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Damage control or definitive repair? A retrospective review of abdominal trauma at a major trauma center in South Africa

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ABSTRACT

Background This study set out to review a large series of trauma laparotomies from a single center and to compare those requiring damage control surgery (DCS) with those who did not, and then to interrogate a number of anatomic and physiologic scoring systems to see which best predicted the need for DCS.

Methods All patients over the age of 15 years undergoing a laparotomy for trauma during the period from December 2012 to December 2017 were retrieved from the Hybrid Electronic Medical Registry (HEMR) at the Pietermaritzburg Metropolitan Trauma Service (PMTS), South Africa. They were divided into two cohorts, namely the DCS and non-DCS cohort, based on what was recorded in the operative note. These groups were then compared in terms of demographics and spectrum of injury, as well as clinical outcome. The following scores were worked out for each patient: Penetrating Abdominal Trauma Index (PATI), Injury Severity Score, Abbreviated Injury Scale-abdomen, and Abbreviated Injury Scale-chest.

Results A total of 562 patients were included, and 99 of these (18%) had a DCS procedure versus 463 (82%) non-DCS. The mechanism was penetrating trauma in 81% of cases (453 of 562). A large proportion of trauma victims were male (503 of 562, 90%), with a mean age of 29.5±10.8. An overall mortality rate of 32% was recorded for DCS versus 4% for non-DCS ($p<0.001$). In general patients requiring DCS had higher lactate, and were more acidotic, hypotensive, tachycardic, and tachypneic, with a lower base excess and lower bicarbonate, than patients not requiring DCS. The most significant organ injuries associated with DCS were liver and intra-abdominal vascular injury. The only organ injury consistently predictive across all models of the need for DCS was liver injury. Regression analysis showed that only the PATI score is significantly predictive of the need for DCS ($p=0.044$). A final multiple logistic regression model demonstrated a pH <7.2 to be the most predictive ($p=0.001$) of the need for DCS.

Conclusion DCS is indicated in a subset of severely injured trauma patients. A pH <7.2 is the best indicator of the need for DCS. Anatomic injuries in themselves are not predictive of the need for DCS.

Levels of evidence Level III.

INTRODUCTION

Damage control surgery (DCS) was first introduced as a concept less than three decades ago, and since that time has become widely accepted.[1–3] The principle underlying DCS is that prolonged operations in trauma patients with profound physiologic derangements and complex injuries must be avoided, in lieu of an abbreviated operation which controls bleeding and soiling. Once this has been achieved, the patient's physiology must be aggressively restored, and only then can the temporized injuries be managed definitively. It must be understood that the majority of trauma patients do not require DCS and should still undergo definitive surgery. Deciding when DCS is indicated requires clinical judgment. Essentially there are two factors which must be considered, namely the extent of the anatomic injury as well as the extent of the physiologic derangement. Most guidelines have focused on physiologic criteria for deciding on the need for DCS.[4–8] Physiologic criteria can be accurately quantified and include preoperative and intraoperative hypothermia (median temperature <34°C), acidosis (median pH <7.2), and/or coagulopathy. There is a degree of latitude allowed if these parameters rapidly improve. If they deteriorate or remain static, then damage control is mandated. However, in recent large surveys and scoping reviews, it has emerged that numerous authors include other criteria such as injury patterns, failure to control bleeding by conventional methods, administration of a large volume of packed red blood cells, the inability to achieve a tension-free abdominal wall closure, or the onset of an abdominal compartment syndrome during attempted abdominal wall closure, as well as the necessity to reassess bowel viability, as indications for DCS.[4–8] These criteria are important, but some of them are subjective and difficult to define. In light of this, this study set out to review a large series of trauma laparotomies from a single center and to compare those requiring DCS with those who did not, and then to interrogate a number of anatomic and physiologic scoring systems to see which ones best predicted the need for DCS. It was hoped that the use of a defined anatomic scoring system in determining the need for DCS would help quantify the anatomic indications for DCS, and thus standardize practice and reduce individual center and surgeon variability.

Clinical setting

Kwa Zulu Natal Province (KZN) is located on the east coast of South Africa and has a population of over 11 million people. Fifty percent of the population resides in rural areas. The city of

Pietermaritzburg is the largest city in the interior of the province and has a population of one million people. The Pietermaritzburg Metropolitan Trauma Service (PMTS) provides trauma care to the city of Pietermaritzburg, KZN, South Africa, as well as to the predominantly rural western third of the province. It also serves as the referral center for 19 other rural hospitals within the western third of the province, and has a total catchment population of over three million people. Over 50% of all trauma managed at our centre are due to penetrating injuries. This is a direct reflection of the very high incidence of interpersonal violence, criminal and gang related activities rampant throughout the region. The PMTS is one of the largest academic trauma center in Western KZN. It is headed by a full time Professor of Surgery (DLC) and five sub-specialist fellowship trained attending trauma surgeons directly oversee the care of all trauma patients. The house staff is composed of surgical interns, residents, career medical officers, fellows and international medical graduate (IMG) doctors of varying levels of skill who rotate through a number of subspecialist units during their training. Our trauma center is a nationally accredited training institute for specialist training in General Surgery and sub-specialist fellowship training in Trauma Surgery for both local and international doctors. The PMTS maintains a prospectively entered hybrid electronic medical registry (HEMR). All surgical patients are captured on this system.

METHODS

All patients over the age of 15 years undergoing a laparotomy for trauma during the period from December 2012 to December 2017 were retrieved from the HEMR. They were divided into two cohorts, namely the DCS and non-DCS cohort, based on what was recorded in the operative notes. These groups were then compared in terms of demographics and spectrum of injury, as well as clinical outcome. Once this had been done, the following scores were worked out for each patient: Penetrating Abdominal Trauma Index (PATI), Injury Severity Score (ISS), Abbreviated Injury Scale-abdomen (AIS-abdomen), and Abbreviated Injury Scale-chest (AIS-chest).

Statistics

Continuous variables are compared using unpaired t-test, and categorical variables using χ^2 analysis. Further stepwise and multiple logistic regression analyses were performed. Statistical analysis was undertaken using STATA V.15.0. Comparison of presenting physiologic parameters between groups was performed using unpaired t-test, and included lactate, systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), respiratory rate (RR), oxygen saturation (SpO_2) (%), pH, partial pressure of oxygen (pO_2) (kPa), partial pressure of carbon dioxide (pCO_2) (kPa), base excess (BE) (mEq/L), and serum bicarbonate (HCO_3) (mEq/L). χ^2 test compared the proportions of visceral injuries between the two groups, including small bowel (SB), large bowel (LB), liver, diaphragm, stomach, spleen, intra-abdominal vascular injury (IAVI), kidney, pancreas, and duodenal injuries. χ^2 analysis was also used to assess other categorical variables between groups, including mortality and injury mechanism.

Regression modeling

Following a stepwise regression model, a multiple logistic regression analysis was performed to assess the most predictive physiologic and intra-abdominal injuries for DCS. Each patient was assigned PATI, ISS, AIS-abdomen, and AIS-chest scores. Their relationship to DCS was assessed in a multiple logistic regression analysis. A stepwise regression method was used to create a final multiple logistic regression model, which included both physiologic criteria and anatomic-based scores.

Table 1 Presenting demographics and physiology for DCS vs. non-DCS cases

	DCS	Non-DCS	
Total=562 (%)	99 (18)	463 (82)	
Sex male/female (%)	84/15 (85/15)	419/44 (90/10)	
Mean age (±SD)	33.6 (±12.3)	28.6 (±10.3)	
	DCS	**Non-DCS**	
Physiology	**n (SD)**	**n (SD)**	**P value**
Lactate	5.25 (±3.71)	2.63 (±2.55)	**<0.001**
SBP	110 (±24)	122 (±19)	**<0.001**
DBP	63 (±21)	72 (±16)	**<0.001**
HR	109 (±23)	96 (±21)	**<0.001**
RR	25 (±8)	20 (±5)	**<0.001**
SpO_2	94 (±7)	96 (±4)	**<0.001**
pH	7.28 (±0.15)	7.38 (±0.09)	**<0.001**
pO_2	10.7 (±6)	10.8 (±6)	0.895
pCO_2	5.3 (±1.6)	5.2 (±1.0)	0.182
BE	−7.14 (±0.72)	−2.06 (±5.52)	**<0.001**
HCO_3	18.86 (±5.65)	22.83 (±4.15)	**<0.001**
Mortality	32 (32)	19 (4)	**<0.001**
Length of hospital stay (days)	16 (±11)	10 (±7)	**<0.001**

Statistical comparison is made using unpaired t-test for continuous variables and χ^2 test for categorical variables.
Bold values indicate statistical significance at the 5% level
BE, base excess (mEq/L); DBP, diastolic blood pressure; DCS, damage control surgery; HCO_3, serum bicarbonate (mEq/L); HR, heart rate (per minute); RR, respiratory rate (per minute); SBP, systolic blood pressure; SpO_2, oxygen saturation (%); pCO_2, partial pressure of carbon dioxide (mm Hg); pO_2, partial pressure of oxygen (mm Hg).

RESULTS

A total of 562 patients were included in this analysis, all of whom underwent trauma laparotomy. Of these, 99 (18%) had a DCS procedure versus 463 (82%) non-DCS. The mechanism was penetrating trauma in 81% of cases (453 of 562). A great proportion of trauma victims were male (503 of 562, 90%), with a mean age of 29.5±10.8.

Presenting physiology

A comparison of presenting physiologic parameters for DCS versus non-DCS procedures was made. There were significant differences in lactate (5.25±3.71 vs. 2.63±2.55, $p<0.001$), SBP (110±24 vs. 122±19, $p<0.001$), DBP (63±21 vs. 72±16, $p<0.001$), HR (109±23 vs. 96±21, $p<0.001$), RR (25±8 vs. 20±5, $p<0.001$), SpO_2 (94±7 vs. 96±4, $p<0.001$), pH (7.28±0.15 vs. 7.38±0.09, $p<0.001$), BE (−7.14±0.72 vs. −2.06±5.52, $p<0.001$), and HCO_3 (18.86±5.65 vs. 22.83±4.15, $p<0.001$) between the DCS and non-DCS groups. There was a non-statistically significant difference between pO_2 and pCO_2 across the two groups. An overall mortality rate of 32% was recorded for DCS versus 4% for non-DCS ($p<0.001$) (table 1).

Table 2 Comparison of organ injury and mechanism in DCS vs. non-DCS cases

	DCS	Non-DCS	
	n (%)	n (%)	P value
Organs (total)			
SB (216)	49 (50)	167 (36)	**0.014**
LB (141)	32 (32)	109 (24)	**0.067**
Liver (112)	34 (34)	78 (17)	**<0.001**
Diaphragm (110)	23 (23)	87 (19)	0.312
Stomach (100)	21 (21)	79 (17)	0.327
Spleen (55)	14 (14)	41 (9)	0.108
Intra-abdominal vessel (53)	22 (22)	31 (7)	**<0.001**
Kidney (42)	12 (12)	30 (6)	0.053
Pancreas (41)	13 (13)	28 (6)	**0.014**
Duodenum (31)	12 (12)	19 (4)	**0.003**
Mechanism			
Blunt	28 (28)	81 (17)	**0.014**
Penetrating	71 (72)	382 (83)	
Penetrating mechanism			
GSW	46 (65)	117 (31)	**0.001**
SW	25 (35)	265 (69)	
Scoring	n (±SD)	n (±SD)	
PATI	17.4 (±13.2)	13.6 (±10.4)	0.058
ISS	13.8 (±8.2)	12.5 (±8.0)	0.208
AIS-abdomen	3.3 (±0.8)	3.0 (±1.0)	**0.045**
AIS-chest	0.67 (±1.2)	0.56 (±1.1)	0.431

Statistical comparison is made using χ^2 test for categorical variables and unpaired t-test for numerical variables.
AIS-abdomen, Abbreviated Injury Scale-abdomen; AIS-chest, Abbreviated Injury Scale-chest; DCS, damage control surgery; GSW, gunshot wound; ISS, Injury Severity Score; LB, large bowel; PATI, Penetrating Abdominal Trauma Index; SB, small bowel; SW, stab wound.

Injury spectrum

In the DCS group, the following injuries had significantly higher rates compared with the non-DCS group: SB (49 [50%] vs. 167 [36%], p=0.014), LB (32 [32%] vs. 109 [24%], p=0.067), liver (34 [34%] vs. 78 [17%], p<0.001), IAVI (22 [22%] vs. 31 [7%], p<0.001), pancreas (13 [13%] vs. 28 [6%], p=0.014), and duodenum (12 [12%] vs. 19 [4%], p=0.003). There was no significant difference in the rates of diaphragmatic, stomach, splenic or renal injuries between groups (table 2).

Repeat procedures

In total, 35 patients (6%) required unplanned, repeat operations, all of which required repeat laparotomy. These were, in descending order, 12 deep wound sepsis, 11 small bowel leak, 4 necrotising fasciitis, 3 deep wound sepsis, 2 mesh sepsis, 2 large bowel leak, and 1 for a bleeding inferior epigastric artery.

Resuscitative products

The resuscitative products given to each patient included an average of 1125 mL of normal saline preoperatively. We do not routinely administer packed red cells preoperatively due to unavailability in the emergency room, so red cells are only administered intraoperatively or postoperatively. The median number of units was 2 intraoperatively and 3 postoperatively. An average of 1 unit of freeze-dried plasma was given to the DCS patient perioperatively.

Table 3 Multiple regression analysis for systolic blood pressure, pH, pancreatic-duodenal injury, IAVI, and liver injury

	OR	SE	CI	P value
SBP <90	3.57	1.40	1.65 to 7.73	**0.001**
pH <7.2	3.11	1.17	1.48 to 6.50	**0.003**
Pancreatic-duodenal injury	1.82	0.60	0.95 to 3.47	0.069
IAVI	2.95	1.01	1.51 to 5.77	**0.002**
Liver	2.22	0.59	1.32 to 3.73	**0.003**

The dependent variable is damage control surgery.
IAVI, intra-abdominal vascular injury.

Regression modeling

Following a stepwise logistic regression model for physiologic parameters and organ injury, the following were significant predictors of the need for DCS: SBP (p=0.001), pH (p=0.003), IAVI (p=0.002), and liver injury (p=0.003). Pancreatic-duodenal injury was not significantly associated with the need for DCS (p=0.069) (table 3).

Regression modeling using severity scores

For each individual patient in the database, PATI, ISS, AIS-abdomen and AIS-chest scores were calculated. In a multiple logistic regression model, the only predictive scoring system significantly associated with the need for DCS was the PATI score, and this was only slightly within the significance level (p=0.044). AIS-abdomen was the only score predictive of the need for DCS on individual t-test (p=0.045); however, this is not deemed significant in a multiple logistic regression analysis of all scores (table 4). Neither ISS, AIS-abdomen nor AIS-chest was statistically significantly associated with the need for DCS (table 4). A final multiple logistic regression model combining the physiologic parameters, organ injury, and PATI score (table 5) revealed a significant association between SBP, pH, PATI score, and liver injury, and the need for DCS. Pancreatic-duodenal injury and IAVI were no longer significant in this model in their prediction for DCS.

Statistical summary

Table 1 illustrates the presenting physiologic parameters which are individually associated with the need for DCS. In general patients requiring DCS had higher lactate levels, and were more acidotic, hypotensive, tachycardic, and tachypneic, with a lower BE and lower bicarbonate, than patients not requiring DCS. The most significant organ injuries associated with DCS were liver and IAVI. Individual unpaired t-test did reveal injury to either the pancreas and duodenum to be predictive of the need for DCS (table 2); however, injury to the pancreatic-duodenal complex failed to prove statistical significance in two multiple logistic regression models (tables 3 and 5). The only organ injury

Table 4 Multiple regression analysis for PATI, ISS, AIS-abdomen and AIS-chest

	OR	SE	CI	P value
PATI	1.02	0.13	1.00 to 1.05	**0.044**
ISS	0.97	0.03	0.91 to 1.03	0.293
AIS-abdomen	1.37	0.34	0.85 to 2.22	0.194
AIS-chest	1.16	0.17	0.87 to 1.54	0.325

The dependent variable is damage control surgery.
AIS-abdomen, Abbreviated Injury Scale-abdomen; AIS-chest, Abbreviated Injury Scale-chest; ISS, Injury Severity Score; PATI, Penetrating Abdominal Trauma Index.

Table 5 Multiple regression analysis for SBP, pH, pancreas-duodenal injury, PATI, IAVI, and liver injury

	OR	SE	CI	P value
SBP <90	3.60	1.66	1.46 to 8.89	**0.005**
pH <7.2	4.34	1.85	1.89 to 10.00	**0.001**
Pancreatic-duodenal injury	1.23	0.47	0.58 to 2.63	0.586
PATI	1.02	0.01	1.00 to 1.05	**0.019**
IAVI	1.83	0.78	0.79 to 4.23	0.156
Liver	2.35	0.70	1.31 to 4.21	**0.004**

The dependent variable is damage control surgery.
IAVI, intra-abdominal vascular injury; PATI, Penetrating Abdominal Trauma Index; SBP, systolic blood pressure.

consistently predictive across all models of the need for DCS was liver injury (tables 3 and 5). Isolated organ injury in itself may be insufficient to identify patients requiring DCS, and aggregated organ injury scores may be more reliable. There are a number of well-established anatomic scores which have been in use for over three decades, namely PATI, ISS, AIS-abdomen, and AIS-chest. These are well-established scoring systems in trauma; however, using regression analysis, only the PATI score was significantly predictive of the need for DCS (p=0.044) (table 4). A final multiple logistic regression model demonstrated a pH <7.2 to be most predictive (p=0.001). Multicollinearity led to the exclusion of BE from this model. The significance of pH is in line with the central tenet of DCS, whereby physiologic derangement comes before any anatomic consideration.

DISCUSSION

Selecting patients for DCS remains challenging and is heavily dependent on clinical judgment. A recent Cochrane review has highlighted the fact that there are no randomized controlled trials to provide firm evidence-based guidelines on which to base clinical algorithms for DCS.[1–3] DCS is associated with its own inherent morbidity, and therefore its use needs to be confined to the subset of patients most likely to benefit from it. Most of the published indications for DCS include physiologic parameters as these are easy to quantify. However, it would appear that many authorities also include anatomic criteria such as the extent and grade of injuries, the state of the viscera, and the presence of intra-abdominal hypertension among the factors that would prompt them to adapt a DCS approach.[4–8] These criteria are not standardized and tend to be associated with a degree of subjectivity.

Our data suggest that physiologic criteria are most useful in predicting the need for DCS, and our final multiple logistic regression model demonstrated a pH <7.2 to be most predictive (p=0.001) of the need for DCS. This is very much in keeping with the central tenet of DCS, whereby physiologic derangement comes before any anatomic consideration.

Anatomic considerations have always been a major consideration in deciding on the need for DCS, and Rotondo *et al*[1–3] in their seminal article demonstrated improved survival rates of 77% versus 11% for DCS versus definitive laparotomy specifically for patients with major vascular injury and two or more visceral injuries. Since then the issue of the role of anatomic injuries in determining the need for DCS has tended to be subjective. A number of recent surveys and scoping reviews have shown that different authors and experts use a variety of clinical and anatomic criteria to decide on the need for DCS.[4–8] Our data have only shown the presence of liver trauma to be predictive of the need for DCS. However, an isolated organ injury in itself is insufficient to identify patients requiring DCS, and the only aggregated injury score shown with regression analysis to be significantly predictive of the need for DCS (p=0.044) was the PATI score, and its complexity makes it unwieldy to use in the acute situation.

This article has a number of limitations as the method of data collection was retrospective. The lack of data on preoperative fluid administration as well as lack of data on intraoperative physiology mean that these important factors were not considered in this study. Future work will need to take these criteria into account when trying to refine the indications for DCS. A trauma laparotomy is a dynamic process, and a single static reading may not truly reflect the situation. Scores that take into account changes in physiology may be more accurate and reliable; however, they will be more complex to obtain in acute situation.

CONCLUSION

DCS is indicated in a subset of severely injured trauma patients. A pH <7.2 is the best indicator of the need for DCS. Anatomic injuries in themselves are not predictive of the need for DCS.

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