) was a British chemist and Alexis Carrel (1873–1944) was a French-American surgeon and Nobel laureate. These two are the main advocates of this method of wound treatment. In addition to the aseptic processing of wounds, the achievements of surgery are also reflected in the use of X-rays for the diagnosis of war injuries and the fine design of surgical operations. The latter have been obtained in the treatment of war wound facial reconstruction and war wounds.

Aseptic technique is an effective preventive method for the source and route of infection, and is the key to determining the effectiveness of the diagnosis and the success or failure of the operation. In 1864, Semmelweis of Hungary first proposed washing hands with bleaching solution before checking the parturient, which is the beginning of antibacterial technology. In 1867, British surgeon Baron Joseph Lister laid the foundation for antibacterial technology and was recognized as the founder of antibacterial surgery. In 1877, Bergmann of Germany invented the high-pressure steam sterilization and established the aseptic technique in modern surgery.

Pain

Surgical pain was one of the important factors that hindered the development of surgery. In 1846, Morton first used ether as a general anesthetic and assisted Warren in performing many major operations with ether anesthesia. Since then, ether anesthesia has been commonly used in surgery. In 1892, Schleich in Germany first advocated cocaine for local infiltration anesthesia. However, due to its high toxicity, it was soon replaced by procaine. Now, procaine is still a safe and effective local anesthetic. The three main stages of anesthesia development include:

(a) The stage of ancient anesthesia development——the discovery and germination of anesthesia.
(b) The stage of modern anesthesia development——the formation of clinical anesthesiology.
(c) The development stage of modern anesthesiology. Since the beginning of the First World War, due to the improvement of anesthesia technology, the surgical procedure can last for more than 12 h, and the safety is greatly improved, which greatly improves the success rate of tissue transplantation repair.

Bleeding

The earliest blood transfusion record was in 1667, when a French aristocrat transfused 280 mL of calf blood to a mentally disordered tramp, trying to heal his mental problems. The unfortunate patient experienced a severe immune reaction. After several times he almost died, but he survived miraculously and maintained a period of calm, so the blood transfusion therapy was accepted by some doctors with innovative ideas. For the next 300 years, transfusion therapy is still in the exploratory phase. Because there is no support of relevant knowledge (such as blood type), blood transfusions have caused many deaths, but doctors have also found that blood transfusions can sometimes save lives. It was not until 1912 that the Frenchman Alexis Carrel won the Nobel Prize for the creation of vascular anastomosis for blood transfusions, blood transfusion therapy gained a wide range of recognition. The person who really made blood transfusion a scientific and effective treatment was Karl Landsteiner, a pathologist in Vienna. He discovered the ABO blood type and agglutination of humans since 1901, providing a solid pathophysiological basis for modern blood transfusion. In the following 20 years, other doctors gradually invented blood anticoagulation and cross-matching techniques, making blood transfusion a routine and effective treatment. Landsteiner also won the Nobel Prize in Physiology or Medicine in 1930.

1.1.3.2 The Establishment and Development of Immunology Provide a Basis for Breakthroughs in Various Types of Transplantation

The so-called "immune" was originally derived from the Latin word "immunis." Its original meaning is "exception from charges" and also contains the meaning of "free of disease." Immunology is the biomedical science of studying immune response to antigenic substances and their methods. The immune response is the body's response to antigenic stimuli and is a biological process that identifies and excludes antigenic material. It is a physiological function in which the body recognizes "self" and "non-self" antigens, forms natural immune tolerance to autoantigens, and produces rejection of "non-self" antigens. Under normal circumstances, this physiological function is beneficial to the body and can produce anti-infective, anti-tumor, and other immune protections that can maintain physiological balance and stability. In some cases, it may become an obstacle to tissue transplantation.

The ancient and emerging discipline of immunology is developed by people in their constant exploration, summarization, and innovation in practice. After four periods of immunology, namely, the period of empirical immunology, the period of classical immunology, the period of modern immunology, and the period of contemporary immunology, tissue transplantation technology has been greatly improved, with allotransplantation and xenotransplantation making breakthrough progress. There have been many successful cases of "changing faces" around the world, and there have been reports of successful handovers.

1.1.3.3 The Emergence of Microsurgery Provides a New Technical Means for Trauma Repair Surgery

In a broad sense, microsurgery is not unique to a specialist, but a surgical technique that can be used by all majors in the surgical discipline. It can even be a specialized subdiscipline from the profession, such as microsurgery in urology, microneurosurgery, etc. Some disciplines, such as surgical surgery, ophthalmology, and otolaryngology, have used surgical magnifier as a conventional surgical instrument for surgical dissection and suturing. However, in a narrow sense, the development of microsurgery itself has its own theoretical system. For example, small blood vessel anastomosis has many principle differences with large and medium blood vessel anastomosis. In the early stage, due to the lack of special small vessel anastomosis surgery, the principle of vascular anastomosis was borrowed, so the postoperative patency rate was not high. After the special rule of small vessel anastomosis was found, the postoperative patency rate was greatly improved. For example, in the past, the flap was limited to the inguinal flap, the dorsal flap, and the intermuscular flap. The larger musculocutaneous branch of the musculocutaneous flap was used as the main blood supply vessel of the flap, such as the anterolateral thigh flap. The use of limbs with blood vessel characteristics developed retrograde flap. These depend on the deepening of theoretical research to develop new methods. Therefore, microsurgery should, on the one hand, vigorously develop new surgical methods using microsurgical techniques in various surgical disciplines and improve the professional level from this aspect. On the other hand, it has its own disciplinary research, discovering its new theories and new laws, and promoting the development of disciplines. As for the research of microsurgical instruments and equipment, it is constantly improving, and the two complement each other.

The emergence of microsurgery provides a powerful means for wound repair and tissue regeneration, greatly expanding the indications for wound repair. Vascular repair is the best treatment for vascular injury. One of the most amazing techniques in the field of surgery is the replantation of the limbs, which is the successful replantation of fingers, hands, arms, or feet that are interrupted by the trauma or cut by the machine. To reattach a broken limb and reinstate it, you need to stitch the blood vessels, nerves, and skin and bones together. As early as 1912, there was a method of replanting a broken limb. At that time, Alexis Carrel invented a method of suturing large blood vessels. In 1952, microsurgery began to be used in the treatment of vascular warfare, reducing the amputation rate from 51.4% to 13.0%. The methods used include side-wall repair, vascular anastomosis, and intervening grafts. Nanobashvili et al. reported a direct anastomosis ratio of 38% after debridement, while approximately 56% of vascular injuries require an interstitial graft. In the 1960s, the advent of better microscopes, fine needles, and filaments made it possible to suture small blood vessels. But the reconstruction of the damaged peripheral nerves was reported only in 1967. In 1968, Kamachu and Tamayo used all the new technologies at the time to replant the broken thumb.

In the field environment, grafts for vascular repair often use autologous saphenous veins or artificial blood vessels. There is no consensus as to which of the two is better or worse. The autologous saphenous vein has a long history as a graft. The earliest in the Vietnam War, Rich et al. began to use it in vascular treatment of warfare trauma. However, the site and length of the autologous vein are limited, new wounds are added, the operation time is prolonged, and there are defects that the diameter of the repaired blood vessel does not match. In addition, although the early limb salvage rate of the autologous saphenous vein as the graft was higher than that of the artificial blood vessel, there was no significant difference in the patency rate and the limb salvage rate. Therefore, artificial blood vessels can replace autologous veins for emergency treatment or autologous veins are not available.

1.1.3.4 The Application of Bioengineering and Various Materials Has Broadened the Field for Wound Repair

The two major leaps in cell biology and molecular biology in the field of life sciences in the twentieth century have made humans' understanding of the life essence reach an unprecedented height. With the development of science and technology, human beings regard the study of life sciences as a main line for their own survival and development, and continue to apply other modern science and technology. It gradually formed an interdiscipline of science, engineering, and medicine——bioengineering.

In 1949, the United States first published a prospective paper on medical polymers. The article, first introduced the use of polymethylmethacrylate as a human skull and joints and the use of polyamide fiber as a surgical suture in clinical treatment. According to incomplete statistics, as of 1990, more than 30,000 academic papers and patents on medical polymers were published in the United States, Japan, and Western Europe. It is predicted that in the twenty-first century, medical polymers will enter a new era. In addition to the brain, all parts of the body and organs can be replaced by polymer materials.

Tissue engineering is an emerging discipline that combines cell biology and materials science to construct tissues or organs in vitro or in vivo. It takes a small amount of living tissue from the body, separates the seed cells from the tissue with special enzymes or other methods, and cultures and expands them in vitro, and then mixes with the absorbable biological materials. Finally, cells adhere to the biological material forming a cell-material complex. The composite is implanted into the lesion site of the body. On the one hand, the biological material is gradually degraded and absorbed in the body; on the other hand, the implanted cells continuously proliferate in the body and secrete the extracellular matrix, and finally form corresponding tissues and organs, thereby achieving the purpose of trauma repair and reconstruction. Because tissue engineering has the potential to replicate "tissues" or "organs," some scholars say that tissue engineering is "a new era of regenerative medicine" or even "a far-reaching medical revolution." At present, bone, cartilage, muscle, tendon, ligament, skin, blood vessels, periodontal, peripheral nerves, etc. have been studied in tissue engineering, and some of them have begun clinical trials or have become commercially available products for clinical application.

1.1.3.5 Information Network Builds a Platform for Improving the Level of Wound Repair

Telemedicine is a new medical service model that combines modern medicine, computer technology, and communication technology by applying telecommunication technique, interactive transmitting information, and carrying out long-distance medical services. Telemedicine services are available in a variety of forms, using a series of modern communication technologies such as satellite transmission, fiber-optic communication, and television transmission for point-to-point remote consultation and multiparty consultation. Doctors and patients can communicate face-to-face through remote video systems, can transmit and store patient data through the network, and accommodate multiple experts from different regions to consult the same patient at the same time. Medical information delivered in telemedicine includes data, text, video, audio, and images. Telemedicine can be divided into global, intercontinental, national, regional, hospital, community, and home telemedicine, depending on the scope of application. The value of the construction and development of military telemedicine for the military medical support work has become more and more concerned by the military of various countries with the successful application of the US military in military operations around the world.

The United States has developed the USAMRMC (US Army Medical Research Material Command) to solve critical medical problems for the frontline battlefields of the US military at home and abroad. The Telemedicine Strategic Project is part of the project, which includes the identification, development, and demonstration of relevant key technologies and biomedical-related technologies that address both medical and military barriers. Its main objectives are:

(a) Provides a fast and flexible way to develop the specialization of the military's important medical field and obtain relevant support.
(b) Integrates health awareness into the battlefield.
(c) Improves the skills and efficiency of medical service personnel.
(d) Improves the quality and collaboration of internal and surgical medical services throughout the battlefield.

The exploration of telemedicine in China since the 1980s has developed rapidly in recent years. In the late 1990s, China's telemedicine moved from theoretical exploration to practical application. The Ministry of Health, the China Medical Foundation, and the Ministry of Health of the People's Liberation Army successively launched the Jinwei Network Project, the China Medical Foundation Internet, and the Junwei II Engineering (Telemedicine Network). Some well-known medical colleges and hospitals have set up remote consultation centers and have carried out various forms of telemedicine work with hundreds of hospitals nationwide. Currently, they can implement real-time expert consultation for patients with acute and severe diseases, transmission of shared medical data, and pathological diagnosis. In the military, with the help of network coverage, our military's telemedicine information system has been equipped with front-line company and remote duty checkpoints. Make full use of existing resources, and take advantage of the comprehensive collection of experts and disciplines. At the same time, actively explore new operating modes and manage the rights by the server. Provide free information browsing services and hospital guide, consultation, initial diagnosis, inspection, treatment, and follow-up for trauma patients. Telemedicine has made the tissue repair of wounded more standardized and popularized.

Network technology is one of the most visible areas for achieving graded treatment, consultation, training, and education. Because wound treatment has the characteristics of intuitive shape and relatively low site requirements, it is suitable for development in grassroots and remote areas. Since 2010, we have used the "4G" and Wi-Fi system to carry out a two-way linkage between the wound healing center of large hospitals and the community health institutions in Shanghai and the two-way linkage with the wound healing specialty of Zhejiang Jinhua Wucheng District Hospital. The effect was highly praised by the internationally renowned peers for "looking in the East."

1.1.3.6 Digital Medicine Provides Guarantee for Accurate Wound Repair

Medicine has also gone from ancient medicine, traditional medicine to today's digital medicine. Many new technologies have been or are being used in medical research and application. Digital human technology and digital medical technology derived from it are such new technologies that are increasingly focused and intensively researched. Professor Dai Kerong, an academician of the Chinese Academy of Engineering, defined in the eleventh Chinese engineering frontier *The Status and Future of Digital Medicine*: "Digital medicine is a discipline of applying digital technology to explain medical phenomena, solve medical problems, explore medical mechanisms, and improve the quality of life." It covers many areas of cross-disciplinary research in life science and information science, medicine and engineering, and its research methods and results benefit the implementation and popularization of precision surgery. At the same time, digital medical technology, as an important part of modern medicine, will also promote the development of modern medical technology in the direction of individualization, precision, microinvasion, and remoteness.

Digital medical technology is an extension of digital human research in medical application. It is a new cross-disciplinary research field integrating medical science, biomechanics, mechanics, materials science, computer graphics, computer vision, mathematical analysis, mechanical mechanics, robotics, and many other disciplines. Through modern computer technology (mainly virtual reality technology), a human body structure model for anatomy, a treatment effect model for restoration evaluation, a pathway model for surgical evaluation, a field model for surgical exercises, etc. are established. The research of digital human body has also evolved from the construction of the originally simple human dataset to digital anatomy and its practical application. Its research direction and focus are mainly on the acquisition of special human tissues such as nerves, lymph and tiny organs, image segmentation and reconstruction techniques, grid computing storage and data synchronization sharing, applications in medicine and related fields, and other fields.

1.1.3.7 New Technologies and Methods of Regenerative Medicine Represented by Growth Factors, Stem Cells, and Gene Therapy Technologies Show a Bright Future for Wound Repair and Tissue Regeneration

In recent years, research on genetic engineering technology and stem cells has advanced by leaps and bounds, and many major advances have been made. As mentioned above, the development of genetic engineering technology has enabled a large number of growth factors to be obtained in clinical and basic research, and these growth factors or cytokines are important factors regulating wound repair and tissue regeneration. At present, epidermal growth factor (EGF) and fibroblast growth factor (FGF) approved by the State Food and Drug Administration (SFDA) have been applied in clinical medicine, which has a good effect on promoting wound repair and tissue regeneration. Relevant data showed that the healing time of acute wounds (such as the donor site, shallow II degree burn wounds, etc.) treated with growth factors was 2–4 days earlier than the control; while the cure rate of chronic refractory wounds increased from the previous 84% to about 94%, it has produced good social and economic benefits. Stem cells are the soul of the development of regenerative medicine. Stem cells and gene therapy are the most representative high-tech biotechnology of regenerative medicine. They have unlimited potential for treatment and repair of war wounds (trauma, burn). A large number of studies have found that mesenchymal stem cells (MSCs) with multidirectional differentiation potential can be transformed into epidermal cells, vascular endothelial cells, etc. by inducing differentiation in vitro and in vivo, directly involved in wound repair. At the same time, MSCs also have the potential to differentiate into sweat gland cells and sebaceous gland cells, providing an important biological basis for the future functional restoration of damaged skin. The gene therapy applied to wound repair mainly involves injecting the growth factor gene into the tissue repairing cells by transfection, and expressing it in the repairing cells to produce a certain amount of growth factors to promote wound healing. At present, scientists have successfully isolated and cultured stem cells from tissues and organs such as skin, bone, bone marrow, and fat, and tried to use these cells for tissue repair. Such as accidental injury and radiation damage in patients with skin grafting; nerve repair, repair of muscle, bone, and cartilage defects; vascular disease or replacement of blood vessels after injury; and removal of tissue or organ replacement. This technology has emerged in some areas and achieved some results, but there are still many difficult technical problems to be applied to the treatment and repair of war wounds (trauma, burn).

In military medicine, the status of regenerative medicine is equally important. In the past few years, the United States has not stopped launching wars of all sizes. More and more American soldiers have lost their arms or legs in battles or accidents. They have to endure the pain of great disability for the rest of their lives. Faced with this problem, US military scientists have challenged the human body limb regeneration technology, stepped up research, hope to speed up the treatment of injured soldiers, find the limb regeneration, and make the disabled soldiers become perfect. In March 2008, the US Department of Defense (DOD) announced that in the next 5 years, they will raise $250 million in the rapidly growing field of regenerative medicine to form the new Armed Forces Institute of Regenerative Medicine (AFIRM). The organization's research focus is on the regrowth of defective fingers, comminuted fracture regeneration, reconstruction of facial disability, and skin that matches the severely burned wounds. The American Academy of Regenerative Medicine (AFIRM) consists of 30 research institutes in two research consortia universities and hospital research centers. Alan Russell, a biochemist at the University of Pittsburgh, who led the McGowan Institute of Regenerative Medicine, will help lead AFIRM, making great efforts to develop regenerative treatments for bones, muscles, tendons, nerves, and blood vessels.

In China, the "biomedical treatment" project of war trauma led by Academician Xiaobing Fu of the PLA General Hospital has been launched. The implementation of this project will have a profound impact on military's application of stem cell technology to comprehensively treat the wounds and improve the medical support capabilities. The platform of "regenerative medicine and stem cell technology" under construction will lay a solid foundation for the comprehensive clinical application of stem cell technology and the wounding of officers and soldiers. At present, the phased results indicate that sweat gland tissue can be regenerated by stem cell-induced differentiation technology, and after 10 years of follow-up, these regenerated sweat gland tissues have stable sweating function. The three-dimensional (3D) bioprinting technology can construct the new tissue-engineered skin with skin attachment in vitro, providing important ideas and technical basis for the new generation of tissue engineering skin construction. Using ladder or cascade induction we can observe that mesenchymal stem cells can synchronize simultaneously differentiation into tissue cells in one culture system. These provide important clues for the simultaneous repair and regeneration of various tissues at the injury site. These preliminary results suggest that a new tissue repair and regeneration target, that is, the perfect repair and regeneration of damaged tissue at the injury site are about to come. Therefore, it can be predicted that the related basic and applied researches on stem cells, tissue engineering, and biological therapy in regenerative medicine will enable humans to realize the dream of repairing and manufacturing tissues and organs, which is an inevitable direction of the medical science development.

1.2 Posttraumatic Tissue Repair and Regenerative Medicine in Military Medicine

1.2.1 Overview

In the military, there were health organizations and doctors who treated officers and soldiers. However, for a long time, the military medicine was in the stage of experience medicine, and it was only after the nineteenth century that it became a scientific military medicine. Military medicine is the science of studying sanitary guarantee both in peacetime and wartime, by using general medical principles and techniques. Through the implementation of health services, we achieve the goal of maintaining the health of the troops, improving the field medical and epidemic prevention, and consolidating and enhancing the combat effectiveness of the troops. In the battle and training, the modern army often encounters many medical problems that are rare in society and needs special research and resolution, which promotes the development of military medicine [20].

Zeng Hengde's "*Xiyuan Lu Biao*" contains: "The gun hurts in the muscle, and the big magnet attracts the bullets." The book of "*Junzhong Yifang Beiyao*" also has this, but there is no way for the copper bullets, and surgery has to be used. This method was first seen in the "*Junzhong Yifang Beiyao*," in the "guns hurts" article said: "if the copper is hard to take out, it must be cut with a sharp knife, take care of it, use the child defecation to wash the wound, wash the dressing, use the Taiyi cream to protect it." The book also contains the method of taking anesthetic drugs to obtain bullets. The use of Chuanwu, Caowu, wildflowers, etc., as for the use of internal medicine to cure bullets, but it is a commonly used medicine. To treat guns and injuries.

Before the establishment of the New Army in the Qing Dynasty, there appeared to be no fixed military doctors in the army. In case of illness, the soldiers will be dispatched. According to the records of *Donghua Lu*, from the Qianlong to the Guangxu, when the senior general is wounded or sick, if the military affairs are urgent or the disease is mild, the emperor will send a doctor or medical officer to treat in the camp, or go to a nearby city or the provincial capital for medical treatment. If the condition is serious, the emperor will let them leave or return to Beijing for treatment. Injured or sick soldiers were nursed in the camp during the war and repatriated after the war. In this way, there are no fixed military doctors in the army, and there are no regular sanitation facilities. It can only temporarily deal with them and cannot solve the medical problems of the military.

After the nineteenth century, the development of general medicine and science and technology created conditions for the rapid development of military medicine. In the Franco-Prussian War, the Prussian army basically established a medical evacuation system from the ambulance to the rear hospital after the field hospital. During the First World War, Russian military doctor V. A. Opelli proposed the idea of ladder treatment. Although the surgery, anesthesia, medication, and treatment techniques have improved compared with the previous generation, they still lag far behind the needs of military medicine at that time. After the Second World War, the number of antibiotics increased, the knowledge of trauma ballistics increased, the development of microsurgery, and the use of helicopters to send the wounded directly to the hospital for treatment, which further reduced the wound infection rate, amputation rate, and death rate. The Soviet Red Army gradually implemented after the victory of the October Revolution, and in the Second World War, the wounded and sick directionally evacuated. The military of other countries also implemented graded treatment in the Second World War.

Russia is the first country to set up a specialized research institution for field surgery in the world, and there have also been many scholars who have made important contributions to the emergence and development of field surgery. At the same time, Russia has experienced numerous wars, large and small, and accumulated rich experience in field surgery, forming its own advantages and characteristics. In many aspects, our military field surgery has developed from Russia. Field Surgery is a discipline that studies the theory, technology, and organization of large numbers of wounded people under field conditions, especially early treatment. It is a branch of surgery and an important part of military medicine. The field surgery of our army was gradually formed in the practice of war wound healing in successive wars, and developed with the development of combat weapons, war forms, tactical changes, and general science and medicine.

In the next few decades, there has been great development in medicine, making tetanus toxoid, synthesizing sulfa drugs, various antimalarials and DDT, producing penicillin, successful researching fresh blood preservation techniques, advocating early trauma debridement and delayed anastomosis, and promoting gypsum blocking therapy for multiple fractures. The US military's death rate was lower in the Second World War, which was closely related to the tetanus.

The development of conventional weapons and the emergence of new weapons have produced traumas of a different nature or degree than in the past. It is necessary to study methods of treatment and protection to improve the treatment rate. For example, the increasing speed of the ball increases the injury; the cluster bombs cause multiple injuries; the widespread use of incendiary bombs causes a large number of severe burns; the nuclear weapons expand the scope of the killing and increase the radiation damage and compound injuries; the emergence of injuries caused by high toxic neurotoxic agents and infectious diseases caused by biological warfare agents, etc. The improvement of military equipment has put forward special physical and psychological requirements for the operators. It is necessary to medically study the special conditions of such soldiers in order to better grasp the new weapons and equipment. With the expansion of the scale of war, more seriously wounded need to be sent quickly. It is necessary to study the war wound pathology and war injury surgery, and implement the most reasonably graded treatment to minimize the death rate (incident mortality rate). The special conditions of the field require the development of lightweight, applicable, and portable medical technology equipment to meet the needs of the army's mobile operations.

Although the possibility of a global world war is small, regional wars or conflicts have continued. In addition, the usual trauma is also a major disease that endangers human health today. Therefore, tissue repair after trauma is always an important topic in clinical medicine and military medicine.

1.2.2 The Development of Tissue Repair and Regenerative Medicine After the Trauma of Our Military

In ancient China's war, in the era of cold weapons, the battlefields were dominated by fists, knives, lances, arrows, and halberds. In the treatment, "jinchuang zheyang" were the mainstay. Therefore, ancient military medicine has very few special works, and it is attached to the traumatology department. After the Song Dynasty, with the development of firearms, guns were used in warfare, and their lethality was 100 times higher than that of the sword and arrow era. But before 1840, there were not many applications of guns. Therefore, in ancient Chinese military medicine, the treatment was still similar to that of cold weapons.

In the early days of the army, the curriculum of war wound surgery and frequent disease prevention and control was set up in the health school of the Red Army. The period of the Agrarian Revolutionary War was the bud of the field surgery of our army. In the many anti-encirclement wars, it accumulated the experience of mass prevention work in difficult circumstances, and the ability to treat war wounds has been improved. On the basis of summing up the experience of war wounds in the battles and the experience and lessons of the medical organizations, our army's field surgery has gradually transited from disorder to order. In October 1927, the first Red Army Hospital was established in Jinggang Shan. It was divided into slight injuries, serious injuries, and patient departments. It unified the various health service systems, issued trauma treatments, and promulgated health regulations and health services outline above the division, making the health work institutionalized. It emphasized the concept of sterility, properly stop bleeding, dressing, fixation, and wound treatment, and paid attention to technical operations such as shrapnel removal and amputation. It relied on military and civilian efforts to use Chinese and Western medicine and took local materials to treat the wounded. Field hospitals have begun to pay attention to emergency surgery and early treatment of wounds. In terms of organization, an organization system with health workers in company, health centers in battalion, health teams in regiment, and health departments in division has been formed. A series of wounded rescue agencies have been set up from the front to the rear, and the relatively complete medical evacuation system from rescue team, the group bandages, the division army field hospital, the military station hospital to the rear hospital has been established.

During the War of Resistance Against Japan, due to the development of the anti-Japanese national united front, more medical personnel at home and abroad came to the base areas, especially the Canadian medical team led by Norman Bethune, which strengthened the health technology of our army. Because of the weak technical foundation and materials shortage, the development of field surgery was still subject to many restrictions. In terms of theoretical technology, extensive self-help and mutual rescue activities were carried out, and first aid in frontline was strengthened. The medical team and the surgical team were as close as possible to the position, and early debridement within 12 h was implemented, which significantly improved the treatment of fracture injuries. The scope of field surgery has been expanded, the dressing method has been changed, and traumatic shock, traumatic infection, and complications have been actively prevented and cured. Some units have adopted techniques such as blood transfusion and infusion, and have had preliminary experience in the prevention and treatment of poisonous injuries. In terms of organization, the tasks of organizations at all levels were stipulated. The health workers in company mainly rescue the wounded on the fire line, carry out dressing, hemostasis, fixation and handling, and educate the soldiers to learn to use first-aid kits and wrap knowledge in order to save themselves and rescue each other in an emergency. The rescue center in the battalion is responsible for bandaging and transporting the wounded. After the initial rescue of the wounded by the rescue center in the battalion, in addition to the short-term survivable, the others are sent to the division or the military hospital for treatment.

During the War of Liberation, we learned of the advanced experience of military health service in the countries of the Second World War and the techniques of war wound treatment. We established a regular ladder treatment system and continuously summarized the practical experience of war wound treatment. Field surgery has developed rapidly. In terms of theoretical technology, the study and application of new technologies for war wound treatment have been generally carried out. They emphasize the early implementation of early surgical treatment based on debridement, the implementation of plaster bandage therapy, and the prevention and treatment of special infections such as tetanus and gas gangrene, the correct method of dressing, comprehensive prevention, and treatment of shock. The Provisional Regulations on Field Ambulance Treatment, the Temporary General Rules for War Damage Treatment, and the War Damage Medical Regulations have been formulated one after another, which has enabled our military's basic technology of war wound treatment to be organized and institutionalized, marking our army's war wound treatment work to a new stage. In terms of organization, the Wartime Health Service Regulations and Interim Health Regulations were formulated, and the medical service organizations at all levels of the company, the battalion, the regiment, and the division were further improved. The organization, tasks, working principles, and requirements of the rescue agencies at all levels were made with clear provisions. This made the treatment of the wounded and sick from the frontline ambulance, regiment rescue center, the division (brigade) station to the column (military) hospital, forming a unified ladder treatment system with both divisions of labor and continuity.

After the founding of the People's Republic of China, the Department of Experimental Surgery was established by the Academy of Military Medical Sciences in 1952. In 1962, it was renamed the Institute of Field Surgery. In 1978, it merged with the Third Affiliated Hospital of the Third Military Medical University and was placed under the leadership of the Third Military Medical University. Among them, Shen Kefei, Sheng Zhiyong, and other experts have made outstanding contributions to the development of our military experimental surgery. In addition, the Field Surgery edited by Professor Wu Gongliang and Professor Zhao Lianbi in the early stage has played a positive role in promoting the development of trauma surgery and tissue repair and regenerative medicine in China. Later, Academician Wang Zhengguo also edited a new *Field Surgery*, which played an important role in inheriting and developing our military field surgery. Field Surgery was approved as a master's degree in 1984. In 1986, it was approved as a doctoral degree. In 1989, it was approved as a national key discipline. In 1994, it was approved as a postdoctoral research station. In 2005, it was approved as a key discipline of Army Project 2110.

In the new historical period, the concept, scope, and treatment techniques of war trauma surgery have undergone significant changes. It is imperative to write a series of new large-scale academic monographs reflecting the latest theories, techniques, and methods of modern war trauma. In 2014, Academician Xiaobing Fu, Academician Wang Zhengguo, and Professor Li Jianxian of Yangming University in Taiwan province as chief editors, the famous trauma medical workers in mainland and Taiwan province as authors, *The Chinese Trauma Medicine* was officially published. This large-scale academic monograph fully reflects the latest achievements in the fields of trauma epidemiology, trauma medicine, clinical treatment, trauma rehabilitation, etc. in the mainland and Taiwan province, especially more than 20 traumatologists in Taiwan province, China participating in it. The compilation has become an important achievement in the academic exchange of traumatic medicine between the two sides.

In order to better reflect the perfect combination of trauma medicine and military medicine, in 2016, Academician Wang Zhengguo, Academician Lu Shibi, Academician Cheng Tianmin, and Academician Sheng Zhiyong served as consultants, and Academician Xiaobing Fu was the chief editor of the large-scale academic monograph *Chinese Trauma* officially published. Different from the *Chinese Trauma Medicine* published in 2014, this large-scale academic monograph not only reflects the traumatic in peacetime, but also pays special attention to the latest developments and future directions in the field of war injury treatment in recent years. It summed up the experience of war wound healing from US military in Afghanistan War and Iraq war. The book contains a total of 11 volumes, including the general theory of war trauma, traumatic brain trauma, oral and maxillofacial trauma, eye trauma, otolaryngology-head and neck trauma, chest and abdomen trauma, limb spine and pelvic trauma, special causes of trauma, special environmental trauma, regeneration and rehabilitation, trauma care, and psychology, a total of 16.5 million words, composed of more than 500 Chinese traumatic medical experts. This series of monographs is the latest, most systematic, and comprehensive academic monograph in the field of traumatic medicine in China. It is believed that its publication will greatly promote the development of traumatic medicine in China.

Since the founding of the People's Republic of China, under the support of medical research, especially after the test of self-defense operations such as the War to Resist US Aggression and Aid Korea and the Sino-Indian border, Chenpao Island, Xisha Islands, and China-Vietnam border, our military's war wound treatment technology has shown new developments on the basis of perfection and improvement over the original treatment system. In 1982, our military listed ventilation and long-term use of hemostasis, dressing, fixation, and handling as five basic techniques for first aid. In 2006, in the new version of the war injury treatment rule, the basic life support technology was added to expand the first-aid technology to six. The cricothyroid membrane puncture, cricothyroidotomy, and hemostasis with peripheral blood vessels were added on the basis of what the original health workers should master.

In response to changes in weapons development, operational concepts, and operational styles, our military has conducted an in-depth research on nuclear weapon wounds, new concept weapon injuries, impact injuries, burns, crush injuries, and special environmental injuries. The principle of prevention and cure has greatly improved the level of wound treatment of our army and enriched the connotation of field surgery. Among them, the basic and clinical research on burns, impact injuries, and nuclear weapon wounds are at the internationally advanced level. In 1999, the Third Military Medical University established three military key (open) laboratories into a "combination laboratory for trauma, burn and combined injury." In 2001, as a key laboratory of the department, it entered the state key laboratory evaluation. In 2003, it was included in the state key laboratory construction plan by the Ministry of Science and Technology. In November 2005, it passed the acceptance of the Ministry of Science and Technology and officially became the first state key laboratory of the army. In August 2012, the seven military units including the Third Military Medical University, the Academy of Military Medical Sciences, the PLA General Hospital, and the China Academy of Engineering Physics, etc. established the first "Community Innovation Center for War-Wound Prevention and Control." The center is led by the Academician Wang Zhengguo. The high-level academic team with the "Talent Project" national-level candidates and the winners of the National Science Fund for Distinguished Young Scholars as the core backbone has undertaken a series of major project researches on the traumatic treatment of the military over the years. Relying on the established state key disciplines—Field Surgery, Burn Surgery, Military Preventive Medicine, and the State Key Laboratory of Trauma, Burn and Combined Injury, which have been functioning well, the center has confirmed four research directions including the innovative theory of war wound prevention and cure, the key technology of war wound prevention and cure, the research of field health equipment, war wound treatment equipment and drug, and the conversion of war trauma theory, technology, equipment, and drug.

Especially in the field of burn wound tissue repair, our military research work has achieved fruitful results. In the early 1990s, the National Natural Science Foundation's first major project involved burn wounds and posttraumatic wound repairs, led by Professor Shi Jixiang of Ruijin Hospital of Shanghai Second Medical University and Professor Li Ao of Southwest Hospital of the Third Military Medical University. The focus is on the pathophysiological mechanism of burn wound repair. In 1999, the field of trauma medicine was funded by the National Major Project "973." The chief scientist was Academician Wang Zhengguo. Later, Professor Jiang Jianxin and Academician Xiaobing

Fu successively assumed the National "973" Trauma and tissue repair and regeneration project as the chief scientist. This series of research has made breakthroughs in "Basic Research on Severe Trauma Treatment and Injury Tissue Repair." Focusing on the two core issues of improving the level of severe trauma treatment and the quality of damaged tissue repair, we work together and carry out a series of studies on vascular reactivity, permeability, and "shock heart" related to the occurrence of ischemia and hypoxia in traumatic shock, and found a new regulatory target. According to the mutual regulator control of neuroendocrine, immunoregulatory cells and immunosuppressive molecules, we proposed a new mechanism of posttraumatic immune dysfunction. According to the aspects of genetic background differences, immune molecules, and immune cell phenotype changes, a series of biological indicators for early detection of traumatic complications have been proposed and a series of comprehensive measures to antagonize pathogen infection, enhance the body's own anti-injury ability, and early prevention and treatment of traumatic complications have been established. This further confirms the important biological phenomenon of dedifferentiation of epidermal cells, and by inoculating transplanted stem cells, the tissue structure resembling sweat glands is cultivated to solve the problem of perspiration in patients with deep burns. From the clinical perspective, the long-term mild hypothermia treatment of patients with severe brain injury better than short-term mild hypothermia therapy has been proved. Breeding more than 10 kinds of mice with transgenic or gene knockout for traumatic research, we found a new target to promote fracture healing. We first proposed the concept of activated Schwann cells and found that activated Schwann cells are more conducive to the repair of peripheral nerve defects, providing a new method for the treatment of peripheral nerve injury. We revealed that the microenvironment of wounds promotes the regulation mechanism of adult stem cell repair and has created a variety of key technologies for adult stem cells to repair damaged tissue. In addition, great progress has been made in the research of chronic wound repair, damage mechanism, and prevention methods of skin soft tissue blast injury and seawater immersion injury, and new techniques for the treatment of traumatic facial deformity.

The related research in the field of tissue repair and regeneration has been highly recognized by the state, and the first class prize of The State Science and Technology Progress Award is taken as an example. It can be seen that the innovation and transformation application in this field promote clinical treatment. In the repair of facial injuries, with the widespread use of high-explosive weapons, the proportion of facial warfare increased from 3.4% in World War II to 23% in the Iraq war. Its repair and treatment is an internationally recognized military medical problem. Professor Zhao Yimin's research team of the Fourth Military Medical University, after 20 years of hard work, formed autologous transplantation repair—"face," allograft repair—"face change," prosthetic simulation repair—"prosthetic face," tissue regeneration repair— "face regeneration" as one of the serious face warfare wounds and deformed morphological repair and functional reconstruction technology system, which can meet the needs of a variety of facial injuries. In 2011, the country selected a total of 20 first class prizes for scientific and technological progress, including "Severe Face Warfare, Wound Defect and Morphological Repair and Functional Reconstruction" as a military-specific project, which stood out from 863 declaration projects and finally won the national first class award.

In the aspect of repairing chronic refractory wounds on the surface of the body, the team of Academician Xiaobing Fu of the People's Liberation Army General Hospital won the first class prize of The State Science and Technology Progress Award in 2015, for the study of the innovative theory and key measures for the new characteristics and prevention of refractory wounds in Chinese human body. This is the unique first class prize of The State Science and Technology Progress Award in China's clinical medicine field in 2015.

Through fruitful collaboration, after more than 10 years of research, the project has achieved four innovations:

(a) Two new characteristics of wound epidemiology were discovered. Through the large-scale multicenter epidemiological study of 1.48 million inpatients, it is the first time in the world that the main cause of refractory wounds in Chinese human body has been changed from trauma and infection 10 years ago to diabetic foot and complications of senile chronic diseases. Based on this, the high-risk factors and wound characteristics of diabetic foot in China were identified through the investigation of 3000 cases of diabetic foot, which pointed out the direction for scientific prevention.
(b) Three special mechanisms for the treatment of diabetic foot and radioactive wounds were first proposed. They are, the "hidden damage" mechanism of cell or matrix dysfunction caused by accumulation of toxic substances such as high sugar and advanced glycation end products (AGEs) in diabetic skin; glycosylation of growth factors and macrophage chemotaxis and abnormal phagocytosis—the difficult immune mechanism; the mechanism of radioactive wounds' "network disorders of healing factors with cell damage as the key link," providing innovative theories for establishing key control measures.
(c) Based on previous treatments, four key prevention measures were created. The first use of photon technology to reduce the "hidden damage" caused by wound glycation products, the use of regulating the internal environment to reduce the "progressive damage" of repair cells, the recruitment of cells, and the provision of scaffold mate-

rials to promote wound healing and the first international adoption of "4G" to realize that complex wounds are treated under the same standard at different levels of medical institutions, so that the cure rate of difficult wounds is significantly improved. The overall cure rate for a typical unit increased from 60% to around 94%. In this achievement, the total amputation rate of diabetic foot was 7.2%, and the large amputation rate was 4.0%. In the same period, the corresponding indicators in Europe reported 22% and 5%, respectively, the difference was very significant (Fig. 1.1).

(d) We innovated treatment mode for the characteristics of refractory wounds with preventable control, large outpatient, and small ward. We also advocated the establishment of more than 50 wound treatment specialists (centers); created a new scientific prevention and treatment model for the two-way linkage and referral of single disease between wound treatment specialists and community medical institutions; established a new strategy by cooperation with international and domestic funds to develop early stage prevention and control education of refractory wounds.

The discipline construction and talent cultivation in the field of trauma and wound repair and tissue regeneration in China have also achieved rapid development. Talents are the key to the development of disciplines. China's trauma medicine has not only a large number of talents, but also qualified successors. There are many founders and pioneers of the older generation of disciplines, such as Academician Li Ao, Academician Sheng Zhiyong, Academician Cheng Tianmin, and Academician Wang Zhengguo. In recent years, a large number of innovative people have emerged. The excellent young and middle-aged generation is not only based on their own work, but also with an international outlook. According to preliminary statistics, there were eight members who served as members of the Chinese Medical Association Trauma Branch and later became academicians of the two academies (Li Ao, Sheng Zhiyong, Cheng Tianmin, Li Jieshou, Wang Zhengguo, Gu Yudong, Zhou Liangfu, Xiaobing Fu). There were nine members who served as members of the Chinese Medical Association Trauma Branch or the Academic Group, or participated in the National "973" Trauma and Tissue Repair and Regeneration Project, and has won the National Science Fund for Distinguished Young Scholars for basic research and clinical treatment of wound healing (Xiaobing Fu, Xia Zhaofan, Huang Yuesheng, Jiang Jianxin, Yao Yongming, Jiang Baoguo, Liu Liangming, Chen Lin, Zhao Min). In particular, the establishment of the State Key Laboratory of Trauma, Burns and Combined Injury at the Third Military Medical University and the "Repair and Regenerative Medicine" innovation research group of the PLA General Hospital was funded by the National Natural Science Foundation of China in 2011, marking the overall level of the field to have been recognized by the state. During the "Eleventh Five-Year Plan" period, Xijing Hospital Plastic Surgery and Changhai Hospital Plastic Surgery have successively become the All-Army Plastic Surgery Research Institute and Plastic Surgery Center. The plastic surgery of the three military medical universities has entered the ranks of national key disciplines. In the field of international wound repair, in 2008, in Toronto, Canada, Professor Xiaobing Fu was awarded the "International Wound Healing Research Lifetime Achievement Award" for "International Discovery in the Field of Tissue Repair and Regeneration and the Role of These Discoveries in Promoting Clinical Therapy."

In the course of decades of development, our military field surgery has grown from scratch, from weak to strong, providing theoretical support and technical services for the research and clinical treatment of postwar tissue repair in our army. It has maintained the health of the officers and soldiers of the army, improved the combat effectiveness of the troops, and made great contributions to the cause of national defense and health. However, the trauma care of our country is still far from the most advanced treatment system in foreign countries. In the future, we should further improve

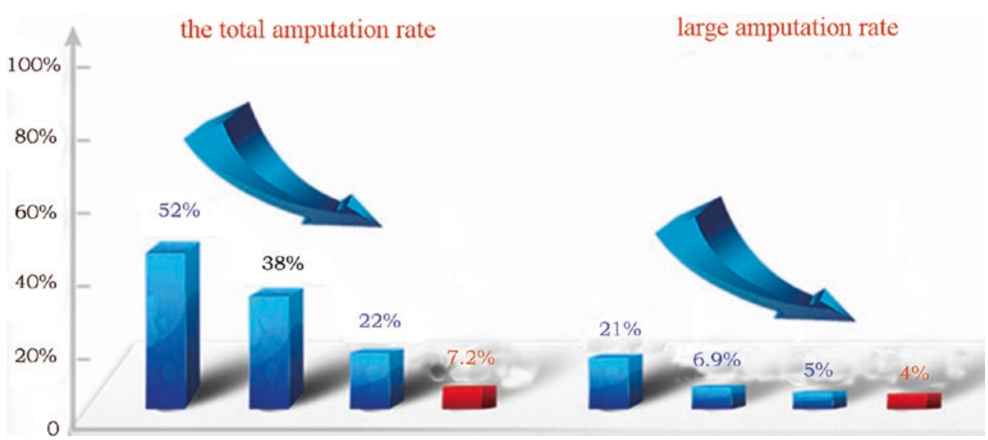

Fig. 1.1 Compared with developed countries, the total amputation rate and large amputation rate of diabetic foot in China are significantly lower

the medical emergency network, standardize first-aid organizations, emergency personnel, medical equipment, transportation and communication equipment, etc., especially strengthen on-site first-aid and transportation, and strive to achieve a coordinated process of prehospital care and hospital treatment.

1.2.3 The Future Development of Posttraumatic Tissue Repair and Regenerative Medicine

Under the new situation of rapid advancement of medical science and technology, new military reforms, and military health preparations, the traumatic treatment and posttraumatic tissue repair in field surgery face severe challenges and major opportunities. The mission is lofty and has a long way to go. I look forward to the writing of a new chapter by the vast number of field surgeons.

Expand the research field of weapon traumatology. In the future war, the increase in the types of new weapons and the killing factors will increase the proportion of nonfirearms war wounds, and the form of warfare that is not directly contacted by air strikes and anti-air strikes will increase. Therefore, first of all, it is necessary to study the injury effects and injury mechanisms of various new killing weapons. Secondly, we must strengthen the study of explosive weapon injuries. From the local wars that have occurred in recent years, explosive weapons are gradually becoming the main killing weapons in modern warfare. Explosive weapons not only have great killing power, but also have many damage factors. The damage caused is characterized by multiple injuries, combined injury and serious injury increasing. It is predicted that under the conditions of high-tech local war in the future, the following characteristics may occur in war injuries.

(a) Increased impact injuries: With the application of high-explosive weapons and burning air bombs, shock waves will play a more important role in killing factors. If the enemy uses a tactical nuclear weapon with strong shock wave bombs, the killing effect of the shock wave will be more prominent, and the resulting impact injury will be more and more serious.
(b) Increased mechanical injuries and multiple injuries: Under the action of strong shock waves, a large number of houses collapsed and the fortifications destroyed. The masonry and wooden blocks from the destroyed building will hit human body in the form of secondary projectiles. There will be many mechanical injuries such as crush injuries and multiple injuries.
(c) Increased burns: Buildings, woods, etc. are often on fire after being hit by bombs. If the enemy uses flaming weapons, anti-tank weapons, or fuel-air bombs, it is more likely to cause fires. In this case, burns will inevitably increase.
(d) Increased combined injury: Two or more of the killing factors simultaneously or successively acting on the human body, the injury is called combined injury. In future wars, weapons with different injury factors may be used at the same time. The same weapon may sometimes have multiple killing factors, so the number of combined injuries will increase. The research on the characteristics of explosive weapons and the treatment should be strengthened, especially the study on the combined effects of punching, burning, fragmentation, and crush. If a tactical nuclear weapon is used, radioactive combined injury may also occur.
(e) Increased psychic trauma: With the suddenness and cruelty of the war, some people who lack experience in warfare, especially young soldiers with poor stability of psychology and spirit, are prone to combat stress reactions caused by tremendous mental stress. If there are other war injuries at the same time, the condition will be heavier.
(f) Other new weapon injuries: Laser damage, microwave damage, infrasound damage, etc., which have never been seen before on the battlefield, may occur under certain local war conditions. Based on these characteristics, research emphasis on tissue repair and clinical applications should be adjusted. Strengthen research on war injuries under special environmental conditions. Under the conditions of high cold, high heat, high altitude, sea, etc., the characteristics of various war wounds and the treatments are obviously different.

Although the injury factors are various and can occur in various parts of the body, after any kind of trauma, the body's systemic reaction and the repair of the damaged tissue have a common law. Strengthening the basic research of war trauma and clarifying these common problems are of great significance for guiding the early treatment of various war wounds and the later tissue repair. In the war-wounded patients who died, at least 50% died of postinjury complications, except that the vital organs were directly injured and immediately killed. Most tissues are structurally repairable after damage, but functional repairs are poor. For example, large-area burn wounds are healed, but there are a lot of scars, especially the lack of skin attachments, so there are still serious disabilities. Therefore, only by further strengthening the basic research of war trauma medicine can we better improve the level of war wound healing.

Early systemic damage, visceral complications, and damaged tissue repair are the common problems of various types of war wounds. The basic laws can guide the treatment of various types of trauma.

(a) Pay attention to the mechanism and prevention of wound infection. Traumatic infections are mainly endogenous infections caused by displacement of the resident bacteria and their toxins in the body. Decreased immune function, mucosal barrier damage, and dysbacteriosis in the body during severe trauma are important mechanisms leading to endogenous infection after trauma.

(b) Focus on the intrinsic relationship between early neurological, endocrine, immune response, and posttraumatic complications in severe trauma, and explore the interaction between injury and anti-injury. In severe trauma, not only is the injury response very serious, but the body's anti-injury reaction and endogenous protection mechanism are also significantly weakened. The serious imbalance between the two is an important basis for further damage after trauma.

(c) Deeply understand the complex mechanisms of tissue repair and regeneration. The contents include the changes in the biological behavior of repair cells and extracellular matrix and their effects on the repair and regeneration of tissue repair, and the role of various repair cells, growth factors, genes, and microenvironment changes in wound healing and regeneration. Combining the research of developmental science and comparative biology, it shows a new understanding of scar healing and delayed healing of tissue, and proposes the scientific hypothesis and research goal of achieving simultaneous repair and regeneration of damaged tissue at the injury site, to achieve perfect repair and regeneration of damaged tissue.

(d) Pay attention to the repair research of bone, peripheral nerve, central nerve, etc. On the one hand, it helps to study the regularity of self-regeneration and repair or cellular and molecular basis of these tissues after damage, and the factors affecting their regeneration and repair. On the other hand, it is used to explore measures to artificially promote the repair of these tissues, mainly including various biological factors (recombinant growth factors, etc.) and physical factors (acoustic, optical, electrical, magnetic field stimulation, etc.).

(e) The application of high-tech biotechnology in wound repair and tissue regeneration is mainly reflected in new intelligent biomaterials, tissue engineering, and stem cell research. Tissue engineering is a new technology in the field of wound repair. It is important to research and develop new biomaterials and tissue substitutes and fillers with better biocompatibility. Using tissue engineering principles and techniques it is possible to construct tissue-engineered tissues and organs. The clinical exploration and basic research of allograft (xenograft) composite tissue transplantation, although far from the clinical application, have initially shown their broad application prospects [21].

In short, paying attention to the research on the repair and regeneration of damaged tissue after trauma is of great significance to improve the level of war wound treatment and enhance the morale of the army. Its position in military medicine is irreplaceable.

1.3 Wound Tissue Repair and Regeneration Concept

Although trauma is an ancient medical problem, it is also a social issue that deserves attention at the same time. According to foreign data, more than 50% of the people wounded by explosions and earthquakes have skin and soft tissue damage. With the development of social productivity, the improvement of industrialization level, and the improvement of medical care level, the incidence of trauma has not only decreased, but has also continued to increase. Trauma has become one of the leading killers of death in both developed and developing countries.

Regardless of the size of the wound, there is a problem of tissue repair. The traditional understanding of wound repair mainly stays at the general and cellular level, which is mainly based on the level of understanding of people in different eras and the limitations of research methods at that time. Since the 1980s, the development of science and technology has enabled people to have the ability to re-recognize the basic processes of wound healing at the molecular and genetic levels, thus laying a good foundation for further basic theoretical research and clinical treatment.

In general, the wound itself initiates the repair process. Posttraumatic tissue repair begins with coagulation and is coordinated by a number of cells, extracellular matrices, and regulatory factors. Initially, platelets, neutrophils, and macrophages enter the wounded area in large quantities to remove the damaged tissue and contaminating microorganisms. Platelets and macrophages also secrete some growth factors associated with fibroblasts and endothelial cells. The fibroblasts and endothelial cells then gradually replace the damaged matrix. At the same time, epithelial cells also grow inward from the wound margin until they cover the wound. Therefore, the speed of wound repair depends on the speed at which the above cells enter the wound and proliferate there, and the entry and proliferation of the cells are dependent on the regulation of chemokines and growth factors.

Chemokines are usually peptides, proteins, and protein fragments that cause cells to move in a certain direction, such as from low to high concentrations. The response of a cell to a chemokine depends on the number of corresponding growth factor receptors. Different cells respond differently to different chemokines. Chemokines are produced in the coagulation process, and aggregated platelets are their main source. Therefore, some cytotoxic drugs that reduce the number of circulating platelets can also affect the wound healing process, such as anti-macrophage antibodies. In addition, macrophages, fibroblasts, and endothelial cells themselves produce some chemokines and cleavage factors.

Growth factors are also proteins or peptides that act alone or in combination with several growth factors to induce DNA synthesis and cell division. There are dozens or even hundreds of growth factors that have been discovered, but there are more than 10 kinds of researches that can be used as basic and clinical. The representative factors are platelet-derived growth factor (PDGF), acidic or basic fibroblast growth factors (FGFs), epidermal growth factor (EGF), transforming growth factor (TGF), insulin-like growth factor (IGF), etc. They participate in wound repair mainly through mechanisms such as autocrine and paracrine. At low concentrations, the responsiveness of cells to growth factors depends on the presence of corresponding growth factor receptors on the cells. For example, PDGF acts only on fibroblasts, whereas FGF has effects on both fibroblasts and endothelial cells. It should be pointed out that some growth factors also have chemotaxis, and this dual action has special significance for wound healing. Therefore, they are sometimes referred to as split chemokines. This dual action factor is required for intercellular action in the early stages of wound healing, and in the later stages, such as DNA synthesis, chemotaxis is no longer needed. Studies have confirmed that these growth factors can show significant effects on treatment without obvious side effects. The basic research and clinical application of growth factors are currently in a positive development stage. Although genetic engineering drugs represented by growth factors have shown unique effects on wound healing, they are still only one of the ways to promote repair, and cannot replace the basic treatments such as debridement, anti-infection, and skin grafting. Therefore, the application of growth factors can only be better if they are based on surgical treatment. Because the growth factor repairs the wound, it is still scar repair, lacking structures such as sweat glands, sebaceous glands, and hair follicles, and even nerve endings. These problems in the recovery and reconstruction of healing tissue function, as well as the adverse reactions that may be caused by the application of growth factors in local wounds, and the regulatory relationship between growth factors and wounds are the focus of current attention and research.

It has a long history of adding certain substances extracted from tissues to the wound site to promote healing. In the past 20 years, with the deepening of research on growth factors, especially the development of genetic engineering technology, people can mass produce such genetic engineering products in vitro. Therefore, there have been many reports on the use of growth factors to promote acute and chronic wound healing. However, some people believe that due to the local addition of growth factors, the effective concentration is difficult to maintain due to the wound environment (including enzymes, salts, and pollution), and it is often necessary to give large doses of growth factors. To solve this problem, a genetically modified approach can now be used to solve this problem. This method uses technology such as gene gun and micro-planting to transfer the target gene into the site to be healed by in vivo and in vitro methods, so that the factors that promote repair can be continuously produced in the wound site. However, since the safety and methodology are not completely solved, this method is not yet practical. The safety and long-term effects of topical application of growth factors remain the focus of attention. Platelet-rich plasma (PRP) is a plasma containing platelets that exceed several times the physiological concentration. It is mainly used to repair by various high-concentration growth factors (such as PDGF, FGF, TGF, and IGF) and has become a research focus in recent years, with a relatively positive effect, it has become one of the new therapies to promote wound healing.

The size of the scar tension depends on the synthesis and deposition of collagen. The latter is related to the number of fibroblasts and to wound oxygen tension, vitamin levels, and nutritional status. Growth factors promote collagen synthesis by enhancing cell division. Most growth factors also promote the production of collagenase, which in turn enhances collagen degradation. In contrast, although TGF-β also promotes collagen synthesis, it also inhibits collagen degradation. Therefore, it is believed that TGF-β may be involved in the development of certain fibrotic diseases.

With the improvement of people's living standards, the past repair mode that aims to achieve the anatomical repair of wounds has been difficult to adapt to people's needs, especially in large-area burn patients. The wounds of scar repair have no sweat glands and hair follicles. It is physiologically difficult to adapt to changes in the environment, and psychologically cannot return to society. Therefore, the transformation of wounds from anatomical repair to functional repair is receiving increasing attention.

It can be predicted that the damage and repair of important internal organs caused by severe trauma and disease will become the focus of further research. On the one hand, it is the active repair after the important organ injury caused by ischemia-reperfusion. On the other hand, it is the excessive repair after the organ damage caused by some diseases, that is, the prevention and treatment of fibrosis. With the deepening of research, both issues are expected to be resolved. The replacement of depleted organs with artificial organs is also a direction that people are working hard.

Stem cell technology, cloning technology, and tissue engineering technology are some of the research contents of wound repair and tissue regeneration, while others provide the basis and conditions for wound repair and tissue regeneration research, which is an important part of trauma repair research in the twenty-first century. They should be taken seriously. Medical workers should work closely with experts in biology, tissue engineering, and materials science to collaborate, so that multidisciplinary collaboration is likely to break through.

The biggest feature of high-tech local warfare is sudden and rapid advancement. If officers and soldiers cannot quickly adapt to the battlefield environment or be deterred by high-tech weapons and equipment in a short period of time, there may be a series of psychological obstacles and even psychological collapse.

Strengthening research on the prevention and control of battlefield stress and mental illness is the focus of attention in recent years. Our military still has some blind spots in military psychological training. For the battlefield stress and mental illness, and their impact on the ability of wound repair, there is still a lack of in-depth systematic research, so it needs to be further strengthened.

1.3.1 Repair and Repair "Out of Control"

Repair is a series of pathophysiological processes that actively repair wounds by proliferation or regeneration, or affect the wound repair by manual intervention after tissue defect due to trauma or other disease, such as through surgical techniques to transfer the flaps to repair wounds. Therefore, the concept includes both the healing process of the organism itself and the impact of human factors on wound healing. There are two types of repair: the repair by the surrounding cells of the same kind is called regeneration; the repair by the fibrous connective tissue is called fiber repair.

Repair "out of control" is an academic concept that needs further clarification. In theory, the growth, development, and repair of organisms is an orderly biological process. After the tissue is damaged, the wounds should be fully recovered by anatomy and function. But this goal is often difficult to achieve after the birth of the human body. At present, the repair outcome of a wound that is unhealed (hard to heal) or repair of excessive hypertrophic scars or keloids for some reason is called repair "out of control" (Fig. 1.2).

Scar tissue is mainly composed of collagen and fibroblasts. In the wound with a small defect, neat wound edge, no infection, and good wound, the scar tissue is not obvious, like a line, and has no effect on function. In wounds with large defects, incomplete wounds, or infections, scars often form large and high out of wounds, which not only affect the tissue function, but also unsightly. According to histopathology, scar tissue can be divided into the following categories: normal scars and pathological scars. The general skin scars gradually heal in a few weeks, may show redness and hardening, but will automatically disappear within 6 months to 2 years, leaving a normal color scar. Pathological scars can be divided into hypertrophic scars, keloids, and unstable scars. These pathological scars differ in morphology, pathology, and biological behavior and the treatment methods are quite different.

The role and impact of scar tissue:

1. The beneficial side of the body: The formation of scar tissue can permanently connect the damaged wound or the defected tissue and maintain the integrity and firmness of the tissue and organs.
2. Adverse effects on the body:
   (a) Due to poor elasticity of the scar tissue, the strength of the tensile force is weak. If the local pressure is

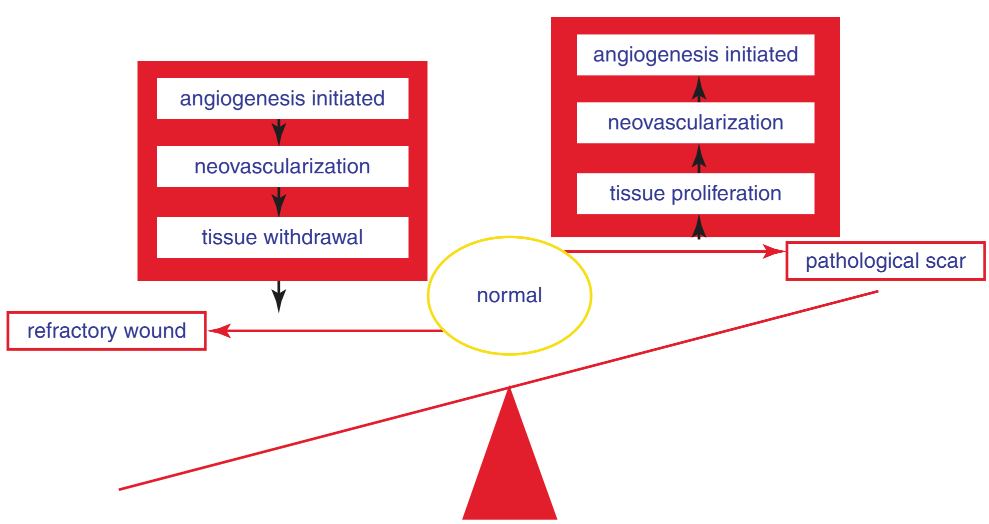

Fig. 1.2 Microvascular formation may have a relationship with different healing outcomes
Note: Various factors cause damage to the microvascular formation of the wound, resulting in insufficient material and energy necessary for tissue repair or failure to remove the metabolites in the wound, which will interfere with the normal procedure of wound repair and abnormal repair outcomes (over and under), including hyperplasia of scars, keloid formation, diabetic microangiopathy, and venous stasis ulcers

excessively applied, the healing scar tissue can bulge outward. Just as the abdominal wall scar due to abdominal pressure increased can form abdominal wall hernia, the scar formed by myocardial infarction protrudes outward to form a ventricular aneurysm.

(b) Scar tissue can contract, which can lead to luminal stenosis, joint movement disorder, organ adhesion, or hardening.

(c) A small number of patients with hyperplasia of scar tissue to form a raised plaque, called keloid. After a long period of time, the collagen fibers in the scar tissue are decomposed and absorbed under the action of collagenase, so that the scar shrinks and softens. Collagenase is mainly derived from macrophages, neutrophils, and fibroblasts.

1.3.1.1 Hypertrophic Scar

Hyperplastic scars, also known as hypertrophic scars, occur mostly in the depth of injury that affects only the dermis. The pathological difference between a hypertrophic scar and a normal scar is only due to the thickening of collagen fibers in the deep scar, which is characterized by an irregular arrangement, or wavy, or wound into a rope. Hypertrophic scars often occur after wound healing in deep burns. Reticular hypertrophic scars are also common in sutures after skin grafting of the III degree burn wound. In addition, any incision scar after suturing is also included in this type. Hypertrophic scars are characterized by prominent surfaces, irregular shapes, uneven heights, flushing and congestion, firmness and toughness, burning, and itching. Excessive hyperplasia is higher than the wound, but is still limited to the wound. There will be obvious atrophy and lightening in the 2 years after the scar is formed.

1.3.1.2 Keloid

Keloid refers to hypertrophic scars that infiltrate the surrounding skin beyond the wound area itself. It is more common in the chest and limbs, and has a higher incidence of colored people (especially black and yellow races). Skin scars continue to proliferate during healing and spread to the surrounding area, like the shape of the foot or butterfly, become hard and are accompanied by red pain. These scars are often called keloids. Keloids are common in the anterior chest, scapular, earlobe, and upper arm, and are highly prevalent in women. The physique of those who are prone to keloids is called scar physique. Some mast cells are common around the blood vessels in the keloid, so it is believed that due to persistent local inflammation and hypoxia, the mast cells are promoted to secrete various growth factors, and the granulation tissue is excessively grown, thereby forming keloids. The current study found that the etiology and pathogenesis of keloids are also related to many factors. Among them are the combination of cytokines and extracellular matrix collagen metabolism, the role of nuclear transcription factor NF-κB signaling pathway in skin physiology, and the family genetic factors. Only a clearer understanding of the pathogenesis of keloids may provide a basis for the clinical treatment of keloids and bring breakthroughs.

1.3.1.3 Scar Ulcer or Unstable Scar

Scar ulcer or unstable scar, also known as chronic wounds, is defined by the International Society for Wound Healing as a state of the wound failing to achieve anatomical and functional integrity through normal, orderly, and timely repair. These wounds often delay healing or even nonhealing, and have specific causes such as diabetes, ischemia, stress, etc. Clinically, chronic wounds refer to wounds formed by various reasons after 1 or 3 months (time is not completely absolute) treatment fails to heal and there is no tendency to heal. It covers a variety of factors such as the size of the wound, the cause of the disease, and the general health of the individual. One type of ulcer is due to unstable scarring. In the early stage of scar formation, fibroblast proliferation, and capillary dilatation, the appearance of redness and thickening is observed, showing a strong proliferation phenomenon; then the scar tissue continues to shrink; after a period of time, the scar tissue enters a stable stage, at which point the scar becomes soft and thin. In some areas (one third of the lower leg, joints, etc.), some are easy to rupture, resulting in chronic ulcers. In particular, some of them can develop into malignant ulcers, namely, marjolin ulcers.

1.3.1.4 Scar Cancer

In 1828, French surgeon Marjolin first described the "warty ulcer" that occurred on the scar and called it "cancroidal ulcers" (also known as "ulcer canchroides"). Later, Dupuytren and Robert Smith made it clear that the scar can be cancerous and called the ulcer "warty ulcers of Marjolin," the Markov ulcer. From scarring to carcinogenesis, the length of time varies, the shortest is 6 weeks, whereas the elderly can reach more than 30 years. The older the patient, the more likely it is to become cancerous. Marjolin ulcers occur in one third of the lower leg, the heel, the joints of the limbs, and other wearable parts, the scalp and trunk are also good sites. The current treatment is still based on surgery.

1.3.2 Compensation and Remodeling

1.3.2.1 Compensation

Compensation refers to the process in which the structure of an organ or tissue is damaged, the metabolism and function are impaired, the organ, the normal part of the tissue, or other organs and tissues are replaced and compensated. There are three main types of compensation: metabolic compensation, functional compensation, and structural compensation.

(a) Metabolic compensation refers to a kind of compensation in the body during the course of the disease, in which the substance metabolism changes adapting to the new situation of the body is the main manifestation. That is, the metabolism of the three major nutrients is strengthened or slowed down.
(b) Functional compensation refers to a compensatory form of the body to compensate for the dysfunction and damage of the diseased organ through the enhancement of organ function.
(c) Structural compensation refers to the body's function enhancement, accompanied by changes in morphological structure to achieve compensation, mainly as the parenchymal cells of organs or tissues volume increased (hypertrophy) or number increased, or both. Structural compensation is divided into two kinds of compensation: physiological hypertrophy and pathological hypertrophy.

1.3.2.2 Remodeling

Remodeling refers to the fact that after the change in the functional burden of organs and tissues, in order to adapt to new functional needs, its morphological structure changes accordingly. It is mainly divided into three types: remodeling of blood vessels, remodeling of bone tissue, and remodeling of connective tissue.

1.3.3 New Concepts Involved in Wound Repair

1.3.3.1 Growth Factor

Growth factor (GF) refers to a polypeptide or protein that is widely present in living organisms and regulates the growth and development of organisms, such as epidermal growth factor (EPF), fibroblast growth factors (FGFs), and platelet-derived growth factor (PDGF), which are closely related to wound repair and tissue regeneration. Growth factor, also known as growth hormone, is an important area of medical and molecular biology research in the past 30 years and one of the milestones in modern medical research. In 1986, biologist Levi-Montalcini and biochemist Cohen were awarded the Nobel Prize in Physiology or Medicine for research on nerve growth factor (NGF). There are about 50 growth factors that have been found to promote cell growth and differentiation. There are a large number of growth factor (GF) receptors on the cell surface. The essence of the GF receptor is a glycoprotein or a simple membrane protein with a molecular weight of 130–170 ku. Its composition is generally divided into three parts:

(a) A ligand-affining site outside the cell.
(b) The tyrosine kinase binding site inside the cell.
(c) The junction of the cell membrane.

The combination of various growth factors with their respective receptors may occur in the following three ways.

(a) GF intracellular migration: After GF binds to the receptor, the cells endocytose it to form a receptorsome, which acts on the nucleus and causes an effect.
(b) Tyrosine phosphorylation: GF binds to the receptor and directly causes this process to have an effect.
(c) Through the second messenger mediated by cyclic adenosine monophosphate (cAMP) and cyclic guanosine monophosphate (cGMP): GF binds to the receptor, causing an increase in the concentration of cAMP to cause an effect.

1.3.3.2 Cytokine

Cytokine is a group of hormone-like regulatory molecules that are extremely small in the human body and function at the level of pictogram (pg.). They act locally mainly by autocrine and paracrine, that is, on secretory cell itself or the adjacent tissue cell. In the past, it was divided into lymphokines and monocyte factor according to its source. In recent years, studies have found that many cytokines can be produced by different types of cells (immune cells and nonimmune cells). To avoid confusion, the name cytokine is now used more. Cytokines produce biological effects by transmitting signals into cells by binding to corresponding receptors on target cells. Many cytokines can act on the same target cell to mediate the same or similar effects, while the same cytokine can act on different target cells, producing different effects. For example, interleukin-1 (IL-1), in addition to regulating the immune system, can also act on different sites of the hypothalamic-pituitary-adrenal axis (HPA) to produce neuroendocrine effects. A network is formed between different cytokines, and mutual regulation produces and exerts effects. In addition to being regulated by the immune system, cytokines are also regulated by the neuroendocrine system. Cytokines can be roughly divided into five groups: interferon (IFN), interleukin (IL), colony-stimulating factor (CSF), tumor necrosis factor (TNF), and transforming growth factor (TGF).

1.3.3.3 Gene Therapy

Gene therapy refers to a method in which a genetic technique is used to introduce a specific foreign gene into a cell and obtain expression, thereby obtaining or enhancing its specific function for therapeutic purposes. For a long time, skin has been one of the most suitable organs for gene therapy. A large number of studies have confirmed that in the process of wound healing, a therapeutic gene with a certain regulatory effect is selected and introduced into cells by the gene transfection technology, which can promote the repair of wounds. The problems that restrict clinical application mainly include safety, transfection efficiency, and economical practicability. At the same time, in vitro isolation and culture of cells, introduction of the target gene, and then transplantation to the wound surface by the in vitro transfection method require a long preparation time. Therefore, exploring safe and effective methods of transfection in vivo is also an important direction of current research. In addition, since wound healing is a multifactorial process, it is not realistic to hope that a single gene transfection will improve the healing process of wounds. Gene therapy methods that explore the comprehensive treatment of multiple growth factors should be able to more effectively regulate the microenvironment of the wound surface to maximize their biological effects. The use of cytokine gene therapy, apoptosis gene regulation, suicide gene, and other treatment of pathological scars is also an important direction in wound repair.

1.3.3.4 Cell Therapy

Cell therapy, also known as live cell therapy, involves the repair of damaged tissue by living cells. Cell therapy has been around for hundreds of years, dating back to the fifteenth–sixteenth centuries, and was proposed by the Aureolus Paracelsus (1493–1541) in the Philippines. In 1912, German doctors used cell therapy for the first time to treat “hypothymism and hypothyroidism in children.” In 1930, Paul Niehans (1882–1971) became a famous doctor of cell treatment for skin rejuvenation, known as the “father of cell therapy.” Cellular treatment classification is given as below:

(a) Cell replacement therapy (fibroblasts, chondrocytes, pigment cells, keratinocytes, osteoblasts, skeletal muscle cells, macrophages, renal epithelial cells, bladder cells).
(b) Cell stimulation therapy (cell regeneration and regenerative medicine). Both types are applied during the wound repair process.

1.3.3.5 Stem Cell

The general concept is that the body exists to self-renew and produce one or more undifferentiated and nonspecific cells with special functions. According to its developmental stage, it can be divided into embryonic stem cells and adult stem cells. According to its differentiation potential, it can be divided into totipotent stem cells, pluripotent stem cells, and special stem cells. With the continuous development of regenerative medicine and the deepening of human understanding of stem cells, the role of stem cells in the treatment of diseases has received more and more attention. In theory, when any tissue or organ of the body is damaged, the stem cells can repair or even replace the tissues and organs that have lost function. The main advantage of using self-stem cells to replace tissues and organs that have lost function is that the source is sufficient, the materials are convenient, and the immune rejection caused by foreign transplant organs and a series of chronic syndromes can be avoided.

1.3.3.6 Tissue Engineering

Tissue engineering (TE) was originally used to describe the theory and technology of constructing tissues or organs in vitro. Now its connotation is expanding, and all methods and techniques that can guide tissue regeneration have been included in the tissue engineering category. Tissue engineering is considered to be a new milestone and a far-reaching medical revolution in the history of life sciences following cell biology and molecular biology. Its scientific significance is not only to propose a new treatment, but more importantly, to propose a new concept of copying tissues and organs, so that regenerative medicine faces major opportunities and challenges. It includes the principles of applied cell biology and engineering to research and develop new medical fields for tissue repair, maintenance, or enhancement of the morphology and function of human tissues and organs. Using the principle of bionics, biodegradable cells are combined with the carrier using a degradable polymer to form a complex having a specific three-dimensional structure and being biologically active. Thereafter, the complex is cultured in vitro or in vivo to finally form a target organ or tissue. At present, there are three main types of tissue-engineered artificial skin produced at home and abroad:

(a) Substitutes only containing cellular components, represented by Epicel.
(b) Substitutes only containing extracellular matrix, represented by Integra, Pelnac.
(c) A composition consisting of cell and extracellular matrix, represented by Dermagraft.

1.3.3.7 Regenerative Medicine

Regenerative medicine (RM) refers to the use of biological and engineering theoretical methods to promote the body’s self-repair and regeneration, or to construct new tissues and organs to repair, regenerate, and replace damaged tissues and organs. This technical field covers many modern bioengineering technologies such as stem cell technology and tissue engineering, and seeks to explore the possibility of tissue and organ regeneration and functional reconstruction from all levels. And its content is still expanding, including cell and cytokine therapy, gene therapy, and micro-ecological therapy. Its core content and ultimate goal is to regenerate a tissue or organ that was the same as the pre-traumatic.

1.3.3.8 Others

1. Biotherapy: A method of treating damage and disease using biotechnology, biotechnology products or methods. It mainly includes immunocytotherapy, tissue engineering and product therapy, stem cell technology and product therapy, and gene therapy technology and product therapy. The application and development of biotherapeutics in tissue repair has always been at a leading position.
2. Skin substitutes: Skin wound covers that have been commercialized for clinical include epidermal grafts, dermal grafts such as allogeneic dermis, synthetic omentum, acellular collagen sponge, and complex skin grafts such as collagen gel skin substitutes.
3. New type dressings: With the in-depth study of the pathophysiology of the wound healing process, people's understanding of the wound healing process has become more and more profound, which has promoted the continuous improvement and development of wound dressings. Today, new types of wound dressings have revolutionized the situation relative to the early days, and a variety of different performance dressings are available to clinical caregivers. New dressings were born with the concept of wet wound healing. There are two factors driving the development of such products, namely, the medical industry's in-depth study of wound healing and management processes and the continuous advancement of materials technology. So far, the domestic new dressing market is rich in variety. Several major new medical dressings include foam dressings, hydrocolloid dressings, alginate dressings, antibacterial dressings, composite dressings, hydrogels, etc.

1.4 Classification of Wound Tissue Repair and Regeneration

War wounds are a kind of special injury to the body. Because the environment, types of damage, and treatment methods of wounds are different from the usual traumas, our army has divided various types of wounds, but the concept of damage classification has not been proposed. Classification is based on certain characteristics of things, according to certain rules. Taxonomy is a method of grouping and combining things according to certain external or intrinsic characteristics of things. It is the preliminary work of statistics and analysis. It is an effective means to understand the law of the development of things and to study the nature of things. Putting forward the criteria for classification of war injuries can make the classification of injuries scientific, standardized, and normalized, which is of great significance.

1.4.1 The Classification of Wounds

For the classification of wounds, the standards used at home and abroad are different due to different classification purposes. The characteristics and meanings of injuries are also different, and there are differences and overlaps between them. The commonly used classification criteria mainly include the injured part, the cause of injury, the mechanism of injury, the type of wound, whether the body cavity is open, the condition of injury, the need for delivery, operation or not, the recovery, and the outcome. If only a few simple criteria are used for classification, they will not fully reflect the nature, current situation, and characteristics of wounds, nor can they meet the needs of modern wound diagnosis, first aid, and treatment. However, if the standard is too complicated and repetitive, it will be difficult to adopt in the process of classification and treatment in front line.

Therefore, the classification of wounds is based on certain characteristics. According to certain rules, the similar wounds are grouped and become an orderly combination. By classifying wounds, we can effectively study the nature of wounds.

Our 2000 version of the injury ticket is classified according to the injury part, injury category, injury condition, injury type, and injury severity. The injury category is essentially the cause of injury, and the injury condition and injury type often cause confusion and even lead to errors in the clinical treatment. The classification of scientific injury should not only comprehensively reflect the nature, condition, and characteristics of wounds, but also meet the needs of early diagnosis, first aid, evacuation, and treatment. Therefore, the new classification of war injuries highlights the principles of science, conciseness, and practicality, and classifies war injuries according to the four aspects: injury part, the cause of injury, injury type, and injury severity. The new classification method can basically describe the characteristics and conditions of the part, the nature, characteristics, and extent of the injury, and the medical staff slightly specifically describe on the basis of the basic frame of the injury severity + injury part + the cause of injury + injury type, forming a relatively complete clinical diagnosis of injury, which can meet the needs of rapid diagnosis and treatment in the early stage of wounds.

1.4.1.1 Injury Part

At present, the classification of the wounded departments varies from department to department. For example, modern war wound surgery and our army's 2000 version of the injury ticket, the injury part of the brain, maxillofacial, neck, chest (back), abdomen (waist), pelvis (perineum), spine, upper limbs, lower limbs, internal organs, etc. 10 parts. At present, the clinical trauma at home and abroad is mostly based on the classification and adoption of the American Affordable

Trauma Score (ais) classification. The injured part is the head, face, neck, chest, abdomen and pelvis, spine, upper limbs, lower limbs, skin, and others. Wait for 9 parts. Ais has detailed description and differentiation of the anatomy, damage properties, and injury scores of the wound, which has been widely recognized and adopted by scholars at home and abroad. Taking into account the distinction between the function of the body and the characteristics of the region, the treatment and research, and the long-term development of war injuries, as well as the international integration and communication, the new classification of war injuries has been wounds into the head, face, neck, and chest (back). 9 parts of the Ministry, abdomen (waist) and pelvis (perineum), spinal cord, upper limbs, lower extremities, other and multiple injuries. The head injury includes craniocerebral injury; the facial injury includes jaw injury; the spinal cord injury includes cervical vertebra, thoracic vertebrae, lumbar vertebrae, and corresponding spinal nerve injury; neck, chest (back), and abdominal (waist) injuries do not include corresponding parts. Spinal and spinal cord and nerve damage; other injuries mainly include electric shock, hypothermia, ionizing radiation injury, microwave damage, etc. It is difficult to determine the damage of specific wounds; multiple injuries refer to the simultaneous or sequential movement of the body under the same injury factor. Two or more anatomical lesions have occurred.

1.4.1.2 Cause of Injuries

According to the different factors of injury, the classification of injuries is a characteristic part of the classification of war injuries. In the past, the classification of injuries (formerly known as injuries) was mainly based on injuries, but because modern weapons are developing very rapidly and the types are increasing, it is almost impossible to enumerate their injuries. Therefore, the new classification method of war damage is to use the injury factor of the weapon as the classification basis, and divide it into injury, bullet wound, blade wound, crush injury, impact injury, impact injury, burn, frostbite, poison injury, ionizing radiation damage, biological weapon injuries, laser damage, microwave damage, other, and composite injuries. For the damage factors of new concept weapons that are not yet weaponized and have no clear effect on personnel injury, they are not included in the cause of war injury and can be included in other. According to the injury factor and the wounded weapon, different types of war wounds are distinguished. According to the type of injury factors: the injury is divided into single injury and composite injury, according to the number of injury factors. The damage caused by single factor is burn, impact injury, radiation injury, injury, gunshot wound, crush injury, frostbite, poisonous injury, etc.; two or more injuries caused by the combination of injuries, including burning, burning, burning, and combined injury. The types of injuries are classified into five categories: conventional weapon injuries, nuclear weapon injuries, chemical weapons injuries, biological weapon injuries, and new concept weapon injuries.

Gunshot Wound

The incidence of gunshot wounds in a conflict depends on the type and intensity of the battle. The proportion of gunshot casualties in large-scale wars is generally lower than that of low-intensity wars or asymmetric warfare. The causes of gunshot wounds are: direct damage to important structures in the injured area, stretching of tissues (cavities) causing rupture of blood vessels and tissue inactivation, secondary pollution. The nature and extent of ballistic damage depends on the energy delivered by the bullet to the body's tissues and is also related to the characteristics of the affected tissue. The bullet causes damage to the body by transferring its energy to the tissue, and the energy transfer is related to the type of bullet. The hollow bomb and the dam can transfer their energy to the maximum. The high-speed bullets fired by military rifles have more energy and have greater damage potential than pistols. However, if the bullet only penetrates the limbs without damaging the bone, this reduces the energy it transmits to the body and causes less damage.

Impact Injury

Explosions such as rockets, aerial bombs, mortars, grenades, etc. can cause impact injuries. A small volume of explosives can generate a large amount of gas in a short time after the explosion, which causes a high pressure at the explosion point, causing the gas molecules to rapidly transfer from the explosion point to the surroundings, thereby forming a so-called shock wave. Its front edge is called the shock wave front. The characteristics of the impact injury are as follows.

(a) Primary impact injury: It is the most common type of injury near the explosion point. It is caused by the interaction between the shock wave front of the explosion and the gas-containing organs in the body (such as the middle ear, lung, intestine, etc.).
(b) Secondary impact injuries: Explosive stimuli impact damage caused by the body, such as prefabricated metal fragments contained in modern weapons. Due to the lack of aerodynamic characteristics, the flying speed of the shrapnel decreases rapidly, so it is mainly caused by low-energy transmission.
(c) The third type of impact injury: The victim is thrown into a fixed object such as a wall and other damage after being subjected to the shock wave.

(d) The fourth type of impact injury: Due to the impact of shock waves, secondary damage is caused by the collapse of various buildings. Shockwave victims often have multisystem injuries, and the types of injuries are complex, such as blunt injuries, penetrating injuries, and burns.

Thermal Injury and Chemical Injury Wound

Thermal and chemical damage is caused by cold or heat, tissue damage rays, acids or alkalis. Skin damage depends on the duration of the injury, the intensity and extent of the action. Thermal injury such as burns, etc., are divided into I degree, shallow II degree, deep II degree, and III degree. Frostbite can also be divided into I–IV grades: erythema in grade I; blister formation in grade II; necrosis in grade III; thrombosis in IV grade, and occlusion of blood vessels.

Combined Wound

Such wounds may be caused by blunt force injuries of penetrating wounds, or by thermal or mechanical injuries, such as large-area soft tissue injuries, open fractures with severe crushing injuries, and avulsion injuries. In the case of combined injuries, there is another important problem, secondary injury, which is mainly caused by ischemia, reperfusion, or vascular injury caused by the compartment syndrome. It is often difficult to distinguish between penetrating wounds and composite wounds.

1.4.1.3 Injury Type

According to the characteristics of the injury of the injured tissue, it can clearly reflect the nature and characteristics of the local injury, which is helpful for the judgment of the injury and the choice of treatment measures. Because the classification criteria of single tissue damage characteristics are difficult to reflect the characteristics and nature of various tissue damages, the purpose and basis of different classification methods are different, which may lead to some overlap between the different types of injuries. If burns and crush injuries are usually classified according to the characteristics of tissue damage, they are repeated with burns and crush injuries in the classification of injuries. The new classification method of war damage can not only reflect the damage characteristics of war wound tissue, but also minimize the overlap between different types of injuries by summarizing and synthesizing the classification criteria. The new war wounds are divided into penetrating wounds, non-through wounds, tangential wounds, skin and soft tissue injuries (scratches, contusions, lacerations, avulsions), fractures, broken limbs and broken fingers (toe)), and others. Since most of the war injuries are mechanical injuries, they are classified by the type of injury. According to the presence or absence of entrance and exit of the injured road, it is divided into: through injury, non-through injury, tangential injury, and rebound injury. The above four types of injuries and closed injuries were classified as injuries in our current injury ticket. Because they are classified according to the characteristics of the projectile producing the wound in the body, it basically reflects the characteristics of local histological damage. For example, penetrating injury refers to the injury that causes the wound to penetrate the body cavity (the cranial cavity, the spinal membranous cavity, the pleural cavity, the peritoneal cavity, the joint cavity, etc.) and causes the body cavity to communicate with the outside. It has distinctive features in the emergency treatment of war wounds. Important position; skin and soft tissue injury (scratch, contusion, laceration, avulsion injury), the injury type basically reflects the type and characteristics of skin soft tissue injury; fracture, broken limb, and broken finger (toe) reflect bone and limb damage The characteristics of the injury type; for other rare nonmechanical injuries (ionizing radiation damage, etc.) and those that cannot be classified, they are classified into other injuries.

1.4.1.4 Injury Severity

In the past, injuries were classified into minor, moderate, and severe, and the classification was based on the length of treatment required after the injury and whether or not there was a disability. Because the length of treatment and the prognosis and outcome are not only related to the degree of injury, but also closely related to the nature of the injury, whether it gets timely and reasonable treatment, and the level of medical treatment, the uncertainty is great. So, the new classification method of war injury is based on accurate data reflecting the severity of the damage to the human tissues and organs, life risk and prognosis. The new classification divides injuries into four categories, namely minor, moderate, severe, and critical. The degree of danger to life can be judged by the vital signs of the wounded, which is conducive to timely and accurate classification and determination of first-aid measures.

1.4.1.5 Others

Divided by Different Operational Environments

Under different conditions, war wounds have their own particularities. Therefore, they are divided into five categories: war wounds in the plateau, war wounds in desert areas, war wounds in alpine regions, war wounds in mountain jungles, and urban war wounds.

Divided by the Anatomy System

The tissues and organs of various parts of the human body have their structural and functional characteristics. The pathological changes after injury are different and can be divided into skin system, exercise system, digestive system, respiratory system, genitourinary system, cardiovascular system, endocrine system, nerve system, sensory (visual, hearing) injury, multiple system organ injury, and 10 types of war wounds.

Others

In addition, according to the time of injury, it can be divided into acute wounds and chronic wounds. According to the depth of the skin involved in the injury, it can be divided into partial cortical damaged wounds and full-thickness wounds. According to the cause of injury, it can be divided into mechanical or traumatic wounds, thermal injury wounds, chemically damaged wounds, ulcerative wounds, and radiation-damaged wounds. Depending on the color, they can be divided into red, yellow, black, and mixed wounds.

1. Acute wounds: It refers to a wound that forms suddenly and heals quickly. This type of wound healing usually involves I stage healing, such as elective surgical incision, II degree burn wound, superficial skin trauma, acute radioactive I degree injury, II degree pressure sore, and other wounds.
2. Chronic wounds: Skin tissue injury caused by various reasons, the healing process is more than 8 weeks, such as ulcerative wounds (III degree and IV degree pressure sore, diabetic foot ulcer, venous lower extremity ulcer, arterial lower extremity ulcer, chronic radioactive II degree and III degree damage), deep burns or burns, granulation wounds formed by trauma, etc.
3. Partial cortical damaged wounds: Wounds involving the epidermis and dermis, such as II degree burns and II degree pressure sores.
4. Full-thickness wounds: It refers to wounds that spread from the epidermis and dermis to subcutaneous fat, sometimes deep into the fascia and muscles, and even invade the tendons and bones, measuring the depth, most of which are at least more than 1 cm, such as III degree and IV degree pressure sores, III degree burns, off-skin avulsion, and so on.

1.4.2 Classification of Wound Healing and Regeneration

1.4.2.1 Classification of Wound Healing

Wound healing is a complex biological process involving bleeding and coagulation, inflammatory exudation, formation of vascular and granulation tissue, reepithelialization, fibrosis, and tissue remodeling. Various growth factors in this series of biological activities play an important role. According to pathology the healing situation can be divided into:

First-Stage Healing

First-stage healing generally refers to the process in which the wound is healed by the newly formed epidermal cells, capillary endothelial cells, and connective tissue on both sides of the wound in a short time. It is the simplest form of wound healing and is also a direct combination of tissues. This type of healing occurs mainly in surgical incisions that have fewer tissue defects, neat wound edges, no infection, and by suture or adhesion. The basic process is that after tissue damage, the blood forms a blood clot on the wound surface, connecting the two ends of the broken end, and protecting the wound surface. The specific pathological manifestations are: early postinjury (within 24 h), the changes in wounds are mainly inflammation, exudation, and dissolution of blood clots. Afterward, the infiltrating macrophages remove fibrin, red blood cells, and cell debris from the wound. From the third day after the injury, it can be seen that the capillary germ grows from the edge and bottom of the wound at a rate of 2.0 mm per day, forming a new blood circulation network. At the same time, adjacent fibroblasts proliferate and migrate into the wound, producing matrix and collagen. One week after the injury, collagen fibers can cross the wound and connect the wound. Then the collagen in the wound continues to increase and is engineered to increase wound tension. In the past, this type of healing has long been thought to be caused by the nascent epidermal cells, capillary endothelial cells, and connective tissue crossing the wound over a short period of time, without the formation of granulation tissue. Recent studies have shown that this process also involves granulation tissue, which is similar to other soft tissue injury repairs, except that the wound edge is lightly damaged, the inflammatory response is weak, and the amount of granulation tissue produced is small, leaving only one linear scar after repair.

1.4.2.2 Second-Stage Healing

Second-stage healing generally means that the healing process of wound is first filled with granulation tissue, followed by the neonatal epidermal cells. Of course, some studies have suggested that such healing is preceded by epidermal cell regeneration, followed by stimulating granulation tissue formation and proliferation, or granulation formation in parallel with epidermal cell regeneration. This process begins with a variety of growth factors (TGF, FGF, etc.) that stimulate the vascular endothelial cells at the bottom of the wound or the "dormant" of the wound edge, activate it, and then generate new capillary germs through "germination" to communicate with each other. The capillary network in the new granulation tissue is formed. Compared with the first-stage healing, the healing by second intention is characterized by the following aspect: due to the large defect of the wound, and the more necrotic tissue, usually accompanied by infection, the time to start regeneration of the epithelium is delayed. Due to the large wound surface, the more granulation tissue, thus forming scars that are large, often have a certain influence on the appearance. Due to the influence of large wounds, infections, etc., the healing time is longer, and usually takes 4–5 weeks. Healing by second intention is mainly seen in wounds with large defects or infections.

Healing Under Scab

Healing under scab is a wound healing process under a special condition. It mainly refers to the second-stage healing process under a layer of dark brown hard scab formed by the exudate, blood, and necrotic material, such as the healing process of leather-like hard scab after deep II degree or III degree burn. The healing process also starts with the epidermal basal cell proliferation of the wound edge, which migrates to the center of the wound while growing under the scab, and the granulation tissue of the wound also proliferates. The healing speed of the under scab is slower than that of the non-scab wound, and the time is longer. The formation of hard scab has the effect of protecting the wound surface, and also hinders the outflow of the wound exudate, which is easy to induce infection and delay healing. Therefore, it is often necessary to adopt the “escharectomy” or “tangential excision” surgery in clinical treatment to expose the wound and facilitate the repair.

1.4.2.3 Classification of Regeneration

Regeneration can be divided into physiological regeneration and pathological regeneration, according to the condition of tissue regeneration. Physiological regeneration refers to the process in which some cells and tissues are aging and depleted during physiological processes, and then supplemented by the same type of cells to maintain the original structure and function. For example, the surface keratinocytes of the epidermis often fall off and are supplemented by the continuous proliferation of the basal cells of the epidermis; the endometrium periodically falls off and is repaired by basal cell proliferation; after blood cell aging and disruption, it is also necessary to continuously export a large number of new cells from the lymphoid hematopoietic organs. Pathological regeneration refers to regeneration that occurs after tissue and cell defects in a pathological state. It can be divided into complete regeneration and incomplete regeneration. Complete regeneration refers to the proliferation and replenishment of cells after necrosis, and the regenerated tissue completely restores the structure and function of the original tissue. Incomplete regeneration (i.e., fibrous repair) means that the defect cannot be repaired by the original tissue, but replaced by granulation tissue, and finally forming scars, also known as scar repair.

The basic process of physiological regeneration is similar to pathological regeneration, in which cells reenter the cell cycle for division and proliferation. A cell cycle refers to the process from the end of the last mitosis to the end of the next mitosis. It consists of G1 phase (pre-synthesis phase), S phase (DNA synthesis phase), G2 phase (pre-division phase), and M phase (division phase). Among them, it can be divided into two categories: physiological regeneration (one-time physiological regeneration, periodic physiological regeneration, continuous physiological regeneration) and pathological regeneration (complete pathological regeneration and incomplete pathological regeneration).

Physiological Regeneration

During normal physiological processes, some tissues and cells are continuously consumed, aged, and disappeared, and are constantly supplemented by the same type of cell division and proliferation. This process of regeneration is called physiological regeneration. It is characterized, in that the regenerated cells and tissues can completely maintain the original structure and function, such as the periodic shedding of the endometrium and the continuous renewal of the skin, so it is also called complete regeneration.

Pathological Regeneration

In the pathological state, regeneration of cells or tissues after damage is called pathological regeneration. If the damage is mild, it can be proliferated by the same kind of cells and maintain the original structure and function. This type of regeneration is called complete pathological regeneration. If the damage is serious, the damage can only be filled by another tissue and the original structure and function are lost. It is called incomplete pathological regeneration.

According to the strength of regenerative capacity, human tissue cells can be divided into three categories.

(a) Labile cells: These cells are constantly proliferating to replace dead or damaged cells, such as epidermal cells, respiratory and digestive tract mucosal cells, covered cells of the male and female reproductive organs, lymphoid cells and hematopoietic cells, mesothelial cells, etc. The regenerative capacity of these cells is quite strong.
(b) Stable cells: Under physiological conditions, this type of cell proliferation is not obvious, it seems to be in the stationary phase (G0) during the cell proliferation cycle, but when stimulated by tissue damage, it enters the early stage of DNA pre-synthesis phase (G1), showing a strong ability to regenerate. This kind of cells includes parenchymal cells of various glands or adenoid organs, such as epithelial cells of the liver, pancreas, parotid gland, endocrine glands, sweat glands, sebaceous glands, and renal tubules; and also includes primitive mesenchy-

mal cells and their differentiated cells. Not only do they have a strong regenerative capacity, but the primitive mesenchymal cells also have a strong ability to differentiate into many specific mesenchymal cells. For example, when the fracture heals, the mesenchymal cells proliferate and differentiate into the chondrocytes and osteoblasts. The smooth muscle cells also belong to stable cells, but generally their ability to regenerate is weak.

(c) Permanent cells: Cells belonging to this class include nerve cells, skeletal muscle cells, and cardiomyocytes. Regardless of the central nervous cells and the ganglion cells of the peripheral nerves, they cannot divide and proliferate after birth. Once they are damaged, the defects become permanent. However, this does not include nerve fibers. Under the premise of nerve cell survival, damaged nerve fibers have an active ability to regenerate. Although myocardium and striated muscle cells have a weak ability to regenerate, it has little meaning for postinjury repair, and they are basically repaired by scars.

1.5 Characteristics of Repair and Regeneration of War Wound Tissue

Through rapid conversion of chemical energy such as gunpowder burning and explosives' explosion into mechanical energy, the projectiles, shrapnel, marbles, and other objects are thrown at high speed and hit the human body, causing firearm injuries. Generally speaking, the targets of light weapons such as bullets are mostly individual, while the targets of heavy weapons such as shells and missiles are mostly groups. Therefore, the former is often referred to as point-killing weapons, while the latter is called surface-killing weapons. However, modern light weapons are not only powerful, high precision, but also have the characteristics of combining point and surface. Therefore, the abovementioned point- and surface killing are just a relative distinction between weapons.

By studying the local wars in the Gulf, the Balkans, and Afghanistan, it can be seen that due to the development of high technology, weapons' performance and damage factors have undergone tremendous changes. The form of war has evolved from a conventional, comprehensive war to a small-scale regional armed conflict that uses high-tech weapons and equipment, that is, local wars under high-tech conditions. The war is multilayered, all-round, and without front and rear boundaries. It is sudden, concealed, destructive, and cruel. To this end, these types of war wounds and treatment system have also begun to take shape.

1.5.1 The Main Features of Tissue Repair After Trauma

1.5.1.1 Characteristics of Modern War Wounds

Due to the improvement of modern weapons and the improvement of performance, the injury factors are superimposed and compounded, especially the simultaneous or alternate use of nuclear weapons, biological and chemical weapons, resulting in burn-blast, blast-poison compound injuries and blast injuries increasing. Shock waves can cause pulmonary edema, pulmonary hemorrhage, lung rupture, hearing and gastrointestinal damage, with external light internal weight, rapid development, and complex injuries. At the scene of the explosion, there was no obvious trauma while in a state of shock, or large areas of burns were mostly combined injuries based on impact injuries. Multiple injuries refer to the same injury factor directly or sequentially resulting in injuries of more than two anatomical sites. Polytraumas refer to wounds with more than two lesions in the same anatomy or organ. In the Gulf War, the wounded had an average of more than nine injuries. The head, chest, heart, liver, and spleen accounted for 20%, 73.3%, 10%, 43.3%, and 6.7%, respectively. The wound is heavily polluted, the infection rate is high, the severe and extremely severe injuries are more, and the shock rate is high. The mutual influence in the treatment is large, involving multiple specialist theories and techniques, and the on-site first aid is time-sensitive.

Large vascular injury, combined injury, mostly causes extensive damage, strong systemic reaction, significant contusion symptoms, central nervous disorders, unconsciousness, and focal softening of the brain. Heart contusion accounted for 45.6% and lung contusion accounted for 22.8%. Forty-two percent of the wounded were treated in the division hospital. As much as 74.5% of the mine injury was accompanied by shock. One out of six patients died on the operating table. The shrapnel was prominent, with more fractures (33.3%) and more non-penetration injuries (92.7%). In modern local wars, various explosive weapons are still the main strategic and tactical weapons. The power of the explosion has increased greatly, and the shrapnel has increased. It can be fanned or stereoscopically projected, and the killing area is enlarged and the target is accurate. Forty percent in the Vietnam War, 56% in the Middle East War, and 74% in the Gulf War were shrapnel or shrapnel compound injuries. The shrapnel enters the body at an initial velocity of 1360 m/s, large amount, high energy, and high density. Due to different tissue morphologies, densities, and elasticities, the resistance varies. The shrapnel is flipped and scattered in the tissue to form a multidirectional secondary blind tube and multiple fractures, which may be accompanied by a residual cavity of up to 2000 mL and down to 50 mL, and residual foreign matter. The rate of disability and death is high. Battlefield deaths accounted for 50% of all deaths, and most of them died within 6 h of injury. The proportion of casualties: The Second World War 3.1: 1, Korean War 4.1: 1, Malvinas War 3.6: 1, and Vietnam War 3.7: 1. In the Second World War, 6% is maimed by war wounds, the Vietnam War is 12.4%, the self-defense counterattack against Vietnam is 29.8%, and Afghanistan War is 30%. Disability and mental disorders increase. With the changes in modern local war forms and methods of warfare, the use of high-tech laser, infrasound, and electromagnetic nonlethal weapons can lead to no obvious wounds, normal visceral function, but combat capability and technical effectiveness play poorly and lack of concentration, etc. The incidence of psychological disorders and even mental abnormalities increases, which is one of the more prominent features of local warfare under high-tech conditions.

In short, the typical characteristics of war injuries are:

(a) The wound has been contaminated.
(b) Injured tissues involving multiple body cavities.
(c) The same patient often has multiple injury sites.
(d) Seventy-five percent injured the limbs.
(e) Symptoms are often heavy.

The development of high-tech weapons and usage in some local wars have led to significant changes in the types and characteristics of war injuries. Limb injuries have increased dramatically, reaching 96.0%, while 70–87% are various blast injuries which are more complicated. The proportion of blast injuries and burns is obviously increased, resulting in an increase in the large defects of soft tissue on the surface, and the damage is more extensive. The negative pressure formed by the damage caused by fragments causes bacteria, foreign bodies, etc. in the surrounding environment invading into the wound cavity deeper and more. Combined with extensive and serious tissue damage, it makes the infection very serious. The incidence of disability and residual deformity increases, and is more serious. High-energy explosion injury can cause damage to distant organs.

In the future war, new concept weapons such as electromagnetic guns, nuclear pulses, lasers, and microwaves may be used. These weapons, known as super killers, make the treatment of the wounded more difficult. We must start from the characteristics of complex electromagnetic environment in the future battlefield, study the characteristics of war wounds in complex electromagnetic environment, and explore new diagnostic methods, classification standards, and treatment plans, so as to do the trauma treatment and repair work in a complex electromagnetic environment.

1.5.1.2 Characteristics of Modern War Wound Tissue Repair

The injury assessment is a guarantee that the organization will be accurately and reasonably repaired After the wounded recover, a thorough examination from head to toe is required. While checking for a penetrating wound with a torso, you cannot ignore the back, buttock, perineum, and armpits. Every wound must be evaluated and recorded. The assessment of the injury included: location and size, cavities or not, degree of contamination, anatomical structural peripheral blood flow, fractures or not, and whether the limb damage is so severe that it cannot be reconnected.

Debridement Is the Basis of Later Tissue Repair

Debridement involves the removal of necrotic or contaminated tissue, if this tissue is left over, it will become the vector of infection. If there are limb injuries, an inflatable tourniquet should be used to reduce blood loss. The first step in debridement is to cut the skin along the longitudinal axis to achieve decompression of the wound and to protect the damaged tissue from swelling. However, such a cut must not cross the joint along the longitudinal axis. When the decompression is completed, the contaminated tissue and the nonviable tissue must be removed. Because the skin tissue is elastic, the incision can be as small as possible, and it is typically done around the edge of the wound. Although all foreign objects in the wound should be removed, it is not worthwhile to remove the small metal foreign objects that are farther away from the wounded path, so as not to damage the healthy tissue too much. At the same time, necrotic and contaminated tissue in the wound should be completely removed, but it is often difficult to determine the extent of necrotic or contaminated tissue. Necrotic muscle tissue usually has a dark red color, no bleeding when cut, and no contraction when clamping muscle fibers. For bone fragments that are completely free from soft tissue, they should be removed. If left, they will cause infection or osteomyelitis. Damaged nerves and tendon tissue should be marked with sutures for delayed repair. After the debridement process is completed, the wound is repeatedly washed with a large amount of physiological saline, then the wound is opened without being sutured and covered with a large amount of dry sterile gauze. Some low-energy wounds, such as pistol wounds, do not require extensive debridement and tissue resection. In some cases, these wounds may not be surgically treated. There is no ideal treatment for the multiple small injuries caused by secondary impact injury. Due to the large number of small wounds, it is not feasible to debride each wound one by one. Moreover, the irregularly flying shrapnel that causes these damages has lower energy and poor penetrability, so the damage is often lighter and the cavity is not formed. Therefore, the appropriate treatment is to wash the wound as thoroughly as possible under general anesthesia, and to remove the main wounds with a lot of pollution or large necrotic tissue by surgical treatment.

Delayed Closure of the First Phase After Debridement Is the Principle of Repairing Wound Tissue

After debridement, the wounded are sent to the ward to continue the monitoring and analgesic treatment. The wound should always be wrapped with dressing until the delayed closure operation. The International Committee of the Red Cross recommended an observation of delayed wound closure for a period of 5 days, but in practice, the developed country tends to shorten the observation time to 2–3 days. Before the end of the observation period, if there is sepsis or an unpleasant smell from wound dressings, it is an indication of reoperation, and the common cause of sepsis is incomplete debridement. The removal of dressings from the wounded should be carried out in the operating room under appropriate anesthesia. If there is no sign of infection, necrosis, or residual contamination, the wound can be sutured or skin grafted. However, there are also patients who need multiple debridements. According to the statistics of the International Committee of the Red Cross, after the first debridement, only 45% of the wounds can be closed, 33% need to be debrided again, and 22% need multiple debridements. If the wound tends to close, it is necessary to ensure that the wound is not strained to facilitate the repair of the wound.

Accurate Amputation Level Is the Feature of War Wound Tissue Repair

Some ballistic injuries, especially mine injuries, sometimes require amputation. Of course, other severe limb injuries may also require amputation. The decision to amputate is made at the time of injury assessment. The scoring system of limb injury is less correlated with the severity of ballistic injury, while the lack of sensation and blood supply of the distal limb is an important indication for amputation. Getting the consent of other surgeons is helpful in deciding whether to amputate. Skin and bone have a relatively large blocking function to impact on shrapnel conduction, while muscle tissue has a weaker blocking function, so contamination may continue to spread across the fascia. The extent of contaminated or inactivated tissue is usually much larger than that seen in the initial appearance. Military surgeons are accustomed to traditional amputation that cuts off skin, muscles, and bones at the same level. Although this method is simple and fast, the wound is difficult to close and the amputation level is often higher than the actual needs. Most humanitarian surgical organizations recommend flap formation prior to amputation, which preserves more residual limbs and facilitates wound closure, and the use of muscle-containing flaps to cover amputation stumps is strongly advocated. In order to reduce blood loss, tourniquet should be used to stop bleeding during amputation. The surgical strategy of injury amputation is similar to other war injuries: debridement removes contaminated and necrotic tissue, determines the optimal amputation level of limb function, and constructs the flap. The wound should remain open and covered with a large amount of dry sterile dressings until the delayed first phase closed surgery.

1.5.2 The Characteristics of Posttraumatic Tissue Repair Research in the Modern Warfare of Foreign Military

Since 2001, the US military has been conducting military operations, so the research on trauma treatment is very important. The US Army Surgery Research Institute is the main institution for studying the trauma of the war in the US military. Its research covers the whole process of self-rescue and mutual rescue, treatment at all levels, and rehabilitation. The progress of the Institute in the field of limb trauma and regenerative medicine, pain management, clinical trials, and transformation studies in the US military is briefly described below.

1.5.2.1 Limb Trauma and Regenerative Medicine

Trauma of the extremities and head and neck has the highest incidence in war injuries, reaching 55% and 30%, respectively. Trauma of the extremities is mainly soft tissue penetrating injury and open fracture. Infection, delayed fracture healing, and muscle dysfunction or loss are the most common complications. The limb trauma and regenerative medicine research team evaluated the injury, prognosis, and complications, and established a military orthopedic trauma database to identify the causes of poor clinical outcomes after fractures, such as combined soft tissue defects, nerve damage, infection, different fixed types, etc. At present, skeletal muscle injury has been identified as the main cause of incomplete functional recovery after fracture. In addition, preclinical studies of treatment method evaluation were conducted. Using traumatic animal models we can evaluate treatment options and technical methods for infection, soft tissue, and bone injury. Clinical guidelines for the treatment of contaminated wounds have been established, and animal models of fascia compartment syndrome, large contaminated defects, and large muscle defects have been constructed. An implanted bone material has been developed for the dual purpose of promoting regeneration and preventing infection. At the same time, the Institute is also conducting research on regenerative medicine projects for the treatment of skin, muscle, and bone injuries by the combination of stem cells and biomaterials. On this basis, the

Institute's clinical trial research in the field of trauma treatment, through the Orthopedic Extremity Trauma Research Program (OETRP), and other military hospital orthopedics for multicenter clinical trials, will promote the use of military medical resources and talent development. In addition, the Army Surgery Institute has established a partnership with the Army's Institute of Regenerative Medicine and other internal and external agencies through the OETRP, and plans to significantly improve the prognosis of limb injuries within the next 5 years.

Anthony Atala, an organ engineer and AFIRM researcher in Wake Forest University, is building an "inkjet printer" that prints the entire organ on demand, in order to replace the severely damaged liver, kidney, and even the heart. The "inkbox" of the device contains a special mixture containing cells from the corresponding organs, auxin, and special nutrients. The printer prints the required organs one layer at a time under computer control. Now, it is possible to initially print out a complex organ like a rat heart. Atala plans to develop a portable version for the battlefield in the next 5 years to print the skin directly into the deep wounds. For surface injuries, such as burns, the American Academy of Regenerative Medicine is working on a handheld spray can, like a cosmetic hair spray, that sprays a thin layer of immature skin cells called keratin to the wound. These cells are extracted from the patient's own skin and stimulate the healing of the wound. Recent clinical trials have been very confident: all 16 burn patients showed "good healing" in 1–3 weeks. Another major focus is the "fascia compartment syndrome": internal muscle damage or other injuries, resulting in rapid swelling of the upper or lower limb, compressing nerves and blood vessels. If you don't deal with it quickly, muscle will die, and amputation is usually necessary. By regenerative medicine to regrow your fingers and toes is a dream that people chase.

1.5.2.2 Pain Management

Acute and chronic pain are considered to be the primary problems faced by US casualties, and 71% of those admitted to the emergency department at levels 2 and 3 have experienced severe pain of grade 5 or above (classified from 0–10). Pain usually combines multiple diseases, including post-traumatic stress disorder (PTSD), anxiety, and depression. Chronic pain and PTSD are often concomitant occurrences and interact. The Institute's pain study covers all pain management studies from battlefield to rehabilitation, such as the molecular mechanisms of new targets and pain pathways, as well as field pain and analgesia for acute and chronic pain syndromes, PTSD incidence, and the influence of long-term prognosis in mentality pathology. Current research focuses on the effects of analgesics on short-term prognosis, the mechanism of PTSD, addiction and tolerance of opioids, and chronic pain. The US military also conducted a "virtual reality" technology assessment to control acute pain to reduce the demand for opioids, improve analgesic effects, increase the level of conscious, and cooperate with daily rehabilitation training. By entering the virtual cold world, the wounded reduce pain, anxiety, and mental stress during trauma and burn dressing change. Other ongoing research projects include:

(a) Assessing the role of rapid opioid detoxification agents in reducing the anesthetic intake and opioid dependence in burn patients.
(b) A standardized electronic prescription system and guideline developed for the anesthetic ketamine significantly improved the use of the drug in burns.
(c) Developed a nasal spray preparation that can be used as an analgesic device for battlefield soldiers.
(d) In the severe burn operation, the use of intravascular temperature control to reduce the incidence of low temperature shock.

1.5.2.3 Clinical Trials and Transformation Studies

Under the responsibility of the Clinical Trial Department of the US Army Surgery Research Institute, it proposes the best treatment plan for the current law of casualties on the battlefield, and transforms relevant research from preclinical research to clinical therapeutic applications, such as testing the performance of dressings, assessing the recovery strategy of burn wounds, etc. Clinical studies include local and remote ambulance equipment and rehabilitation programs, protective equipment, continuous renal replacement therapy, blood loss control in the operating room of the burn, nutrition supplementation during inpatient, ICU, outpatient, and rehabilitation. In addition, the US Army Surgery Research Institute, as the only burn center certified by the American Burns Federation, which belongs to the Ministry of Defense, received all the severely burned from the Iraqi and Afghan battlefields and studied the causes of burns. At the same time, in order to deal with a large number of hand burns, an equipment research plan for fire-resistant gloves was developed. For the thermal damage of the trunk part that the body armor covered, improved protective clothing was developed. The standardized clinical path of burn rehabilitation was carried out to ensure a good prognosis.

1.5.3 The Characteristics of Wound Ballistics in Modern Warfare and the Principle of Postinjury Tissue Repair

1.5.3.1 The Characteristics of Modern War Wounds in Wound Ballistics

Trauma ballistics is a branch of science that studies the movement law, injury effect, and mechanism of projectiles such as warheads and fragments in the body. It is not only an integral part of the terminal ballistics, but also an important part of field surgery, and it is the theoretical basis for guiding the treatment of modern firearm injuries. In theory, there are firearms in the case of firearm wounds, and firearm wounds can be treated. However, the so-called firearm wounds treatment before the First World War was only a simple record of injury type, injury part, injury condition, and projectiles by some medical personnel and very primitive and simple surgical treatment. Before and after the Second World War, due to the establishment and development of wound ballistics, people had a systematic and in-depth understanding of firearm injuries. Especially since the American M16 automatic rifle (launched M193 type 5.56 mm projectile, initial velocity 970 m/s) was introduced in 1962 and put into the Vietnam War, the research on wound ballistics has been greatly developed from both technology and theory, which not only deepens people's understanding of modern firearm injuries, but also makes the treatment of modern firearm injuries more correct and standardized under the guidance of theory. For example, in mastering the characteristics of firearm injuries, it is recognized that the damage effect of the projectile is not only related to its quality, but also depends on its speed, shape, and structure, and also closely related to the structural characteristics of the injured tissue. In terms of treatment, people have enhanced the awareness of debridement and formulated the principle of early debridement and delayed suture. In the judgment of the scope of firearm injury, the obvious and repeated pulsation of the temporary cavity has deepened people's understanding of the scope of damage. At the same time, it is also aware of the inevitability and seriousness of contaminated wound caused by firearms. The extensive and serious systemic reaction makes people deeply understand the importance and necessity of the overall inspection and treatment of the wounded.

The blast injuries have broadened the research content of wound ballistics and firearm injuries. Due to the introduction of precision guidance technology, explosive weapons have been widely used in modern warfare, resulting in a large number of explosive wounded. The main physical factors of explosive weapon injuries are fragments and shock waves, so the content of wound ballistics and firearm injuries must be broadened. As far as the fragment is concerned, the shape of the fragment is different, and the resistance coefficient, the speed attenuation, the energy release, the energy transmission, and the like are also different, so the damage characteristics are different. The triangular and square fragments have a fast decay rate, but the energy transfer rate is high, so they often form a wound with a large entrance and a small exit, or a non-penetrating injury without an exit. The surface of the spherical fragment is smooth, so that on the one hand, it has low resistance, slow decay, penetrating the tissue deep, but the energy transfer rate is relatively low. On the other hand, when encountering different densities of tissues in the body, it often changes the direction of the ballistic, forming twists and turns complex wound tract, thus injuring multiple organs. Cylindrical fragment damage occurs between the triangle and the spherical fragment. The shape of the fragments is different, and the volume of the wound cavity formed is also different. When the speed and shape are the same, the triangular fragment has the largest volume of wounds, which in turn is square, cylindrical, and spherical. Because different materials have different specific gravities and structural characteristics, the energy transfer and physical state when hitting the tissue are also different, so the damage must be different. The constituent material of the fragment itself is also one of the important factors affecting the damage ability of the fragment. In terms of shock waves, previous research on impact injuries mainly focused on the relationship between physical parameters and injury effects and the mechanism of impact injuries. In terms of dose-effect relationship, the peak pressure, positive pressure action time, pressure rise time, and negative pressure damage have been studied intensively, and many protection standards have been developed based on it. In the mechanism of impact injury, it is revealed under the direct action of positive pressure and negative pressure, the body can be injured by hemodynamic changes, implosion effect, fragmentation effect, inertia effect, and pressure difference between different parts, thus summing up the impact damage has on the characteristics of external light internal weight, complex injury, and rapid development. As far as the combination of fragmentation and shock wave is concerned, it is characterized in that not only is the local damage range large, the tissue defect is large, the wound is heavily polluted, the injury tract is complicated, and the combined injury is more, the multiple injuries are more, the associated injury is more, and the complications are more. Therefore, the explosion wounded have a high rate of death, a high rate of injury, and a high rate of disability. Fragments and shock waves also have the effect of aggravating each other.

Environmental factors have increased the research direction of wound ballistics and firearm injuries. Military struggles are not always carried out in the normal environment according to people's wishes. Military struggles often occur in special environments such as plateaus, cold regions, hot regions, deserts, islands, etc. Especially when political, economic situations and certain beliefs are mutated and cannot be solved by peaceful means, a particular environment becomes a highly sensitive area where war occurs. The special meteorological conditions in different geographical environments and the unique atmospheric physical characteristics will inevitably affect the ballistic characteristics of the projectile and the local injury, overall response, and injury outcome after the firearm injury. Therefore, the principle of firearm injury treatment in a special environment is inevitably different from the conventional environment. Based on these considerations and needs, domestic research on wound ballistics and treatment has been carried out since the 1990s on firearm injuries in high altitude, high cold, high temperature, and high humidity, and seawater conditions. For example, when the plateau is damaged by the same projectile and distance as the plain, the degree of damage to the animal is much more serious. In addition, because the plateau climate is cold, dry, and strong in ultraviolet rays, the infection rate of firearm wounds is also relatively low, but the systemic reaction is heavy, and complications such as pulmonary edema and cerebral edema are prone to occur. Another example is the firearm wound after seawater immersion, because we cannot use the usual 4C (color, consistency, contractility, capillary bleeding) as surgical criteria to judge the inactivation of muscle tissue in firearm injury, but only 3C methods other than color.

There are many kinds of modern weapons, and the purpose of weapons is increasing. Although weapons have a lot of generality, different weapons and weapons with different combat objectives must have their own characteristics and mechanisms of injury. Therefore, the principles and methods of treatment must be different. The injury characteristics and mechanisms of special bombs such as multiheaded, arrow-shaped, hollow, and shell less bombs should be studied. The injury characteristics and treatment methods of personnel in closed combat weapons should also be confirmed through research, especially with earth penetration bombs continuing to be put into combat, and the personnel in the shelter and underground fortifications are no longer safe. Although the rescue equipment is not a professional content of wound ballistics, its development is inseparable from the theoretical guidance of wound ballistics, such as the principle of early treatment of firearm injuries as far as possible is directly from the research results of firearm injuries. Although the research on the damage of new concept weapons such as laser, microwave, infrasound, gene, kinetic energy, and particle beam is largely unlisted in the category of firearm injuries, there is no doubt that it is the object of concern for weapon trauma. Weapon traumatology solves not only damage and treatment problems, but can also assess the combat capabilities of the troops at the military command level.

1.5.3.2 Tissue Repair of Ballistic Wounds

Unlike the principle of conventional wounds repair, the principle of conventional tissue repair is to reduce or cover the wound, prevent reinjury and promote tissue regeneration, and recover from anatomical and functional levels. In 2002, Sibbald and other scholars dedicated to wound repair at the 14th International Wound Healing Society Annual Meeting proposed the TIME principle of wound bed preparation based on the current understanding of wound healing mechanisms and the experience of wound healing. TIME is the abbreviation of the first English letter of four wound bed preparation principles in the wound treatment process, that is, T refers to the removal of necrotic tissue (tissue); I refers to the control of inflammation, infection (infection/inflammation); M refers to keeping the wound under normal moisture creating conditions for the growth of the granulation tissue and the epithelialization (moisture); and E refers to the removal of the damaged epidermis (epidermis, nonmigrating). The four principles of wound treatment were first published in the form of a table in *Wound Repair Regeneration* in early 2003, and revised in September 2003, changing "epiderm is" to "edge of wound."

War wounds are often caused by high-energy explosion, which is characterized by severe and extensive tissue defects, ischemia, complications, and high mortality. Such soft tissue defects place new demands on wound repair surgery. The traditional view is that blast injury is extensive, and it is difficult to completely debride at one time. The wound is easy to be infected and the failure rate of vascular anastomosis at early stage is high. Repair surgery should be performed after the wound is clean and the granulation is good.

Leininger et al. believe that high-energy projectiles can produce hollowing and impact effects, resulting in a tissue ischemic area similar to the "stagnation zone" in burns. There is no obvious abnormality during the initial debridement, but it will show progressive embolization and tissue inactivation in 24–72 h after injury, so wound closure at the time of initial debridement is dangerous. According to the modern view, due to the use of highly effective antibiotics, wounds can be repaired in advance under the premise of thorough debridement and wound improvement. It has been reported in the literature that the early repair of common wounds is conducive to the recovery of patients. Explosive wounds cause extensive wound damage, and the damaged tissue and necrotic tissue are alternately existing. Simply relying on debridement cannot prevent secondary infection. The wound loses the barrier function of the skin, leading to the loss of water and protein, the rate of bacterial infection increasing, causing hypermetabolism and sepsis. The blood supply and anti-infective ability of the wound tissue after injury is poor, so it is very important to reconstruct the physiological barrier of the wound. Early closure of the wound can save more reversibly damaged tissue, use "bioscavenging" to remove necrotic tissue and bacteria, reduce the proliferation of pathogenic microorganisms, prevent infection, and promote healing. In recent years, more and more war injury experts have emphasized the importance of early repair and have studied the repair of soft tissue blast injuries. By comparing the characteristics of the injuries in the Iraq War and the Vietnam War, it was found that the chest, abdomen, head, and neck of the combatants were well protected by protective equipment, but the limbs were prone to injury and the injuries were relatively heavy. Compared with the oral and maxillofacial region, the blood supply of the extremities and the trunk is poor, and the anti-infective ability and repair ability are weak. Domestic and foreign scholars have conducted related research. Lerner et al. performed limb salvage surgery on 18 patients with severe limb injury, and tissue flap repair after 5–7 days. These patients have a good functional recovery after surgery. The flaps and myocutaneous flaps have good blood supply, strong anti-infective ability, and wide indications. The blast injury has a wide range of tissue damage, and it is generally impossible to perform local flap transplantation. It is necessary to choose free flap with vascular anastomosis or distal flap. Free flap transplantation has a long hospitalization period, and there are risks such as infection, embolism, and skin flap necrosis, secondary deformity in the donor site. The operation is difficult and the requirements for medical personnel are high. Therefore, the free flap transplantation is not suitable for the wound repair of a large number of wounded in the battlefield environment. The operation of distal flap transplantation is simple, but it takes a long time to fix the limbs, which is easy to cause adhesion and rigidity of the joints. Patients with war wounds often have fractures. Early activities are very important, so there is less choice for distant flap. The operation of the skin graft is simple, deformity in the donor site is light, and the impact on the patient's activity is not obvious. The mesh skin graft is elastic, which can reduce the swelling after operation. The permeability is good, and the tissue fluid is easy to be taken out. And the early closure of the wound can reduce the infection. Regarding the skin graft repair after soft tissue blast injury, some field surgery experts believe that the survival rate of early skin graft is low, and advocate delayed skin grafting. It has been reported that two cases of gunshot wounds were immediately taken for debridement and foreign body removal after injury, and the fascial space syndrome appeared on the second day. After relieving tension, the reticular skin graft was performed and good results were obtained.

The improvement of wound preparation method provides conditions for skin graft of soft tissue blast injury. In recent years, negative pressure wound therapy (NPWT) has been gradually applied to the treatment of war wounds, achieving good results and broadening the indication of skin graft. The wounds in war are seriously damaged, often accompanied by serious pollution. Evacuating the wounded has to go a far distance and takes a long time. The characteristics of negative pressure drainage determine that it is suitable for the treatment of such wounds, which can isolate the wound surface from the battlefield and the ward, and can effectively maintain wound cleaning and reduce wound infections, as well as washing the wounds. For patients with huge soft tissue defects caused by explosion and combined with tendon and bone exposure, Helgeson et al. combined NPWT and Integra artificial skin for wound preparation, after the wound condition is improved, taking the skin graft. The postoperative effect is good, avoiding complicated skin flap transplantation and reducing the risk of donor deformity and skin flap necrosis. Sharony et al. summarized the experiences of treating wounded in the Second Lebanon War, emphasizing the application of the NPWT and Ilizarov external fixation system. It is believed that NPWT can be used almost at all stages of wound healing, can close multiple subcutaneous sinus, and strengthen the attachment of tissue flaps with the periphery of the wound surface and the base, for the preparation of the wound or covering the wound of the donor site. Soft tissue blast injury is the most common cause of injury to military personnel in the battlefield. Because of the threat of terrorist bombs, the probability of these injuries appearing among civilians is also increasing. The key to the repair of high-speed high-energy soft tissue blast injury is early, timely, and thorough debridement, removal of necrotic tissue, adequate drainage, attention to dressing fixation, rational use of antibiotics, elective repair of bone and soft tissue defects, delayed wound coverage or closure, postoperative enhancement of rehabilitation exercises, and patient education. There are a variety of causes of explosive injuries and the injury conditions are different, we must thoroughly study and have a comprehensive understanding of the damage mechanisms of soft tissue blast injuries and the characteristics of injury conditions. That is a prerequisite for effective treatment of soft tissue defects after blast injury. On this basis, clinicians actively use surgical procedures and combine new methods and techniques, to reconstruct damaged tissues and organs, improve deformity, and restore function.

Academician Xiaobing's Fu key laboratory for wound healing in the whole army has conducted research on the negative pressure wound treatment of contaminated wounds after blast injury. It confirmed that on the first day after treatment, the negative pressure wound treatment group showed more fibroblasts and vascular endothelial cells, which have no obvious edema, and the number of vascular endothelial cells is also significantly increased. The main reason is that negative pressure drainage can help reduce the edema of the peri-wound. At the same time, it can reduce the bacterial load in the infected wounds, thereby reducing the range of secondary necrosis of explosive wounds, quickly starting the wound repair process of infected wounds, and shortening the time for the granulation tissue to fill the wound.

1.6 The Basic Process of Repair and Regeneration of War Wound Tissue

1.6.1 The Basic Pathophysiological Process of Wound Healing

The development of modern high-tech biotechnology has revealed many mysteries of wound healing from the cellular, molecular, and even genetic levels. However, traditionally, people describe the pathophysiological process of tissue repair in the field of pathology, although different scholars have different stages/deletion methods in the stage of wound healing. Generally speaking, the more commonly used staging method is still to roughly divide the basic pathophysiological processes of wound healing into four stages: early bleeding and coagulation, inflammatory response, granulation tissue proliferation, and scar formation. Of course, there is no clear dividing line between them, they are interconnected and characterized.

1.6.1.1 Bleeding and Coagulation Process

From the moment of the formation of the wound surface, the first reaction of the body is its own hemostasis process. This process involves some very complex biological reactions: first, small blood vessels, capillaries around the wound cause reactive contractions to reduce the local blood flow, followed by the exposure of collagen fibers to attract platelets forming blood clots. Later platelets release vasoactive substances such as 5-hydroxytryptamine and prostaglandins, which cause further contraction of blood vessels, slowing of blood flow, and release phospholipids and ADPs to attract more platelets. Finally, endogenous and exogenous coagulation processes start. After the end of the coagulation process, the body begins the next stage of wound healing.

1.6.1.2 Inflammatory Response Period

The posttraumatic inflammatory response period occurs mainly from 48 h after injury. In the first few minutes, after a short period of contraction of the blood vessels in the injured area, thrombosis begins in the damaged blood vessels. Locally unclosed small blood vessels dilate. Platelets interact with the damaged vascular endothelium and exposed collagen to form an embolus that blocks the damaged blood vessel. The complement system is activated and stimulates a range of inflammatory responses including: the local hemagglutination system, the fibrinolytic system, and the kallikrein system. Fibrin deposition and dissolution occur locally in the wound and release many inflammatory mediators, especially bradykinin, free radicals, hydrogen peroxide, and histamine. During this period, various mediators produced by the inflammatory reaction increase the permeability of the blood vessels, causing the liquid, protein, and enzymes in the normal blood vessel to leak into the extracellular space through the blood vessel wall to cause local edema and redness. At this time, the inflammatory cell infiltration is mainly neutrophils, and after 3 days, the macrophage becomes the dominant cell for performing immune function in the wound area.

In the process of inflammation, on the one hand, inflammatory cells such as monocytes and mast cells phagocytose and remove harmful substances such as bacteria in the vicinity of the wound, and at the same time release inflammatory factors and growth factors to coordinate with each other to promote repair and healing of the damaged tissue. On the other hand, it shows an increase in vascular permeability. Due to the destruction of vascular endothelial integrity and permeability changes, a large amount of protein-rich fluid exudes outside the blood vessels, forming inflammatory edema. Local tissue edema can dilute toxins, reduce the damaged effect of toxins on local, bring nutrients to the locally infiltrated white blood cells, and transport metabolites. The antibodies and complement contained in the exudate help to eliminate pathogens and create favorable conditions for wound healing. If the inflammatory response is too strong, cellular immunity and humoral immunity cause degeneration and necrosis of cells and tissues, and vascular permeability increasing, including a large number of neutrophils and protein-rich fluids exuded outside the blood vessels, causing tissue edema and suppurative lysis disruption, delaying wound healing. Therefore, the inflammatory response is a double-edged sword for wound healing. The proper inflammatory response is beneficial to wound healing, while too strong inflammatory reaction and exudation are unfavorable for wound healing.

The latest research shows that the essence and core of the inflammatory response period is the regulation of growth factors and their results. After tissue injury, various growth factors such as PDGF, FGF, and TGF-β released during bleeding and coagulation can play the following roles during the inflammatory response phase:

(a) As a chemotactic agent, neutrophils, macrophages, etc. aggregate to the wound surface. A variety of proteolytic enzymes are released to dissolve the necrotic tissue, and these inflammatory cells themselves release new growth factors, further regulating the inflammatory process of the wound.
(b) Chemotaxis and direct stimulation to fibroblasts, vascular endothelial cell division and proliferation, laying the foundation for later repair.

It should be pointed out that at this stage, the aggregation of inflammatory cells and a large amount of local exudation can play the following roles:

(a) The aggregated leukocytes can phagocytose and remove foreign bodies and cell debris.
(b) Local exudates can dilute local toxins and irritants.
(c) Antibodies in plasma can specifically neutralize toxins.
(d) The exuded fibrin solidifies to form a local barrier.
(e) Activated macrophages not only release a variety of growth factors, but also further regulate the inflammatory response, and also affect the formation of collagen in granulation tissue. In short, this phase of change is the basis for the later restoration.

Immune Response

The body has an acute inflammatory response period after the wound. On the one hand, the contracted small arteries near the wound expand under the action of vasoactive substances such as histamine, 5-hydroxytryptamine, and kinin, which increases the blood perfusion of the wound and strengthens the local metabolism to help in the removal of harmful substances. At the same time, the wound exposes the nerve endings, and a large amount of inflammatory mediators such as bradykinin, etc. stimulate the wound and cause local pain. On the other hand, cell phagocytosis and immune response run through the whole process. In addition to coagulation and hemostasis, platelet lysis during inflammation also produces platelet-activating factor (PAF) and platelet-derived growth factor (PDGF). These cytokines have the chemotaxis of granulocytes and macrophages to promote the accumulation of these immune cells to the wound. After the phagocytic cells move into the wound, they recognize foreign bodies, then move and adhere to the foreign bodies. Finally, the pseudopods are extended to envelop foreign bodies, phagocytose them. Phagosomes and lysosomes form a phagolysosome, and finally the foreign bodies are digested, this process is called the first cleaning of the wound. The migration of white blood cells lasts about 3 days until the wound is "clean." The proper inflammatory response is beneficial to wound healing. However, if the infection occurs during the inflammatory phase and the inflammatory response is strong, the white blood cells continue to migrate and the phagocytic activity is strengthened. The inflammatory period is prolonged and the wound is delayed in healing.

Peripheral white blood cell count increasing is another typical manifestation of inflammatory response, especially when inflammation is caused by bacterial infections. The increase in white blood cell count is mainly due to the accelerated release of leukocytes from the bone marrow pool caused by interleukin-1 (IL-1) and tumor necrosis factor-α (TNF-α), and an increase in the proportion of relatively immature rod-shaped neutrophils. This phenomenon is called "nuclear left shift." Therefore, most of the researches at home and abroad have selected specific cytokines, such as IL-6, IL-8, TNF-α, etc., as indicators of the degree of inflammation. Controlling the degree of inflammatory response plays a crucial role in the wound healing, so infection prevention and anti-inflammatory are particularly important in promoting wound healing.

Vascular Permeability

In the inflammatory response induced by wounds, inflammatory cells release a large number of inflammatory mediators and oxidation products. The accumulation of these substances can lead to dysfunction of vascular endothelial cells, the main manifestations are: permeability of endothelial cells increasing, abnormal expression of adhesion molecules, the adhesion of endothelial cells and inflammatory cells increasing, and vascular dysregulation leading to localized edema. Local inflammatory edema contributes to wound healing, but excessive blood and protein exudation cause excessive tissue edema, which can delay the wound healing. Therefore, in the study of promoting wound healing, attention to vascular permeability is particularly important.

Increased vascular permeability is mainly mediated by two pathways: the cell-through pathway and the paracellular pathway. The cell-through pathway is achieved by the "vesicle-vacuole organelles" (VVOs). VVOs are a string of glucose-like unencapsulated vesicles and a variety of vacuoles formed by the endothelium membrane internalized, which are composed by vesicle-vacuole fusion. It is surrounded by three layers of unit membranes, each membrane and the endothelium membrane interconnected by small pores, macromolecular tracers (such as ferritin, horseradish peroxidase, etc.) can rapidly exude from the venules to the outside of the blood vessels through VVOs. Using continuous high-level ultrathin sections, transmission electron microscopy, three-dimensional reconstruction, and other techniques, an acute inflammatory state is formed under the action of high heat, high-pressure, vascular endothelial growth factor (VEGF), etc., and it is found that endothelial cells have openings through cells. These openings are not located in the endothelium. However, it is located in the peripheral part of the endothelial cells itself, which may be the cell passage formed by the intracellular vesicles fuse, thereby increasing the permeability of the blood vessels. In addition, inflammatory mediators (such as TNF-α) cause the formation of perforating cell channels, while also shrinking the endothelial cytoskeleton, thinning the cytoplasm, and promoting the formation of channel openings, which is also a factor that increases the permeability of the cell-through pathway. Another pathway for increased vascular permeability is the paracellular pathway, which is an important pathway for increased vascular permeability and macromolecular material exudation. Studies have shown that when endothelial cells are subjected to various endogenous or exogenous stimuli, endothelial cells are affected by exogenous signaling pathways, opening the intercellular junctions and forming fissures between endothelial cells, resulting in increased permeability. SP in neuropeptides can cause an increase in tracheal vascular permeability, the mechanism of which is accomplished by the paracellular pathway. There is an overlap of 1–2 μm in the interstitial junction of normal venules, and there is no fissure. At the time of inflammation (1 min after injection of substance P), 48% of the junctions of endothelial cells showed fissures, indicating that the inflammatory response disrupted the tight junction of endothelial cells. The paracellular pathway increases vascular permeability. The integrity and tightness of vascular endothelial cell connections directly affect the permeability of blood vessels. The structure that maintains its tightness relies on vascular endothelial junctions and their associated proteins, including tight junctions and adhesion junctions between endothelial cells-cells, and adhesion junctions between endothelial cells and basement membranes. Vascular endothelial cadherin (VE-cadherin) is the main structural protein of vascular endothelial cell adhesion and connection. Its essence is a transmembrane protein, and its extracellular N′ end and adjacent cell VE- cadherin N′ end are interconnected, allowing VE-cadherin to aggregate into clusters at the junction between cells. Thereby allowing the endothelial cells to closely adhere together to form a selective semipermeable membrane, forming a barrier between the blood and the tissue, and controlling the material exchange on both sides of the vessel wall. When an inflammatory response occurs, under the influence of inflammatory mediators, the function and structure change, causing dissociation, and the gap between the cells is increased, resulting in an increase in vascular permeability. In the inflammatory response, inflammatory cells and inflammatory mediators eventually lead to the disintegration of the VE-cadherin complex through different pathways, resulting in the breakdown of endothelial cell junctions and increased endothelial permeability.

1.6.1.3 Granulation Tissue Proliferative Phase

On the third day after injury, with the regression of inflammatory response and the gradual proliferation of tissue repair cells, the pathophysiological process of granulation tissue hyperplasia and epidermal cell proliferation was observed. At this time, histomorphology is characterized by capillary germ formation and fibroblast proliferation, and produces a large amount of extracellular matrix called granulation tissue.

The growth of granulation tissue in proliferative phase is the key link in the process of wound repair and healing. The quality of new granulation tissue directly affects the repair, healing degree, and prognosis of wounds. The granulation tissue is composed of fibroblasts, endothelial cells, and new capillaries. Its formation can fill and repair the tissue defects of the wound, which is beneficial to the anti-infection and absorption of the wound, and the removal of necrotic tissue. At the same time, granulation tissue shrinks the wound, which is good for wound healing and creates the necessary conditions for epithelial crawling. The growth rate and growth amount of granulation tissue are directly proportional to the healing rate of the wound. The growth of granulation tissue is closely related to the degree of vascularization of the wound. The angiogenic activity is enhanced, and the granulation tissue is easy to grow. On the contrary, if the angiogenic activity is lowered, the granulation tissue is not easy to grow and the wound is not easy to heal. Therefore, the growth of granulation tissue is largely determined by vascularization.

Newborn capillaries are formed primarily by "germination." First, a variety of growth factors act on the bottom of the wound or the vascular endothelial cells (especially the venous endothelial cells) in the "dormant" state, causing them to "activate" and generate capillary germs. After the formation of capillary germs, they grow into the wounded area with a loop shape and get mutually connected to form a capillary network. The capillaries grow at a rate of 0.1–0.6 mm per day, and their directions are mostly perpendicular to the wound surface. Since there is no nerve in the granulation tissue, there is no feeling. However, the basement membrane of these neovascular vessels is incomplete, very fragile, and prone to leakage. Capillary endothelial cells secrete a collagenase that degrades the collagen secreted by fibroblasts and facilitates the movement of capillary endothelial cells. Capillaries formed in this way can participate in the formation of large blood vessels or stop functioning in the future and then degeneration and disappearance.

Angiogenesis refers to the process of new microvessels existing from the mature vascular sprouts. It begins at 24–48 h after wound formation and reaches its peak on the fifth day, playing an important role in wound repair. Microvessels are mainly composed of lining endothelial cells and peripheral pericytes. Angiogenesis involves important processes such as differentiation, proliferation, migration, and interaction of these two kinds of cells. According to previous studies, angiogenesis is initiated after the balance of pro-angiogenic factors and inhibitors is broken in the absence of oxygen. First, endothelial cells activate to form an angiogenic phenotype, while the matrix metalloproteinase activates to degrade the basement membrane and extracellular matrix. Therefore, endothelial cell migration is possible. Endothelial cells proliferate and migrate to form neovascular sprouts. Thereafter, the vascular buds form lumen under the impact of blood flow, and the pericytes in the interstitial adhere to the neovascularization, completing the shape of new blood vessels. Angiogenesis is an important part of wound repair, and a variety of cells and regulatory factors are involved in this process. A mouse skin injury model study showed that angiogenesis in neonatal granulation tissue is most pronounced at 5 days, and the measurement of neonatal microvessel density is consistent with the pathological observation. When the wound has hemorrhage, necrosis, and inflammatory reaction, the local pro-angiogenic factors are increased, such as VEGF, PDGF, transforming growth factor-β (TGF-β), basic fibroblast growth factor (bFGF), etc. Growth of vascular bud of surrounding tissues and transformation of precursor cells of vascular constitutive cells initiate angiogenesis. At the same time, mesenchymal stem cells in the stroma are activated and converted into fibroblasts, myofibroblasts, etc., together forming granulation tissue to repair the wound.

VEGF plays an extremely important role in the process of promoting wound vascularization and wound healing. It is the most potent angiogenic growth factor found so far. VEGF can promote cell proliferation and migration, vascular endothelium growth and wound vascularization, enhance vascular permeability, and improve the ability of glucose to transfer into endothelial cells, so that the high energy required by angiogenic cells is supplemented accordingly. Many aspects promote the healing of wounds. Immunohistochemistry confirmed that neutrophils near the wound began to express VEGF on the first day after wound formation in rats and were detected in macrophages, fibroblasts, and endothelial cells on 3rd–7th days after injury. And its expression in wound tissue is much higher than those in surrounding normal tissues. At the same time, by RT-PCR (reverse transcription polymerase chain reaction), the expression of VEGF on the first day is much higher than those on the third day and the seventh day after injury, confirming that VEGF expression is mainly produced by inflammatory cells in the early stages of wound healing. Therefore, promoting VEGF expression in the early stage is considered to be an important way to promote wound healing. VEGF is widely recognized as an angiogenic substance, and it was found to have mitogenic function of ROS in addition to pro-angiogenic function 10 years ago. A large number of studies in the last 5 years have pointed out that VEGF expression has a close relationship with endogenous H2O2 and VEGF signaling factors. These new findings provide a large number of new theoretical bases for the development of drugs and treatments for the promotion of angiogenesis.

Another kind of vascular endothelial growth factor with strong promotion and high specificity is bFGF, which is also a multifunctional cytokine, which has a strong role in promoting cell division and blood vessel growth. Its biological functions during tissue repair include promoting capillary angiogenesis and reconstruction of capillary structures, promoting the growth and proliferation of endothelial cells, fibroblasts, smooth muscle cells, and the like. During the inflammatory response phase, bFGF stimulates the directional migration of fibroblasts and endothelial cells, initiating the formation and vascularization of fibrous tissue. During the granulation tissue formation stage, bFGF activates fibroblasts to migrate to the edge of the wound, proliferate and synthesize new intercellular substances (such as collagen), and also induces capillary endothelial cell migration and proliferation to form vascular sprouts, and causes new blood vessels extending to the wounded regional matrix to provide nutrients to local cells and improve the excretion of local metabolites, thus creating conditions for promoting wound healing. Experiments have confirmed that bFGF can accelerate the proliferation of epithelial cells and promote wound healing. bFGF promotes angiogenesis in vivo and in vitro, and synergizes with VEGF to upregulate VEGF production by regulating VEGF gene expression, thereby affecting angiogenesis.

The extracellular matrix is mainly composed of hyaluronic acid, chondroitin sulfate, collagen, and acid mucopolysaccharide, and its main component is derived from fibroblasts. Fibroblasts produce collagen fibers which are formed by stepwise polymerization of three peptide chains with glycine, hydroxyproline, and hydroxylysine as basic components. Collagen fibers have a high degree of toughness, which increases the tensile strength of the wound. The formation of collagen fibers peaked on 14th–21st days. The clinical manifestations are scarred red, slightly elevated, often itchy, and the texture is hard and tough.

The significance of granulation tissue formation is to fill the wound defect, protect the wound to prevent bacterial infection, reduce bleeding, mechanized blood clot, necrotic tissue, and other foreign bodies, provide nutrients for the newborn epithelium, and create further conditions for reepithelialization. The reepithelialization process is generally performed in synchrony with granulation tissue proliferation, mainly by proliferation, differentiation, and migration of epidermal cells (including stem cells) remaining at the edge or the bottom of the wound. Under the influence of a series of regulatory factors, the new epidermis of the wound crawls to the center of the wound in a "crawling" manner, eventually covering the wound.

1.6.1.4 Scar Formation Period

The formation of scars is one of the final outcomes of soft tissue wound repair. The stage of granulation tissue transformed into scar tissue and collagen tissue continuously forming lasts several months. Fibroblasts are transformed into myofibroblasts to contract the wound, collagen tissue is produced in large amounts, and keratinocytes cover the wound surface by epithelialization.

The proliferation, differentiation, and migration of epithelial cells exert new epithelium on the edge of the wound skin until it covers the entire wound. This process is also accomplished by a variety of cells and regulatory factors, of which keratinocyte growth factor (KGF) is widely considered to be a more potent and highly specific one. As an epithelial-specific growth factor, KGF can promote the proliferation, migration, and differentiation of epidermal cells, which is closely related to skin wound healing and can improve the quality of wound healing. Fibroblasts at the basal part of the skin wound are capable of synthesizing and releasing KGF, inducing proliferation of epidermal cells around the wound, and migrating to the wound. In addition, KGF, insulin-like growth factor-1 (IGF-1), and their composite cDNA can significantly increase the expression of IGF-1, KGF, FGF, VEGF, and type IV collagen, accelerate neovascularization, enhance dermal and epidermal regeneration, accelerate reepithelialization, and promote the migration of keratinocytes from the edge of the wound to the wound matrix. Experiments have confirmed that fibroblasts are capable of producing and releasing KGF and promoting the proliferation and migration of epidermal cells through KGF, thereby promoting wound healing.

KGF-2 is another highly specific growth factor that promotes epithelial cell proliferation. The experiment confirmed that the specific target cell of KGF-2 is epithelial cell. Its main physiological role is to undertake signaling between mesenchymal cells and epithelial cells, promote proliferation of keratinocytes and epithelial cells, and stimulate regeneration, differentiation, and migration of epithelial cells around the wound, thereby promoting wound healing. At the same time, it has no direct effect on fibroblasts and endothelial cells, and can reduce the formation of scar tissue during wound healing.

There are many factors affecting the formation of scars. If the wound defect is small, the alignment is neat, and no infection occurs (such as a clean surgical incision), the repair (healing) can be completed 2–3 weeks after the injury. At this time, the scar is not obvious, and the function has no effect. For wounds with large defects, irregularities, or infections, it usually takes 4–5 weeks to heal. At this time, the scar is wide, affecting the appearance and even causing dysfunction. The morphological features of scars are the deposition of a large number of fibroblasts and collagen fibers, and their biochemical and molecular biological characteristics are caused by abnormal collagen metabolism in fibroblasts. Studies have shown that the ratio of type I and type III collagen precursor mRNA in abnormal scar fibroblasts is as high as 22:1, while normal skin is only 6:1, indicating that the transcription selectivity of type I collagen precursor mRNA is enhanced. These genetic changes are associated with changes in local wound growth factors (TGF, TNF), local immunity (IgG, IgA, IgM). The formation and regression of scars often depend on the balance between collagen fiber synthesis and catabolism. In the early stage of wound healing or in the stage of fibroproliferation, local collagen fibers will increase due to the predominance of synthesis. When the synthesis is balanced with catabolism, there is no change in the size of the scar. When collagenase is dominant in the decomposition and absorption of collagen, the scar will gradually soften and shrink, and the time varies depending on the size of the scar, which usually takes several months. The study found after skin damage, there is no scar healing in early embryo, but scar healing in the postembryonic development and after birth.

1.6.2 The Characteristics and Repair of Gunshot Wounds

The damage caused by bullets is the process of releasing a large amount of energy in a very short time. The physical factors involved include the mass, speed, shape, and flight state of the bullet. It is also related to the characteristics of the target tissue, such as density, elasticity, viscosity, and toughness. Traditionally, there are three types of bullet injury mechanisms.

(a) Direct damage: It mainly refers to the tear effect, similar to cold weapons. It is the tissue breaking and tearing caused by the projectile passing through the tissue. For the low-speed bullet with a speed of not more than 340 m/s, the tearing effect is the main effect; while for the high-speed bullet, the tearing effect is in a secondary position. The tearing effect does not transfer much energy to the surrounding tissue.
(b) Instantaneous cavity effect: The pressure wave generated after the bullet entering the soft tissue pushes the tissue around the injured road forward and outward in a few milliseconds or even microseconds to form an instant cavity which is several times or even tens of times larger than the diameter of the primary wound. The cavity is timed and repeatedly contracted and expanded. The rapid change of pressure in the cavity causes the tissues and organs around the wound to be compressed and pulled in a very short time. Extensive tears and contusions have occurred.
(c) Pressure wave effect: When the bullet injures the body, part of the energy is transmitted to the surrounding tissues and organs in the form of pressure waves and shock waves, causing damage.

Chinese scholars have earlier noted the importance of pathological observation and zoning of injured tissues, and realized that reasonable pathological zoning can provide a scientific basis for determining the scope of debridement and clinical treatment. In the early 1980s, Wang Zhengguo suggested that the gun wounds and surrounding tissues can be divided into the primary wound zone, the contusion zone, and the oscillation zone. The primary wound zone is the cavity caused by the bullet passing through; the contusion zone is the tissue necrotic zone closed to the primary wound zone; outside the contusion zone is the oscillation zone.

The North Atlantic Treaty Organization (NATO) 1975 version of the War Damage First-Aid Manual has clearly stated that gunshot wounds caused by high-speed bullets must be extensively debrided. Because the instantaneous cavity effect of such a bullet can cause all tissues within

30 times its diameter to be inactivated. However, the 1988 edition of the manual corrects this. In a war environment, rescuers often tend to adopt methods similar to the removal of malignant tumors. All necrosis, injury, and suspected tissue are removed, which may result in greater damage than the gunshot itself, but it is reasonable and necessary from a military medical perspective. The wounds on the battlefield are often heavily polluted, the wounds are not treated in time, and the objective conditions such as the large number of wounded, limited medical resources, and insufficient doctor experiences make it easy for people to adopt a thorough debridement method. The experience of previous war treatments also suggests that incomplete debridement often leads to higher infection rates and mortality, leading to unnecessary waste of medical resources. However, in the past two or three decades, more and more people have advocated conservative treatment. It has been found that the cavity effect is only the tissue displacement caused by mechanical traction. If the decompression and infection are controlled in time, the damaged skeletal muscle may recover.

1.6.2.1 Characteristics of Gunshot Wound

(a) Often it occurs in multiple parts, in the brain, maxillofacial, thoracic cavity, abdominal cavity, and limbs and can have unique characteristics.
(b) Often it is accompanied by bone, joint, nerve, and soft tissue damage, heavy pollution, and severe damage to blood vessels, nerves, and adjacent soft tissue beds.
(c) Except the tissue and vascular damage directly caused by firearm injury, the range of shock waves and thermal indirect damage are larger than those of the naked eye, and the edge of the defect is not neat.
(d) High-energy damage in the local area of the wound causes severe embolization of the damaged blood vessel, damage and defects of the intima.
(e) Warheads or metal foreign objects are embedded in the damaged blood vessels. There is no major bleeding before surgery, but you should be alert.

1.6.2.2 Repair Principle of Gunshot Wound

Due to the different characteristics of each part, the repair is very different (refer to the introduction of each specialist). Usually gunshot wounds include the primary wound zone, the contusion zone, and the oscillation zone. Due to their unique pathological changes, the surgical field should be fully exposed, and nerves, blood vessels, and tendons should be routinely explored to determine the presence or absence of nerve and blood vessel damage, and the location, nature, and extent of the injury. Look for damaged blood vessels, thoroughly debride and remove foreign bodies, and repair and reconstruct according to the order of bones, blood vessels, nerves, and soft tissues. At the same time, look for vigorous muscle nearby to cover, and if necessary, move adjacent muscles to provide a good tissue bed for repair or the reconstruction of blood vessels. In the case of defective blood vessel transplantation, the vessel should be cut to the normal endometrium. Otherwise, thrombosis may occur and the operation may fail. If the patient's general condition is extremely poor, the amputation should be decisive to save the life. If there is no condition for the amputation, the vascular end should be found and ligated, and the operation is terminated immediately after effective hemostasis.

1.6.3 Soft Tissue Blast Injury

Blast injuries are the most common cause of injury to military personnel on the battlefield.

1.6.3.1 Classification of Modern Soft Tissue Blast Injuries

Explosion is a phenomenon of instantaneous release of energy. The explosion effect is divided into the following four types:

(a) Type 1 blast injury. The damage comes from the overpressure and negative pressure caused by the shock wave. The target organs are the hollow organs like ear, lung, and intestine.
(b) Type 2 blast injury. The injury comes from penetrating damage caused by projectiles.
(c) Type 3 blast injury. The collapse of buildings and fragments of vehicles caused by explosion, leading to crush injury, contusion, traumatic amputation of fractures, opened or closed head injury.
(d) Type 4 blast injury. It includes burns, asphyxia, and toxic gas damage. Explosive weapons generate a large amount of high-pressure gas, heat, shock waves, and scattered fragments at the moment of explosion, forming a variety of damage factors such as fragments, impact, burns, etc., which jointly cause damage to the human body.

1.6.3.2 Clinical Features of Blast Injury

Multiple Sites, Multiple Organs, Multiple Tissue Damage

There are many types of explosive weapons, and the methods of injury are varied, the sites and extents are different. Peleg et al. analyzed 1155 terrorist-related injuries in the Israeli National Trauma Registry from October 1, 2000 to September 30, 2002, and compared the differences between gunshot wounds and explosive wounds. They concluded that the explosive wounded have more injury sites, 62% of them combined with multiple site injuries, while gunshot wounds 47%; and patients with blast injuries are in a more serious condition, 17.3% of blast injuries with Injury Severity Score (ISS) > 25 points, while gunshot wounds just 14.9%.

Severe Soft Tissue Defect

The pressure wave propagates in different density media, causing various effects such as spallation, explosion, polymerization, acceleration, deceleration, and pressure difference, resulting in tearing and blast injury of the tissue, severe damage of soft tissue, and deep tissue exposure. In recent years, suicide bombings have brought new changes to the characteristics of blast injuries. A variety of foreign bodies have been added to explosives, resulting in an increase in damage sites, aggravation of soft tissue damage, and more retention of foreign bodies. The US military conducted statistics on the causes of injuries from the wounded in Iraq, and the roadside homemade improvised explosive devices ranked first. Such explosions often cause damage to the chest and limbs through the unprotected sub axillary area, which causes crush injury of the limbs, which is manifested by severe damage to the soft tissues, bones, and blood vessels of the extremities, and the potential fatality rate is high. According to Geiger, lower extremities are more likely to be damaged than upper limbs, with lower limb injuries accounting for 61.76% and upper limbs accounting for 29.4%; lower extremity injuries are wide, the defect degree of muscle and neurovascular are different, and the former is significantly more damaged than the latter.

Complex Infection, Difficult to Handle

Explosive soft tissue defects are serious. There are foreign bodies such as sediment, debris, and hair around the wound and deep surface, which aggravate the wound pollution, and the infection rate is high. The disease develops rapidly, and the immune response is inhibited after severe damage to various tissues. It is susceptible to infection and other complications. In the modern war wounds, the spectrum of infected bacteria has changed significantly. The multidrug-resistant *Acinetobacter baumannii* infection in the Iraqi warfare has shown an upward trend. Analysis of the results shows that it may be related to the use of drugs and the colony of the soldiers. According to statistics, 50% of the wounds are positive for bacterial culture and 57% of them are infected with *Acinetobacter baumannii*.

High Limb Damage Rate, Heavy Functional Impact, Difficult to Repair

The blast injury is severely damaged, the soft tissue and bone are extensively deficient, the vascular and nerves in the deep and injured areas are damaged. The joints, bones, and tendons are exposed, which seriously affects the function. The surgical repair is difficult, and some of the wounded are eventually amputated. The main reason for the failure of limb salvage is the presence of other organ damage, life-threatening severe blood loss, and sepsis.

E. Delayed Delivery, Delay the Best Treatment Opportunity

Under the conditions of war, the number of wounded people is large and the injuries are complicated.

Medical treatment is limited by various factors such as medical environment, instruments, and human resources. Coupland and Samnegaard counted 18,877 civilian wounded admitted to the International Red Cross Hospital, and only 2012 wounded were delivered to the hospital within 6 h after injury. The delayed delivery causes the injured to miss the best treatment opportunity. The bacteria in the injured wounds multiply and the infection rate increases. Some reversibly damaged tissues develop ischemic necrosis or inflammation progresses, resulting in increased damage and eventually tissue necrosis. Some wounded fail to get timely first-aid resuscitation treatment and eventually die.

1.6.3.3 Repair of Explosive Injuries

The key to the repair of high-speed and high-energy soft tissue blast injury is early, timely, and thorough debridement, removal of necrotic tissue, adequate drainage, attention to dressing fixation, rational use of antibiotics, elective repair of bone and soft tissue defects, delayed wound coverage or closure, postoperative enhancement of rehabilitation exercises, and patient education.

The traditional view is that blast injury is extensive, and it is difficult to completely debride at one time. The wound is easy to be infected. The failure rate of early anastomosis is high. Surgery should be performed after the wound is clean and the granulation is good. Negative pressure wound treatment (NPWT) has been gradually applied to the treatment of war wounds, achieving good results and broadening the indications for skin graft repair. The wounds in war are seriously damaged, often accompanied with serious pollution. The wounded are sent far away and have a long time. The characteristics of NPWT determine that it is suitable for the treatment of such wounds, which can isolate the wound from the surrounding battlefield and the environment of the hospital, effectively maintain the wound clean, and reduce wound infection while washing the wound. For patients with huge soft tissue defects caused by explosion and combined with tendon and bone exposure, Helgeson et al. combined the application of NPWT and Integra artificial skin for wound preparation, and when the wound condition is improved, skin graft repair is performed and the postoperative effect is good. This method can avoid complicated skin flap transplantation and reduce the risk of donor deformity and skin flap necrosis. Sharony et al. summarized the experiences of rescuing the Second Lebanon War wounded and emphasized the application of NPWT and external fixation systems. It is believed that the NPWT can be used in various stages of wound healing, which can close multiple subcutaneous sinuses, strengthen the adhesion of tissue flaps and wound periphery and basement, ready for wound preparation or cover the donor site.

Explosive injury causes are various and injury conditions are different. It is necessary to conduct an in-depth research on them and comprehensively understand the damage mechanisms and injury conditions of soft tissue explosive wounds. This is the prerequisite for an effective treatment of soft tissue defects after a blast injury. On this basis, clinicians actively use surgical procedures and combine new methods and techniques to reconstruct damaged tissues and organs, improve deformity, and restore function.

1.7 Progress and Prospects of Research on Repair and Regeneration of War Wound Tissue

In the past 20 years, with the continuous development of science and technology, the research of molecular biology, materials science, tissue engineering, and other aspects has been deepened, and the overall level of wound healing has been greatly improved. The goal of wound healing and regeneration has also gradually changed from the pursuit of healing speed to the emphasis on healing quality, from the repair of a single tissue component to the simultaneous repair of multiple tissue components, from local tissue repair to the whole body, paying more attention on how to solve psychological, functional repair problems, etc.

1.7.1 Posttraumatic Tissue Repair Research from Local Tissue Repair to Overall (Whole Body) Repair

The human body is a harmonization of the whole composed of multilevel structures. The life movement of the human body is an advanced movement in the natural world. The internal and the body with the external environment are always in the process of dynamic contradictory movement. The scientific view of the human body will guide people to better reveal the laws of movement of human life activities. People are the product of long-term differentiation in nature. The human body contains more than 60 chemical elements, which are basically consistent with the chemical composition of the Earth’s surface, and are mostly light and even elements in the top 20 of the element periodic table. From microscopic to macroscopic, the human body can be summarized into: quantum→molecular→subcellular→cell→tissue→organ→system→body. The high level is composed of low levels, but the high level is not a simple accumulation of low levels. Different levels have different morphological structures and functional activities. The organic connection between different levels forms the whole of the human body system and forms an ecosystem with the external environment. Therefore, the overall unity of the human body is mainly manifested in the unity of morphological structure and functional activities, the unity of the local and the whole, and the unity of the body and the environment. Firstly, the unity of structure and function. In the human body, the unity of material and movement is the unity of morphological structure and functional activity. Morphological structure is the material basis of functional activities, and certain functional activities are the performance of certain morphological structures. Therefore, the morphological structure and function are mutually restricted. Different organs perform different functional activities in different morphological structures. The certain morphological structure of each organ is expressed as a certain functional activity. Different systems composed of individual organs have different functional roles. The morphological structure of the cells is consistent with the functional activity. Just as muscle cells with a fusiform and long cylindrical shape, rich in myofibrils, are suitable for contraction and relaxation. Nerve cells with axons and dendrites are suitable for stimulation, conduction excitation, and so on. At the molecular level, the strict ordering of linear primary structures of nucleic acids and protein molecules determines the specificity of their functional activities. If the structure of an organ, cell, or biomacromolecule changes, it will affect the corresponding functional activity. Conversely, functional activity also affects morphological structure. The morphological structure of various organs of the body is actually the result of continuous evolution of the body under the influence of the environment, with the adaptation of functional activities. Secondly, the unity of the local and the whole. The human body is composed of numerous cells, tissues, and organs. There are complex interactions between local and whole, local and local, which constitute a unity of the whole and the local. The overall function is accomplished by the coordination and cooperation of various local activities. In the unified whole of the human body, any local change is not isolated, it will affect other parts later or early, more or less, and eventually lead to overall changes. The functional activities of various systems and organs of the human body are accomplished through the neurohumoral regulation. Thirdly, the unity of the body and the environment. The human body is an open system, a dissipative structure that constantly links with the external environment. Input various substances, energies, and information, and output processed materials, energies, and information to the environment through changes in the internal environment of the body. The external environment includes climate, water, soil, sunlight, air, and working conditions, spiritual life factors, they are intertwined, intricate, and constantly changing.

On the basis of modern science and technology, medicine is rapidly developing in both micro- and macro directions. The deepening of the microscopic is not only a deepening from the subcellular, molecular, to the quantum level, but also a deepening of intrinsic mechanism for the activities of life and disease. The expansion to the macro is not only an extension of the human body, people, and the ecological environment, but also an increasingly close combination of medicine and sociology. The social functions of medicine are continuously strengthened. The deep development of modern medicine in these two directions, combined with each other, penetrates each other and crosses each other to form a trend of comprehensive research and development. To the micro level, it is the requirement of the development of life science and medical science itself, and it is also an objective requirement that medical practice is increasingly urgently proposed. With the development of molecular biology and the penetration into medicine, molecular physiology, molecular pathology, molecular pharmacology, molecular genetics, molecular immunology, etc. have been formed, which directly promoted the medical research from the description of the phenomenon into the analysis of the internal mechanism. Understanding this holistic and partial concept will contribute to the study of tissue repair in trauma and postinjury.

At present, the development of modern medicine is increasingly characterized by a combination of micro and macro. The deepening of the microscopic level enables people to explain the complex changes and interrelationships of various parts of the overall connection, forming a qualitative description of the overall complex system. The study of macroscopic phenomena in life activities reveals the premise of local changes and the interrelationships in the reality, driving the discussion of microscopic changes. Therefore, micro-in-depth and macro-level researches are mutually reinforcing, and the combination of the two is objective and inevitable. Complex life activities are the results of the regular integration of various parts according to certain relationships. The combination of micro and macro in modern medicine will lead to a leap in the understanding of the nature of life activities.

The effects of nerve, endocrine, and hormonal changes on skin repair and regeneration have recently received great attention. From an anatomical point of view, with the deep understanding of subcutaneous tissue and skin attachments, especially fat cells and mesenchymal cells, the adipose tissue has not only been regarded as an energy storage organ, but also as a metabolic organ of sex hormones and endocrine organ. Adipose tissue is capable of producing a large number of bioactive peptides, including adipokines and leptin, which act in an autocrine and paracrine form in combination with specific receptors on the surface of adipocytes in local. Functionally, the function of the skin among mammalian populations is more or less different. Among them, human skin functions mainly include maintaining endogenous homeostasis, such as regulating body temperature and body fluid equilibrium; participating in substance metabolism, such as vitamin D synthesis; performing sensory afferent; blocking external damage such as infection, mechanical damage, and ultraviolet rays' irradiation. In addition, it is also the most initial and basic part of the body's immune system. Except these previously discovered functions of the skin, more and more evidence shows that the skin is a highly active "biological plant" capable of synthesizing or participating in the metabolism of many biologically active substances (e.g., structural proteins, glycoproteins, lipids, and signaling molecules). People's understanding of skin function has become clearer and more complete. The immune-nerve-endocrine system cross-talk has opened up many new fields for the research of skin tissue repair and regeneration, which has led to many new ideas.

1.7.2 Posttraumatic Tissue Repair Research from Passive Repair to Active Repair

People have paid more and more attention to the damage caused by trauma, surgery, organ transplantation, and other serious diseases and consequences, and they are competing to carry out research on its mechanism and prevention. The traditional treatment method is mainly based on "guarantee," that is, the self-repair of the damaged organ is dominant, waiting for the metabolism of the damaged organ to self-heal. This passive repair method not only prolongs the treatment time, but also leads to a series of adverse complications, and also increases the psychological and economic burden of the patient, which is extremely unfavorable for treatment. In the 1980s, the research on the effect of growth factors on wound repair caused fundamental changes in the concept of modern wound repair. Firstly, the connotation of repair has expanded from simple surface wound repair to internal organs and the whole body. Secondly, with manual intervention, the natural process of wound healing can be somewhat "promoted" or "accelerated." Under the guidance of this modern understanding, research on the role of growth factors in wound repair has become a hot topic in the field of tissue repair in the past 10 years. The theoretical basis for the active repair of damaged tissue by growth factors is derived from the interdependence and interaction of growth factors and systemic organs in biological processes such as embryogenesis and tissue growth. Studies have shown that in tissues such as liver, pancreas, and gastrointestinal tract in early embryonic development, epidermal growth factor (EGF), insulin-like growth factor (IGF), hepatocyte growth factor (HGF), and transforming growth factor (TGF) have been found to show the gene expression increasing, and with organ embryo development, levels of above growth factor mRNA increasing. The above facts indicate that growth factor is one of the intrinsic components of these organs. It not only participates in the process of embryogenesis of organs, but also plays an important role in the maintenance and repair of mature organs.

1.7.3 Posttraumatic Tissue Repair Research from Anatomical Repair to Functional Restoration

The ideal wound healing and tissue regeneration repair should enable the injured tissue to achieve complete repair in anatomical structure and physiological function. This phenomenon can only be seen in fetal skin repair. In clinical work, a large number of tissue repair results are that the anatomical structure of the injured tissue is basically restored, and its physiological function is only partially restored, and some scar tissue is left in the affected part. In addition, there are two kinds of repair anomalies, which we call repair out of control, which is the main problem we are facing and need to solve. One is the healing of scars after extensive full-thickness skin burns. Although patients have preserved their lives, there are no skin appendages such as sweat glands, sebaceous glands, and hair follicles in large areas of scars, so these patients cannot regulate their body temperature by sweating. The physiological dysfunction reduces the quality of life. In addition, due to scar hyperplasia and/or keloids, it seriously affects the physical and mental health of patients, and some cannot even integrate into social life, resulting in a significant decline in the quality of life. The other is insufficient wound healing or difficulty in healing, leading to the formation of chronic ulcers. Chronic refractory ulcers and scar hyperplasia are two different manifestations of repairing out of control. Although the repair out-of-control does not cause death as quickly as cancer, but because they occur on the surface, long course, difficult treatment, and high cost, they do cause great pain to the patient and seriously affect the quality of life of the patient. In order to solve the problem of repair out-of-control, we advocate vigorously carrying out basic research on tissue repair from anatomical repair to functional repair. On the one hand, it is hoped that medical scientists will pay attention to the functional rehabilitation of patients in the early stage of trauma treatment, and try to avoid loss of function; on the other hand, it is hoped to achieve breakthroughs through in-depth and meticulous basic research, laying a groundwork for a revolution in clinical therapeutics. At present, the research on the functional repair of wound tissue has been paid enough attention at home and abroad. The focus of the research is mainly on exploring the mechanism of tissue regeneration and how to transform high-tech biotechnology in the field of tissue regeneration and repair into clinical treatment and other aspects. In particular, our goal of "achieving the simultaneous repair and regeneration of multiple damaged tissues at the injury site" marks the formation of a new research direction in this field, with more specific goals and a better future.

1.7.4 Posttraumatic Tissue Repair Research from the Emphasis on Basic Research to Clinical Transformation and Precision Treatment

Translational Medicine first appeared in the literature in 1993, also known as the clinical translational research (CTR). In 2003, the National Institutes of Health (NIH) developed a long-term plan for the development of biomedicine. In 2004, an initial investment of $125 million was made. In 2009, the total investment reached $2 billion. One of the most important goals is to cultivate a new research team with different professional backgrounds, who can collaborate on basic research and clinical work. By 2012, 60 Clinical and Translational Science Centers (CTSCs) were established in the United States. In the field of burn wound research, translational medicine has received extensive attention from researchers. In September 2010, the 218th Young Scientists Forum of China Association for Science and Technology was held in Chongqing. The theme was "Thinking and Countermeasures of Translational Medicine Leading Burn Research." At the meeting, the translational prospects in research areas, such as burned clinical nutrition, sepsis, wound repair, stem cells, and diabetes wounds, were discussed in depth. At the 8th National Burn Treatment Symposium on the theme of "Regeneration Medicine and Translational Medicine" held in June 2011, Academician Sheng Zhiyong emphasized the importance of translational medicine and affirmed the transformation significance of the major burns from clinical to basic research to the clinical. Many experts have made an in-depth interpretation of the importance of the "bench to bedside and bedside to bench" (B2B). Reproductive medicine has been listed as a major research direction in the scientific and technological planning of the Chinese Academy of Sciences' *China's Population Health Science and Technology Development Roadmap to 2050* and the Chinese Academy of Engineering's *China's Engineering Technology Medium and Long-term Development Strategy Research*. The Ministry of Health has organized the *Regulations for the Management of Tissue Engineering Tissue Transplantation Therapy* (*Trial*) and classified stem cell technology into "Third Class Medical Technology" for management. Recently, the relevant departments have further strengthened the management of stem cell therapy. At the same time, the academic community held three “Reproductive Medicine” Xiang Shan Science Conferences in 2005, 2010, and 2015, fully discussing the concept, scope, key breakthrough directions, technical routes, and the key scientific issues that need to be solved for the development of regenerative medicine in China. These have laid a good foundation for the future development of Chinese regenerative medicine and provided relevant guarantees. Academician Xiaobing Fu pointed out that China’s tissue repair and regeneration is not only actively in line with the international mainstream direction, but also highlights its own innovative features and unique research ideas. This is the idea of using the results of basic research through the concept of translational medicine, in some key field realizes theoretical and technological breakthroughs, applies relevant results to various fields of tissue repair and regeneration as soon as possible, and hopes to benefit patients with injuries as soon as possible. Of course, the existing problems are also quite prominent. On the one hand, there are not many original things, especially some innovative ideas and research directions that can lead the trend; on the other hand, the efficiency of conversion is still relatively low, and the advantages of the overall research are not very prominent, which need further attention and enhancement. In general, through further research, in the future, China’s regenerative medicine may make substantial progress and breakthroughs in stem cell differentiation and simultaneous repair and regeneration of multiple damaged tissues, the construction of large organs in tissue engineering, tissue engineering products from basic research to large-scale application, further establishment and improvement of systems and regulations involving regenerative medicine and the large-scale construction of regenerative medicine transformation bases.

Precision medicine comes from the State of the Union Address of US President Barack Obama in early 2015. Its core philosophy is no strange. It aims to incorporate individual differences into the strategies of disease prevention and treatment. It is based on DNA sequencing and genomics analysis to better tailor the body for more targeted treatment. In general, precision medicine is still mining data, looking for evidence, and targeting the more microscopic genes, trying to use big data to find evidence that has not been discovered in the past, and using it for more targeted treatment of the diseases.

In the field of trauma, how to apply these new concepts and theories to guide the trauma treatment in a scientific, normative, and more rational way is a question that everyone should consider. As mentioned earlier, translational medicine has a good practice in the field of war wounds and tissue repair and regenerative medicine. Many new treatment techniques, methods, and products are derived from the practice of transforming the innovative theory into clinical treatment. At the same time, precise debridement and precise suturing of wounds are actually the practice and application of precision medicine in the field of trauma treatment. At present, although the occurrence of war trauma has certain genetic factors, especially the complications may involve the participation of some genes. In general, precision medicine is a systematic process in the field of wound healing and tissue repair and regeneration. It is not necessary to pin the success rate of the treatment on the genetic changes. It should be noted that traditional trauma treatment often focuses on the treatment of specific parts and specific mechanisms. However, referring to multiple injuries involving multiple organs, multiple mechanisms, and multiple levels of regulation, the treatment, prognosis, and clinical practice are often weak. The important role of translational medicine in the clinical practice of trauma will be reflected in the following aspects:

(a) Prognosis of multiple injuries and critical injuries. Establish a more sensitive and efficient early warning diagnosis technique for high-risk patients and detect early patients with a poor prognosis.
(b) Reevaluate the existing diagnosis and treatment techniques with the system biology orientation and screen a more targeted and specific diagnosis or treatment combination.
(c) Damage repair and regeneration. Combine new materials and new technologies to develop repair techniques for central nervous system damage, large-area tissue defects, and complex wounds.

China’s trauma research and practice must actively participate in this wave of translational medicine, which is the only way to gain a place in the fierce competition with international counterparts in future. In the next few decades, research and research institutions that further integrate medical practice with laboratories to produce clinically usable outcomes will emerge in the field of trauma, thereby greatly improving the service level of traumatic care. As the country with the largest population, the number of traumas and critically wounded people also top in the world, we should grasp the trend and create a group of internationally advanced trauma-transforming medical research institutions to make greater contributions to human health.

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