Lessons learnt from the Pietermaritzburg experience with damage control laparotomy for trauma

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ABSTRACT

Introduction The modern concept of damage control surgery (DCS) for trauma was first introduced less than three decades ago. This audit aims to describe the spectrum and outcome of patients requiring DCS, to benchmark our experience against that reported from other centres and countries and to distil the pertinent teaching lessons from this experience.
Methods All patients over the age of 15 years undergoing a laparotomy for trauma over the period from December 2012 to July 2016 were retrieved from the trauma registry of the Pietermaritzburg Metropolitan Trauma Service, South Africa. Physiological parameters and visceral injuries were assessed. Statistical analysis was performed using STATA V.15.0.
Results A total of 562 patients underwent trauma laparotomy during the period under review. The mechanism was penetrating trauma in 81% of cases (453/562). A great proportion of trauma victims were male (503/562, 90%), with a mean age of 29.5±10.8. A total of 99 of these (18%) had a DCS procedure versus 463 (82%) non-DCS. Out of the 99 who required DCS, there were 32 mortalities (32%). The mean physiological parameters for the DCS patient demonstrated acidosis (pH 7.28±0.15) with a raised lactate (5.25 mmol/L±3.71). Our primary repair rates for enteric injuries were surprisingly high.
Conclusion Just under 20% of trauma laparotomies require DCS. In this cohort of patients, the mortality rate is just under one-third. Further attention must be paid to refining the appropriate indications for DCS as the margin for error in such a cohort is very small and poor decision-making is difficult to correct. The major lesson from this analysis is that the decision to perform DCS must be made early and communicated appropriately to all those managing the patient.

Key messages

- The damage control surgery (DCS) patient demonstrates physiological derangement. A significant proportion (81%) were injuries secondary to penetrating trauma.
- The decision to perform DCS must be made early and communicated appropriately to all those managing the patient.
- The indications for DCS still rely heavily on surgical judgement.
- Major colonic injuries should not be repaired. These injuries should be ligated and placed back inside the abdomen.
- Any complex operative procedures should be avoided in favour of minimalistic, temporising measures.

INTRODUCTION

The modern concept of damage control surgery (DCS) for trauma was first introduced three decades ago. Since then, it has become widely accepted. The principle underlying DCS is that a prolonged operation in a patient with profound physiological derangements must be avoided. Instead, an abbreviated procedure must be undertaken to control bleeding and soiling and once this has been achieved definitive repair is delayed until such a time as the patient's physiology has been restored. Despite the widespread acceptance of the use of DCS there are few series in the literature documenting the use of the technique, especially from low/middle-income countries. This retrospective audit of a prospectively maintained database comes from a busy trauma unit in South Africa. Our objectives were to describe the spectrum and outcome of patients requiring DCS, to benchmark our experience against that reported from other centres and countries and to extract the pertinent teaching lessons from these data. Physiological parameters, and four comprehensive scores, namely penetrating abdominal trauma index (PATI), injury severity score (ISS), abbreviated injury scale (AIS)-abdomen and AIS-chest, were used to assess this benchmark. The spectrum of solid organ injuries is also presented.

METHODS

Clinical setting

KwaZulu-Natal (KZN) province is located on the east coast of South Africa and has a population of over 11 million people. Fifty per cent of the population resides in the rural areas. The city of Pietermaritzburg is the largest city in the interior of the province and has a population of 1 million people. The Pietermaritzburg Metropolitan Trauma Service (PMTS) provides trauma care to the city of Pietermaritzburg, KZN province, South Africa, as well as to the predominantly rural western third of the province, KZN. It also serves as the referral centre for 19 other rural hospitals within the western third of the province, and has a total catchment population of over 3 million people. All patients over the age of 15 years undergoing a laparotomy for trauma over the period from December 2012 to July 2016 were retrieved from the trauma registry. The PMTS maintains a prospectively entered electronic surgical registry known as the Hybrid Electronic Medical

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Registry (HEMR), which commences in December 2012. All surgical patients are captured on this system.

Participants

The details of all patients over the age of 15 who required a laparotomy for trauma between December 2012 and July 2016 were retrieved from the HEMR. All those who required a DCS were then selected out for more in-depth analysis. Once these two groups had been broadly defined they were compared in terms of their physiology and outcome. The DCS cohort was then analysed in more detail.

Variables

Physiological parameters were assessed including: systolic BP (SBP), diastolic BP (DBP), HR, RR, SpO_2, pH, pO_2 (kPa), pCO_2 (kPa), base excess (BE, mEq/L) and HCO_3 (mEq/L). Visceral injuries assessed included: small bowel (SB), liver, large bowel (LB), diaphragm, intra-abdominal vascular injury (IAVI), stomach, spleen, pancreas, kidney and duodenum. Injury mechanism was divided into blunt versus penetrating, and penetrating was then further subdivided into gunshot wound (GSW) versus stab wound (SW). A calculation of four comprehensive scores was performed, including PATI, ISS, AIS-abdomen and AIS-chest.

Statistical analysis

Statistical analysis was performed using STATA V.15.0©. Physiological parameters were assessed using unpaired t-test, and categorical variables assessed with X^2 test.

RESULTS

A total of 562 patients underwent trauma laparotomy during the period under review. A total of 99 of these (18%) had a DCS procedure versus 463 (82%) non-DCS. The mechanism was penetrating trauma in 81% of cases (453/562). A great proportion of trauma victims were male (503/562, 90%), with a mean age of 29.5±10.8.

Presenting physiology and time

A comparison of presenting physiological parameters for DCS versus non-DCS procedures was made (table 1). Those with DCS has higher lactate, HR, RR, as well as lower SBP, DBP, SpO_2, pH, BE and HCO_3 (all $p<0.001$). There was no difference in pO_2 ($p=0.895$) or pCO_2 ($p=0.182$) between groups. An overall mortality rate of 32% was recorded for DCS versus 4% for non-DCS ($p<0.001$). The mean time of a damage control procedure was 97 min (±52) vs 101 min (±48) for non-DCS ($p=0.529$).

The DCS cohort

Out of the 99 patients who underwent DCS, there were 32 mortalities (32%). The mean age was 33.6 years (±12.3). The majority of cases were male (n=84, 85%) versus female (n=15, 15%). The mean physiological parameters for the DCS patient demonstrated acidosis (pH 7.28±0.15) with a raised lactate (5.25 mmol/L±3.71). The majority of cases (71, 72%) were for penetrating trauma, of which the majority (n=46, 65%) were secondary to GSW. The most common organ injury was to the SB, n=49 (49%), with the least common being the kidney and duodenum, both n=12 (12%). Demographic data are displayed in table 1.

Table 1 Presenting demographics and physiology for DCS versus non-DCS cases

	DCS	Non-DCS	P values
Total=562 (%)	99 (18)	463 (82)	
Sex: M/F (%/%)	84/15 (85/15)	419/44 (90/10)	–
Mean age (±SD)	33.6 (±12.3)	28.6 (±10.3)	–
Physiology	n (SD)	n (SD)	
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 (min)	109 (±23)	96 (±21)	**<0.001**
RR (min)	25 (±8)	20 (±5)	**<0.001**
SpO_2 (oxygen saturations, %)	94 (±7)	96 (±4)	**<0.001**
pH	7.28 (±0.15)	7.38 (±0.09)	**<0.001**
pO_2 (mm Hg)	10.7 (±6)	10.8 (±6)	0.895
pCO_2 (mm Hg)	5.3 (±1.6)	5.2 (±1.0)	0.182
BE (base excess, mEq/L)	−7.14 (±0.72)	−2.06 (±5.52)	**<0.001**
HCO_3 (mEq/L)	18.86 (±5.65)	22.83 (±4.15)	**<0.001**
Mortality	32 (32)	19 (4)	**<0.001**

Statistical comparison is made using unpaired t-test for continuous variables and X^2 test for categorical variables.
DBP, diastolic BP; DCS, damage control surgery; SBP, systolic BP.
Values in bold are statistically significant at the 5% level

Impact of mechanism

Table 2 compares the different organs injured between blunt and penetrating mechanisms. Penetrating injuries had significantly higher rates of the following injuries compared with blunt: LB (41% vs 11%, p=0.04), diaphragm (30% vs 7%, p=0.017), IAVI (28% vs 7%, p=0.023) and duodenal (75% vs 25%, p=0.001). For the penetrating subgroup, GSW had significantly higher rates of the following injuries compared with SW: liver (41% vs 20%, p=0.070), LB (50% vs 24%, p=0.033), diaphragm (39% vs 12%, p=0.017) and stomach (40% vs 12%, p=0.026).

Spectrum of injuries

The total number of abdominal organ injuries was counted for each case. These included injuries to the SB, liver, LB, diaphragm, IAVI, stomach, spleen, pancreas, kidney and duodenum. The numbers of organs injured were divided into subgroups of ≤1, 2–3 and 4+. Penetrating injuries had a significantly higher number of 4+ injuries compared with blunt (23% vs 4%) (Table 3A). Within the penetrating subgroup, GSW had the greatest frequency of multiple organ injuries compared with SW (33% vs 4% involving 4+ organs) (Table 3B). The mean scores for DCS versus non-DCS were as follows: PATI 17.4 (±13.2) vs 13.6 (±10.4), p=0.058; ISS 13.8 (±8.2) vs 12.5 (±8.0), p=0.208; AIS-abdomen 3.3 (±0.8) vs 3.0 (±1.0), p=0.045; AIS-chest 0.67 (±1.2) vs 0.56 (±1.1), p=0.431 (table 2).

Management of injuries

A total of 15 liver injuries were packed; in two cases the liver injuries were simply drained and in one case each the liver was sutured or a necrotic segment debrided. A total of 25 SB injuries were repaired, 22 were ligated and 25 repaired, and 27 underwent a resection and anastomosis. Of the SB injuries repaired, the American Association for the Surgery of Trauma (AAST) grade ranged from 2 to 5. A total of 20 large bowel injuries were ligated, and 10 underwent primary repair and 2 primary diversion. The AAST

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

	DCS n (%)	Non-DCS n (%)	P values
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 X^2 test for categorical variables and unpaired t-test for numerical variables.
AIS, abbreviated injury scale; 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.
Values in bold are statistically significant at the 5% level

grades of those repaired were: grade 1 (3), grade 2 (2), grade 3 (3) and grade 4 (1). In seven cases, a renal injury was dealt with by nephrectomy and in five cases the perirenal haematoma was simply not explored. Four IAVIs were repaired. These included injuries to the external iliac vein and artery, the aorta, and two inferior vena cava injuries. A total of 15 vascular injuries were ligated. These included the following injuries: LB mesentery (3), right gastroepiploic artery (1), middle colic artery (1), sacral venous plexus (1), right external iliac vein (1), pancreaticoduodenal vein (1), splenic artery (1), superior mesenteric vein and inferior mesenteric artery (1), left external iliac vein (1), SB mesentery (1), left common iliac vein (1), sigmoid artery and vein (1), and left renal vein (1). Two vascular injuries to the liver were managed by packing alone. Primary closure or the abdomen was performed in 26 cases, and temporary abdominal closure in 73 patients.

Table 3 (A)The number of organs injured compared between blunt and penetrating mechanisms for all 99 DCS cases. (B)The number of organs injured compared between GSW and SW mechanisms for all 71 penetrating DCS cases

	Number of organs injured			
Mechanism	**≤1**	**2–3**	**4+**	**Total**
(A)				
Blunt (%)	19 (68)	8 (29)	1 (4)	28
Penetrating (%)	30 (42)	25 (35)	16 (23)	71
Total (%)	49 (49)	33 (33)	17 (17)	99 (100)
P value	0.028			
(B)				
GSW (%)	11 (24)	20 (44)	15 (33)	46
SW (%)	19 (76)	5 (20)	1 (4)	25
Total (%)	30 (42)	25 (35)	16 (23)	71 (100)
P value	0.001			

DCS, damage control surgery; GSW, gunshot wound; SW, stab wound.

DISCUSSION

DCS is derived from the US Navy, and refers to the emergency measures needed to keep a ship afloat until definitive repairs can be undertaken. It has a long prehistory and in 1908, the Australian-born Scottish surgeon James Pringle described the packing of liver injuries.[3] Modern DCS was described by Rotondo *et al* in 1993.[2] They demonstrated a significant survival benefit in DCS compared with definitive laparotomy for patients with severe trauma.

However, the indications for DCS still rely heavily on surgical judgement and in this cohort of compromised patients, the margin for error is extremely small and poor decision-making can have significant negative sequela. Most trauma surgeons emphasise that both anatomic and physiological factors must be considered when deciding to adopt a DCS approach. These criteria include an arterial pH <7.2, SBP persistently <90 mm Hg, as well as injuries to the pancreatic-duodenal complex and to the liver.[1] Our cohort demonstrated physiological compromise as evidenced by the elevated mean lactate at 5.75 (±3.71) and mean BE of −7.14 (±0.72) (Table 1). The mechanism of trauma also appears to be very predictive of the need for DCS with the well over two-thirds of the patients requiring DCS having sustained (72%) penetrating torso trauma, which is associated with a greater number of intra-abdominal injuries than blunt trauma (Table 3A). In the penetrating cohort, GSWs are more likely to require DCS than SWs as reflected by the increased number of intra-abdominal injuries associated with GSW to the abdomen (SW) (table 3B). A third of GSW injuries presented with injuries to more than four intra-abdominal structures.

DCS techniques eschew complex operative procedures in favour of minimalistic and temporising procedures. Reviewing the techniques used in this cohort suggests that the principles of DCS are being applied incompletely. Packing of liver injuries is now widely accepted and was the most common management of liver injuries in our setting. Non-expanding perirenal haematomas can be safely left unexplored in the acute setting, if exploration is undertaken then it is highly likely that a nephrectomy will be necessary. For these solid organs it would appear that our staff are well versed in DCS and tend to apply the approach appropriately to these injuries. The management of visceral injuries in this cohort however suggests that decision-making for these injuries is more opaque. Major colonic injuries should not be repaired primarily, neither should they undergo primary diversion. The role of primary diversion of colonic injuries during the initial operation should be extremely limited. If the patient cannot withstand a primary repair, then the injury should be ligated and placed back inside the abdomen. The high rates of primary repair of SB and colonic injuries during DCS suggest that the decision to opt for a DCS procedure is not being made timeously enough and that surgeons are tending to use DCS as a bailout option. The fact that the operative length between DCS and non-DCS procedures was not significantly different is reflective of this. With vascular injuries staff are more likely to adopt a DCS approach and almost all non-essential major vessels (15) were simply ligated. The four vessels which were repaired were

Table 4 An international comparison of the demographics, physiology and outcome of DCS laparotomy

	Rotondo *et al*[2] (n=24)	Johnson *et al*[4] (n=21)	Kisat *et al*[5] (n=47)	Present study (n=99)
Country	USA	USA	Pakistan	South Africa
Age (years)	30.6	25.6	33 (±15)	33.6 (±12.3)
Gender, M/F	23/1	21/0	43/4	84/15
Penetrating mechanism (%)	24 (100)	21 (100)	32 (68)	71 (72)
SBP	108 (±25)	122 (±24)	81 (±32)	110 (±24)
pH	7.20 (±0.18)	7.18 (±0.15)	7.06 (±0.6)	7.28 (±0.15)
Survival (%)	14 (58)	19 (90)	26 (55)	67 (68)

± denotes SD.
DCS, damage control surgery; SBP, systolic BP.

major vessels and external iliac vein and artery in one case, aorta, and two Inferior vena cava (IVC) injuries. Patients who undergo DCS should have their abdomen left open to prevent the development of intra-abdominal hypertension. However, this was only performed in 73% of cases, once again suggesting deficits in the understanding of DCS among our staff.

Our data are similar to that reported from major international series as shown in table 4. Both the demographics and the presenting physiology appear to be similar.[2 4 5] There is no significant variation in survivability in our study (2012–2017) (68%) versus the Pakistani group[5] (1996–2011) (55%) versus Rotondo *et al* (USA) (1993) (58%)[2]; however, Johnson *et al* (1997–2000)[4] have survival rates of 90%. The international consensus that physiological derangement should supersede anatomic consideration is shared in Brazil[6] and India.[7] This is an important lesson as prolonged operating prior to adopting a DCS approach is not prudent. The decision to opt for DCS should be made early. One of the major limitations of this study is that the surgical decision-making process remains opaque and is almost impossible to tease out with a retrospective analysis. DCS should be a conscious decision made extremely early in the care pathway. Unfortunately, DCS is frequently used as a bailout procedure when the surgeon realises the magnitude of the derangement and suddenly beats a hasty retreat. The two situations are not analogous. Our data suggest that there is an incomplete understanding of the principles of DCS even in a high-volume centre such as ours. DCS techniques seem to well applied to solid visceral and vascular injuries, however they are applied inconsistently to SB and colonic injuries. In addition, there appears to be incomplete understanding about the optimal approach to managing the abdominal wound in these patients with critical injury.

Lessons learnt

Damage control is a minimalistic, truncated procedure. The fact that the length of procedure across DCS and non-DCS groups in this series was not significantly different is reflective of an incomplete understanding of the principles of DCS and this is especially apparent in the management of SB and colonic injuries and of the abdominal incision.

Relevance to the Medical Officer

The arena of warfare is changing. Enduring operations such as those in Afghanistan commonly saw casualties bypass the Role 1 treatment facility and head straight for the Role 2 enhanced facility at Camp Bastion. As operations become less enduring, without the support of a nearby Role 2 facility, the Medical Officer at a Role 1 will become more integral in providing damage control resuscitation, and damage control procedures should form the very foundation of a military surgeon's skill set.

CONCLUSION

Just under 20% of trauma laparotomies require DCS. In this cohort of patients, the mortality rate is just under one-third. Further attention must be paid to refining the appropriate indications for DCS as the margin for error in such a cohort is very small and poor decision-making is difficult to correct. The major lesson from this analysis is that the decision to perform DCS must be made early and communicated appropriately to all those managing the patient. Although DCS approaches are applied appropriately to solid organ and vascular injuries, the same cannot be said for the management of enteric injuries and of the abdominal incision. Further refinement of our algorithms is necessary to assist with surgical decision-making in these patients.

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