The Canadian Forces trauma care system

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According to the Trauma Association of Canada, a trauma system is a preplanned, organized and coordinated injury-control effort in a defined geographic area. An effective trauma system engages in comprehensive injury surveillance and prevention programs; delivers trauma care from the time of injury to recovery; engages in research, training and performance improvement; and establishes linkages with an all-hazards emergency preparedness program. To support Canada's combat mission in Afghanistan, the Canadian Forces (CF) developed a comprehensive trauma system based around its trauma hospital — the Role 3 Multinational Medical Unit (R3MMU) at Kandahar Airfield. This article reviews the essential components of a modern trauma system, outlines the evidence that trauma systems improve care to injury victims and describes how the current CF trauma system was developed.

Selon l'Association canadienne de traumatologie, un système de traumatologie consiste en un effort organisé, coordonné et planifié d'avance de surveillance et de prise en charge des blessures dans une région géographique donnée. Un système de traumatologie efficace comprend des programmes exhaustifs de surveillance et de prévention des blessures, s'occupe des traumatisés du moment de la blessure jusqu'au rétablissement, fait de la recherche et offre de la formation, s'efforce d'améliorer continuellement son rendement et entretient des liens avec tous les programmes de protection civile et d'intervention d'urgence. Pour appuyer la mission de combat du Canada en Afghanistan, les Forces canadiennes (FC) ont mis en place un système exhaustif de traumatologie basé à son hôpital de traumatologie — l'Unité médicale multinationale de rôle 3 au Terrain d'aviation de Kandahar. Cet article passe en revue les éléments essentiels d'un système moderne de traumatologie, présente brièvement des données démontrant que les systèmes de traumatologie améliorent les soins aux blessés et décrit les étapes du développement du système actuel de traumatologie des FC.

The mission of the Canadian Forces Health Services (CFHS) is to provide full-spectrum, high-quality health services to Canada's fighting forces wherever they serve.[1] This obligation dates back to the Constitution Act of 1867, which assigned sole responsibility of all military matters, including health care, to the federal government.[2] As a result, the Canadian Army Medical Corps (CAMC) was formed in July 1904 and initially consisted of 8 physicians and 36 orderlies.[3] The CAMC expanded substantially during the 2 world wars and again during the Korean War. At its peak, the CAMC consisted of almost 35 000 military health care providers who cared for about 84 000 Canadian soldiers.[3] The CAMC became the Canadian Forces Medical Services in 1959; in 1995 it united with the Dental Services under the Surgeon General as the CFHS.[3]

Canada's combat engagement in Afghanistan, which just ended this past summer, was the largest Canadian military undertaking abroad since the Korean War.[4] In addition, this mission represented the largest deployment of CFHS personnel and equipment since the Korean War.[5] The CFHS deployed almost 200 of its personnel with each successive rotation to provide seamless, continuous care for Canadian Forces (CF) members from point of injury (or illness) in Afghanistan to rehabilitative care back in Canada.

To fulfill its mission in Afghanistan, the CFHS had to overcome significant challenges. Defense budget cutbacks dating back to the mid-1990s seriously reduced available CFHS resources and personnel from levels maintained during the Korean War and Cold War era: 3 of 6 CF hospitals were closed within 2 years, and the number of military health care providers was reduced from

3000 to 2400.[3] Furthermore, trauma care had become increasingly complex and centred on highly specialized trauma systems, hospitals and practitioners that were not a normal part of the Canadian military health care system.[5] Despite these challenges, to support the combat mission in Afghanistan, the CFHS developed a comprehensive trauma system based around its trauma hospital — the Role 3 Multinational Medical Unit (R3MMU) at Kandahar Airfield. The hospital developed a reputation for providing outstanding care, and CF members have taken comfort in the motto "If you arrive alive, you will leave alive."[6]

This article reviews the essential components of a modern trauma system and outlines the evidence that comprehensive trauma systems improve care to injury victims. It then traces the genesis of the current CF trauma system. Although the CF combat mission in Afghanistan has ended, this article argues why the established trauma system should continue to be the basis for providing medical/trauma support to CF members deployed on future missions.

Trauma systems

Trauma system definition

According to the Trauma Association of Canada, a trauma system is a preplanned, organized and coordinated injury-control effort in a defined geographic area that functions to

- engage in comprehensive injury surveillance and prevention programs;
- deliver trauma care from the time of injury to recovery, including
  - immediate access to emergency medical services;
  - rapid transport to appropriate level of care;
  - acute services, including resuscitation, surgery, critical care and specialty services; and
  - rehabilitation and reintegration into the community and workforce;
- engage in research, training and performance improvement; and
- establish linkages with an all-hazards emergency preparedness program.[7]

It is important to appreciate that a trauma hospital does not constitute the trauma system, which is a coordinated, multiagency collaboration. A comprehensive and fully inclusive system will have administrative, surveillance, prevention, clinical, training and research elements working in unison.[7] Each clinical component is a vital link in a chain ensuring that patients move quickly and safely along the continuum of care. The nonclinical components are required to enable and improve the system, and they provide a broad injury-control perspective.

Trauma systems and mortality

Trauma systems reduce mortality among injury victims. Nathens and colleagues[8] studied the effect of implementing organized systems of trauma care across the United Sates from 1979 to 1995 on mortality associated with motor vehicle crashes. They found that mortality was reduced by 8% after adjusting for possible confounders, including other secular trends in crash mortality. Likewise, Shackford and colleagues[9] reported a greater than 50% reduction in the proportion of deaths deemed potentially preventable before and after trauma system development. More recently, Mullins and colleagues[10] evaluated the outcome of hospitalized patients after the organization of trauma care in Oregon and found a 35% reduction in mortality within 2 years after implementation.

One key reason that trauma systems may reduce mortality is that the risk of death is significantly lower when care is provided in a trauma centre than in a nontrauma centre. MacKenzie and colleagues[11] compared mortality among patients treated in 18 trauma centres and 51 other hospitals (nontrauma centres) and found that the overall risk of death was 25% lower when care was provided at a trauma centre than when it was provided at a nontrauma centre. Birkmeyer and colleagues[12] showed that patients of high-volume surgeons who had greater clinical experience had lower death rates for certain types of major surgery than patients whose surgeons performed these surgeries less frequently; therefore, the association between trauma centre volumes and mortality may, in part, be mediated by surgeon volumes. In effect, the old adage "practice makes perfect" likely applies to trauma surgeons and the survival of their patients. Other critical factors might include perioperative processes, such as consultant availability; laboratory and blood-banking services; and intensive, respiratory and nursing care.[13]

Another reason why trauma systems may reduce mortality is that they include performance-improvement programs to systematically assess quality of care and reduce the number of preventable deaths. An Institute of Medicine report stated that medical errors cause between 44 000 and 98 000 deaths every year in American hospitals.[14] Trauma care creates a "perfect storm" for medical errors: unstable patients, incomplete histories, time-critical decisions, concurrent tasks and involvement of many different medical disciplines.[15] Implementation of a regional trauma system, however, has been shown to dramatically reduce the rate of preventable trauma deaths owing to critical errors from more than 10% to less than 5% of all deaths.[16]

The US military trauma system: Joint Theatre Trauma System

The US Department of Defence has recognized the importance of trauma systems to improving its soldiers' chances of surviving combat-related injuries. Therefore, the joint military forces of the United States initiated the development of a theatre trauma system, the Joint Theatre

Trauma System (JTTS), in May 2004. Formal implementation of the system occurred in November 2004 through the collaborative effort of the Surgeons General of the US military, the United States Army Institute of Surgical Research and the American College of Surgeons.[17]

The clinical components of this trauma system can be classified into 5 different levels. Each echelon of care provides progressively more advanced care than the next.[18] After injury in Afghanistan or Iraq, US soldiers are first treated by combat medics who are integral to each fighting unit; this is Level 1 care, which provides immediate first aid (Tactical Combat Casualty Care) at the front line. Level 2 care consists of surgical resuscitation provided by highly mobile forward surgical teams that directly support combatant units in the field; these teams surgically stop hemorrhage or other life-threatening problems but do not provide definitive care. Level 3 care is provided through combat support hospitals — large facilities that take time to become fully operational but offer much more advanced medical, surgical and trauma care. They are similar to a civilian trauma centre. Level 4 care is the first echelon at which definitive surgical management is provided outside the combat zone. For the US Central Command, the Level 4 facility is Landstuhl Regional Medical Centre (LRMC) in Germany.[19] Level 5 care is provided at one of the major military centres in the United States, where definitive reconstruction and rehabilitation are performed. All of these clinical components predate the establishment of the JTTS.

Another integral clinical component of the JTTS is its aeromedevac capability. After Level 1 care, injured US soldiers are generally transported by helicopter to Level 2 and/or Level 3 care. Depending on the tactical situation, formation-level medevac helicopters or combat search and rescue units are employed for this role.[20] After Level 3 care, the US Air Critical Care Air Transport (CCAT) teams are used to move patients through the system. A CCAT team is able to care for up to 6 critically injured patients in flight. Each team consists of a critical care physician, an intensive care unit (ICU)-qualified nurse and a respiratory therapist as well as the equipment needed to continue ICU care for several hours. In addition, such CCAT flights (usually in a C-17 cargo plane) can carry a large number of walking wounded.[19] These CCAT flights transport patients from combat support hospitals in theatre to Level 4 care at LRMC and then back to the United States for Level 5 care.

Administratively, the JTTS includes 1 trauma surgeon who acts as a trauma system director and a team of 6 trauma nurse coordinators; these personnel evaluated trauma system component issues. The backbone of the system has been the Joint Theatre Trauma Registry (JTTR), which has collated demographic, mechanistic, physiologic, diagnostic, therapeutic and outcome data from all injured patients presenting to US military hospitals in Iraq and Afghanistan. This registry has allowed for quality of care to be assessed and improved and for research that has improved care in theatre to be conducted. It has also contributed to injury-prevention initiatives, such as improved body armour development.[17]

The CF trauma system

Shortly after taking over the R3MMU in 2006, the senior leadership of the CFHS recognized the need to fully develop the administrative and nonclinical components of a CF trauma system. The essential organizational and clinical components of the trauma system were already in place; however, the performance improvement/patient safety and injury research aspects of the trauma system were not centrally coordinated.

Organization of the CF trauma system

Canada is one of only few countries in the world where the military health services are fully under the command and control of the Surgeon General. This means that responsibility, authority and accountability for health care lies within the Surgeon General's office, permitting clear lines of authority, responsibility and most importantly, full accountability for health outcomes. The CF Surgeon General, therefore, remains ultimately accountable and responsible for the performance of the CF trauma system. In Afghanistan, the Task Force Surgeon was the Surgeon General's delegate and was the senior medical officer with responsibility and accountability for all health care delivered to CF members in Afghanistan. None of these responsibilities changed during Canada's mission in Afghanistan.

Clinical components of the CF trauma system

The CF entered the combat mission with all clinical aspects of its trauma system developed and ready to treat CF members from point of injury to rehabilitative care. Like the US military system, Level 1 care was provided by CF combat medical technicians, who were embedded with each fighting unit. Details of the CF prehospital trauma program and its evolution during the war in Afghanistan are discussed in more detail in the article by Savage and colleagues[21] in this special supplement of the *Canadian Journal of Surgery*. Evacuation to the R3MMU was carried out either by CF armoured ambulances or by US military helicopters. From Feb. 7, 2006, to Oct. 15, 2009, Canada was the lead nation for the R3MMU. Most of the command, administrative and clinical positions at the hospital were filled by CFHS personnel. The hospital functioned as the regional trauma centre for southern Afghanistan. For more details about the R3MMU, see the article by Brisebois and colleagues[22] in this supplement. The US Air Force CCAT teams then evacuated injured CF members to LRMC, which provided Level 4 care. The CF airevac

teams brought injured CF members back to Canada, usually to civilian trauma centres across the country. From there, the injured soldiers entered the CF rehabilitation centre, which is described in the article by Besemann in this supplement.[23]

Nonclinical gaps in the CF trauma system at the outset of the war

As discussed previously, the CFHS was fully capable of providing clinical care to injured soldiers at the outset of the deployment to Kandahar Airfield. However, the CFHS recognized that it needed to further develop the administrative and nonclinical components of its trauma system. The research, performance-improvement and patient safety initiatives required data. The CFHS did not have an established trauma database, therefore before the initial deployment of the R3MMU, the CHFS initiated a trauma registry pilot project. A trauma registry was developed and populated with data collected from all trauma patients assessed by the R3MMU's trauma team during the initial 6 months of the deployment. The project captured data on patient demographic characteristics, injury mechanism and scoring, initial physiologic and laboratory findings, resuscitative interventions, operative procedures and outcomes. Some follow-up data were gathered once patients were repatriated back to Canada, but this was difficult to systematically organize from Kandahar.

The trauma registry pilot project was successful in capturing this data and providing some preliminary mortality data, stratified by injury severity, to benchmark the performance of the CFHS against other combat support hospitals.[24] Furthermore, the data for this project were used for performance-improvement and patient safety (PIPS) issues within the CF trauma system. For example, this registry identified that Canadian soldiers injured in Afghanistan were at risk for multidrug-resistant infections from *Acinetobacter baumannii* and potentially bringing this organism back to Canadian hospitals.[25] As a result, the CFHS partnered with the Public Health Agency of Canada to inform hospitals of the potential for importation of *A. baumannii* and the appropriate precautionary measures that should be taken to prevent secondary spread within hospitals.[26] The registry was also used to improve the performance of prehospital trauma interventions performed by the trauma medics. The registry identified that combat medics were performing needle decompression of tension pneumothoraces too medially, risking injury to the heart and great vessels.[27] As a result, training protocols for the combat medics were changed to address this problem.

Joining the US JTTS and JTTR

Although the CF trauma registry pilot project was deemed a success, the CFHS still had the logistical challenge of implementing a PIPS plan within the system and developing a permanent trauma registry. Fortunately, the CF were part of a coalition military force, where many different nations contributed different capabilities. As the US military had already established the JTTS and JTTR, the CFHS were able to join this system and house Canadian data within the JTTR.

Organization of the CF trauma system

The participation of the CFHS in the JTTS required establishing 3 new positions within the CFHS that would help the Surgeon General monitor the quality of care being delivered to injured CF members on deployment:

- National Practice Leader — Trauma (NPL-Trauma)
- National Trauma Nurse Coordinator (NTNC)
- R3MMU Trauma Nurse Coordinator (TNC)

The NPL-Trauma was a senior trauma clinician who had the primary function of advising the Surgeon General on issues related to trauma care. The NPL-Trauma advised the Surgeon General on how to ensure consistency in care provided to injured CF members from rotation to rotation, helped identify performance improvement and patient safety issues and provided advice on how to resolve issues when they arose, and ensured that there was adequate knowledge translation such that lessons learned and clinical practice guidelines (CPGs) were passed to clinicians deploying on each successive rotation.

The 2 most important "new jobs" created within the CF trauma system were the NTNC and TNC positions. They were responsible for the implementation and monitoring of a standardized multidisciplinary approach to trauma care throughout the CF trauma system from point of injury to rehabilitative care back in Canada. As such, they ensured standardization of documentation, helped develop and institute process-improvement programs, ensured accurate data collection and transmission of casualty records to the JTTR, monitored trauma program effectiveness through coordination of the Trauma System Performance Improvement Program and submitted the appropriate reports required by the trauma system. The TNCs were the ones who were constantly monitoring and working at improving the CF trauma dystem on a daily basis.

Performance improvement and patient safety

The goal of the PIPS plan was to ensure that soldiers who sustained battle and nonbattle injuries received optimal care. To accomplish this goal, the TNCs, Trauma Directors, physicians, senior nurses, department chiefs and other clinicians assessed for and identified parts of the trauma system that did not perform well. Various system problems were possible, and these included patient movement issues, equipment failure, communication breakdown, resource deficiencies and clinician-specific difficulties. As effective

performance-improvement processes were executed, involved personnel not only identified issues, but also determined why the issue existed and reconciled it in a professional manner.

Performance improvement requires accurate and timely data. As mentioned previously, one of the key jobs of the TNC was to collect data on patients presenting to the R3MMU. Likewise, one key job of the NTNC was to collect follow-up data on injured CF members after their return to Canada. Sources of data included

- prehospital reports (e.g., Field Medical Cards);
- ICU and intermediate care ward (ICW) daily rounds;
- occurrence, safety and incident reports;
- word-of-mouth/email communication;
- direct observation of trauma care;
- medical charts, including operative and diagnostic reports;
- JTTR;
- feedback from the Level 4 (LRMC) and Level 5 facilities back in North America;
- teleconferences (weekly case review conference) and regular morbidity/mortality rounds; and
- staff-assistance visits.

In theatre, the TNC also helped implement CPGs and monitored compliance with them. The CF adopted the CPGs formulated at the Institute for Surgical Research for the JTTS.[28] Compliance with CPGs was an important audit filter in the system. The TNC also used other JTTS user-defined performance improvement audit filters to help improve care. They used JTTR software to track, monitor and report on performance-improvement processes. Many JTTS user-defined indicators for Role 3 facilities were reported to the Task Force Surgeon at the R3MMU, the NPL-Trauma and the JTTS leadership. See Box 1 for a list of important audit filters.

The TNCs collected all these data in both an ongoing prospective fashion and intermittently in a retrospective fashion. Prospectively, the TNCs would review performance-improvement issues from the previous 24 hours that were identified during daily clinical rounds. The entire team would discuss and validate identified issues, and the Task Force Surgeon would review the patient's chart. The TNC would then enter performance-improvement issues that pertained to a specific patient into the JTTR. The TNC documented performance-improvement indicators of interest and deviations from CPGs or identified care issues by selecting the most appropriate audit filter(s). Cases could be closed after review. If the issue was system-wide or extended beyond the R3MMU, the issue would also be referred to the NPL-Trauma, who would advise the Surgeon General/Task Force Surgeon on the issue and suggest possible solutions. Periodic retrospective reviews were performed for major complications, deaths, complex cases, system issues and unexpected outcomes. Judgments were rendered based on the American College of Surgeons' definitions of preventability, severity and acceptability as well as the input of identified clinical experts. Loop closure is a critical component of every PIPS plan; for these retrospective reviews, loop closure occurred with the appropriate level of review (e.g., facility, system-wide, national).

Trauma research

The Surgeon General formulated a health research strategy to better formalize, coordinate and revitalize research within the CFHS and to better coordinate with external partners to maximize benefits derived from limited resources. The aim of the Health Research Program is to continually assess and improve health programs and capabilities for optimal CF health and operational success.

To achieve this goal, 8 health research "blocks" were formed, each with a Block Leader. Not surprisingly, Trauma was one of the key "blocks" within the program. During the combat mission in Afghanistan, the trauma block focused its

Box 1. Joint Theatre Trauma System audit filters

Death

Penetration of PPE

Missed injury(ies) or missed diagnosis(es)

Definitive airway adjunct placed in an adult trauma patient by EMT

Comatose patient (GCS ≤ 8) discharged from EMT or transferred to or from facility without a definitive airway

Delay of more than 8 hours between arrival at your facility and primary débridement of an open fracture or open joint laceration

Delay of more than 4 hours between arrival at your facility and laparotomy (excluding planned reoperations)

Delay of more than 2 hours between arrival at your facility of immediate category patients during a mass casualty and laparotomy for patients with abdominal injuries and hypotension (systolic BP < 90 mm Hg)

Delay of more than 4 hours between arrival at your facility and neurosurgery

Compartment release indicated on initial assessment at your facility (clinical evidence of compartment syndrome on arrival, not preventive)

Administration of 10 or more units of PRBCs and/or whole blood within first 24 hours of injury

Laboratory problem (e.g., values not available, turnaround time excessive, blood sample error, or failure to report critical laboratory value)

Medical equipment problem (e.g., CT scanner not working, no rapid volume infuser available)

Staffing problem (e.g., unable to reach surgeon, not enough OR or ICU nurses, delay in administering an ordered medication)

Radiology problem (e.g., lost film, turnaround time excessive, failure to report critical value, misread scan)

Pharmacy problem (e.g., delay in administering an ordered medication)

Unplanned return to OR

Temperature greater than 96°F on arrival to your facility

Transfer paperwork from other Level 1–3 facilities missing when patient arrived at your facility

Burn flow sheet from previous facility missing or incomplete (for patients with > 20% BSA burn)

Trauma transfer paperwork not sent with patient on transfer to another facility

Interfacility (theatre) event/problem

BP = blood pressure; BSA = body surface area; CT = computed tomography; EMT = emergency medical technician; GCS = Glasgow Coma Scale; ICU = intensive care unit; OR = operating room; PPE = personal protective equipment; PRBC = packed red blood cells.

efforts on improving prehospital trauma care (Tactical Combat Casualty Care research) and improving the in-hospital assessment and treatment for coagulopathy. Notable achievements by the trauma research block include completion of a large, prospective trial on the etiology of trauma-associated coagulopathy and the completion of the first pilot randomized controlled trial on damage control resuscitation using high ratios of plasma to packed red blood cells. In addition, the CFHS will now partner with the US Army to conduct a multicentre trial on damage-control resuscitation at multiple civilian trauma centres.

Trauma research, however, remains responsive to the operational needs of the CF. As Canada's combat mission ends and its new mentoring mission begins in Afghanistan, the trauma research block may focus its energies on developing knowledge-translation strategies that are effective in helping Afghan surgeons and physicians care for their injured patients, using methods and technologies appropriate for their setting.

Conclusion

Trauma systems save lives. The clinical aspects of the CF trauma system are well developed. One key lesson learned from this war in Afghanistan was the importance of establishing an effective and well-organized performance-improvement/patient safety program within the trauma system. This program contributed to improved outcomes. In addition, a well-developed and centrally administered trauma research program was another cornerstone of the CF trauma system. As this conflict ends, the importance of maintaining such programs within the CF is critical if we are to continue to provide outstanding care to injured CF members in future conflicts.

Competing interests: None declared.

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