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ORIGINAL ARTICLE

A decade long overview of damage control laparotomy for abdominal gunshot wounds

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Abstract

Purpose Over the last three decades, damage control laparotomy (DCL) has become important in the management of abdominal gunshot wounds (GSW). This paper reviews the experience of a single institution over a decade with the use of DCL for GSW of the abdomen.

Methods Longitudinal data (2013-2022) was collected from the Hybrid Electronic Medical Registry database to identify all patients with an abdominal GSW over the study period. The data was stratified based on patients who underwent DCL and those who did not. Descriptive analysis was completed to summarise the raw data. Univariate and multivariate analysis was completed to identify variables associated with undergoing DCL.

Results There were 135 patients (32%) who underwent DCL and 290 patients (68%) who did not. Colonic, small bowel, mesenteric, hepatic, pancreatic and intra-abdominal vessel injuries were associated with the need for DCL ($P<0.05$). In total, 85 of the 135 (63%) patients who underwent DCL required more than one damage control technique. There were 45 (33%) mortalities in the DCL group compared to 16 mortalities (6%) in the non-DCL group ($P<0.001$).

Conclusion One third of patients who underwent a laparotomy following a gunshot wound to the abdomen had a DCL. The indications for DCL include both physiological criteria and injury patterns. DCL is associated with significant morbidity and mortality. Efforts need to be directed towards refining the indications for DCL in this group of patients to prevent inappropriate application of this potentially lifesaving technique.

Keywords Trauma · Surgery · Laparotomy · Gunshot wound · Abdominal injury

Introduction

There have been major changes in the approach to the management of abdominal gunshot wounds (GSW) over the last three decades. A mandatory laparotomy approach has been replaced by a selective non-operative approach (NOM) in a well-defined subset of patients [1]. The use of pre-operative imaging to select patients for non-operative approaches as well as to better refine and plan the operative strategy, has increased [2, 3]. In addition, the philosophy of damage control laparotomy (DCL) has come to the fore. This approach eschews prolonged definitive operations in favour of abbreviated surgery and blood-based resuscitation. The surgical principle remains control of haemorrhage and soiling, followed by rapid abbreviated procedures [4, 5]. The patient is then taken to the Intensive Care Unit (ICU) where goal directed resuscitative measures attempt to restore physiology to normal. Once this has been achieved, the patient returns to the operating room for definitive surgical management. The indications for DCL were generated by a combination of expert consensus and focus discussion groups [6]. Despite these attempts to provide evidence based indications for DCL, clinical discernment remains key to the correct application of this approach. Most authors and clinicians use a combination of physiological parameters and the injury complex to decide on the need for DCL.

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Numerous damage control techniques have been developed [7]. These include solid organ packing, the resection of complex splenic or renal injuries, so called 'clip and drop' approaches to the management of penetrating enteric wounds, vascular ligation, temporary vascular shunting, simple external drainage, and temporary abdominal containment strategies. Abdominal GSWs result in a wide spectrum of intra-abdominal injuries. This makes the clinical scenario difficult as there are multiple injuries with competing operative demands. Generally, a wider spectrum of damage control techniques need to be applied in the management of abdominal GSWs than in the management of other mechanisms of abdominal trauma. This paper reviews the experience of a single institution over a decade. The aim was to compare those patients who underwent DCL with those who did not, in terms of physiology and indication for DCL, as well as clinical outcome. It also seeks to document the DCL techniques and procedures applied.

Materials and methods

Clinical setting

The Pietermaritzburg Metropolitan Trauma Service (PMTS) is based at Grey's Hospital in the city of Pietermaritzburg, South Africa. Since its inception in 2006, the PMTS has provided definitive trauma care to the city of Pietermaritzburg and the surrounding catchment area with a total population of over four million people. It is one of the largest academic trauma centres in the region with over 4000 admissions for trauma annually, of which and over half are secondary to penetrating injuries. The Hybrid Electronic Medical Registry (HEMR) is a regional electronic trauma database and all trauma admissions to Grey's Hospital are captured by this registry.

The study

Longitudinal ten-year data (2013-2022) data was retrieved from the HEMR trauma database and all patients who sustained an abdominal gunshot wound (GSW) over the study period were identified and their data extracted. Out of this cohort, all patients who required a laparotomy were identified. Those who underwent a DCL for an abdominal GSW were compared to those who did not. Ethics approval for the maintenance of our registry and for this study was formally approved by the Biomedical Research Ethics Committee of the University of Kwa Zulu Natal (BCA 221/13).

Management protocol

All patients who sustain an abdominal GSW and who present to Grey's hospital are resuscitated by our staff. Haemodynamic instability, peritonitis, and organ evisceration remain absolute indications for operation. In the absence of these features, all patients who sustain an abdominal GSW are assessed clinically. Based on clinical examination and plain radiography, the potential tract is delineated. Where the trajectory is across the anterior abdomen or flank there is a high likelihood of intra-abdominal hollow visceral injury. Although CT imaging may not be absolutely necessary in this cohort, it may limit the extent of surgery, by allowing for an assessment of retroperitoneal structures such as major vessels or the pancreatic duodenal complex. Tracts across the pelvis or perineum raise the spectrum of rectal or bladder neck injuries and CT imaging may help define these injuries. Tracts with a thoracoabdominal path can result in significant injuries in both the chest and abdomen. A variety of adjuncts can help delineate injuries in these cavities. These include pericardial ultrasound to exclude a cardiac tamponade and CT scanning. Gunshot wounds with a trajectory confined to the right thoracoabdominal region with hepatic injuries are typically suitable for non-operative management. CT scan of the chest and abdomen/pelvis is obtained selectively based on this assessment.

Statistical analysis

The data was stratified based on patients who underwent DCL and those who did not (non-DCL). Descriptive analysis of the raw data was undertaken. In univariate analysis, categorical outcomes were compared using chi-squared testing and continuous variables were compared using the independent samples Student's t-test or Mann-Whitney-U test as appropriate. Variables with a P value <0.15 were then entered into a multivariate logistic regression analysis to identify independent variables associated with receiving DCL. Patients with missing data were excluded from the analysis. Two-tailed P-values <0.05 were considered statistically significant. All analyses were conducted using SPSS (version 29, IBM Corp, Armonk, NY, USA).

Results

Overview

During the study period, 425 patients with abdominal gunshot wounds underwent laparotomy. Of these, 135 patients (32%) underwent damage control surgery (DCL) and 290 patients (68%) did not. There were 119 (88%) males and 16 (12%) females in the DCL group, and 262 (90%) males and 28 (10%) females in the non-DCL group. The median age was 30 years (range 3-69 years in DCL, 6-77 years in non-DCL) in both groups. Apart from median age, gender and pH, all differences in demographics and mean physiology (respiratory rate, heart rate, systolic blood pressure,

Glasgow Coma Score, Revised Trauma Score, temperature, pH, lactate, Injury Severity Score) between the two groups were statistically significant. In the DCL group, 81 (60%) patients had a plain X-ray, and 38 (28%) patients underwent a CT scan. In the non-DCL group, 164 (57%) patients had a plain X-ray, and 95 (37%) patients underwent a CT scan. None of these differences were statistically significant on univariate analysis.

Injuries

Table 1 details the spectrum of intra-abdominal injury for DCL patients according to organ/vessel damage. Damaged structures included the stomach, duodenum, diaphragm, spleen, kidney, pancreas, liver, gallbladder, small bowel, large bowel, rectum, mesentery, bladder, ureter, and intra-abdominal vessels. Also shown in Table 1 are details of the median shock index, Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) associated with each type of intra-abdominal injury. Note that a single patient may sustain injuries to multiple organs.

Predictors of DCL

In the multivariate analysis, four variables were independent predictors of undergoing DCL or non-DCL management: respiratory rate (odds ratio (OR) 1.107, 95% confidence interval (CI) 1.048-1.169, P <0.001), temperature (OR 0.661, 95% CI 0.463-0.944, $P = 0.023$), ISS score (OR 1.069, 95% CI 1.024-1.117, $P = 0.003$), and large bowel injury (OR 3.248, 95% CI, 1.815-5.815, $P < 0.001$).

Management and complications

Table 2 outlines the common surgical damage control intervention for each type of injury in the DCL group, as well as the number of complications and mortality rate for each type of organ injury. A single patient may sustain multiple injuries to multiple organs. This may mandate multiple damage control interventions during a single DCL. Thus, the total number of interventions (n=208) exceeds the total number of patients in the DCL group (n=135). Respiratory complications and renal complications were most common in the gastric repair group, gastrointestinal complications were most prevalent in the small bowel repair group, and wound sepsis was most common in the diaphragm repair group. Anaemia, poor GI tolerance, wound sepsis and pressure sores were most common in the liver packing group. In total, 85 of the 135 (63%) patients who underwent DCL required more than one injury specific intervention. There were 19 (14%) patient deaths prior to re-laparotomy in the DCL group. Of the 135 patients who underwent DCL, 39 patients (29%) underwent more than one repeat laparotomy.

Table 3 details the most common interventions undertaken at repeat laparotomy.

Overall morbidity and mortality

Overall, 63% of DCL patients experienced one or more complications. This rate was lower (27%) in non-DCL patients (P<0.001). The most affected system was "other" (22%) in DCL patients (e.g. anaemia, poor feeding, sepsis, pressure sores, etc.), compared to the gastrointestinal system (8%) in

Table 1 Spectrum of intra-abdominal injury with associated injury severity

Organ Injury	Number of Patients (% of DCL)	Median Shock Index	Median ISS	Median AIS
Stomach	36 (27%)	1.0	16	3
Duodenum	14 (10%)	0.9	16	5
Diaphragm	28 (21%)	1.0	16	3
Spleen	10 (7%)	0.8	25	4
Kidney	14 (10%)	0.8	17	5
Pancreas	13 (10%)	1.0	15	4
Liver	42 (31%)	1.0	16	4
Gallbladder	6 (4%)	1.0	13	4
Small bowel	78 (58%)	0.9	16	3
Large bowel	80 (59%)	0.9	16	3
Rectum	8 (6%)	0.8	13	4
Mesentery	25 (19%)	0.9	18	3
Bladder	10 (7%)	0.8	16	4
Ureter	6 (4%)	1.1	11	4
Intra-abdominal vessel	18 (13%)	1.0	13	5

DCL damage control laparotomy, *ISS* injury severity score, *AIS* abbreviated injury scale

Table 2 Operative Intervention and associated morbidity and mortality by type of organ injury*

Organ Injury	Procedures	$N = 208$	Complications (% of procedures)	Mortality (% of procedures)
Liver	Packing	25	48%	40%
Stomach	Repair	35	54%	49%
Duodenum	Repair	12	42%	50%
Small Bowel	Repair	26	46%	31%
	Clip and drop	32	41%	28%
Large Bowel	Repair	20	40%	35%
	Clip and drop	36	36%	22%
Diaphragm	Repair	22	36%	36%

*Only operations with ten or higher numbers performed are included in the table

Table 3 Number of interventions undertaken at re-laparotomy in descending order

Procedure	Number ($N = 129$)
Small bowel anastomosis	30
Small bowel resection	20
Ileostomy	14
Large bowel anastomosis	13
Large bowel resection	12
Liver packing	11
Small bowel repair	10
Colostomy	9
Large bowel repair	5
Stomach repair	5
Diaphragm repair	3
Cholecystectomy	2
Bladder repair	1
Rectal repair	1

non-DCL patients (e.g. anastomotic leak, ileus, constipation, etc.). Respiratory complications were relatively common in both DCL and non-DCL groups, with hospital or ventilator associated pneumonia being most common. The DCL group had a higher rate of ICU admission (73%) compared to the non-DCL group (29%) ($P<0.001$). There were 45 (33%) mortalities in the DCL group, compared to 16 mortalities (6%) in the non-DCL group ($P<0.001$). Sepsis/shock was the most common cause of mortality in both DCL patients ($n=18$, 40% of mortalities) and non-DCL patients ($n=7$, 44% of mortalities). The most common Clavien Dindo grade in patients who underwent DCL was grade 2 ($n=22$, 35%), which was the same in non-DCL patients (n=34, 12%).

Discussion

Since the initial description of damage control surgery in the previous millennium, the concept has been extended to include resuscitation and extra-abdominal procedures. The debate around DCL now revolves around selection and the optimal goals of resuscitation to determine return to the operating room. The indications for DCL are based on physiological predictors of mortality, such as acidosis, hypothermia and the need for major fluid replacement [8]. These indications were developed by a combination of scoping reviews, qualitative research methods, and expert consensus. There is little hard evidence to support these various indications [1, 9]. Although we use these criteria in our selection of patients for DCL, we also rely heavily on the presence of specific anatomical injuries. Although the DCL cohort all had significantly worse physiology, a number of specific organ injuries were associated with the use of DCL. These included colonic, small bowel, mesenteric, hepatic, pancreatic and intra-abdominal vessel injury. DCL must be applied highly selectively. Although the decision to perform DCL can be entertained pre-operatively based on physiological and metabolic parameters, a pre-operative decision must be revised once the full extent of the injuries is established. The operative and anaesthetic teams must maintain open channels of communication. The widespread uptake of damage control may have resulted in overuse, and there is an emerging body of literature highlighting this concern [6, 10, 11]. In this series, a third of patients underwent a DCL. Although we have demonstrated a significant difference between the two groups (DCL vs non-DCL) in terms of physiological and metabolic parameters, this high rate of DCL is cause for reflection. DCL is not a benign technique and Talving and colleagues have raised the issue that stapled off bowel as part of DCL is a risk factor for infective complications [12]. Educational efforts need to emphasise that DCL is to be used in a restrictive approach.

The commonest DCL operative technique for abdominal GSW is hepatic packing [13, 14]. This was described by Pringle and was the first major DCL technique to be widely adopted [15]. In regard to renal and splenic injuries, the modern DCL philosophy is one of non-intervention if clinically appropriate. There is good evidence that non-expanding peri-renal haematomas do not need to be explored routinely at the initial operation [14]. Opening the peri-renal fascia releases the tamponade effect and precipitates acute bleeding, which may mandate nephrectomy. Not exploring a peri-renal haematoma at index laparotomy allows for the haemorrhage to resolve. Injuries to the ureter or ongoing bleeding can be dealt with as interval procedures either via endo-urological procedures or with angio-embolization.

There is little support for the operative splenic preservation techniques from the pre DCL era. Splenic injuries in the modern era can be managed by angio-embolization if required [14]. This philosophy is reflected in our results. In the DCL group, 90% of splenic injuries were managed by splenectomy, and 64% of renal injuries by nephrectomy, demonstrating the limited role of operative salvage procedures in the damage control setting. Selective exploration of non-expansile peri-renal and lateral retroperitoneal haematomas is appropriate in patients undergoing damage control surgery. The management of pancreatic trauma is complex. If there is a ductal injury, external drainage is essential to prevent the egress of pancreatic fluid into the abdomen. This can be achieved by placing closed suction drains. In cases of a destructive injury of the pancreatic head, the best option in the acute phase remains drainage, followed by a formal pancreatic-duodenectomy once physiology has been restored. Complex reconstruction must not be attempted in the DCL setting. Injuries to the tail of the pancreas can be managed by distal pancreatectomy and drainage. Temporary closure of duodenal injuries is not feasible, and definitive duodenal repair at index laparotomy is indicated regardless of the need for DCL.

The commonest DCL technique for enteric injury is a so-called clip and drop approach. This was applied in our series to both large and small bowel injuries. There is no DCL option for a penetrating wound of the gallbladder, and cholecystectomy is definitive. This is reflected in a cholecystectomy rate of 83% in patients with a penetrating gunshot wound of the gallbladder. Gastric injuries are not amenable to a 'clip and drop' approach and must be repaired. Ureteric injury is relatively rare and should be repaired over a stent. These injuries are also amenable to endo-urological management once the acute resuscitation phase is over. The most common vascular injury seen in this cohort is to the inferior vena cava (IVC). These can be ligated if the injury is inferior to the renal veins. Supra-renal IVC injuries are challenging, and repair should be attempted in order to preserve renal venous drainage. We did not make use of temporary vascular shunting in this cohort of patients, although this remains a valid temporising technique.

Of all patients who underwent DCL for abdominal GSW, 63% had more than one organ specific intervention. A combination of techniques are often required for penetrating trauma to the abdomen. This is in contrast to blunt trauma, where there is usually a single predominant injury requiring a single damage control technique. The abdominal wall should not be closed after DCL and a temporary abdominal closure (TAC) strategy must be adopted [16]. All patients undergoing a DCL will require at least one repeat laparotomy. In this series, 14% of patients died prior to repeat laparotomy. This highlights the enormous physiological insult these patients experience. Of those who did not undergo DCL, one fifth (21%) underwent a repeat laparotomy.

Limitations

This paper is a retrospective review of a prospectively entered database, and this makes it difficult to ascertain whether DCL was truly indicated in each patient. The resultant cohorts are patients who underwent DCL and patients who did not. This makes it impossible to ascertain the appropriateness of each individual decision.

Conclusion

One third of patients who underwent a laparotomy following a gunshot wound to the abdomen underwent a DCL. The indications for DCL included both physiological criteria and injury patterns. Multiple DCL techniques were frequently utilised in a single patient. DCL is associated with significant morbidity and mortality. Efforts need to be directed towards refining the indications for DCL in this group of patients to prevent inappropriate application of this potentially lifesaving technique.

Author contributions R.H. - data extraction, analysis, table preparation, manuscript writing, manuscript review.
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J.K. - data extraction, table preparation.
A.N. - manuscript review.
H.W. - manuscript writing, manuscript review.
J.B. - manuscript review.
G.L. - manuscript review.
V.M. - manuscript review.
W.B. - manuscript review.
D.C. - manuscript writing, manuscript review.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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