Pediatr Surg Int (2017) 33:587–592
DOI 10.1007/s00383-017-4061-z

ORIGINAL ARTICLE

Damage control laparotomy for abdominal trauma in children

Stephanie F. Polites[1,3] · Elizabeth B. Habermann[2] · Amy E. Glasgow[2] · Martin D. Zielinski[1]

Accepted: 10 January 2017 / Published online: 6 February 2017
© Springer-Verlag Berlin Heidelberg 2017

Abstract

Background Damage control laparotomy (DCL) is not well studied in the pediatric trauma population. The purpose of this study was to develop a surrogate definition of DCL compatible with national and administrative data sources so that the rate and outcomes of DCL in pediatric trauma patients could be determined.

Methods Using the 2010–2014 National Trauma Data Bank, children ≤18 with an abdominal AIS ≥ 3 who underwent a laparotomy within 3 h of arrival were identified ($n = 2989$). DCL was defined as occurring in children who underwent a second laparotomy within 5–48 h from the index laparotomy ($n = 360$). Children meeting these criteria were compared to those children who had the initial definitive operative management ($n = 2174$) and those who died prior to 48 h ($n = 455$).

Results DCL occurred in 12% of children with operative abdominal trauma. Children who underwent DCL had a greater median ISS (25 vs 18) and heart rate (112 vs 100), lower systolic blood pressure (104 vs 113), and GCS (12 vs 13), and were more likely to receive a preoperative blood transfusion (19 vs 11%) than those who had definitive initial operative management (all $p < .05$). Median length of stay (17 vs 8 days) and mortality (9 vs 2%) were greater following DCL than definitive initial operative management ($p < .001$). No differences in rate of DCL were seen based on ACS pediatric verification ($p = .07$).

Conclusions Few children with operative abdominal trauma undergo DCL. DCL was associated with worse physiology rather than anatomic injury severity in this study. As expected, outcomes were worse following DCL.

Keywords Pediatric trauma · Damage control · Laparotomy · Resuscitation

Background

Trauma is the most common cause of morbidity and mortality in children. In 2013, abdominal trauma comprised 13% of pediatric injuries, with a case fatality rate of 5% [1]. While emphasis is placed on non-operative management of pediatric abdominal injuries, hemodynamically unstable children who do not respond to resuscitation require operative intervention [2]. The "lethal triad" of hypothermia, coagulopathy, and metabolic acidosis can preclude definitive operative management, which prompted use of damage control resuscitation protocols [3]. A major component, and the most common damage control procedure, is damage control laparotomy (DCL). This procedure involves control of hemorrhage and contamination followed by intra-abdominal packing and expedient temporary closure [4]. Patients are then further resuscitated and subsequently return to the operating room for definitive management.

This paper was presented at the Pediatric Trauma Society in Chicago, IL on November 15, 2014.

✉ Stephanie F. Polites
habermann.elizabeth@mayo.edu

Amy E. Glasgow
glasgow.amy@mayo.edu

Martin D. Zielinski
zielinski.martin@mayo.edu

1 Division of Trauma, Critical Care, and General Surgery, Mayo Clinic, Rochester, MN, USA

2 Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery, Rochester, MN, USA

3 Department of Surgery, Mayo Clinic, 200 1st Street SW, Rochester, MN 55905, USA

The benefits of DCL in critically injured adults have been shown, including a long-term mortality benefit, despite the increased short-term morbidity associated with an open abdomen and multiple operations. Due to the relative infrequency of operative abdominal trauma in children, pediatric experience on DCL is limited and draws from children with necrotizing enterocolitis and other non-trauma pediatric surgical conditions [5–7]. These small series have demonstrated feasibility of DCL in children, but the true risks and benefits remain unknown. Given the rarity of DCL in injured children, it is difficult to study within single centers. Multicenter studies are expensive and the lack of billing codes specific to DCL has precluded use of secondary data. Therefore, the purpose of this study was to develop a definition of DCL for children usable with national or administrative data sources. Secondary aims were to determine the rate, characteristics and outcomes of children who undergo DCL based on the developed surrogate definition.

Methods

Patient selection and definitions

There is no ICD-9-CM procedure or CPT code for temporary abdominal closure or damage control procedure; therefore, a surrogate definition for DCL was required. Children 18 years of age and under with an abdominal abbreviated injury scale (AIS) score of 3 or greater were identified from the 2010–2014 National Trauma Data Bank (NTDB). Patients who underwent laparotomy within 3 h of arrival were included (ICD-9-CM 54.11, 54.19) and subsequently divided into three groups. (1) DCL was defined as a second laparotomy within 5–48 h of the first (ICD-9-CM 54.11, 54.12, 54.19) (2) definitive management as those without a second laparotomy within 48 h, and (3) death within 48 h without returning to the operating room. Patients who underwent an intestinal anastomosis (ICD-9-CM 45.9) at the initial laparotomy were excluded from the DCL group. Patient demographics, injury characteristics, outcomes (length of stay (LOS) and mortality), and characteristics of the treating facility were collected.

Data source

The NTDB Research Data Set (RDS) contains deidentified patient-level data provided voluntarily by trauma centers to the American College of Surgeons Committee on Trauma (ACSCOT) that are released on an annual basis. In 2011, the NTDB contained more than five million patient entries from more than 900 institutions in the United States and Puerto Rico [1]. Participating institutions utilize standard inclusion criteria and variable definitions according the NTDB data dictionary and all contributed data are reviewed by the NTDB Validator prior to inclusion. The NTDB RDS includes all of the ICD-9-CM codes for each patient. AIS data were obtained from the NTDB RDS, which utilizes ICD-9-CM codes to calculate AIS in a standardized fashion using the ICDMAP-90 crosswalk.

Statistical analysis

Values were presented as *N* (percentage), mean (standard deviation; sd), or median (interquartile range; IQR). Characteristics of children who underwent DCL, definitive management at the initial laparotomy, and who died within 48 h of laparotomy were compared using *t* tests for continuous variables and chi-square tests for categorical variables. Outcomes, including LOS and mortality, were also compared. Mann–Whitney–Wilcoxon rank sum tests were used to compare medians. Statistical significance was acknowledged when $p < .05$. Analysis was completed with SAS (SAS Institute, Cary, NC).

Results

We identified 2989 children with abdominal AIS ≥ 3 who underwent laparotomy within 3 h of arrival. The mean age was 15 (4) years and 21% were female. The majority (59%) suffered penetrating trauma, but the minority (31%) received care at a pediatric trauma center. The in-hospital mortality rate was 18%. Of the 2989 children, 360 met criteria for DCL (Group 1), 2174 underwent definitive operation (Group 2), and 455 died within 48 h of the initial laparotomy (Group 3). The DCL rate in this study was 12%.

DCL vs definitive management

Patients who underwent DCL were older than those who underwent definitive operation (16 ± 4 vs 15 ± 4 years, $p = .001$), but there was no difference in sex (21 vs 19% female, $p = .52$) (Table 1). Median (IQR) ISS was greater for children who underwent DCL (25 [17, 35] vs 18 [10, 27], $p < .001$). AIS scores were similar. Children who underwent DCL also had a greater mean initial pulse, lower mean systolic blood pressure, lower mean temperature, and lower mean GCS. While a preoperative transfusion was required in DCL patients more frequently, abdominal CT was done less frequently. No differences in DCL vs definitive operative management were found based on ACS pediatric trauma verification level of the treating center; however, DCL occurred most frequently at centers with adult ACS level I verification.

Table 1 Characteristics of children who underwent DCL vs definitive operation

	All patients		
	Definitive operation ($n=2174$)	DCL ($n=360$)	p value
Mean (sd) age, years	15 (4)	16 (4)	0.001
Female sex	410 (19%)	76 (21%)	0.52
Median [IQR] ISS	18 [10, 27]	25 [17, 35]	<0.001
Median AIS			
Head	4 [2, 4]	4 [2, 5]	0.31
Thorax	3 [3, 3]	3 [3, 3]	0.52
Abdomen	3 [3, 4]	3 [3, 4]	0.019*
Spine	2 [2, 2]	2 [2, 2]	0.12
% Blunt	772 (36%)	135 (38%)	0.32
Mean (sd) SBP	113 (30)	104 (31)	<0.001
Mean (sd) pulse	100 (29)	112 (32)	<0.001
Mean (sd) temperature (ºC)	36 (5)	34 (8)	<0.001
Mean (sd) GCS	13 (4)	12 (5)	<0.001
% Preoperative transfusion	211 (11%)	67 (19%)	<0.001
% Preoperative ultrasound	88 (4%)	20 (6%)	0.20
% Preoperative CT	232 (11%)	24 (7%)	0.018
ACS pediatric verification			
I	226 (83%)	45 (17%)	0.07
II	151 (84%)	28 (16%)	
None	1797 (86%)	287 (14%)	
ACS verification			
I	877 (82%)	188 (18%)	<0.001
II	335 (90%)	37 (10%)	
III	12 (100%)	0	
Other	950 (88%)	135 (12%)	

Values are represented as mean (standard deviation; sd), median [interquartile range; IQR], or n (%)

ISS injury severity scale, *AIS* adjusted injury scale, *SBP* systolic blood pressure, *GCS* Glasgow Coma Scale, *CT* computed tomography, *ACS* American College of Surgeons

*Difference statistically but not clinically significant due to different rank sums despite equal medians [15]

Several complications were more frequent following DCL, including deep venous thrombosis (DVT), pneumonia, severe sepsis, and acute renal failure (Table 2). There was no difference in occurrence of acute respiratory distress syndrome (ARDS). Overall, length of stay was greater following DCL, as was number of ventilator days and number of intensive care days. Patients who underwent DCL were also at significantly greater risk of in-hospital mortality (9 vs 2%, $p < .001$).

DCL vs early death

When compared to the 455 children who died within 48 h of trauma laparotomy, the DCL group had lower median ISS, abdominal AIS, and head AIS (Table 3). In addition, physiologic parameters, including systolic blood pressure, temperature, and GCS, were worse in the early death group. The head AIS and GCS differences suggest more severe head injuries in the early death group, likely contributing to the early mortality. Utilization of transfusion was similar between these groups. While there was no difference in DCL vs early death based on ACS pediatric trauma verification level, those who underwent laparotomy at level I adult centers were least likely to die within 48 h.

Discussion

Damage control laparotomy for trauma allows control of hemorrhage and contamination followed by resuscitation to correct coagulopathy, hypothermia, and acidosis prior to definitive operative management [4]. Patients who undergo DCL are more severely injured and have greater short-term morbidity and mortality. Adult trauma literature, however, has shown long-term benefits to DCL when used appropriately [8]. Due to the relative infrequency of pediatric operative abdominal trauma, single institutions are unable to amass sufficient sample size to study indicators for DCL in children and outcomes. In addition, there is little known about the overall utilization of DCL in injured children in the United States. Further study of this important technique is needed, as limited case series of children undergoing DCL were promising [6, 7]. In this study, we defined DCL using administrative data and evaluated pediatric utilization and outcomes.

When compared to children who underwent definitive management, children meeting criteria for DCL had significantly worse physiology but similar anatomic severity. These data suggest that the need for damage control procedures in children is based on physiology, which is similar to adult literature and supports the surrogate definition created in this study. When DCL was first described in 1993, the intention was for this approach to be used in patients with physiology that precluded successful completion of definitive operative management [4]. Recent studies in adult trauma patients, however, have questioned overutilization of damage control procedures given high rates of fascial closure at first take back [9, 10]. While further studies need to be completed to identify criteria for DCL in injured children, physiology should continue to guide this decision rather than institutional practices.

As expected, the DCL group in our study had greater postoperative morbidity and mortality as well as length

Table 2 Outcomes of DCL vs definitive operation

Outcome	Overall	Definitive operation	DCL	*p* value
Superficial SSI	39 (2%)	30 (1%)	9 (3%)	0.16
Deep SSI	49 (2%)	33 (2%)	16 (4%)	0.001
Organ space SSI	69 (3%)	46 (2%)	23 (6%)	<0.001
DVT/thrombophlebitis	84 (3%)	57 (3%)	27 (8%)	<0.001
Pneumonia	167 (7%)	122 (6%)	45 (13%)	<0.001
Pulmonary embolism	18 (1%)	13 (1%)	5 (1%)	0.16
Severe sepsis	33 (1%)	18 (1%)	15 (4%)	<0.001
Acute renal failure	70 (3%)	41 (2%)	29 (8%)	<0.001
ARDS	89 (4%)	73 (3%)	16 (4%)	0.28
LOS, days	9 [6, 27]	8 [6, 15]	17 [10, 28]	<0.001
ICU days	3 [0, 7]	2 [0, 6]	8 [4, 15]	<0.001
Ventilator days	0 [0, 3]	0 [0, 2]	4 [2, 8]	<0.001
In-hospital mortality	84 (3%)	51 (2%)	33 (9%)	<0.001

Values are represented as mean (standard deviation, sd), median [interquartile range, IQR], or *n* (%)

SSI surgical site infection, *DVT* deep venous thrombosis, *ARDS* acute respiratory distress syndrome, *LOS* length of stay, *ICU* intensive care unit

Table 3 Characteristics of children who underwent DCL vs early death

	All patients		
	Early death (*n* = 455)	DCL (*n* = 361)	*p* value
Mean (sd) age, years	14 (5)	16 (4)	0.001
Female sex	141 (31%)	76 (21%)	0.001
Median [IQR] ISS	34 (25,43]	25 [17,35]	<0.001
Mean AIS			
Head	5 [4,5]	4 [2,5]	<0.001
Thorax	3 [3,3]	3 [3,3]	0.053
Abdomen	4 [3,4]	3 [3,4]	<0.001
Spine	2 [2,2]	2 [2,2]	0.22
% Blunt	247 (54%)	135 (37%)	<0.001
Mean (sd) SBP	79 (45)	104 (31)	<0.001
Mean (sd) pulse	102 (45)	112 (32)	0.06
Mean (sd) temperature, ºCelsius	32 (10)	34 (8)	<0.001
Mean (sd) GCS	6 (4)	12 (5)	<0.001
% Preoperative transfusion	99 (22%)	67 (19%)	0.29
% Preoperative ultrasound	13 (3%)	20 (6%)	0.07
% Preoperative CT	15 (3%)	24 (7%)	0.03
ACS pediatric verification			
I	43 (49%)	45 (51%)	0.11
II	41 (59%)	28 (41%)	
None	371 (56%)	288 (44%)	
ACS verification			
I	194 (51%)	189 (49%)	0.024
II	62 (63%)	37 (37%)	
III	3 (100%)	0 (−)	
Other	196 (59%)	135 (41%)	

Values are represented as mean (standard deviation), median [interquartile range, IQR], or *n* (%)

ISS injury severity scale, *AIS* adjusted injury scale, *SBP* systolic blood pressure, *GCS* Glasgow Coma Scale, *CT* computed tomography, *ACS* American College of Surgeons of stay. Many children in this study who died within 48 h of the initial laparotomy likely had a damage control procedure; thus, the in-hospital mortality following DCL was underestimated. This study found that severity of head injury as well as physiologic parameters of systolic blood pressure and body temperature were associated with death within 48 h of the initial laparotomy. This is consistent with adult literature which demonstrates poor short-term outcomes associated with DCL. Those who survive the initial hospitalization, however, have excellent long-term outcomes. Similar long-term data are needed in the pediatric population.

Several studies have shown improved outcomes for pediatric and adolescent trauma patients at verified pediatric trauma centers; thus, the association between trauma center verification and DCL utilization and outcomes was of interest in this study [11, 12]. We did not find differences in utilization of definitive vs damage control approach in this study based on pediatric verification. Of interest, however, was the increased utilization of DCL vs definitive management in children treated at adult level I centers when compared to level II centers and those without ACS adult verification. Similarly, the early deaths after laparotomy were less frequent compared to DCL among children treated at adult level I centers than those treated elsewhere. The reasons for these differences based on adult verification level cannot be elucidated from this study and require further investigation. It is conceivable that centers with adult verification draw from their adult trauma experience and the adult trauma literature, and are more likely to implement damage control practices in pediatric patients with the resulting benefits when utilized appropriately.

In this study, we created a definition for DCL in the NTDB, as there is no variable or billing code for DCL or open abdomen. This definition, including the criteria of AIS ≥ 3 and return to the operating room within 48 h of the initial laparotomy, was created based on existing adult literature on damage control procedures [13, 14]. While further, prospective, multi-institutional validation of this definition is needed, we found DCL to be associated with physiologic rather than demographic or anatomic characteristics and poorer short-term outcomes than definitive initial operative management. Though these findings corroborate our definition, it is not without weaknesses. It is possible that patients in the DCL group underwent a definitive initial procedure and returned within 48 h for complications. Inclusion of damage control procedures in administrative databases is needed for improved tracking and analysis of these important procedures. The Pediatric Trauma Quality Improvement Program (TQIP) may provide a route by which this important aspect to care of pediatric trauma patients can be further investigated on a multi-institutional level.

Conclusion

We estimate that DCL is performed in 12% of children with operative abdominal trauma. Physiologic derangements rather than demographics and anatomic injury severity are associated with the need for DCL as opposed to definitive initial operative management. Though short-term morbidity is high as expected, long-term outcomes remain to be studied. Most importantly, improved methods of studying this important procedure are needed through multicenter studies and development of administrative codes specific to DCL.

The NTDB remains the full and exclusive copyrighted property of the American College of Surgeons. The American College of Surgeons is not responsible for any claims arising from works based on the original Data, Text, Tables, or Figures.

Compliance with ethical standards

Conflict of interest The authors have no financial disclosures or conflict of interest.

References

1. American College of Surgeons Committee on Trauma. NTDB Pediatric Report 2013. Nance, ML (ed.). American College of Surgeons, 2013. https://www.facs.org/~/media/files/quality%20programs/trauma/ntdb/ntdb%20pediatric%20annual%20report%202013.ashx. Accessed 5 Nov 2014
2. Dodgion CM, Gosain A, Rogers A, St Peter SD, Nichol PF, Ostlie DJ (2014) National trends in pediatric blunt spleen and liver injury management and potential benefits of an abbreviated bed rest protocol. J Pediatr Surg 49 (6):1004–1008; discussion 1008. doi:10.1016/j.jpedsurg.2014.01.041
3. Duchesne JC, McSwain NE Jr, Cotton BA, Hunt JP, Dellavolpe J, Lafaro K, Marr AB, Gonzalez EA, Phelan HA, Bilski T, Greiffenstein P, Barbeau JM, Rennie KV, Baker CC, Brohi K, Jenkins DH, Rotondo M (2010) Damage control resuscitation: the new face of damage control. J Trauma 69(4):976–990. doi:10.1097/TA.0b013e3181f2abc900005373-201010000-00042 **[pii]**
4. Rotondo MF, Schwab CW, McGonigal MD, Phillips GR 3rd, Fruchterman TM, Kauder DR, Latenser BA, Angood PA (1993) 'Damage control': an approach for improved survival in exsanguinating penetrating abdominal injury. J Trauma 35(3):375–382 **(discussion 382–373)**
5. Markley MA, Mantor PC, Letton RW, Tuggle DW (2002) Pediatric vacuum packing wound closure for damage-control laparotomy. J Pediatr Surg 37(3):512–514
6. Pearson EG, Rollins MD, Vogler SA, Mills MK, Lehman EL, Jacques E, Barnhart DC, Scaife ER, Meyers RL (2010) Decompressive laparotomy for abdominal compartment syndrome in children: before it is too late. J Pediatr Surg 45(6):1324–1329. doi:10.1016/j.jpedsurg.2010.02.107
7. Neville HL, Lally KP, Cox CS Jr (2000) Emergent abdominal decompression with patch abdominoplasty in the pediatric patient. J Pediatr Surg 35(5):705–708. doi:10.1053/jpsu.2000.6027

8. Sutton E, Bochicchio GV, Bochicchio K, Rodriguez ED, Henry S, Joshi M, Scalea TM (2006) Long term impact of damage control surgery: a preliminary prospective study. J Trauma 61 (4):831–834. doi:10.1097/01.ta.0000239504.35149.c5**(discussion 835–836)**
9. Hatch QM, Osterhout LM, Ashraf A, Podbielski J, Kozar RA, Wade CE, Holcomb JB, Cotton BA (2011) Current use of damage-control laparotomy, closure rates, and predictors of early fascial closure at the first take-back. J Trauma 70(6):1429–1436. doi:10.1097/TA.0b013e31821b245a
10. Hatch QM, Osterhout LM, Podbielski J, Kozar RA, Wade CE, Holcomb JB, Cotton BA (2011) Impact of closure at the first take back: complication burden and potential overutilization of damage control laparotomy. J Trauma 71(6):1503–1511. doi:10.1097/TA.0b013e31823cd78d
11. Sathya C, Alali AS, Wales PW, Scales DC, Karanicolas PJ, Burd RS, Nance ML, Xiong W, Nathens AB (2015) Mortality among injured children treated at different trauma center types. JAMA Surg 150 (9):874–881. doi:10.1001/jamasurg.2015.1121
12. Webman RB, Carter EA, Mittal S, Wang J, Sathya C, Nathens AB, Nance ML, Madigan D, Burd RS (2016) Association between trauma center type and mortality among injured adolescent patients. JAMA Pediatr 170 (8):780–786. doi:10.1001/jamapediatrics.2016.0805
13. Cirocchi R, Montedori A, Farinella E, Bonacini I, Tagliabue L, Abraha I (2013) Damage control surgery for abdominal trauma. Cochrane Database Syst Rev 3:CD007438. doi:10.1002/14651858.CD007438.pub3
14. Pommerening MJ, DuBose JJ, Zielinski MD, Phelan HA, Scalea TM, Inaba K, Velmahos GC, Whelan JF, Wade CE, Holcomb JB, Cotton BA, Group AOAS (2014) Time to first take-back operation predicts successful primary fascial closure in patients undergoing damage control laparotomy. Surgery 156(2):431–438. doi:10.1016/j.surg.2014.04.019
15. Why is the Mann-Whitney significant when the medians are equal? UCLA: Statistical Consulting Group (2016) http://www.ats.ucla.edu/stat/mult_pkg/faq/general/mann-whitney.htm. Accessed 27 December 2016