Indications for Use of Damage Control Surgery in Civilian Trauma Patients: A Content Analysis and Expert Appropriateness Rating Study

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Running Head: Indications for Damage Control Surgery

Text Word Count: 3687

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Conflict of Interest and Source of Funding:

The authors have no conflicts of interest to declare. This study was supported by an Alberta Innovates – Health Solutions Clinician Fellowship Award, a Knowledge Translation (KT) Canada Strategic Training in Health Research Fellowship, a KT Canada Research Stipend, and funding from the Canadian Institutes of Health Research.

Mini-Abstract

This study identified a number of indications for damage control surgery that were suggested by authors of peer-reviewed articles and assessed by experts to be appropriate. These indications may provide a practical foundation to guide clinical practice while studies are conducted to evaluate their impact on patient care and outcomes.

Abstract

Objective: To characterize and evaluate indications for use of damage control (DC) surgery in civilian trauma patients.

Summary Background Data: Although DC surgery may improve survival in select, severely injured patients, the procedure is associated with significant morbidity, suggesting that it should only be used when appropriately indicated.

Methods: Two investigators used a grounded theory approach to synthesize indications for DC surgery reported in peer-reviewed articles published between 1983 and 2014 into a reduced number of named, content-characteristic codes representing unique indications. An international panel of trauma surgery experts (n=9) then rated the appropriateness (expected benefit-to-harm ratio) of the coded indications for use in clinical practice.

Results: The 1,107 indications identified in the literature were synthesized into 123 unique pre- (n=36) and intraoperative (n=87) indications. The panel assessed 101 (82.1%) of these indications to be appropriate. The indications most commonly reported and assessed to be appropriate included pre- and intraoperative hypothermia (median temperature <34ºC), acidosis (median pH <7.2), and/or coagulopathy. Others included 5 different injury patterns, inability to control bleeding by conventional methods, administration of a large volume of packed red blood cells (median >10 units), inability to close the abdominal wall without tension, development of abdominal compartment syndrome during attempted abdominal wall closure, and need to reassess extent of bowel viability.

Conclusions: This study identified a number of candidate indications for use of DC surgery that may provide a practical foundation to guide clinical practice while studies are conducted to evaluate their impact on patient care and outcomes.

Key Words: Content Analysis, Damage Control Surgery, Expert Appropriateness Rating Study, Indications, Wounds and Injuries.

Introduction

In patients requiring operation for major injury, surgeons must decide whether to perform a definitive or damage control (DC) procedure.[1] In contrast to definitive surgery (where all injuries are repaired and the explored cavity is closed), DC includes a brief initial operation used to rapidly control exsanguinating hemorrhage, a massive air leak, and/or gross contamination.[1, 2] The patient is subsequently admitted to the intensive care unit (ICU) for further resuscitation before returning to the operating room (OR) for additional surgery.[1] The commonly proposed goal of DC surgery is to prevent the onset of and/or interrupt the "vicious cycle" of hypothermia, acidosis, and coagulopathy.[3-5]

Although DC surgery is now widely utilized and has been reported to result in improved survival in select, severely injured patients,[6-10] the procedure is associated with a high incidence of potentially severe complications (e.g., enteroatmospheric fistulae), hospital readmissions, and subsequent surgical procedures as well as a reduced quality of life among those with a planned ventral hernia.[1, 11-16] The unclear benefit-to-harm profile of DC surgery, combined with the fact that emergent surgical decisions must be made quickly and often with limited information,[17] makes it difficult to determine the optimal "operative profile" in many clinical situations.[2] This difficulty has likely contributed to recent reports of a variation in use of DC surgery across level 1 trauma centers and concerns that the procedure may be overutilized.[14, 18, 19]

Although the decision to perform DC over definitive surgery often requires the simultaneous consideration of multiple factors, there are also a number of relatively common clinical circumstances that have been reported to be indicative of the need for DC.[1] The identification of a single yet complete list of these indications would provide a practical foundation to focus future studies and (until results of these studies become available) guide clinical practice.[1]

Thus, we conducted a content analysis and expert appropriateness rating study of the indications reported in peer-reviewed articles between 1983 and 2014. Our objectives were to create a comprehensive and well-defined list of the indications that have been suggested to date, determine which have been most commonly reported in the peer-reviewed literature, and evaluate the opinions of experts regarding the appropriateness (expected benefit-to-harm ratio) of the identified indications for use in clinical practice.

Methods

Content Analysis:

We elected to perform a content analysis as it is an objective, validated, and reproducible method of systematically synthesizing a large amount of information (i.e., the entire list of reported indications for use of DC surgery in the literature) into a reduced number of named, content-characteristic codes (i.e., unique indications for use of DC surgery).[20-23] A previously published protocol details our methods.[24]

Data Source:

In a previously conducted scoping review, we searched 11 bibliographic databases (1950-February 14, 2014), abstracts from five conferences held between 2009 and 2013, 12 trauma websites, Google Scholar, two clinical trials registries, and 30 textbooks.[1] Of the 27,732 citations identified in the literature, we included 175 peer-reviewed articles that reported 1,107 indications for use of civilian trauma DC surgery in the scoping review (see the published report for details).[1] We excluded citations involving exclusively burn or non-civilian trauma patients, and those focusing exclusively on DC surgery for patients with orthopedic or neurologic injuries.[1, 24] We defined an indication as a clinical finding/circumstance or hypothetical scenario that advised use of DC over definitive surgery.[1, 24] DC surgery was defined as a multi-step operative intervention, which included a brief initial surgical procedure that aimed to control mechanical bleeding, a massive air leak, and/or gross contamination.[1, 24]

Codebook Development:

We developed a detailed codebook to guide coding of the 1,107 indications identified by the scoping review.[20] This was done using a grounded theory approach to allow codes (and subcategories and categories of codes) to emerge inductively from the reported indications themselves instead of relying on pre-existing theory.[21, 25]

We began by grouping the indications identified by the scoping review according to whether they were based on prehospital, Emergency Department (ED), or intraoperative findings or events. Two investigators (D.J.R., N.B.) then read all indications contained within these groupings and independently sorted similar indications together. They then used constant comparative methodology and a mixture of manifest and latent open coding to independently create codes representing the unique indications within these sortings.[21, 24] These indication codes were subsequently grouped into higher order subcategories and categories. This process continued iteratively until no new indication codes (or subcategories or categories of indication codes) could be identified by either investigator.[23]

We used the organizational system recommended by the RAND/University of California, Los Angeles Corporation Appropriateness Rating Method (RAM) to organize indication codes into principal clinical findings or injuries (e.g., juxtahepatic venous injury) and associated decision variables (e.g., hemodynamic instability).[24, 26] We assumed that injury patterns/mechanisms, vital signs, amounts or types of resuscitation provided, and arterial blood gas and laboratory test results were the principal clinical findings (in that order) when more than one clinical finding was included in the definition of the code. For indications that included a decision threshold (e.g., pH <7.2), we created a code for the underlying concept (i.e., acidosis) and a separate code (i.e., pH <X) with a linked numerical value (e.g., 7.2) for the cutoff.

The initial set of independently created codes were compared and discussed by both investigators until consensus regarding the number, types, and definitions of codes was achieved. The coding framework was then sent to the other study investigators who were asked to examine each indication and identify poorly worded, unclear, or redundant indications. Based on this feedback, the coded indications were revised and/or reduced in number. The final codebook is included in **Supplemental Digital Content 1**.

Coding of the Indications Reported in the Literature:

Two investigators (D.J.R., N.B.) subsequently used the coding instructions, indication code definitions, and example indications included in the codebook to independently code all of the 1,107 indications identified by the scoping review. During coding, new codes were added (or existing codes were refined) when indications were encountered that did not fit into an existing code.[21] Coding disagreements were resolved by consensus.

We calculated kappa (κ) statistics to quantify inter-investigator coding reliability.[27] We used counts and percentages to describe the prevalence of indication, subcategory, and category codes in the literature. Cutoff values for reported indications with included decision thresholds (e.g., pH <X) were summarized using medians and interquartile ranges (IQRs).[24] Stata MP version 13.1 (Stata Corp., College Station, TX) was used for statistical analyses.

Expert Appropriateness Rating Study:

Panel Formation:

To evaluate the face validity of the indication codes, we invited a panel of 10 geographically-diverse trauma surgery experts to participate in an appropriateness rating study.

Panelists were identified by consulting the peer-reviewed trauma and DC literature, major trauma and surgery textbooks, and websites of key trauma care societies or associations in the United States, Canada, and Europe.[1] Each expert was widely known to have significant experience in the practice of trauma surgery and in training surgeons residing in high-income Countries in the conduct of operative trauma care. The panel included senior members (including five current or past presidents and one vice president) of the American Association for the Surgery of Trauma (AAST), Australasian Trauma Society, Eastern Association for the Surgery of Trauma, European Society for Trauma and Emergency Surgery, International Association for Trauma Surgery and Intensive Care, Trauma Association of Canada, Trauma Society of South Africa, and the Western Trauma Association.

Appropriateness Survey Administration:

Panelists who agreed to participate were sent a link to an electronic survey containing all of the indication codes identified during content analysis (see **Supplemental Digital Content 2** for the survey instrument). For each indication code, they were asked to rate the benefit-to-harm ratio of conducting DC over definitive surgery in an adult requiring or currently undergoing operation for a torso injury and/or major peripheral vascular injury using the validated 1-9 scale recommended by the RAM (where 1 means that the expected harms of conducting DC greatly outweigh the benefits, 5 means that the expected benefits and harms are about equal, and 9 means that the expected benefits greatly outweigh the harms).[26] Panelists were instructed to answer on behalf of an average trauma or general surgeon who would take call at a trauma center. For indications that included a cutoff value in its definition (e.g., temperature <X°C), only the median value calculated across those reported in the literature was rated. An assessment of the survey's

clarity, flow, and administrative ease was performed through pre-testing during which 4 independent trauma or general surgeons completed the survey and provided written feedback.

Analysis of Appropriateness Ratings:

Using the panelists' ratings, we classified indication codes as appropriate (panel median of 7-9, without disagreement), uncertain (panel median of 4-6 or any median with disagreement), or inappropriate (panel median of 1-3, without disagreement). Disagreement was defined using the RAM classic definition (at least three panelists rating the indication 1-3 and at least another three rating it 7-9).[26]

Results

Prevalence of Indications in the Peer-Reviewed Literature:

Of the 1,107 indications for DC surgery identified by the scoping review, 195 (17.6%) were based on pre- and 719 (65.0%) on intraoperative findings or events. For the remaining 193 (17.4%), the setting for their application was not specified and could not be determined. In total, we created 123 indication codes describing 36 preoperative and 87 intraoperative indications for use of DC surgery. **Figure 1** displays the flow of indications through the content analysis and expert appropriateness rating study while **Table 1** and **Table 2** display the prevalence of pre- and intraoperative categories, subcategories, and unique types of indications reported in the literature, respectively (see the Table in **Supplemental Digital Content 3** for indications where the setting was not specified). Agreement between investigators regarding coding of the 1,107 indications was excellent (median κ-statistic=1; range, 0.67 to 1), with 94.7% of κ-statistics being equal to 1 (indicating perfect inter-rater reliability).

Preoperative Indications:

Most of the reported preoperative indications were based on the degree of physiologic insult (38.5%), injury pattern (20.0%), and overall injury or disease burden (12.8%) of the patient identified during the primary or secondary survey. Others were dependent on information relayed about prehospital findings or events (10.3%), hospital facility and/or staff resources (9.7%), and the amount and/or type of resuscitation administered preoperatively (7.7%).

The most prevalent preoperative indication in the literature was significant hemodynamic instability (median systolic blood pressure <90 mmHg; IQR, 90-90 mmHg) (14.9%) in the ED. Preoperative hypothermia (median temperature <34°C; IQR, 34-35°C) (7.2%), acidosis (median

pH <7.2; IQR, 7.2-7.2) (4.6%), and coagulopathy (5.1%) were also commonly reported. The preoperative injury pattern most frequently suggested to indicate use of DC surgery was multiple injuries spanning across more than one anatomical region or bodily cavity that each required surgery with or without angioembolization (10.3%). Other commonly reported preoperative indications included a high Injury Severity Scale (ISS) score (median >25; IQR, 25-35) (7.2%), occurrence of a mass casualty incident (6.2%), requirement for an ED thoracotomy (3.6%), significant prehospital hemodynamic instability (1.5%) or a prehospital cardiopulmonary arrest (3.1%), and transfusion of a large volume of packed red blood cells (PRBCs) before the start of operation (median >10 units; IQR, 2-16 units) (2.1%).

Intraoperative Indications:

Most of the reported intraoperative indications were dependent on the degree of patient physiologic insult (38.8%) in the OR; injury pattern identified during operation (28.2%); amount, rate, and/or type of resuscitation provided to the patient (14.7%); need for staged abdominal or thoracic wall reconstruction (5.2%) or to reassess the extent of bowel viability after a period of further resuscitation in the ICU (2.7%); and the (anticipated) time required to complete definitive surgery (4.9%).

The most commonly reported intraoperative indications included the finding of coagulopathy (14.7%), acidosis (8.1%), hypothermia (6.3%), or hypothermia, acidosis, and coagulopathy (3.6%) during operation. These signs were most often defined as the absence of visible blood clots during operation/diffuse oozing from all injured tissues or median prothrombin (PT) and/or partial thromboplastin time (PTT) >1.5 (IQR, 1.5-2) times normal, pH <7.2 (IQR, 7.2-7.25), and temperature <34°C (IQR, 34-35°C), respectively. A smaller number of intraoperative

indications were dependent on the finding of hypothermia (0.4%) or acidosis (0.7%) at the beginning of operation or the presence of a persistent hypothermia (0.3%) or acidosis (0.6%) during operation.

The identification of one of several intraoperative injury patterns were reported to indicate use of DC surgery even in the absence of any physiological abnormalities. These most often included a difficult to access major venous (intrahepatic, retrohepatic, retroperitoneal, or pelvic) injury (4.5%); devascularization or massive disruption of the duodenum, pancreas, or pancreaticoduodenal complex (2.8%); and an abdominal vascular injury, either alone (1.4%) or in combination with one (1.7%) or two (0.6%) associated major abdominal solid and/or hollow organ injuries. Moreover, 5.4% were again dependent on the presence of multiple injuries spanning across more than one anatomical region or bodily cavity.

A total of 7.2% of the reported intraoperative indications were dependent on the cumulative administration of a large volume of PRBCs (median >10 units; IQR, 10-16 units) across the pre- and intraoperative settings. Others included the cumulative administration of a large volume of PRBCs and/or whole blood (1.4%) or other blood products (0.7%) (median >5 L; IQR, 4-5 L) or whole blood, other blood products, and crystalloids combined (median >12 L; IQR, 12-13.5 L) (0.7%). Finally, 1.5% were based on the requirement for rapid PRBC transfusion rates (median >2.4 units/h; IQR, 1.7-2.9 units/h).

Inability to close the abdominal wall without tension (3.6%) or development of signs of abdominal compartment syndrome during attempted abdominal wall closure (0.8%) were also commonly reported intraoperative indications. Others included an anticipated prolonged operative time with an associated suboptimal response to resuscitation (1.5%) or an operative (1.3%) or

combined resuscitation and operative (1.3%) time that exceeded a median of 90 (IQR, 90-90) minutes.

Expert Appropriateness Rating Study:

Of the 10 experts invited to participate in the appropriateness rating study, 9 agreed and completed the ratings of the indication codes. **Table 3** shows characteristics of the 9 panelists. In total, 27 (75.0%) preoperative (**Table 1**) and 74 (85.1%) intraoperative (**Table 2**) indication codes were assessed by the panel to be appropriate. There was no disagreement between experts on the ratings of any of the indications.

The pre- and intraoperative indications that were assessed to have an uncertain appropriateness yet commonly reported in the literature included a high ISS score, the intraoperative identification of multiple injuries spanning across more than one anatomical region or bodily cavity that require surgery with or without angioembolization, an abdominal vascular injury, requirement for rapid transfusion rates, an anticipated prolonged operative time (without a suboptimal response to resuscitation), and an operative time or combined resuscitation and operative time that exceeded 90 minutes. The indication codes that were assessed to have the greatest expected benefit-to-harm ratio (median panel RAM score of 9) included administration of >10 U of PRBCs in the preoperative setting or >12 L of PRBCs and/or whole blood, other blood products, and crystalloids combined across the pre- and intraoperative settings; pre- or intraoperative hypothermia, acidosis, and/or coagulopathy; a difficult to access major venous injury; a combined pancreaticoduodenal injury with massive hemorrhage from the head of the pancreas; devascularization or massive disruption of the duodenum, pancreas, or pancreaticoduodenal complex; a major liver or combined pancreaticoduodenal injury with

intraoperative hemodynamic instability; development of intraoperative ventricular arrhythmias or persistent cellular shock; inability to close the abdominal or thoracic wall without tension; development of abdominal or thoracic compartment syndrome during attempted wall closure; and need to reassess the extent of bowel viability after a period of further resuscitation in the ICU.

Discussion

In this study, we identified 101 unique pre- and intraoperative indications from a total of 1,107 indications reported in the literature that were independently assessed by a panel of experts to appropriately indicate use of DC surgery in civilian trauma patients. These indications were most often based on the degree of physiologic insult of the patient; injury pattern identified during operation; amount of resuscitation provided to the patient; and the need for staged abdominal wall reconstruction or to reassess the extent of bowel viability after a period of further resuscitation in the ICU (see **Table 4** for a summary of the highest rated indications). We also identified a number of indications that were commonly reported in the literature yet assessed by the panel to have an uncertain appropriateness or to be inappropriate.

Nearly half (47.5%) of the 101 candidate indications required that the patient exhibit hypothermia, acidosis, and/or coagulopathy in the pre- or intraoperative setting. These signs were most commonly defined in the literature as a temperature <34°C, pH <7.2, and the absence of visible blood clots during operation or a PT and/or PTT >1.5 times normal. Interestingly, while persistent hypothermia or acidosis during operation have been proposed as key determinants of the need for DC,[28-30] the panel rated both pre- and intraoperative (either at the beginning or during the operation) hypothermia or acidosis to be appropriate indications. The above findings suggest that measuring the core temperature, pH, and coagulation status of injured patients requiring surgery upon presentation to the ED and again during operation may facilitate surgical decision-making.

Although the above indications may be important for identifying patients who are already suffering from “physiological exhaustion,” many surgeons believe that the decision to perform DC surgery should optimally be made before the patient develops hypothermia, acidosis, and coagulopathy.[2, 31-33] In this study, the indications that were independent of these signs and assessed

to be highly appropriate by the panel (and therefore may aid in selecting patients for DC surgery independent of their physiology) included a difficult to access major venous injury; a devascularized or destroyed pancreas, duodenum, or pancreaticoduodenal complex; a combined pancreaticoduodenal injury with an associated massive hemorrhage from the head of the pancreas; and a major liver or combined pancreaticoduodenal injury with significant hemodynamic instability in the OR. Other appropriate indications included an injury pattern requiring both surgery and angioembolization to achieve hemostasis and a major liver injury with two or more associated solid and/or hollow abdominal organ injuries. These injury patterns are characteristic of those with competing management priorities, that have the potential for intraoperative exsanguination with attempts at definitive repair (or that frequently respond better to therapeutic compressive packing), or that require a pancreaticoduodenectomy, a procedure infrequently performed by most trauma surgeons (and likely unable to be tolerated by many severely injured patients).[34-37]

Additional indications assessed to be highly appropriate by the panel included the requirement for administration of a large volume of PRBCs (or PRBCs, other blood products, and crystalloids combined) in the pre- and/or intraoperative settings. These indications are likely related to an increasing understanding of the potential risks of development of dilutional coagulopathy (and therefore uncontrollable hemorrhage), abdominal visceral edema, and intra-abdominal hypertension and abdominal compartment syndrome in patients given large volumes of unbalanced ratios of PRBCs or crystalloid fluids.[38-41] Other commonly reported indications assessed to be highly appropriate included an inability to close the abdominal fascia without tension or the development of signs of abdominal compartment syndrome during attempted abdominal wall closure. Finally, although it has commonly been suggested that prolonged

operations should be avoided in severely injured patients, the panel only rated an anticipated prolonged operative procedure as being appropriate when the patient also had a suboptimal response to resuscitation. This suggests that experts may believe that if severely injured patients do not present already in physiological extremis, it may be appropriate to complete a definitive operation as long as they demonstrate a response to resuscitation.

The indications assessed to be appropriate by the panel in this study may be used to inform further research. Subsequent steps should include determining existing DC surgery practice patterns and barriers to use of indications for DC surgery as well as the surgical community's willingness to conduct prospective observational studies of the outcomes associated with performing DC versus definitive surgery for patients with these indications. These studies would inform whether experimental studies are feasible or warranted to robustly evaluate DC surgery in the future. A similar process was successfully used to successfully guide development of indications for coronary artery bypass grafting.[42] In the interim, the candidate list of appropriate indications outlined in this study may be used to guide clinical practice and quality improvement initiatives pending the results of further research.

This study has several potential limitations. First, although this is the first study to comprehensively evaluate indications for use of DC surgery, we did not assess the association between the identified indications and patient outcomes. Second, as the goal of the expert appropriateness rating study was to assess the face validity of the reported indications, we only performed one round of ratings. The indications may have therefore been rated more conservatively by the panelists, especially because those who perform a procedure tend to rate higher on the appropriateness scale than those who do not,[26, 43] and some indications with borderline appropriate/uncertain scores may have changed if we had performed additional

rounds.[26] Despite this, it seems unlikely that those that were assessed to be highly appropriate would have changed given that these ratings exhibited very little variability and were made anonymously and without knowledge of the other panelists' ratings. Moreover, conservative estimates of appropriateness are likely most useful when they are to be used for future research, including broader studies of appropriateness among the broader surgical community. Finally, as the physiologic and survival benefit of use of thromboelastography and DC resuscitation in trauma patients is currently an area of active investigation, the definition or frequency of the indications identified in this study may change in the future pending the results of ongoing research.[44-48]

Conclusion:

This study identified a number of candidate indications for use of DC surgery that were suggested by authors of peer-reviewed articles and assessed by a panel of independent experts to be appropriate. Most were related to the finding of severe physiological derangement in the pre- or intraoperative settings, the amount of resuscitation fluids administered, or the inability to complete the needed definitive procedure safely, efficiently, or expediently in one operation. These indications may provide a practical foundation to guide clinical practice while studies are conducted to evaluate their impact on patient care and outcomes.

Acknowledgements:

This study was supported by an Alberta Innovates – Health Solutions Clinician Fellowship Award, a Knowledge Translation (KT) Canada Strategic Training in Health Research Fellowship, a KT Canada Research Stipend, and funding from the Canadian Institutes of Health Research. We thank Jamie M. Boyd, BSc for assistance with creation of the electronic appropriateness rating survey as well as Rohan N. Lall, MD; Bryan J. Wells, MD, MSc; Steven Smith, MD; and Sarah Lai, MD, MSc for their feedback during pilot testing of the survey instrument.

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Figure Legends:

Figure 1. Flow of Indications Through the Content Analysis and Expert Appropriateness Rating Study.

Table 1. Candidate Preoperative Indications for Damage Control Surgery in Civilian Trauma Patients Requiring Operative Exploration/Treatment of a Torso Injury and/or Major Peripheral Vascular Injury.

Indication Category *Subcategory* Indication Code(s) (Median Decision Threshold Value; IQR; No. Indications that Included a Decision Threshold) Associated Decision Variable Code(s)	**No. Indications (%) (N=195)**	**Expert Panel (N=9) Evaluation***	
		Median RAM Scale Rating (IQR)	**Verdict**
Information relayed about prehospital findings or events	20 (10.3)		
Injury kinematics	11 (5.6)		
High energy blunt torso trauma	7 (3.6)	7 (6-9)	Appropriate
Multiple high velocity GSWs	3 (1.5)	8 (8-9)	Appropriate
Blast injury	1 (0.5)	6 (5-9)	Uncertain
Signs indicating significant prehospital blood loss	9 (4.6)		
Significant prehospital hemodynamic instability	3 (1.5)	8 (7-9)	Appropriate
Prehospital cardiopulmonary arrest	6 (3.1)	8 (7-9)	Appropriate
Primary and secondary survey findings	141 (72.3)		
Injury pattern	39 (20.0)		
RUQ GSW or bullet location with a bullet retained in the same quadrant and hemodynamic instability	2 (1.0)	7 (6-9)	Appropriate
Upper quadrant abdominal GSW with a horizontal shift trajectory across the abdominal midline and hemodynamic instability†	2 (1.0)	8 (7-9)	Appropriate
Entry wound in the back with a bullet in the body and hemodynamic instability	1 (0.5)	7 (7-8)	Appropriate
Partially stable or unstable (Tile B or C) pelvic fracture	7 (3.6)	6 (5-8)	Uncertain
An injury requiring adjunctive use of angioembolization to achieve hemostasis	2 (1.0)	8 (7-9)	Appropriate
Multiple injuries spanning across more than one anatomical region or bodily cavity that each require surgery with or without angioembolization	20 (10.3)	7 (6-8)	Appropriate
Overall injury/disease burden	25 (12.8)		
Associated significant pre-existing medical comorbidities	1 (0.5)	7 (6-9)	Appropriate
High ISS (>25; 25-35; n=13) score	14 (7.2)	6 (5-7)	Uncertain
Associated severe traumatic brain injury	5 (2.6)	6 (5-6)	Uncertain
Associated bilateral pulmonary contusions	3 (1.5)	5 (5-6)	Uncertain
Associated multiple long bone fractures	1 (0.5)	6 (5-7)	Uncertain
Anticipated that >60 min (60-60 min) will be required to complete definitive surgery	2 (1.0)	6 (5-8)	Uncertain
Degree of physiological insult in the ED	75 (38.5)		
Significant hemodynamic instability (SBP <90 mmHg; 90-90 mmHg; n=10)‡	29 (14.9)	7 (6-9)	Appropriate
And >12.5 (12.5-12.5) U of PRBCs were administered in the ED	2 (1.0)	9 (9-9)	Appropriate
And coagulopathy	1 (0.5)	9 (8-9)	Appropriate

And hypothermia, acidosis, and coagulopathy	1 (0.5)	9 (9-9)	Appropriate
Hypothermia (T <34°C; 34-35°C; n=6)	14 (7.2)	9 (8-9)	Appropriate
Acidosis (pH <7.2; 7.2-7.2; n=6)§	9 (4.6)	9 (8-9)	Appropriate
Coagulopathy (PT >19 sec or PTT >60 sec; n=1 each)	10 (5.1)	9 (8-9)	Appropriate
T <35.5°C and BD >5 mmol/L	1 (0.5)	8 (7-9)	Appropriate
Hypothermia and coagulopathy	1 (0.5)	9 (8-9)	Appropriate
Hypothermia, acidosis, and coagulopathy**	3 (1.5)	9 (9-9)	Appropriate
A low Revised Trauma Score (<5; 5-6; n=3)	4 (2.1)	6 (5-7)	Uncertain
Amount and/or type of resuscitation provided preoperatively	15 (7.7)		
Volume of resuscitation fluid administered	8 (4.1)		
A large volume of crystalloids	2 (1.0)	7 (5-8)	Appropriate
A large volume of PRBCs (>10 U; 2-16; n=3)	4 (2.1)	9 (8-9)	Appropriate
A large volume or PRBCs and hypothermia and coagulopathy	1 (0.5)	9 (8-9)	Appropriate
A large volume of crystalloids (>2 L) and PRBCs (>2 U) and acidosis (pH <7.2)	1 (0.5)	9 (8-9)	Appropriate
A thoracotomy was performed for resuscitation or a penetrating thoracic injury with a witnessed post-injury cardiac arrest	7 (3.6)	8 (7-9)	Appropriate
Significant clinical deterioration after angioembolization of a major liver or spleen injury	2 (1.0)	6 (5-8)	Uncertain
Hospital facility and/or staff resources	19 (9.7)		
When a trauma patient presents to a rural hospital with signs of physiologic derangement	2 (1.0)	7 (6-8)	Appropriate
Civilian mass casualty incident	12 (6.2)	7 (6-8)	Appropriate

Where BD indicates base deficit; ED, Emergency Department; GSW, gunshot wound; ISS, Injury Severity Score; LUQ, left upper quadrant; PRBCs, packed red blood cells; PT, prothrombin time; PTT, partial thromboplastin time; RUQ, right upper quadrant; SBP, systolic blood pressure; T, temperature; and UCLA, University of California, Los Angeles.

*Ratings for indications with an included decision threshold refer to the median value where more than one cutoff value was reported in the literature. On the RAM scale, 1 means that the expected harms of conducting damage control over definitive surgery greatly outweigh the benefits, 5 means that the expected benefits and harms are about equal, and 9 means that the expected benefits greatly outweigh the harms.[26] Using these ratings, the indications were classified as appropriate (panel median of 7-9, without disagreement), uncertain (panel median of 4-6 or any median with disagreement), or inappropriate (panel median of 1-3, without disagreement), with disagreement being defined as at least three panelists rating the indication in the 1-3 region and at least another three rating it in the 7-9 region.[26]

†An example of a horizontal shift abdominal bullet trajectory includes one that travels from the RUQ to the LUQ.

‡Hemodynamic instability was required to be persistent in 8 (27.6%) and prolonged in 5 (17.2%) of the 29 indications. Three of the 5 prolonged hemodynamic instability indications defined this as a SBP <70 mmHg.

§One additional indication defined acidosis as a BD >12 mmol/L while another defined this as a bicarbonate <15 mEq/L.

**Defined as a T <34°C (34-34°C), pH <7.2 (7.2-7.2) or [lactate] >5 mmol/L, and PT >19 (19-19) sec and PTT >60 (60-60) sec or platelets <90 (90-90) across these three indications.

Table 2. Candidate Intraoperative Indications for Damage Control Surgery in Civilian Trauma Patients Who Are Currently Undergoing Operative Exploration/Treatment of a Torso Injury and/or Major Peripheral Vascular Injury.

Indication Category *Subcategory* Indication Code(s) (Median Decision Threshold Value; IQR; No. Indications that Included a Decision Threshold) Associated Decision Variable Code(s)	**No. Indications (%) (N=719)**	**Expert Panel (N=9) Evaluation***	
		Median RAM Scale Rating (IQR)	**Verdict**
Injury pattern identified during operation	203 (28.2)		
Vascular	83 (11.6)		
A difficult to access major venous (intrahepatic, retrohepatic, retroperitoneal, or pelvic) injury	32 (4.5)	9 (6-9)	Appropriate
Major thoracic vascular injury	3 (0.4)	6 (5-6)	Uncertain
Abdominal vascular injury†	10 (1.4)	6 (6-6)	Uncertain
And one major abdominal solid or hollow organ injury	12 (1.7)	7 (6-7)	Appropriate
And ≥2 major abdominal solid and/or hollow organ injuries‡	5 (0.6)	7 (6-8)	Appropriate
And hemodynamic instability in the OR	1 (0.1)	8 (8-9)	Appropriate
And hypothermia in the OR (T <34°C at the beginning of operation; n=1)	2 (0.3)	9 (7-9)	Appropriate
And acidosis in the OR (pH <7.0 or BD >20 mmol/L at the beginning of operation; n=1 each)	9 (1.3)	8 (7-9)	Appropriate
And coagulopathy in the OR	5 (0.7)	9 (8-9)	Appropriate
And hypothermia, acidosis, and coagulopathy in the OR	2 (0.3)	9 (9-9)	Appropriate
Iliac vessel injury and ≥2 of the following: T <34°C, pH <7.1, or BD >15 mmol/L at the beginning of operation or T <35°C, pH <7.3, or BD >6 mmol/L at the end of operation	1 (0.1)	9 (9-9)	Appropriate
A combined iliac vessel and colon injury and hypothermia, acidosis, and coagulopathy in the OR	1 (0.1)	9 (9-9)	Appropriate
Liver and/or biliary tract	38 (5.3)		
Major (AAST grades III-V) liver injury	20 (2.8)	7 (5-8)	Appropriate
And a major (AAST grades III-V) spleen injury	1 (0.1)	7 (6-8)	Appropriate
And ≥2 abdominal solid and/or hollow organ injuries	1 (0.1)	8 (6-8)	Appropriate
And hemodynamic instability in the OR	1 (0.1)	9 (8-9)	Appropriate
And a T <35°C in the OR	1 (0.1)	9 (8-9)	Appropriate
And a pH <7.3 in the OR	1 (0.1)	8 (8-9)	Appropriate
And coagulopathy in the OR	7 (1.0)	9 (8-9)	Appropriate
And hypothermia, acidosis, and coagulopathy in the OR§	5 (0.7)	9 (9-9)	Appropriate
Extrahepatic biliary duct injury and hemodynamic instability, hypothermia, acidosis, and coagulopathy	1 (0.1)	9 (9-9)	Appropriate
Duodenum and/or pancreas	33 (4.6)		
Full-thickness duodenal injury (i.e., AAST grade II duodenum injury)	1 (0.1)	3 (2-5)	Inappropriate
A proximal main pancreatic duct injury (i.e., AAST grades III-V pancreas injury)	2 (0.3)	5 (2-5)	Uncertain
Combined pancreaticoduodenal and adjacent abdominal vascular injury	2 (0.3)	7 (6-9)	Appropriate

Combined pancreaticoduodenal injury with massive hemorrhage from the head of the pancreas	1 (0.1)	9 (8-9)	Appropriate
Combined pancreaticoduodenal injury and >10 U PRBCs were administered in the OR	1 (0.1)	9 (8-9)	Appropriate
Combined pancreaticoduodenal injury and hemodynamic instability	3 (0.4)	9 (8-9)	Appropriate
Combined pancreaticoduodenal injury and hypothermia	1 (0.1)	8 (8-9)	Appropriate
Combined pancreaticoduodenal injury and acidosis	1 (0.1)	8 (8-9)	Appropriate
Combined pancreaticoduodenal injury and coagulopathy	1 (0.1)	9 (8-9)	Appropriate
Devascularization or massive disruption of the duodenum, pancreas, or pancreaticoduodenal complex with involvement of the ampulla/proximal pancreatic duct and/or distal CBD (i.e., AAST grade IV-V duodenum or pancreas injury)	20 (2.8)	9 (9-9)	Appropriate
Urinary tract	3 (0.4)		
Major (AAST grades III-V) ureter injury and hemodynamic instability in the OR	1 (0.1)	6 (5-8)	Uncertain
Major (AAST grades III-V) ureter injury and hypothermia, acidosis, and coagulopathy in the OR	2 (0.3)	9 (8-9)	Appropriate
Multiple injuries spanning across more than one anatomical region or bodily cavity that require surgery with or without angioembolization	39 (5.4)	6 (6-7)	Uncertain
Multiple combined abdominal solid and/or hollow organ injuries	7 (1.0)	6 (6-8)	Uncertain
Inability to control bleeding by conventional methods	18 (2.5)	9 (8-9)	Appropriate
Time required to complete definitive surgery	35 (4.9)		
Anticipated prolonged operative time (>270 min; 180-360 min; n=2)	6 (0.8)	6 (5-8)	Uncertain
Anticipated time-consuming procedure in a patient with suboptimal response to resuscitation	11 (1.5)	8 (8-9)	Appropriate
Resuscitation and operative time >90 (90-90) min	9 (1.3)	6 (5-7)	Uncertain
Prolonged operative time (>90 min; 90-90 min; n=7)	9 (1.3)	6 (5-6)	Uncertain
Extent or rate of blood loss	22 (3.1)		
Estimated large volume blood loss (>4 L; 4-4 L; n=11)	12 (1.7)	8 (7-8)	Appropriate
Estimated large volume blood loss (>5 L; n=1) and hypothermia (T <34°C; n=1) in the OR	2 (0.3)	8 (7-9)	Appropriate
Estimated blood loss >5 L and pH <7.2 in the OR	1 (0.1)	9 (8-9)	Appropriate
Estimated blood loss >4 (4-5) L, T <34°C (34-35°C), and pH <7.25 (7.2-7.3)	5 (0.7)	9 (8-9)	Appropriate
Hemoperitoneum >1.5 L, T <35°C, BD >8 mmol/L, and NISS >35	1 (0.1)	9 (8-9)	Appropriate
Estimated blood loss >15 mL/min (~3.6 U/h)	1 (0.1)	8 (6-8)	Appropriate
Amount, rate, and/or type of resuscitation provided	106 (14.7)		
Volume of resuscitation fluid administered across the pre- and intraoperative settings	76 (10.6)		
A large volume of PRBCs (>10 U; 10-16 U; n=50)	52 (7.2)	8 (7-9)	Appropriate
>5 (4-5) L of PRBCs and whole blood combined	10 (1.4)	8 (7-9)	Appropriate
A large volume of PRBCs and other blood products combined (>5 L; 4-5 L; n=4)	5 (0.7)	8 (8-9)	Appropriate
>12 (12-12.5) L PRBCs and crystalloids combined	2 (0.3)	9 (8-9)	Appropriate
And hypothermia, acidosis, and coagulopathy	2 (0.3)	9 (9-9)	Appropriate

A large volume of PRBCs and/or whole blood, other blood products, and crystalloids (>12 L; 12-13.5 L; n=4)	5 (0.7)	9 (9-9)	Appropriate
Volume of resuscitation fluid administered in the OR	15 (2.1)		
>10 U PRBCs	1 (0.1)	8 (7-9)	Appropriate
>4 L PRBCs and/or whole blood combined	1 (0.1)	8 (7-8)	Appropriate
>12 (12-12) L PRBCs and/or whole blood, other blood products, and crystalloids combined	13 (1.8)	9 (8-9)	Appropriate
Requirement for rapid transfusion rates [>10 mL/min (~2.4 U/h); 7-12 mL/min (~1.7-2.9 U/h); n=10]	11 (1.5)	5 (5-8)	Uncertain
An emergent thoracotomy was required in the OR	4 (0.6)	6 (5-7)	Uncertain
Degree of physiologic insult	279 (38.8)		
Significant hemodynamic instability in the OR (SBP <70 mmHg; 70-70 mmHg; n=2)	15 (2.1)	7 (7-9)	Appropriate
And patient age >55 years	1 (0.1)	8 (7-9)	Appropriate
And hypothermia	1 (0.1)	8 (8-8)	Appropriate
And acidosis	1 (0.1)	8 (8-8)	Appropriate
And coagulopathy	1 (0.1)	9 (8-9)	Appropriate
And hypothermia and coagulopathy	4 (0.6)	9 (9-9)	Appropriate
Persistent cellular shock**	4 (0.6)	9 (9-9)	Appropriate
T <35°C (34-35.5°C) at the beginning of operation	3 (0.4)	7 (6-7)	Appropriate
Hypothermia (T <34°C; 34-35°C; n=36)	45 (6.3)	8 (7-8)	Appropriate
Persistent hypothermia approximating 35°C (35-35°C) during operation	2 (0.3)	7 (7-8)	Appropriate
Acidosis at the beginning of operation (pH <7.2; 7.1-7.2; n=3 or BD >11 mmol/L; 7.5-15 mmol/L; n=2)	5 (0.7)	8 (7-9)	Appropriate
Acidosis	58 (8.1)		
pH <7.2 (7.2-7.25)	34/58 (58.6)	9 (7-9)	Appropriate
BD >15 (14-15) mmol/L	4/58 (6.9)	9 (7-9)	Appropriate
BD >15 (15-15) mmol/L in a patient aged <55 years	3/58 (5.2)	9 (8-9)	Appropriate
BD >6 (6-6) mmol/L in a patient aged >55 years	3/58 (5.2)	8 (6-8)	Appropriate
[Bicarbonate] >15 (15-15) mEq/L	6/58 (10.3)	6 (6-8)	Uncertain
[Lactate] >5 (5-5) mmol/L	2/58 (3.4)	7 (6-8)	Appropriate
Persistent pH approximating 7.2 (7.2-7.2; n=2) or BD approximating 7.5 mmol/L (5-10 mmol/L; n=2) during operation	4 (0.6)	8 (7-9)	Appropriate
Coagulopathy¶	106 (14.7)		
Clinical (absence of visible blood clots/diffuse oozing from all injured tissues)	35/106 (33.0)	9 (8-9)	Appropriate
PT >16 (16-16) sec and/or PTT >50 (50-50) sec	5/106 (4.7)	7 (6-8)	Appropriate
PT and/or PTT >1.5 (1.5-2) times normal	8/106 (7.5)	7 (6-9)	Appropriate
INR >1.5 (1.5-1.5)	2/106 (1.9)	7 (6-7)	Appropriate
Hypothermia, acidosis, and coagulopathy#	26 (3.6)	9 (9-9)	Appropriate

Development of intraoperative ventricular arrhythmias	3 (0.4)	9 (8-9)	Appropriate
Need for staged abdominal or thoracic wall reconstruction	37 (5.2)		
Inability to close the abdominal fascia without tension because of visceral edema	26 (3.6)	9 (9-9)	Appropriate
Signs of abdominal compartment syndrome develop during attempted abdominal wall closure	6 (0.8)	9 (9-9)	Appropriate
Inability to close the thoracic wall without tension because of visceral edema	4 (0.5)	9 (8-9)	Appropriate
Signs of thoracic compartment syndrome develop during attempted thoracic wall closure	1 (0.1)	9 (9-9)	Appropriate
Need to reassess extent of bowel viability	19 (2.7)	9 (9-9)	Appropriate

Where AAST indicates American Association for the Surgery of Trauma; BD, base deficit; BE, base excess; CBD; common bile duct; D2, the second part of the duodenum; PRBCs, packed red blood cells; RAND/UCLA, RAND/University of California, Los Angeles; SBP, systolic blood pressure; T, temperature; and VO2I, oxygen consumption index.

*Ratings for indications with an included decision threshold refer to the median value where more than one cutoff value was reported in the literature. On the RAM scale, 1 means that the expected harms of conducting damage control over definitive surgery greatly outweigh the benefits, 5 means that the expected benefits and harms are about equal, and 9 means that the expected benefits greatly outweigh the harms.[26] Using these ratings, the indications were classified as appropriate (panel median of 7-9, without disagreement), uncertain (panel median of 4-6 or any median with disagreement), or inappropriate (panel median of 1-3, without disagreement), with disagreement being defined as at least three panelists rating the indication in the 1-3 region and at least another three rating it in the 7-9 region.[26]

†The abdominal vascular injury was arterial in 7 (70.0%) of the indications, venous in 2 (20.0%), and involved the iliac vessels in 8 (80.0%).

‡One of these 5 indications also required the presence of intraoperative hemodynamic instability while another also required the presence of both hypothermia and coagulopathy in the OR.

§Defined as a T <35°C (35-35°C), pH <7.2 (7.2-7.2), and PT >60 (16-16) sec across 2 of 3 of these indications.

**Defined as a VO2I <100 mL/min/m^2, lactate >5 mmol/L, pH <7.2, BD >15 mmol/L, and core T <34°C.

¶Two (1.9%) indications also required the concomitant presence of hypothermia.

#Defined as a T <34°C (34-35°C; n=6); pH <7.2 (7.2-7.2; n=6) or BD >8 mmol/L (n=1); and PT >16 sec (n=1), PT and PTT >1.5 times normal (n=1), or INR >1.5 (n=1).

Table 3. Characteristics of the Panelists (N=9).

Characteristic	Value
Mean age (SD)	52 (9.6)
No. of years practicing	
Trauma surgery, mean (SD)	19.9 (11.4)
General surgery, mean (SD)	21.4 (11.9)
Current practice location, no.	
United States	3
Europe	2
South Africa	2
Canada	1
Australia	1
Estimated no. of damage control procedures performed during career, median (IQR)*	
Neck	10 (5-20)
Thoracic	25 (12-50)
Abdominal/pelvic	100 (100-120)
Extremity	15 (10-20)

Where IQR indicates interquartile range and SD, standard deviation.

*Where the panelists were informed that an example of a neck damage control procedure included balloon catheter tamponade of a bleeding neck vessel; an example of a thoracic damage control procedure included pulmonary tractotomy or wedge resection or intrathoracic packing; an abdominal/pelvic damage control procedure included therapeutic perihepatic packing or extraperitoneal pelvic packing; and an extremity damage control procedure included temporary intravascular shunting in a patient with multisystem injuries.

Table 4. Highest Rated Candidate Indications for Use of Damage Control Surgery in Civilian Trauma Patients.

Indication
Injury pattern identified during operation
A difficult to access major venous (intrahepatic, retrohepatic, retroperitoneal, or pelvic) injury
A major liver or combined pancreaticoduodenal injury with hemodynamic instability in the OR
A combined pancreaticoduodenal injury with massive hemorrhage from the head of the pancreas
Devascularization or massive disruption of the duodenum, pancreas, or pancreaticoduodenal complex with involvement of the ampulla/proximal pancreatic duct and/or distal CBD
Inability to control bleeding by conventional methods
Amount of resuscitation provided
A large volume of PRBCs (median >10 U) or PRBCs, other blood products, and crystalloids combined (median >12 L) were administered preoperatively or across the pre- and intraoperative settings
Degree of physiologic insult
Hypothermia, acidosis, and/or coagulopathy in the pre- or intraoperative settings*
Persistent intraoperative cellular shock†
Development of intraoperative ventricular arrhythmias
Need for staged abdominal or thoracic wall reconstruction
Inability to close the abdominal or thoracic wall without tension because of visceral edema
Signs of an abdominal or thoracic compartment syndrome developed during attempted abdominal or thoracic wall closure
Need to reassess the extent of bowel viability after a period of further resuscitation in the ICU

Where CBD indicates common bile duct; ED, emergency department; ICU, intensive care unit; OR, operating room; and PRBCs, packed red blood cells.

*Where hypothermia, acidosis, and coagulopathy were most commonly defined in the literature as a temperature <34°C, pH <7.2, and the absence of visible blood clots during operation/diffuse oozing from all injured tissues or PT and PTT >1.5 times normal. These indications were rated highest alone and when combined with the finding of a major abdominal vascular, liver, combined pancreaticoduodenal, or ureter injury during operation.

†Where cellular shock is defined as an oxygen consumption index <100 mL/min/m^2, lactate >5 mmol/L, pH <7.2, base deficit >15 mmol/L, and core temperature <34°C.

Supplemental Digital Content 3. Table Summarizing Candidate Indications for Use of Damage Control Surgery for Which the Setting for Application was Not Specified.

Indication Category Indication Code(s) (Median Decision Threshold Value; IQR; No. Indications that Included a Decision Threshold)	**No. Reported Indications (%) (N=193)**
Degree of physiologic insult	191 (99.0)
Significant hemodynamic instability (SBP <70 mmHg; 70-70 mmHg; n=13)	30 (15.5)
Significant hemodynamic instability and hypothermia, acidosis, and coagulopathy	1 (0.5)
Hypothermia (T <34°C; 34-35°C; n=48)	52 (26.9)
Acidosis	74 (38.3)
pH <7.2 (7.2-7.3)	45/74 (60.8)
BD >10.5 mmol/L (8-14 mmol/L)	8/74 (10.8)
BD >15 mmol/L in a patient aged <55 years or with a concomitant TBI	2/74 (2.7)
BD >8 mmol/L in a patient aged >55 years	1/74 (1.4)
[Lactate] >4.4 mmol/L (4-5 mmol/L)	7/74 (1.4)
[Bicarbonate] >15 mEq/L (15-15 mEq/L)	2/74 (2.7)
Coagulopathy	20 (10.4)
PT >19 sec (16-19 sec) and/or PTT >60 sec (60-60 sec)	10/20 (0.5)
PT and PTT >2 times normal	1 (5.0)
INR >1.9	1 (5.0)
Hypothermia and acidosis	1 (0.5)
Hypothermia and coagulopathy (PT >19 sec and PTT >60 sec)	1 (0.5)
Hypothermia, acidosis, and coagulopathy*	10 (5.2)
Oxygen consumption index <110 mL/min/m^2	2 (1.0)
Overall injury/disease burden	2 (1.0)
An ISS >25, pH <7.2, and T <34°C	1 (0.5)
An ISS >25, SBP <70 mmHg, T <34°C, and pH <7.1	1 (0.5)

Where BD indicates base deficit; INR, international normalized ratio; IQR, interquartile range; ISS, Injury Severity Score; PT, prothrombin time; PTT, partial thromboplastin time; SBP, systolic blood pressure; T, temperature; and TBI, traumatic brain injury.

*Defined as a T <34.5°C (34-35°C; n=2), pH <7.2 (7.1-7.3; n=2), and PT and PTT >1.5 times normal (n=1).