ORIGINAL ARTICLE

Damage control surgery: 6 years of experience at a level I trauma center

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ABSTRACT

BACKGROUND: Damage control surgery (DCS) has been a well-established practice in the management of trauma victims for more than 2 decades now. The primary aim of this study was to review and analyze the presentation and outcome of patients with torso trauma who underwent DCS at Level I trauma center.

METHODS: Retrospective study was conducted using database records prospectively maintained over period of 6 years from 2008 through 2013 at an urban Level I trauma center. Data available from hospital medical records were analyzed to study presentation, mechanism of injury, organs injured, associated injuries, and outcome in patients who underwent DCS following torso trauma. Primary outcome measure was survival.

RESULTS: Total of 61 patients were identified who had undergone DCS during the study period. Majority of these patients were males (n=59), had sustained blunt trauma as result of road traffic injury, and had presented with shock (n=49). The 30-day mortality rate was 54%. Mortality was significantly associated with shock (63% cases died; p=0.008), and with Glasgow Coma scale ≤8 (85% died; p=0.001). Injuries significantly associated with high mortality were hepatic injury (n=15; 11 died), major vascular injury (n=10; 3 died), cardiac injury (n=5; 3 died), and pelvic fracture (n=17; 10 died). Re-exploration was required in 28 cases with 13 deaths. Mesh laparostomy was performed in 24 cases, with mortality in 58%.

CONCLUSION: In the absence of more effective alternative, especially at facilities with limited resources, DCS may be appropriate in critically injured patients; however, it continues to be associated with significant morbidity and high mortality, even at tertiary care centers.

Keywords: Damage control surgery; emergency surgery; lethal triad; torso trauma; trauma.

INTRODUCTION

The concept of damage control approach is a paradigm shift from definitive repair of all injuries to focused hemorrhage control, containing contamination, and deferring definitive repair for a later stage at an appropriate time after initial stabilization of the physiological parameters.[1,2] This change has increased survival rate after major trauma to over 50%.[3–5] The term "damage control" was defined by Rotondo et al.[6] in 1993 as "initial control of hemorrhage and contamination followed by intra-peritoneal packing and rapid closure, resuscitation continued in the intensive care unit (ICU), followed by re-exploration for definitive repair." These represent the first stage, namely the decision to perform DCS, and the final stage of abdominal wall closure. Two further stages have been added to the 3 traditional stages of operation, restoration of physiology, and definitive surgery.[7] However, little has been documented on factors predicting mortality in DCS setting. The aim of this study was to analyze presentation and to determine factors that may predict mortality in patients undergoing damage control surgery (DCS).

The vicious triad of death in trauma, namely hypothermia, acidosis, and coagulopathy, should be tackled by either initial abbreviated laparotomy or any other damage control procedure, correction of physiological derangements, and finally, definitive repair of all injuries at a later stage. The concept requires a dedicated team effort with careful patient selection to achieve favorable results.

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MATERIALS AND METHODS

Retrospective study was conducted using prospectively maintained database records of 61 consecutive patients with torso trauma who underwent various DCS procedures at JPN Apex Trauma Centre, All India Institutes of Medical Sciences, New Delhi, India, over a period of 6 years from January 2008 through December 2013. Data of patient's age, gender, mode of injury, presence of shock at presentation, Focused Assessment by Sonography in Trauma (FAST) report, Glasgow Coma Score status, organ(s) injured, DCS procedure performed, type of closure, frequency of re-exploration, length of intensive care unit (ICU) stay, length of ventilator support, outcome, and if the patient died, cause and time of death, were collected from hospital medical records and recorded.

All patients of all age groups who presented with organ-specific injuries or polytrauma following blunt or penetrating trauma, and who required immediate surgery for hemorrhage control or to contain contamination were included in the study. Patients who died in the emergency department (ED) during resuscitation or during surgery were excluded. Blood and blood products were transfused in patients who presented with features suggestive of class III or class IV hemorrhagic shock. For refractory cases, massive transfusion protocol was activated with transfusion ratio of packed red blood cells, fresh frozen plasma, and platelet concentrate of 1:1:1.

DCS was performed in patients with lethal triad of coagulopathy, acidosis, and hypothermia.

Operative Procedure

Exploratory laparotomy was performed using midline incision. Perihepatic packing, splenectomy, and pelvic packing were most common procedures performed to achieve hemostasis (Table 1). In most patients, exteriorization of bowel was done to prevent contamination in presence of bowel injuries (Table 1). Bilateral anterolateral thoracotomy was performed in 5 patients with cardiac injury using clamshell incision. Cardiac chamber injuries were repaired using polypropylene sutures.

All statistical calculations, including chi-square analysis and unpaired t-tests, were performed using SPSS Statistics for Windows, Version 17.0. (SSPS Inc., Chicago, IL, USA); p value <0.05 was considered statistically significant.

RESULTS

Total of 2025 emergency trauma surgeries were performed during the study period and 61 (3%) of these surgeries were DCS for torso trauma. Majority of the patients were males (n=59), and the predominant mechanism of injury was blunt trauma, seen in 54 cases. Among the various modes of injury, motor vehicle crashes were responsible for causing injuries in half of these patients (Table 2). Average delay in presentation to ED was 2 hours, and average disposition time from ED to operation room (OR) was 45 minutes. Forty-nine patients were in state of hemorrhagic shock at presentation, and of these, 41 were FAST positive and 38 were non-responders. Polytrauma was seen in 54 patients.

Table 1. Details of damage control procedures

Procedure	Frequency
Perihepatic packing	15
Splenectomy	19
Pelvic packing	13
Thoracotomy	8
External pelvic fixation	3
Major vessel ligation	7
Nephrectomy	3
Bowel stapling/ligation	4
Bowel stomas	15
External fixation of long bones	10
Laparostomy	24
Post packing therapeutic/ prophylactic angioembolization	7

Table 2. Mode of injury

Mode of injury	Injured	Survivors
Road traffic crash	32	25
Fall from height	8	3
Railway track injury	5	2
Gunshot wound	5	2
Assault	6	4
Mechanism unknown	5	2
Total	61	38

Figure 1. Thoracoabdominal injury managed with tube thoracostomy and perihepatic packing.

Table 3. Frequency of injured organs

Injured organ	Frequency
Liver	15
Spleen	19
Major intra-abdominal vessel	10
Pelvic fracture	16
Genito urinary	15
Chest	21
Cardiac	05
Bowel/mesenteric	06
Long bone fractures	15
Retroperitoneal hematoma	06
Spine	05
Maxillofacial	03
Morel lavallee	02
Pancreatoduodenal	02
Traumatic brain injury (TBI)	24

Liver and spleen were the 2 most frequently injured organs requiring DCS (Table 3) and hence, perihepatic packing (Figure 1) and splenectomy were the 2 most frequently performed DCS procedures (Table 1). There were 5 patients with cardiac injuries who were managed with thoracotomy and repair of cardiac chamber injury. Sixteen patients with pelvic fractures were managed either with pelvic packing (13 cases) or external pelvic fixators (3 cases). Mesh laparostomy was performed in 24 patients who had undergone perihepatic packing, pelvic packing, significant bowel contamination, or bowel edema, to minimize occurrence of abdominal compartment syndrome (ACS) (Table 4). Average blood requirement during first 24 hours was 4 units. Post packing prophylactic angio-embolization was performed in 5 cases after hemodynamic stabilization in ICU. All the patients were monitored in ICU postoperatively and re-explorations were carried out after 48 to 72 hours. Twenty-eight cases were re-explored; 8 of them were re-explored twice and 1 case was re-explored 3 times. None of the patients developed ACS postoperatively. Average number of ventilator days, ICU stay, and hospital stay were 7 days (range: 1–30 days), 9 days (range: 4–37 days), and 14 days (range: 9–45 days) respectively. Average injury severity score (ISS) was 28.3 (range: 16–75), and average New ISS (NISS) was 34.1 (range: 16–75).

Table 4. Primary damage control procedures and techniques of abdominal closure

Serial No	Primary damage control procedure(s)	n=61
1	Mesh laparostomy	24
2	Splenectomy with primary abdominal closure	6
3	Thoracotomy and primary closure	8
4	External pelvic fixation	3
5	External fixation of long bones	10
6	Nephrectomy with primary abdominal closure	3
7	Major abdominal and limb vessel ligation with primary abdominal closure	7
	Total	61

Twenty-eight patients were alive at the end of 1 month. Major-

Table 5. Relationship between organ damage, physiological status, and mortality rate

Serial No	Organ(s) damaged	Shock Y/N	Mortality rate (n=33)	
			n	%
1	Liver alone	Y	2	3.2
2	Spleen alone	Y	3	4.9
3	Pelvis alone	Y	3	4.9
4	Head, lungs, liver	Y	6	9.8
5	Liver, spleen, mesentery, portal vein, pelvis	Y	3	4.9
6	Head, heart, long bones	Y	3	4.9
7	Head, long bones, face	N	2	3.2
8	Head, kidneys, mesentery, bowel	Y	4	6.5
9	Pancreaticoduodenal, head, maxilla, spine, long bones	Y	2	3.2
10	Head, soft tissues, pelvis	Y	2	3.2
11	Pelvis, retroperitoneum, IVC, head	Y	1	1.6
12	Lungs, mesentery, liver, spleen, IVC, retroperitoneum	Y	2	3.2
	Total		33	54

IVC: Inferior vena cava.

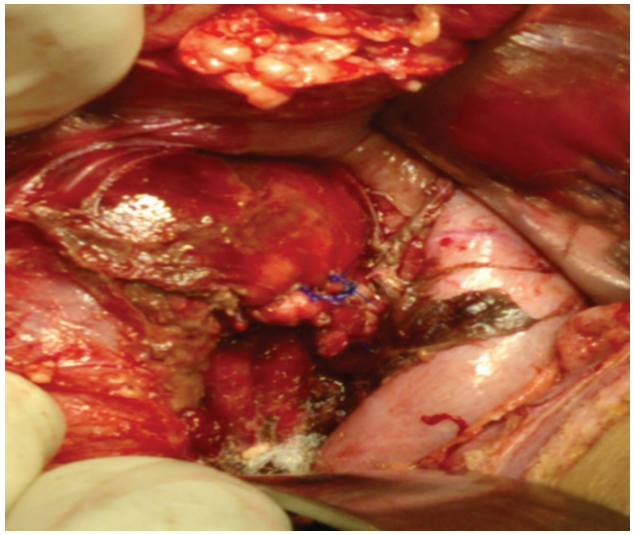

Figure 2. Ligation of right hepatic artery followed by perihepatic packing done for a grade V liver trauma

ity of the remaining 33 patients died of hemorrhagic shock (Table 5). In 29 of 33 cases, mechanism of injury was blunt trauma and all were FAST positive during primary survey. Of these 33 patients, 7 died within 6 hours of arrival, 19 died within 24 hours, and the remaining 7 died after more than 24 hours. Average ISS of these 33 fatal cases was 32 and average NISS was 40. Of 49 patients who were in shock at presentation, 31 died. Mortality rate was 85% in patients who had associated severe traumatic brain injury. Of 5 cases of cardiac injury, 3 died. Mortality in 17 cases of thoraco-abdominal injuries (Figure 2) was 41%, whereas it was 59% in those with pelvic trauma. Thirteen of 28 patients who were re-explored died.

DISCUSSION

Basic philosophy of DCS has evolved within the continuum of military and civilian trauma care since the Napoleonic Wars, and these techniques have firm foundation within the history of military medicine.[8] In the latter part of the 18th century, during the Napoleonic campaign, French military surgeon Jean Larrey alluded to the rationale for expedited battlefield procedures with his conclusion, "When a limb is so much injured by a gunshot wound that it cannot be saved, it should be amputated immediately. The first 24 hours is the only period during which the system remains tranquil, and we should hasten during this time, as in all dangerous diseases, to adopt the necessary remedy."[9] Historical military references to techniques of DCS in the United States appear around the time of the Civil War.[10]

The concept of "damage control" was borrowed from the United States Navy. It represents the capacity of a ship to absorb damage and maintain mission integrity.[11] In surgery, "damage control" refers to staged strategy for treatment of severe exsanguinating injuries designed to ensure patient survival. To begin with, concept of DCS was applied to abdominal trauma, but now it is also being extended to other serious and life-threatening extra-abdominal injuries in which performing definitive and prolonged surgeries may end up in losing the patient. We also applied DCS principles not only to all patients with abdominal trauma, but included patients with thoraco-abdominal, head, pelvic, long bone, soft tissue, and vascular trauma as well. DCS was most commonly required for abdominal and pelvic trauma, which represented 75% of our cases.

The concept of abdominal packing for uncontrolled hemorrhage is one of the initial damage control maneuvers described in 1908 by Pringle, the first to describe the concept of hepatic packing in patients with portal venous hemorrhage.[12] Halsted later encouraged the placement of rubber sheets between the packs and the liver to protect the liver parenchyma.[13] We packed the perihepatic space or the pelvic cavity with multiple abdominal mops with radio-opaque tracers, which were removed after achieving hemodynamic stability and correcting coagulopathy after 48 to 72 hours.

In World War II, the Second Auxiliary Surgery Group treated over 22,000 combat casualties, including 8800 severely wounded, between 1943 and 1945.[14] The ensuing 912-page report and scientific publications produced after the war yielded insight into the surgical treatment of the severely wounded and the utility of techniques aimed at the correction of profound physiological derangements immediately endangering life, which is now described as damage control. In the present study, we observed that DCS principles were applied to 3% of entire emergency trauma surgeries performed during 6 years of study period.

It was recognized in several case series that temporizing surgical procedures during the Vietnam War often provided a survival advantage when compared with definitive surgical therapy.[15] Several reports since the Vietnam War revalidated the concept in civilian trauma, as reported for the first time by Lucas and Ledgerwood in a prospective 5-year evaluation of 637 patients treated for liver injury.[16] Three of these patients had their liver therapeutically packed and all 3 survived. Five years later, Feliciano et al. reported 90% survival rate in 10 patients with severe liver injury treated with liver packing.[17] Stone introduced the concept of abbreviated laparotomy and intra-abdominal packing for the exsanguinating hypothermic and coagulopathic trauma patient in 1983.[18] Definitive surgical repairs were accomplished once hemodynamic stability was restored and coagulopathy corrected. This strategy resulted in survival of 11 patients out of 17 who were found to have coagulopathy.[18] Application of these techniques to trauma patients, including major vascular injuries, continued to evolve over the next several years. In our study, average ISS and NISS were found to be 28.3 and 34.1, respectively, which were suggestive of high potential for mortality and morbidity. But adopting DCS philosophy translated into survival in 46% of these patients.

Potential lethal links between hypothermia and coagulopathy in trauma victims have been studied extensively.[19,20] Hypothermia, acidosis, and coagulopathy are associated with high

mortality.[21–24] DCS is used in patients who would not survive regular surgery because of their deranged physiological state. Sharp and Locicero demonstrated that packing the abdominal cavity to prevent development of acidosis, hypothermia, and coagulopathy can be done safely.[22] We performed perihepatic packing in 15 cases and pelvic packing in 13, resulting in survival of 4 and 5 cases, respectively. Many authors have reported success with similar salvage techniques.[4,25,26] During the last decade, a number of authors have also described use of DCS in cases of thoracic, vascular, orthopedic, and neurosurgical trauma.[27–31]

Rotondo and Schwab coined the term "damage control" and outlined logistics of performing 3-phased approach in 1992.[6] They reported survival rate of 77% in patients with major vascular injury and 2 or more visceral injuries. Johnson and Schwab recently introduced a fourth phase to the existing 3, and referred to it as "Damage Control Ground Zero" or DC 0.[32] It represents the earliest phase of damage control in the pre-hospital arena or ED, and focuses on injury pattern recognition and early decision to proceed with damage control.[32] It includes strategies such as minimizing pre-hospital time and abbreviated ED resuscitation that includes intubation, blood transfusion, and rapid access to the OR. Throughout damage control, they also emphasized rewarming as well as restoring red cell and plasma volume. They reported 90% survival in their damage control population, confirming the effectiveness of these strategies.[32] A recent collective review by Shapiro et al. of over 1000 damage control patients reported an overall survival rate of 50%.[33] We also observed similar survival rate (46%) in our study.

Incidence of DCS among emergency surgeries varies in the literature from 8.9% to 18%.[31,34,35] In our study, 3% of emergency surgeries for trauma were DCS. A possible explanation for this difference is that most patients with severe trauma did not reach the hospital early as result of inefficient pre-hospital care compared with developed countries. Mortality rate for DCS has been reported in the range of 26% to 67%.[34,35] In our series, mortality rate was 54%, and most was seen during the first 24 hours after surgery.

Aoki et al.[21] performed a retrospective study to identify risk factors associated with mortality in 68 patients who underwent DCS. They found overall mortality rate of 66%. Another study showed that there is a window of opportunity of 60 to 90 minutes to salvage a patient before temperature drops below 32°C.[36] Beyond this point, mortality is as high as 100% as described by Jurkovich et al.[37] We observed a statistically significant association between severe head trauma (p=0.001) and shock (p=0.008) with mortality. Other injuries that significantly contributed to mortality were hepatic injury, pelvic trauma, major vascular injury, thoraco-abdominal injury, and cardiac injury. In a recent study conducted by Talia et al., adoption of DCS principles led to significant decrease in trauma coagulopathy mortality from 46% to 19%.[38] In a nutshell, the entire philosophy of DCS focuses on early control of major hemorrhage and optimization of the physiology, to be followed by staged definitive anatomical or structural repair.[39–43]

Summary

The concept of damage control surgery is rapid initial control of hemorrhage and contamination with packing and temporary closure, followed by resuscitation in ICU, and subsequent re-exploration and definitive repair once normal physiology has been restored. Damage control techniques are both feasible and effective, not only on the battlefield, but also in civilian practice. This damage control paradigm challenges surgeons, especially those in resource-constrained environments, to have a low threshold to perform damage control procedures in order to mitigate the deleterious consequences of the lethal triad of trauma. The damage control philosophy is grounded in the principle that the survival of the patient is the only priority, and thus, the potential for significant morbidity must be accepted. It is better to have a live problem than a dead solution.

Compliance with Ethical Requirements

Approval by an ethics committee was not applicable.

Conflict of interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Hasar kontrol cerrahisi: Birinci seviye travma merkezinde altı yıllık deneyim

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AMAÇ: Yirmi yıldan uzun zamandan beri travmalı hastaların tedavisinde hasar kontrol cerrahisi (HKC) iyi kanıtlanmış bir uygulama olmuştur. Bu çalışmanın ana amacı, beden travması sonrası 1. seviye travma merkezinde hasar kontrol cerrahisi (HKC) geçirmiş hastaların başvuru belirtileri ve sonuçlarını gözden geçirmek ve analiz etmekti.

GEREÇ VE YÖNTEM: Kentsel 1. seviye travma merkezinde 2008 ile 2013 arası altı yıllık dönem boyunca ileriye yönelik olarak muhafaza edilmiş veri tabanı ile geriye dönük bir çalışma yürütüldü. Beden travması sonrası HKC'si geçirmiş hastalarda başvuru semptomları, travmanın mekanizması, yaralanan organlar, eşlik eden yaralanmalar ve sonuçlarını incelemek için hastane tıbbi kayıtlarından elde edilen veriler analiz edildi. Birincil sonuç ölçümü sağkalım idi.

BULGULAR: Çalışma dönemi boyunca HKC'si geçirmiş toplam 61 hasta tanımlandı. Bu hastaların çoğu erkek bireyler (n=59) olup trafik kazasında yaralanma sonucu künt travmaya maruz kalıp şokla (n=49) gelmişti. Otuz günlük mortalite oranı %54 idi. Mortalite şokla (olguların %63'ü hayatını kaybetmişti; p=0.008 ve ≤8 puanlık Glasgow Koma Ölçeğiyle (GKÖ) (olguların %85'i hayatını kaybetmişti: p=0.001) anlamlı derecede ilişkiliydi. Karaciğer (n=5; 11 hayatını kaybetme), majör vasküler (n=10; 3 hayatını kaybetme), kalp (n=5; 3 hayatını kaybetme) yaralanması ve pelvis kırığı (n=17, 10 hayatını kaybetme) yüksek mortalite oranlarıyla anlamlı derecede ilişkiliydi. Yirmi sekiz olguda yeniden eksplorasyon gerekti ve 13 ölüm olayı meydana geldi. Meş laparostomisi %58 mortalite oranıyla 24 olguda gerçekleştirildi.

TARTIŞMA: Özellikle kaynakları kısıtlı kurumlarda kritik önemde yaralanması olan hastalarda hasar kontrol cerrahisi düşüncesi uygun olabilir. Daha etkili tedavi alternatiflerinin olmadığı üçüncü basamak merkezlerde bile önemli derecede morbidite ve yüksek derecede mortaliteyle ilişkili olmayı sürdürmektedir.

Anahtar sözcükler: Acil cerrahi; beden travması; hasar kontrol cerrahisi; ölümcül üçleme; travma.

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