

Damage Control Management in the Polytrauma Patient

Second Edition

Hans-Christoph Pape
Andrew B. Peitzman
Michael F. Rotondo
Peter V. Giannoudis
Editors



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ISBN 978-3-319-52427-6 ISBN 978-3-319-52429-0 (eBook)
DOI 10.1007/978-3-319-52429-0

Library of Congress Control Number: 2017935020

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Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword by C.W. Schwab

The value of damage control surgical approach will only continue to increase in importance within the context of casualty care as the complexity of intentional injury continues to escalate in both the civilian and military environments.

Brian Eastridge MD, FACS

Out of the Crucible.¹

Throughout the history of medicine, physicians and surgeons have been forced to react with unconventional approaches to massive anatomic destruction and rapid physiologic depletion. To prevent death, they invented, innovated, and forged solutions. This “forced empiricism” is a unique characteristic of the surgery for trauma and, over time, has improved man’s ability to survive physical trauma.²

The benefits of damage control in both the military and civilian sectors have been validated over the last 15 years. The term “damage control” was initially adapted to surgery to describe a three-staged approach to exsanguinating abdominal injury by using a truncated laparotomy for bleeding and contamination control. Its utility in response to the American urban gun violence epidemic of the 1990s resulted in improved survival. At the same time, it resulted in serious complications like abdominal compartment syndrome and the prolonged “open abdomen.” These, in turn, precipitated novel management schemes and innovations in critical care and forged groundbreaking surgical techniques. During this same period, many young surgeons training in our busy intercity trauma centers learned the principles of damage control surgery and later, as military surgeons, applied the concepts to critically wounded soldiers in Iraq. The DC approach was expanded to orthopedic, vascular, thoracic, and neurologic surgery with the development of techniques to swiftly control bleeding, relieve compartment pressure, and reestablish perfusion and afford skeletal stabilization. On these same battlefields, an improved understanding of resuscitation and the need to reverse coagulopathy led to the use of early whole blood, component therapy, and procoagulants as an effective prototype of promoting hemostasis and oxygen

¹Out of the Crucible, Capt. Eric Elster and Dr. Arthur L. Kellermann (editors), published by The Borden Institute, Washington, DC (in press).

²A national trauma care system: integrating military and civilian trauma systems to achieve zero preventable deaths after injury. Washington, DC: The National Academies Press doi: 1.0.17226/23511.

delivery – damage control resuscitation. By combining damage control surgery and damage control resuscitation, the allied military medical teams reported unprecedented survival with wounding patterns that historically had been mortal.

Several other important concepts emerged from Iraq and Afghanistan. Damage control applied in mass casualty events in these austere environments was verified as an approach to match limited human and material resources with the critical needs of a maximum number of wounded soldiers.³ Damage control management was adapted to the worldwide military trauma system where minimal acceptable care delivered at intervals across geographically separated medical units was established and ingrained in the fabric of military medicine. Individual patient care was supplemented with video feedback between forward surgeons, critical care transport medical teams, and reconstructive surgeons across the globe and led to standardized approaches and improved outcomes. As the formal war period was winding down, these broader concepts of military damage control translated to the civilian sector and proved their value in Boston, San Bernardino, and Orlando.

Frequent mass casualty events from active shooters and explosive devices are increasing and appear almost as daily events in our world. Suddenly, our emergency systems and hospitals provide the safety net for dozens of patients with wounds more commonly seen in combat than in civilian life. Thus, there is an *imperative* that all medical personnel be expert in the use of damage control for an individual patient and as an effective mass casualty and disaster management process.

The second edition of *Damage Control Management in the Polytrauma Patient* benefits from editors who are experts in the concepts and techniques of damage control. The flow of knowledge between the disciplines of trauma orthopedics and surgery and integration of the military and civilian experiences provide critical information that is new, uniquely broad, and rare to find in a single compendium. The selected topics are contemporary, relevant, and contributed by military and civilian authors who have applied and verified the uses of damage control in orthopedics, trauma, and emergency surgery. Thus, in my opinion, this edition will be *required reading* for all who provide the medical readiness to protect human life.

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³Remick KN, Shackelford SA, Oh JS, Seery J, Grabo D, Chovanes J, et al. Adapting essential military surgical lessons for the home front. *AmJDisaster Medicine* (in press).

Preface by P.M. Rommens on behalf of the European Society for Trauma and Emergency Surgery (ESTES)

The second edition of the book *Damage Control Management in the Polytrauma Patient*, edited by Pape, Peitzman, Rotondo, and Giannoudis, is a milestone publication for the European surgical community. It answers to a real need for modern, high-quality trauma care in most European countries.

Thanks to many new member countries, the European Union (EU) has grown rapidly during the last decades. The unification process is a complex task and will go on for several more generations. Harmonization of medical care – for us of special interest is the care of the emergency surgical patient – is one of many topics on the to-do list of the EU. Looking at incidence of accidents, organization of trauma care and mortality after trauma in the member countries of the EU, we are confronted with most diverse facts and figures. Quality of road infrastructure, of motorcycles and motorcars, and density of population are very different from country to country. Prevention of accidents by limit of speed, obligation to wear a helmet or security belt, restriction of alcohol consumption, and the implementation of these regulations by intense control is also very variable. Due to continuing industrial and social development, the number of motorcycles and motorcars has grown quickly. The consequence is that the incidence of heavy traffic accidents is still raising and the *polytrauma patient* continues to be sad and daily reality.

In contrast with this, regional organization of trauma care, establishment of trauma centers, basic and postgraduate training of medical and paramedical staff involved in trauma care have not evolved parallel with the increasing challenge.

The European Society for Trauma and Emergency Surgery (ESTES) is an umbrella organization of national societies of trauma and/or emergency surgery. Thirty-two European societies are institutional members and more than 500 surgeons are individual members. The vision of ESTES is enhancing and harmonizing the care of the critical ill surgical patient. Different sections have been founded to realize these goals: skeletal trauma and sports medicine, visceral trauma, disaster and military surgery, emergency surgery, and polytrauma. The last section is a compilation of the most important European guidelines on primary and secondary care of the severely injured.

This publication is an important instrument for all medical and paramedical care providers, who are involved in the management of the polytrauma patient. It gives a comprehensive overview of modern organization and evidence-based principles of care of the severely injured. Several eminent ESTES members have contributed as chapter editors. We therefore are very

happy to endorse this publication with our logo and recommend it to a European readership of emergency physicians, anesthetists, general surgeons, (orthopedic) trauma surgeons, and rehabilitation staff. We very much hope that this work will be accepted as a guide for treatment in the different settings of trauma care all over Europe. With these different realities, we should not overlook our common and unique goals of treatment: the polytrauma patient should survive, independent of the country, the place and the time of his/her accident, he or she should suffer the least morbidity, and have the best rehabilitation and recovery possible. This book gives theoretical background as well as practical evidence for good polytrauma care. We congratulate the editors to this initiative, also, ESTES is grateful for being involved in sharing their knowledge and wish the second edition of the book *Damage Control Management in the Polytrauma Patient* good acceptance and distribution.

Prof. Dr. Dr. h. c. Pol M. Rommens
ESTES Secretary-General

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Part I

Introduction: Pathophysiology

Robert J. Winchell

1.1 Introduction

By any measure, injury is a serious public health problem. Worldwide, road traffic injuries are the leading cause of death among the young (aged 15–29 years), responsible for over a million deaths per year [1]. In the United States, unintentional injury is the leading cause of death for persons under the age of 45 years and is among the top ten causes of death for all decades of life [2], a pattern that has not changed significantly in decades (Fig. 1.1). Overall, injury is responsible for almost a third of all years of potential life lost. Moreover, it is a substantial economic burden [3]. In real numbers, highway transportation-related events in the United States were responsible for about 2.2 million injuries and 33,000 deaths in 2010 [4]. And yet, there is no focused public health policy at the federal level to address the problem of injury in a systematic fashion. Moreover, state and regional approaches are nonuniform, ranging from the very robust to the

nonexistent. This lack of policy-level response is not universal. By comparison, the 2014 West African Ebola outbreak drew tremendous headlines and produced a massive public health response worldwide, despite accounting for only about 23,000 identified cases and about 9,800 deaths worldwide in its first year, according to CDC statistics [5] (Fig. 1.2). Over 50 years after *Accidental Death and Disability: The Neglected Disease of Modern Society* [6] was published by the National Academy of Science, injury remains the “neglected epidemic [6]” of modern society.

When *Accidental Death and Disability* was published in 1966, the field of injury care consisted of largely disconnected elements: ambulance services, emergency departments, intensive care units, and trauma research units. The report established the foundational and seminal elements of what has come to be recognized as a trauma system, recommending measures to address the entire spectrum of injury including epidemiology, prehospital care, definitive care, rehabilitation, research, and injury prevention. Significant progress has been made in these individual areas, including the evolution of the Emergency Medical Services (EMS) system, establishment of national standards for trauma centers, dramatic improvements in automobile safety, as well as a greatly expanded base of scientific knowledge in the areas of injury, shock, and resuscitation. The Injury Prevention and Control Center was established within the

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	Age Groups											
Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	All Ages	
1	Congenital Anomalies 4,758	Unintentional Injury 1,316	Unintentional Injury 746	Unintentional Injury 775	Unintentional Injury 11,619	Unintentional Injury 16,209	Unintentional Injury 15,354	Malignant Neoplasms 46,185	Malignant Neoplasms 113,324	Heart Disease 488,156	Heart Disease 611,105	
2	Short Cestation 4,202	Congenital Anomalies 476	Malignant Neoplasms 447	Malignant Neoplasms 448	Suicide 4,878	Suicide 6,348	Malignant Neoplasms 11,349	Heart Disease 35,167	Heart Disease 72,568	Malignant Neoplasms 407,558	Malignant Neoplasms 584,881	
3	Maternal Pregnancy Comp. 1,595	Homicide 337	Congenital Anomalies 179	Suicide 386	Homicide 4,329	Homicide 4,236	Heart Disease 10,341	Unintentional Injury 20,357	Unintentional Injury 17,057	Chronic Low-Respiratory Disease 127,194	Chronic Low-Respiratory Disease 149,205	
4	SIDS 1,563	Malignant Neoplasms 328	Homicide 125	Congenital Anomalies 161	Malignant Neoplasms 1,496	Malignant Neoplasms 3,673	Suicide 6,551	Liver Disease 8,785	Chronic Low-Respiratory Disease 15,942	Cerebrovascular 109,602	Unintentional Injury 130,557	
5	Unintentional Injury 1,156	Heart Disease 169	Chronic Low-Respiratory Disease 75	Homicide 152	Heart Disease 941	Heart Disease 3,258	Homicide 2,581	Suicide 8,621	Diabetes Mellitus 13,061	Alzheimer's Disease 83,786	Cerebrovascular 128,978	
6	Placenta Cord Membranes 953	Influenza & Pneumonia 102	Heart Disease 73	Heart Disease 100	Congenital Anomalies 362	Diabetes Mellitus 684	Liver Disease 2,491	Diabetes Mellitus 5,899	Liver Disease 11,951	Diabetes Mellitus 53,751	Alzheimer's Disease 84,767	
7	Bacterial Sepsis 578	Chronic Low-Respiratory Disease 64	Influenza & Pneumonia 67	Chronic Low-Respiratory Disease 80	Influenza & Pneumonia 197	Liver Disease 676	Diabetes Mellitus 1,952	Cerebrovascular 5,425	Cerebrovascular 11,364	Influenza & Pneumonia 48,031	Diabetes Mellitus 75,578	
8	Respiratory Distress 522	Septicemia 53	Cerebrovascular 41	Influenza & Pneumonia 61	Diabetes Mellitus 193	HIV 631	Cerebrovascular 1,687	Chronic Low-Respiratory Disease 4,619	Suicide 7,135	Unintentional Injury 45,942	Influenza & Pneumonia 56,979	
9	Circulatory System Disease 458	Benign Neoplasms 47	Septicemia 35	Cerebrovascular 48	Complicated Pregnancy 178	Cerebrovascular 508	HIV 1,246	Septicemia 2,445	Septicemia 5,345	Nephritis 39,080	Nephritis 47,112	
10	Neonatal Hemorrhage 389	Perinatal Period 45	Benign Neoplasms 34	Benign Neoplasms 31	Chronic Low-Respiratory Disease 155	Influenza & Pneumonia 449	Influenza & Pneumonia 881	HIV 2,378	Nephritis 4,947	Septicemia 28,815	Suicide 41,149	

Fig. 1.1 Leading causes of death in the United States, 2013 (Source: CDC WISQARS. http://webappa.cdc.gov/sas-web/ncipc/leadcaus10_us.html)

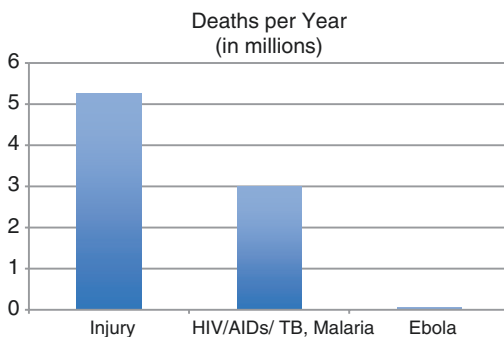


Fig. 1.2 The relative impact of injury [5, 46]

Centers for Disease Control and Prevention in 1985. These advances have been associated with substantially lower death rates from injury over the last 30 years (Fig. 1.3). Though there is significant evidence to demonstrate that coordination of these individual elements into a comprehensive system of trauma care leads to improved outcomes after injury [7–15], these data have not led to a broad implementation of trauma systems across the country [16, 17]. At the present time, systems for the provision of injury care remain a patchwork, dependent upon

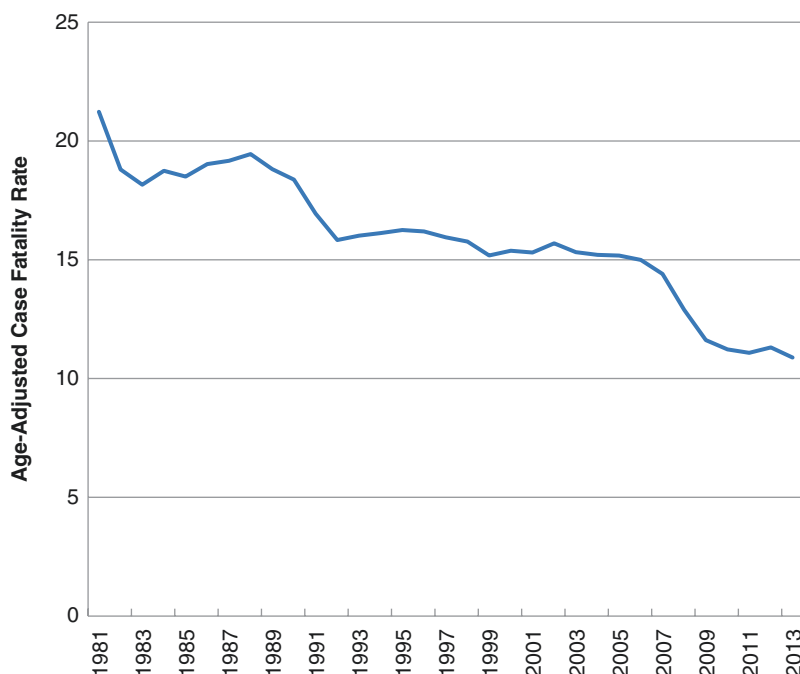
the degree to which state and local government has been inspired to address the problem and the extent to which volunteer efforts by engaged system stakeholders can drive improvement.

The sections that follow trace the historical evolution of the approach to injury care within the context of changing socioeconomic circumstances, the emergence of a set of essential elements that define a trauma system, and the integration of these elements into a functional design. The legislative and structural challenges to effective implementation of trauma systems will be discussed, and strategies of successful models will be explored with the objective of framing future efforts to expand the coverage of trauma systems throughout the nation.

1.2 The Process of Evolution

In the current age of highly technical and institution-based medical care, it is worth looking back to realize that it has not always been this way. At the start of the twentieth century, only a bit more than 100 years ago, the majority of

Fig. 1.3 Age-adjusted case fatality rate from motor vehicle incidents (Source: CDC WISQARS. http://www.cdc.gov/injury/wisqars/fatal_injury_reports.html)



health care was delivered in the home. Large hospitals existed primarily for the care of the indigent or casualties of war, a state of affairs that dated back to antiquity. Outside of the military, these hospitals were usually established and operated as private charities or as elements of social infrastructure funded through local government to care for the poor.¹ There was often little differentiation between the care of the sick and the housing of the poor and indigent, and many hospital facilities served both purposes. In either case, these facilities were places to be avoided by those with the means to do so. The sick and injured were cared for at home by their family, and “no gentleman...would have found himself in a hospital unless stricken by insanity or felled by epidemic or accident in a strange city” [18]. Based upon the care available and the associated high mortality, this conception of hospital care was well founded. Prior to the late nineteenth century, medicine had little to offer by way of curative therapy, and the hospital environment

itself often carried a great risk of death through infectious complications. Only with the rise of the Lister’s antisepsis, the bacterial theory of disease, and the expansion of surgical capabilities that followed did the balance shift. Hospitals began to take their current form as places that offer highly technical therapies well beyond what could be accomplished in the home and as places that offered the potential to cure.

Even though the development of the hospital was well under way in the early decades of the twentieth century, the concept of the modern trauma center is much newer. Through the 1950s, hospitals and hospital care were defined by the conquering of infectious diseases, the evolution of modern surgical techniques, and the progressive interdependence of the hospital and the academy of medicine, including training and research. In both the historical and the practical literature on hospital development from the mid-twentieth century, the care of the injured is a passing comment, if it is mentioned at all. Only since the late 1980s, with the development of national standards and the Trauma Center Verification program of the American College of Surgeons Committee on Trauma, has the idea of the modern trauma center become firmly

¹In fact, prior to the advent of Social Security in the 1930s, the provision of aid to needy populations was felt to be completely outside the Constitutional mandate of the Federal government.

established as a highly sophisticated institution that is focused on improving injury care through clinical excellence, teaching, and research.

The first hospitals to embody the concept that care of the injured should be an area of specialty and focus, recognizing the importance of this idea in improving outcomes, arose in the 1960s. Their roots were firmly in the traditional past of the public hospital. These hospitals were a refuge for the indigent sick by intent and the injured by necessity. They were also at the heart of medical education and research. Two hospitals among the first with organized trauma services were the Cook County Hospital [19] and San Francisco General Hospital, but the public hospitals in many US cities also functioned increasingly as centers for the care of the injured. Over the next decade, an expanding number of such facilities became known for their hard-earned trauma expertise. Initially the hospitals that could claim the title of “trauma center” were almost exclusively located in large urban areas with high rates of poverty and violence. Outside the sphere of influence of these centers, injury care remained haphazard, undertaken in the facility that happened to be the closest and by the practitioner who happened to be available. Injury care was largely a matter of chance, a situation that persisted well into the 1970s, and, it might be argued, persists to the present day. These chances could be improved if the patient, or those bringing the patient to the hospital, had the knowledge of the receiving hospital’s capabilities and the ability to choose their destination. The principle that injured patients fared better at a hospital experienced in trauma care was initially based upon the experience of the providers of direct patient care but has subsequently been upheld by objective data [20–22]. The fact that all hospitals are not created equal in terms of care of the injured has been well established, and it follows that one key element of establishing a system to improve care after injury is the ability to identify hospitals with the commitment to care for the injured and to verify their capabilities.

The next logical step in the process is to establish a way to ensure that injured patients are treated at the appropriate trauma center. Historically, patients literally applied for

admission to a hospital. The decision to admit was often made by the hospital board and weighed many factors beyond need for medical care [18]. Not all types of illness were admitted for treatment, nor were all socioeconomic groups. Even into the middle of the twentieth century, the mission of the hospital to care for certain diseases, including contagion and mental illness, was a topic of debate [23]. Patients presented themselves to the hospital either under their own power or with the assistance of friends and family. The first hospital-based ambulance system in the United States, providing a vehicle and a trained attendant to be summoned to transport patients to the hospital for care, was established by Bellevue Hospital, in New York City, in 1869. The system began with two horse-drawn vehicles, which were to be kept “in good order and fit for service at all times,” and presaged modern regulations regarding ambulance equipment lists by requiring that a box be kept beneath the driver’s seat containing among other things a quart flask of brandy and two tourniquets [24]. Ambulance systems soon appeared in other major cities, transitioning from horse to internal combustion engine in the early twentieth century. These systems focused primarily on getting the patient to the hospital rather than initiating care and did not evolve far beyond the provision of the most basic prehospital care until much later.

For the next 100 years, through the 1950s and 1960s, there was also little evolution in the standards regarding ambulance equipment or training of attendants. Because the focus of ambulances remained primarily that of transporting bodies, vehicles were designed for use interchangeably as ambulances and hearses, and mortuaries often functioned as ambulance agencies due to the interoperability of the vehicles. The principle that a modern network of Emergency Medical Services (EMS), with the expectation that properly equipped vehicles, manned by medically trained staff, would respond within minutes of a call as an essential public service, arose from recommendations made in the 1966 white paper *Accidental Death and Disability* and from the provisions of the Highway Safety Act of 1966 [25], which was enacted later the same year. This

act included provisions for funding as well as requirements that states take action or face penalties. Implementation was further accelerated by the passage of the 1973 Emergency Medical Services Systems Act [26], which established guidelines and provided funding for regional EMS development. With this stimulus, EMS systems rapidly developed and matured during the next 25 years of the twentieth century, coincident with the differentiation of hospitals into trauma centers. Combined with the recent wartime experience in Korea and Vietnam, which clearly demonstrated the advantages of rapid evacuation and early definitive treatment of casualties [27], it became increasingly apparent that coordination of field treatment and transportation to ensure that injured patients arrived at a capable trauma care facility was of critical importance, and the conception of a trauma system, as opposed to an isolated trauma center, began to evolve.

Initially, the concept of a trauma system was centered upon the large urban trauma centers, which established standards and protocols within their region, promulgated through their own EMS systems or through their relationship with EMS providers in the region. For hospitals with their own large EMS, or those with clearly pre-existing roles in the community, the destination hospital was preordained. It was common knowledge that serious injured patients were best cared for at the trauma center, even though there were no established rules or regulations directing the flow of ambulance traffic. The growing knowledge that outcomes for seriously injured patients were better in hospitals that had the experience and resources to care for them, combined with an increasing perception of the element of chance involved in unregulated choice of ambulance destination, led to the first efforts to coordinate the prehospital system to transport injured patients with the dedicated facilities that provided definitive care.

Drawing on the experience at the Cook County Hospital, the State of Illinois passed legislation establishing a statewide coordinated network of trauma centers in 1971 [28]. This statewide plan identified many of the terminologies and concepts that would come to be considered key ele-

ments of trauma system design, including the concept of an administrative lead agency to govern system operations, the identification of different levels of trauma hospital capability, the integration of EMS, and the role of process improvement. The first operational statewide trauma system was created with the establishment of the Maryland Institute for Emergency Medicine in 1973. The small size of the state of Maryland allowed for implementation of a system in which all severely injured patients within the state were transported by air to a single dedicated trauma facility. In the years that followed, similar efforts were made to establish cooperative networks of trauma centers that were connected by a coordinated EMS system and linked by shared quality improvement processes. These efforts were driven both by the Vietnam experience and by the finding that a large proportion of deaths after injury in non-trauma hospitals were due to injuries that could potentially have been better managed and controlled [29]. The implementation of such systems led to dramatic decreases in what was perceived to be “preventable death,” [7] as well as overall improvements in post-injury outcomes that were duplicated in widely varying geographic settings. Following the models established in Illinois and Maryland, these regional systems were founded upon the premise that all critically injured patients should be transported to a trauma center and that other acute care facilities within a region would be bypassed. Based upon the “exclusion” of non-designated hospitals from the care of the severely injured, this approach is frequently referred to as the exclusive model of trauma system design.

The exclusive model works well in urban and suburban settings, where there are sufficient trauma centers to provide access and to care for the expected number of injuries. Though often described as a regional system, an exclusive system functions as a funnel, not a network, and it does not utilize, let alone maximize, the resources of other health-care facilities within the region. This approach has the advantage of focusing patient volume and experience at the high-level centers and the disadvantage of leading to attenuation of skills in non-designated centers, with

resultant loss of flexibility and surge capacity. Paradoxically, because of the attrition of local resources, the model may serve to decrease access to competent care in larger geographical areas and in low-resource areas. In such circumstances, transport times to the trauma center may be very long, especially in periods of inclement weather when aeromedical transport cannot be used. Moreover, the volume of injuries seen may overtax the resources of the few available trauma centers, and the number and length of inter-facility transfers may place a severe burden on EMS resources. The only way to increase the depth of coverage within an exclusive system is to recruit or build additional trauma centers, which can be both expensive and politically difficult, given the complex set of drivers that lead a hospital to undertake the significant commitment to being a trauma center.

The limitations of the exclusive model, and the difficulties in deploying the model on a large scale, were experienced throughout the 1990s [30]. Despite evidence of the benefit of trauma systems, very few states and regions were able to establish a system as a matter of governmental policy, and fewer still were able to fulfill a set of eight criteria that had been proposed as cornerstones of exclusive system design [31]. This stagnation in system development arose in part due to the difficulties inherent in extending the exclusive system model and from a lack of public support for system finance and governing policy. In a broader sense, exclusive systems often lacked a truly integrative overarching structure that could tie together and build upon the significant gains achieved by the individual components in the trauma system universe. The 1999 Institute of Medicine report *Reducing the Burden of Injury: Advancing Prevention and Treatment* [32] helped to open the aperture through which injury care was perceived and identified five broad areas of focus for future development: improving coordination and collaboration between individual programs, strengthening capacity for research and practice, integrating the full spectrum the injury field, nurturing public awareness and support, and promoting informed policy making. In this context, the thrust of trauma system development

embraced a different paradigm: the inclusive model of trauma system design.

As the name suggests, the inclusive model involves the design of a system in which all health-care facilities within a region are involved with the care of injured patients, at a level commensurate with their commitment, capabilities, and resources. Ideally, through its regulations, rules, and interactions with EMS, the system functions to efficiently match an individual patient's needs with the most appropriate facility, based upon resources and proximity. Under this paradigm, the most severely injured would be immediately recognized and either transported directly or expeditiously transferred to the top-level trauma care facilities. At the same time, there would be sufficient local resources and expertise to facilitate the optimal management of the less severely injured, avoiding the risks and resource utilization incurred for transportation to a high-level facility whose resources were not truly needed. The basic concepts of the inclusive model were described in the 1992 *Model Trauma System Care Plan* [33] and refined in the 2006 *Model Trauma Systems Planning and Evaluation* [34] document, both published by the Health Resources and Services Administration of the US Department of Health and Human Services. Consistent with the findings of the 1999 IOM report, the 2006 *Model Trauma Systems Planning and Evaluation* document places the previously identified elements of trauma system function within an overarching public health framework, emphasizing the need to integrate the entire spectrum of injury care, from prevention through rehabilitation. The document also highlights the importance of coalition building at the grassroots level and of policy development and implementation at the governance level. The inclusive system model has been the primary guiding framework for systems development for the last 10 years.

Despite its relatively universal acceptance at the theoretical level, the inclusive model is often misconstrued and misapplied in practice, not as a system with global involvement of all facilities but as a *voluntary* system in which any hospital that wishes to participate is *included* at whatever level of participation they choose.

This approach fails to fulfill the primary goals of an inclusive trauma system that all resources in the region are involved and to ensure that the needs of the patient are the primary driver of resource utilization. An inclusive system does mean that all hospitals must participate in the system and be prepared to care for injured patients at a level commensurate with their resources and capacity, but it does not mean that hospitals are free to determine their level of participation based upon their own perceived best interest. Objectively assessed, the needs of the patient population served are the parameters that should determine the apportionment and utilization of system resources, including the level and geographic distribution of trauma centers within the system. When this maxim is forgotten, system function suffers, and problems of either inadequate access or oversupply can develop.

The implementation of a scheme for the distribution of system resources that is based solely on the needs of the patient population served can be fraught with conflict. While the potential for such conflict exists at all levels of resource allocation, it is often most prominent involving decisions around trauma center designation because these decisions often carry heavy political and financial consequences that extend well beyond matters of patient care. To heighten the challenge, these difficult policy implementation decisions are generally the responsibility of the lead agency governing the system, which is most often a relatively underfunded state or regional agency. In addition to lacking staff and resources, these agencies are most often led by political appointees and government employees who do not stay in a particular job for more than a few years at a time. These factors have the combined effect of limiting both the stability of institutional direction and the ability of agency leaders to take a strong stand in the face of opposition from large and well-funded health-care organizations. These challenges have proven the Achilles' heel of inclusive system development and have hampered their broad implementation, which continues to fall far short of a nationwide system for the care of the injured.

1.3 The New Era

The period of time from the 1980s through the early years of the twenty-first century saw the rise of the trauma center as a center of excellence, a place where injured patients had better care with demonstrably better outcomes, and the concomitant understanding that with such differences in care, all injured patients deserved to be treated at a trauma center. At the same time, major changes in health-care finance in the age of managed care and managed competition increased the financial pressure on hospitals, especially those caring for the most severely ill patients and those patients with insufficient funding. At a time when the system-based approaches to trauma care were trying to grow, and there was a need for more high-level trauma centers, the economic pressures on hospitals made trauma care an undesirable mission, one that could lead to financial ruin. The 1990s saw a rising tide of trauma center closings and contractions, even involving some of the iconic public hospitals and foundational trauma centers. One study reported that while 60 trauma centers closed between 1981 and 1991, over 300 closed between 1990 and 2005 [35]. The same study identified that, not surprisingly, financial pressures were one of the chief risk factors for trauma center closure.

The crisis atmosphere engendered by the real and threatened loss of trauma care capacity led many regions to develop methods of funding support to assist trauma centers in their care mission. In the first years of the twenty-first century, the decline of managed care and managed competition, a nationwide decrease in levels of interpersonal violence, and other changes in the climate of health-care finance combined to create a sea change in the financial attractiveness of providing care for the injured in many geographic regions. Hospitals began to look upon the care of the injured population not as a burden to be shifted but as a potentially profitable line of business to be actively sought after.

Somewhere in the first 5 years of the twenty-first century, the balance of forces shifted to the point that the number of hospitals claiming trauma center status was larger than the number

of traditional trauma centers threatened with closure. According to self-designation data collected annually by the American Hospital Association [36], in the year 2000, 258 (6.1%) of hospitals reported having a level I trauma center. In 2010 the number had risen to 387 (9.4%), and in 2013 there were 416 hospitals claiming level I trauma center status. This data is concordant with that collected by the Trauma Center Verification Review and Consultation program of the American College of Surgeons Committee on Trauma, which reports a similar increase in verified trauma centers, rising from 208 in 2005 to 430 in 2014, with level I centers rising from 81 to 120 over the same period. This new economic climate, while having the benefit of increasing the number of participants in the inclusive trauma system, has done so at the cost of a major redistribution in the way resources and patients are deployed. Not surprisingly, the largest number of new trauma centers arose not in the major urban areas, which remain relatively poor and where trauma center closings remain a concern, but in more affluent suburban areas. These new centers can encircle the pre-existing centers and decrease their patient volumes, as well as cutting into government incentives intended to stabilize those pre-existing centers. Increasingly, providing care for the population of patients suffering injuries as a result of motor vehicle crashes, falls, or other accidents could be a profitable undertaking, especially if the patients with the highest level of acuity could still be transferred to larger traditional centers, avoiding the financial risks associated with handling complex cases, with associated high resource utilization, under current strategies implemented to control health-care costs. As a result, established centers find themselves once again facing an unpredictable economic future, and decisions around the designation of new trauma centers in many geographical areas have become increasingly contentious. This trend may well result in decreased access to trauma center resources for highly vulnerable populations [37], despite larger overall numbers of centers.

This new era, in which the concern has shifted from trauma center closings to trauma center

“propagation,” carries with it a new set of challenges. These challenges cut to the very core of many unique elements that drive the social and political philosophy of the United States and have clearly placed the determination of need for a new trauma center as much in the political arena as the scientific one. In the political climate of the second decade of the twenty-first century, governments have been generally unwilling to regulate free markets, including health care. Yet Adam Smith’s “invisible hand” of the marketplace is not likely to provide wise guidance for the development of a sustainable network for the care of the injured, which is arguably a central feature of the social structure. Recent history has demonstrated that changes in economic factors can easily lead hospitals to exit the trauma “market” regardless of the burden of injury within the population and that the commoditization of trauma care has the potential to disrupt stable access to trauma care across the board. The current debate over “trauma deserts” [38] identified in the city of Chicago, the most prominent of which has at its center a large and capable hospital that closed its trauma center in the late 1980s, brings the issue of the potential conflict between public service and economic performance into sharp relief.

Ultimately, the model of the inclusive trauma system has been well developed, and there is substantial evidence to show the efficacy of these systems in improving outcomes after injury, but it is undeniable that inclusive systems are difficult to develop, finance, operate, and sustain. The system has a scale and function that undeniably places it in the realm of an essential element of the public service sector, yet it operates primarily within the private sector, the largely market-driven world of health-care delivery. In most areas, the public health elements of the trauma system are not well recognized and not well funded within the governmental bureaucracy of the state or region. This infrastructure has been increasingly challenged to find funding for many other critical social elements, including the overall provision of health care itself. If trauma system development is to proceed, these barriers must be identified and overcome.

1.3.1 Optimal Design Elements

The functional development of trauma systems has paralleled an evolving understanding of the problem of injury. Trauma centers and the coordinated EMS systems that bring patients to them began as a reactive element; trauma was seen as a sporadic event, an “accident” that could not be prevented or predicted. The best a system of care could do was to be very efficient in delivering care to those affected. Early system advances were logically driven by the frontline care providers, whether in the field or the hospital, and resulted in substantial improvements in outcome for the injured. Increasing sophistication in the acute care of the injured also highlighted the fact that most injury mortality occurs at the scene, prior to any intervention, and can never be addressed by post-injury treatment, no matter how well optimized. This realization, as well as a deepening body of research on the causes and mechanisms of injury, illustrated the need to focus efforts on prevention of injury if further progress was to be made.

This evolution of understanding is analogous to the course of historical progress made in the treatment of epidemic diseases and the development of modern public health systems, an observation not lost on those involved with trauma system development. If injury is viewed not as a sporadic event but as an *epidemic*, it is a logical next step to apply well-proven principles of public health that have been so successful in the management of infectious epidemic diseases to the broader problem of injury. This concept was at the heart of the 2006 *Model Trauma Systems Planning and Evaluation* document, which adopted the public health framework developed by the CDC.

The CDC framework builds upon the 1988 Institute of Medicine report *The Future of Public Health* [39], which proposed that there were three core functions of public health agencies: assessment, policy development, and assurance. The report placed the primary responsibility for public health on the state. It recommended that the federal government function to establish nationwide objectives and provide technical

assistance and funding to strengthen state capacity while at the same time assuring “actions and services that are in the public interest of the entire nation [39].” This basic framework was further expanded by the 1994 Core Public Health Steering Committee into ten essential services, represented graphically in relation to the three IOM core functions in Fig. 1.4. This framework was applied, utilizing functional elements felt to be critical from experience in trauma systems, to create an injury-specific diagram of essential services that was put forward in the *Model Trauma Systems Planning and Evaluation* document (shown in Fig. 1.5). The public health structure is a good model to use for setting the structure and outlining what we need from a trauma system from a high-level strategic perspective. It is based upon broad principles that are global in application and as a result provides a working framework that is largely independent of specific circumstances.

The challenge of the public health model for trauma system development, like the larger public health model from which it is derived, is that it offers no tactical advice as to how the specific goals are to be achieved. Further, the high degree of variability in geography, resource availability, and political climate across the country requires that any such implementation be context dependent and thus tailored to specific local circumstances. There is no global approach or proven framework to assist in pulling the elements of a trauma system together. Further, the federal government has not taken up the role outlined by the Institute of Medicine of assuring “actions and services that are in the public interest of the entire nation.”

In this evolution to an expanded public health model, the approach to trauma care has grown far beyond the frontline providers of emergency care and into a complex and interconnected entity that touches on a large group of people distributed across many professions, some far removed from direct health care. This multidisciplinary and integrative process brings together groups who approach the problem of injury in fundamentally different ways, melding the epidemiologists, the statisticians, and the regulators, all of whom

Fig. 1.4 The CDC model of public health: the ten essential functions and their relationship to the three goals defined by the IOM [33]

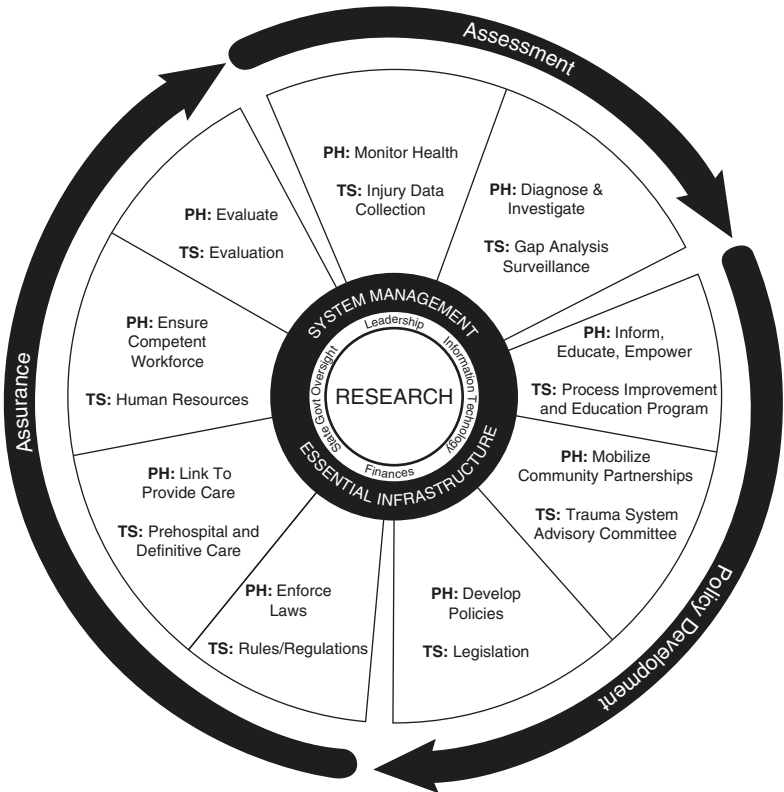
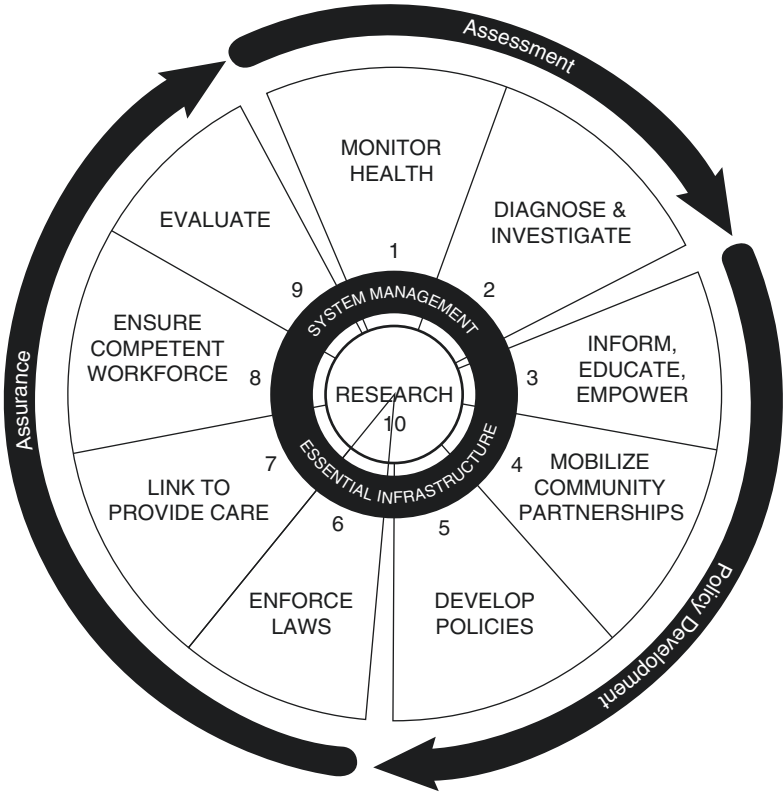


Fig. 1.5 The public health model of trauma system design [33]

manage problems at a broad population level, with the clinicians and other providers in acute care and rehabilitation, who approach the problem from the level of the individual patient. The development and maintenance of such a coalition is a considerable project, as is the governance and leadership necessary to ensure its longevity, sustainability, and success. These factors alone would be sufficient to make trauma system development a long and arduous process.

The funding mechanisms for trauma systems and trauma care are equally complex and in many cases work to make the problem of cooperative system development event more difficult. Elements of the trauma system that address the larger population-based issues of epidemiology, prevention, and governance have most frequently arisen from governmental agencies already working in more traditional public health arenas. These agencies are often relatively poorly funded and have been even more vulnerable in difficult economic times. As a result, resources are chronically scarce, and efforts are often divided across a number of different project areas. Further, the time frame for progress is on a longer scale and considers data and trends longitudinally. Those collecting and analyzing the data are often far removed from the front lines of patient care and the individual patient perspective. Thus, the problem of injury has not often been uniformly enough of a priority within the public health bureaucracy.

In contrast, direct patient care after injury is funded through the health-care delivery system and has been subject to the variations in the health-care market, payer reform, and efforts toward cost containment. The expenditures are generally orders of magnitude larger than those seen for the more population-based functions and typically funded through a combination of government benefits and private insurance. The work in direct patient care follows a much shorter time frame, as the episodes of care typically extend over days and weeks, rather than years. Frontline providers work almost exclusively at the level of the individual patient and rarely see the problem of injury framed in the context of population health or overall health-care costs. This relatively narrow focus often limits the

degree to which frontline care providers become involved in the broader area of policy development and implementation around the problem of injury across its full spectrum.

This differential in both funding and focus, between the public health and direct patient care sectors, is a major challenge to the cohesion of trauma systems. While trauma centers and EMS agencies deal in millions of dollars, most of which are external to the governance of a trauma system, the necessary elements of infrastructure that form the essential glue binding the system together are often sacrificed to lean governmental budgets at the state level. Thus, in many systems, the medical elements are fairly well developed at the level of the individual center or small cooperative network, while development has stalled at the level of system integration, large-scale prevention, and quality assurance because there are insufficient resources to carry out these large-scale system tasks on a daily basis. The situation is perpetuated by a lack of public understanding of the need and resultant inability to mobilize legislation that produces structural change. This is the impasse that most regional trauma systems face in the second decade of the twenty-first century. There are a few systems that have been able to allocate and preserve the critical infrastructure needed to administer the system and continue to grow, but most have not.

1.4 Barriers to Implementation

Given a general acceptance of the primary elements that make up a trauma system, and the previously cited evidence of their effectiveness in improving the care of the injured, it is perplexing that trauma system development remains so haphazard and inconsistent, raising the question of why trauma systems have not really caught on. A significant component is undoubtedly the nature and perception of injury among the general population and, even more importantly for trauma system development, the role of post-injury care in modulating that risk. From a psychological perspective, studies suggest that individual estimates of risk are inaccurate, tending to overestimate more sensational and

dramatic causes [40], leading individuals to rate the risks of injury lower than what they actually are. Moreover, media coverage is highly influential on societal perception of risk [41] and hence supports for policies to reduce that risk [42, 43]. Media coverage that addresses injury is generally focused on the event and its immediate aftermath, with relatively little coverage of the availability and impact of post-injury care or celebration of trauma survivors, in direct contrast to disease entities such as cancer, in which the opposite is generally true. These elements combine to lessen public awareness of the personal risks of injury and impact of trauma care. Data show that over half of those surveyed did not know that injury was the leading cause of death in the first decades of life and that though the public generally supports the concept of trauma care, most believe it to be already in place [44].

Another significant element in the complexity of trauma system development and implementation lies in the multifaceted nature of trauma systems. By their very nature, trauma systems involve a large number of people and agencies, each with their own focus and expertise and each with unique and sometimes divergent culture, objective, and focus. This reality puts the design and operation of a trauma system beyond the purview of one single professional group or single sector of the trauma care spectrum; an effective solution requires the creation and maintenance of a broad coalition. It further establishes the need for a neutral governance process that can balance competing priorities while keeping the needs of the population served as the guiding principle. Finally, it can be argued that a system of care for the injured, for that matter, a system of health care in general, is part of the essential network of public services provided by government. These considerations place a large portion of trauma system development firmly in the governmental, and hence the political and legislative, arena. This is especially true with decisions mediating complex issues of resource allocation, financial support, and governance. In this arena, scientific arguments alone are insufficient to make the case, and the problem of injury has rarely held public attention in a way that has engendered decisive politi-

cal action. In the complex interplay of the political process, market forces, and patient needs, it has proven impossible for most regions to achieve public policy support and significant stable funding. Without these elements, systems struggle to make consistent and lasting progress in trauma system implementation beyond a level that can be sustained by the largely volunteer efforts of system stakeholders who share the mission.

The nature of health care, and particularly the nature of injury care, presents a particularly difficult challenge within the context of the socioeconomic structure of the United States. A majority of US citizens will endorse the concept of emergency care for the sick and injured as a fundamental human necessity, and that the provision of such care is a vital function of society. This concept dates back to the founding principles for the original public hospitals and gained increasing prominence in US policy through the mid-twentieth century, reaching a peak with the establishment of the Medicare and Medicaid programs in the 1960s. The momentum was focused on the problem of road traffic accidents during the Kennedy administration and carried over to the care of the injured with the publication of *Accidental Death and Disability* and the subsequent burst of progress in EMS and trauma system development that it enabled.

The era of strong public support, and thus of federal support, came to an end in the last decades of the twentieth century, as policy turned more toward deregulation, limited government, and the culture of individual financial responsibility that characterized the 1980s and 1990s. In this setting, the model of the large publically financed hospital providing care for those in need became largely untenable, and most city and county governments have divested themselves of this responsibility or operate their health-care facilities on increasingly austere budgets. Private hospitals have been forced to assume an increasing share of the care for patients with little or no funding, while insurers have exerted intense downward pressure on payments. Health-care facilities have become increasingly competitive for patients with a funding source and face increasing risk in providing care for those who do

not. Injury care can be either a catastrophic loss or a significant profit, depending upon the population treated and the severity of injury encountered.

As a result, health care today is characterized by intense competition between health-care systems and health-care providers, driven by economic forces that create a focus on individual patient encounters rather than the broad provision of emergency care to the population as a whole. The result is an atmosphere that is highly disruptive to the coalition building and cooperation necessary in a public health-based trauma system model. The implementation of the ACA contains financial incentives for health-care systems to think more broadly in terms of “population health,” but these incentives may not have a beneficial effect on trauma care, as the populations referred to are actually small diagnosis or disease-based groups rather than the entire population at risk of injury. Moreover, the uncertainty created by widely variant projections of the true financial impact of the ACA has led to further cost-cutting measures on the part of health-care systems and increased economic pressures that work to make trauma system development more difficult.

This situation is compounded by the national trend toward decreased social services and minimization of government intervention that leaves most state legislatures and state bureaucracies unwilling to take a strong position in establishing standards and regulations governing emergency medical care. With no stabilizing authority to intervene, health-care facilities may engage injury care in areas where it is profitable, while abandoning injury care in others that are less so. The result is a maldistribution of resources, leading either to lack of access as described above or to an oversupply with duplication of efforts, resources, and increased cost to the region as a whole.

1.5 The Road Ahead

The challenges to trauma system development are substantial, but not insurmountable. Several regions, usually of smaller geographic scale,

have created successful and sustainable trauma systems, despite economic and political challenges. The single most important factor in these regions has been the crystallization of a focused political effort resulting in strong governing policy, both in the establishment of authority for operations and in the financing of critical system infrastructure. The difficulty in generalizing these successful models lies in the inherently unique local factors that tipped the political scale to the side of decisive action. In some circumstances, the impetus has arisen from successful grassroots efforts to raise public interest and awareness, which drive legislative action; while in others, the progress has been driven because of a focused interest in the executive branch. In either circumstance, the essential turning point has been in finding the political will to create policy that provides some objective authority over the resources necessary for the care of the injured and for that matter all patients with emergency or “unscheduled” illness, in order to ensure availability and access, but without a degree of governmental control that some factions with current society find unacceptable. The other key element of successful solutions has been in the ability to find stable funding for essential trauma system infrastructure, in order to support system oversight, quality improvement, and day-to-day operations. Efforts that focus solely on supporting trauma centers for underfunded care often result in adverse incentives for overall system development.

The Affordable Care Act (ACA) will certainly change the balance of forces and dynamics affecting trauma systems. However, it is difficult to predict in which direction, as some elements within provisions of the Act stand to increase funding available for trauma care, while others remove existing funding streams; and both of these elements occur in a setting intended to decrease overall expenditures for health care. Although as yet there has been no grassroots support or political agenda sufficient to drive a policy-level solution to the nationwide problem of uniform systems for trauma care, the ACA and the tools being used in its implementation do

contain some elements that may prove to be useful in this arena. In a recent perspective paper, Sylvia Burwell, the US Secretary of Health and Human Services, outlined three strategies that will be used to guide reform of the health-care payment system under the ACA [45]. The first strategic area centers on creating incentives to provide value-based care that center on alternate payment models, including the potential for shared responsibility for a particular patient group, both among providers and among health-care facilities. The second focuses on the integration of facilities and coordination of health-care efforts with an emphasis on population health. Both of these areas have the potential to provide financial incentives and a financial basis for the development of truly sustainable and effective systems of care. This is a stark contrast to the current fee-for-services models, which are most often a strong disincentive to cooperative regional systems.

The primary challenge to these options lies in the way the word *population* is generally understood in the world of accountable care organizations and bundled payment, where the concept of *population* referred to is in fact a subgroup of patients with a specific disease process (e.g., diabetics or patients with heart disease), rather the entire population of the region, who are all at risk for injury. Payment reforms have potential to provide a strong impetus to drive regionalization of emergency care, if they are implemented in a way that either coalesces the health-care market to large integrated systems with such broad coverage that there is a financial incentive to provide efficient injury care for the entire regional population or if similar pressures create an environment in which the major health-care providers within a region have a financial incentive to cooperate and to decrease duplication of expensive efforts. Any change in the pattern of health-care funding, away from current competitive fee-for-service structures that focus on individual patient encounters toward mechanisms that incentivize a population-based approach, will greatly aid the normative commitment to progress toward public health centered trauma systems.

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2.1 Historical Management of Injury

Trauma surgery is just general surgery, but faster and under blood. – Anonymous

As the majority of trauma resuscitation and operation was historically performed by general surgeons, the practice of trauma and surgical critical care developed slowly as a general surgical subspecialty by those with special interest in this patient population. Surgical procedures for injury care, therefore, have been based entirely on elective general surgical procedures. Hence, injury to the stomach would receive an operative approach similar to that of a perforated ulcer. This was gradually modified by war experiences. Patients from the war zone generally had massive

destructive wounds, and there was also delay to definitive care. This resulted in the development of novel operative techniques for trauma, such as pyloric exclusion and distal rectal washout, some of which have stood the test of time and some of which have not.

2.2 Failure of a General Surgical Approach in Trauma

The operation was a success but the patient died anyway. – Anonymous

Since general surgeons have long been trained to identify and repair operatively any diagnosed injury or disease, prolonged operative procedures for definitive repair were the norm. Patients who bleed during elective operative procedures either have control maneuvers instituted prior to the vascular incision as in vascular surgery or rapid pressure or clamp control of inadvertent vascular injury during a case. Additionally, hemorrhage nearly always occurs only moments before control is achieved when the patient is already in an operating suite, draped, and in many cases already open.

This is radically different from the physiologic pattern in trauma patients who are injured minutes to hours prior to arriving in the operating room and hence have been bleeding for an extended period of time prior to instituting surgical control. Additionally, this bleeding results in

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difficulty in obtaining rapid surgical control by obscuring the operative field and tissue planes. Similarly, intestinal contamination, ongoing prior to operative control, results in an increased degree of contamination by virtue of both the length of contamination time and the high energy of intestinal content distribution.

Finally, elective general surgeons usually have time and information, such as imaging and history, to allow planning for operative procedures, even if only during the brief initial workup. In contrast, surgeons faced with a trauma patient do not know what disease process they will find on opening, even when guided by a CT scan, resulting in further delay in control while determining injuries. Moreover, these patients are more likely to be unstable and/or unresponsive, resulting in less information and time for operative planning.

Taken in their entirety, these factors – delay in operative presentation, unknown pathology at the start of operation, difficult and delayed control of hemorrhage, and contamination – result in a major difference between general surgical and trauma patients. This is the concept of physiologic exhaustion that is found commonly in traumatized patients and occasionally in emergency general surgical patients. While elective general surgical patients should be fully evaluated and optimized before surgery, and emergency general surgical patients should be briefly “tuned-up” prior to surgery with fluid boluses, blood, and/or antibiotics, many trauma patients cannot wait even minutes for operative intervention due to extreme instability. These patients do not have any physiologic reserve and arrive in the OR in extremis. They may not tolerate the time under anesthesia needed to complete a full operative exploration and repair. Hence, using traditional approaches, these patients died either on the table during the course of their operation or shortly thereafter, due to ongoing nonmechanical bleeding, usually from coagulopathy or from subsequent multisystem organ failure. The underpinning for damage control is that the patient is incapable of undergoing a traditional operative approach due to physiological exhaustion and thus needs an abbreviated initial operation controlling only hemorrhage and contamination to expedite the aggressive resuscitation in the intensive care unit.

2.3 The Development of the Abbreviated Laparotomy

He who fights and runs away, may live to fight another day. – JA Aulls, 1876

Gradually, changes in the operative approach toward this group of extremely ill trauma patients began to be discussed and published in the literature. Stone and colleagues were the first to describe aborting a laparotomy by the use of abdominal packing when intraoperative coagulopathy developed [1]. This report was published in 1983. Several subsequent reports of this technique, specifically for hepatic injury, and then a large series showing survival advantage by Burch and colleagues followed [2]. Unfortunately, adoption of this technique was slow and in some cases was deemed a failure to finish operating or an attempt to shift work to another time.

The next iteration of this technique by Rotondo and colleagues resulted in renaming this care pattern “Damage Control” [3]. It should be noted that despite the name, derived from the navy ship damage management, this was a civilian trauma development rather than military. The “Damage Control” sequence was defined. Since then, and with a new name, the technique has become increasingly accepted and has resulted in undoubted decreases in mortality.

2.4 Basic Tenants of Damage Control

2.4.1 Damage Control Part 0: Rapid Transport to Definitive Care

A crucial part of salvage in the selected extremely unstable trauma patients is the rapid transportation to a center capable of providing definitive care. The most direct method of transportation with the fewest delays in transitional facilities is necessary to maximize survival [4]. During this period, judicious resuscitation should be under

way. The traditional approach of normalizing vital signs in patients with prolonged transport times is inadvisable. Permissive hypotension, resuscitating patients to goal systolic pressure of approximately 90 mmHg with concomitant signs of end-organ perfusion, allows for adequate tissue perfusion while decreasing the potential for clot disruption from increased hydrostatic pressures. For patients who present with injury complexes generally leading to hemodynamic instability or those who exhibit instability, this approach should be extended in the trauma resuscitation area at the trauma center where Damage Control Resuscitation (blood-plasma-platelets), limiting crystalloids and utilizing goal-directed hemostatic resuscitation, is preferred. Damage Control Resuscitation, the details of which are covered in subsequent chapters of this text, complements the Damage Control Surgery Concept, and when utilized together, mortality can be significantly reduced.

2.4.2 Damage Control Part 1: Rapid Control of Hemorrhage and Contamination

Operative intervention is focused on full exposure and rapid hemorrhage control. For major hepatic injury, packing is optimal, though multiple other more time-consuming methods may be necessary. Major vascular injury that cannot be safely treated by ligation can be considered for vascular shunting. However, ongoing arterial bleeding, whether in a viscera or cavity, will not be controlled by packing alone – surgical control is required. Intestinal contamination should be controlled by whipstitch, intestinal ligation, or stapling. No attempts at formal resection are undertaken, and the intestine is left discontinuous. Details of management of specific organs are found in further chapters. The abdomen is closed by one of many quick temporary methods. The entire operative intervention should take about 1 h and certainly no longer than 90 min. Effective utilization of Damage Control Resuscitation may indeed extend this window of operative intervention.

2.4.3 Damage Control Part 2: Resuscitation

Once out of the operating room, attention is turned to full resuscitation in the intensive care unit. Coagulopathy, anemia, acidosis, electrolyte abnormalities, and hypothermia should be aggressively corrected. Normalization of physiology is an indication to return for definitive operative care and is usually accomplished in 24–36 h. With the advent and effective use of Damage Control Resuscitation techniques, the frequency and degree of physiologic perturbation is decreasing, and the time to normalization is reduced.

However, patients who fail to improve or have subsequent worsening of parameters must be considered as having either ongoing bleeding or a missed injury. These patients are returned to the operating room as an emergency for another look, which should be thought of as a return to Damage Control Part 1, with limited goals of hemorrhage control, identification of injury, and prevention of ongoing contamination. In some patients, several cycles through Damage Control Parts 1 and 2 may be necessary.

2.4.4 Damage Control Part 3: Return for Completion of Operative Repairs

When fully resuscitated and physiologically normalized, patients will tolerate a second surgical insult and longer operative times. They are then returned to the operating room for unpacking, second look, and definitive management of injuries. During this operation, all injuries should be clearly identified and repaired, including recreation of intestinal continuity. The luxury of the second look as well as potential difficulties with abdominal wall closure has led to an increase in primary anastomosis for colonic injuries, with good results. Feeding access should be considered in all of these patients. About half of this selected population will be able to tolerate primary fascial closure during this operation. The remainder is managed with sequential closure methods, primary allograft closure, or granulation and skin grafting (Figs. 2.1 and 2.2).