

# Damage control surgery for abdominal emergencies

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**Background:** Damage control surgery is a management sequence initiated to reduce the risk of death in severely injured patients presenting with physiological derangement. Damage control principles have emerged as an approach in non-trauma abdominal emergencies in order to reduce mortality compared with primary definitive surgery.

**Methods:** A PubMed/MEDLINE literature review was conducted of data available over the past decade (up to August 2013) to gain information on current understanding of damage control surgery for abdominal surgical emergencies. Future directions for research are discussed.

**Results:** Damage control surgery facilitates a strategy for life-saving intervention for critically ill patients by abbreviated laparotomy with subsequent reoperation for delayed definitive repair after physiological resuscitation. The six-phase strategy (including damage control resuscitation in phase 0) is similar to that for severely injured patients, although non-trauma indications include shock from uncontrolled haemorrhage or sepsis. Minimal evidence exists to validate the benefit of damage control surgery in general surgical abdominal emergencies. The collective published experience over the past decade is limited to 16 studies including a total of 455 (range 3–99) patients, of which the majority are retrospective case series. However, the concept has widespread acceptance by emergency surgeons, and appears a logical extension from pathophysiological principles in trauma to haemorrhage and sepsis. The benefits of this strategy depend on careful patient selection. Damage control surgery has been performed for a wide range of indications, but most frequently for uncontrolled bleeding during elective surgery, haemorrhage from complicated gastroduodenal ulcer disease, generalized peritonitis, acute mesenteric ischaemia and other sources of intra-abdominal sepsis.

**Conclusion:** Damage control surgery is employed in a wide range of abdominal emergencies and is an increasingly recognized life-saving tactic in emergency surgery performed on physiologically deranged patients.

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## Introduction

During the past two decades, damage control surgery has become the standard of care in the treatment of injured patients with severe physiological compromise who require surgical intervention<sup>1–3</sup>. Damage control is not a surgical manoeuvre but an alternative treatment mode to primary definitive surgical care. The principles of damage control surgery in trauma care include abbreviated surgery to control blood loss and contamination in the abdomen, simultaneous resuscitation of physiology, and definitive surgical management at a later stage after restoration of the physiology<sup>4,5</sup>. This approach resulted in improved survival of critically injured and shocked patients based on retrospective case series and when compared with historical

controls<sup>6–9</sup>. Acute-care/emergency general surgeons who regularly practise damage control surgery in injured patients have applied these principles to severely ill surgical patients in the non-trauma setting<sup>1,2,10,11</sup>. This review summarizes the damage control concept and presents the current evidence to support the extension of its principles in non-traumatic abdominal emergencies.

## Methods

A literature review was conducted to present the current understanding of damage control surgery, with a focus on the applicability of this strategy in patients with non-traumatic abdominal emergencies. A comprehensive search was undertaken of PubMed, MEDLINE and

Embase, using the following keywords: damage control, general surgery, acute care surgery and emergency surgery. Articles were screened by title and abstract to identify papers reporting clinical experiences of applying damage control surgery in non-trauma, emergency general surgery. Reference lists of identified articles were searched to identify further articles of interest. Acute physiological derangement was a necessary component in the definition of damage control surgery.

### Developing the rationale from trauma surgery to emergency general surgery

Primary definitive repair of severe injuries in patients with deranged physiology is detrimental to outcome<sup>1–5,10</sup>. Where surgery is unavoidable, damage control surgery, with rapid haemorrhage and contamination control, and without further major tissue injury or delay, makes it possible to correct the physiology and save some of the most critically injured patients<sup>1–5,10</sup>. The phases of damage control surgery are defined by five steps (*Table 1*): first, identification of the ill patient based on injury pattern (or underlying disease) and pathophysiology; second, abbreviated surgery to control bleeding and contamination; third, reassessment of the parameters while the patient is still on the operating table; fourth, continued restoration of the physiology in the intensive care unit; and, finally, definitive surgical repair<sup>5</sup>. This staged management prevents the physiological exhaustion of the traumatic shock and allows definitive reconstruction with the patient in a more favourable physiological condition.

The damage control concept has been transferred to patients undergoing emergency general surgery for non-traumatic abdominal conditions by trauma surgeons also practising in acute general surgery<sup>1,2,10,11</sup>. However, there are significant differences between the physiological insults experienced by these two patient populations. In trauma, the pathophysiology is traumatic shock (the combination of tissue injury and haemorrhagic shock), whereas in emergency general surgery the shock is typically either haemorrhagic (without tissue injury) or septic (from perforation and/or obstruction of the gastrointestinal tract, with or without abdominal organ ischaemia/necrosis). This extension of the damage control strategy to abdominal emergencies has been a relatively intuitive next step for the general surgeon, who is frequently treating both types of patient. The application to general surgical abdominal emergencies instinctively acknowledges that many critically ill general surgical patients do better with a staged approach to surgical care overarched by modern critical and intensive care management<sup>1,2,10,12,13</sup>.

### Application of damage control surgery to abdominal emergencies

Only level III and IV data exist to establish the role of damage control surgery in abdominal general surgical emergencies<sup>14–29</sup>. Studies identified by the literature review are presented in *Table 2*; case reports are not included. In spite of the minimal, published, direct

**Table 1** Phases of damage control for trauma and abdominal emergencies

		Non-traumatic abdominal emergencies	
		Haemorrhagic shock	Septic shock
Phase 0	Initiation of goal-directed haemostatic resuscitation without delaying surgery	Initiation of goal-directed haemostatic resuscitation without delaying surgery	Preoperative resuscitation with fluids and vasoconstrictors Hypothermia correction Antibiotic administration
Phase 1	Identification of the patient: Injury pattern Physiology	Identification of the patient: Pathology Physiology	Identification of the patient: Pathology Physiology
Phase 2	Control haemorrhage Control contamination	Control haemorrhage	Decontamination Sepsis source control
Phase 3	Reassessment during surgery	Reassessment during surgery	Reassessment during surgery
Phase 4	Physiological restoration in intensive care Optimization of haemodynamics Correction of acidosis, hypothermia and coagulopathy Optimization and support of vital organs	Physiological restoration in intensive care Optimization of haemodynamics Correction of acidosis, hypothermia and coagulopathy Optimization and support of vital organs	Physiological restoration in intensive care Optimization of haemodynamics Correction of acidosis, hypothermia and coagulopathy Optimization and support of vital organs Specific antibiotic therapy based on resistance
Phase 5	Definitive repair Abdominal wall closure	Definitive repair Abdominal wall closure	Definitive repair Abdominal wall closure

**Table 2** Studies reporting on damage control surgery in general surgical abdominal emergencies

Reference	Year	Study design	Level of evidence	No. of patients	Pathology (n)	Comparison cohort
Finlay <i>et al.</i> <sup>14</sup>	2004	Prospective comparative study	III	14	Intra-abdominal sepsis, secondary visceral perforation (9) Ruptured abdominal aortic aneurysm (3) Postoperative bleed (1) Retroperitoneal bleed (1)	POSSUM P-POSSUM
Freeman and Graham <sup>15</sup>	2005	Retrospective comparative study	III	3	Acute mesenteric ischaemia	Non-randomized concurrent patients
Banieghbal and Davies <sup>16</sup>	2004	Prospective series	IV	27	Neonatal generalized necrotizing enterocolitis	–
Tamijmarane <i>et al.</i> <sup>17</sup>	2006	Retrospective series	IV	25	Complicated elective pancreatic surgery	–
Stawicki <i>et al.</i> <sup>18</sup>	2008	Retrospective comparative study	III	16	Sepsis (6) Intraoperative bleeding (5) Ischaemia (3) Necrotizing pancreatitis (2)	APACHE II POSSUM
Person <i>et al.</i> <sup>19</sup>	2009	Retrospective comparative series	III	31	Peritonitis (15) Mesenteric ischaemia (10) Bleeding (3) Obstruction (2) Other (1)	Non-randomized concurrent patients
Ball <i>et al.</i> <sup>20</sup>	2010	Retrospective series	IV	6	Haemorrhage during pancreatic necrosectomy	–
Filicori <i>et al.</i> <sup>21</sup>	2010	Retrospective comparative study	III	8	Intra-abdominal haemorrhage	APACHE II
Gong <i>et al.</i> <sup>22</sup>	2010	Retrospective series	IV	15	Acute mesenteric ischaemia	–
Morgan <i>et al.</i> <sup>23</sup>	2010	Retrospective series	IV	8	Complicated elective pancreatic resections Intraoperative haemorrhage (4) Sepsis at reoperation (2) Haemorrhage at reoperation (2)	–
Perathoner <i>et al.</i> <sup>24</sup>	2010	Prospective comparative series	III	9	Complicated diverticulitis	Non-randomized concurrent patients
Subramanian <i>et al.</i> <sup>25</sup>	2010	Retrospective series	IV	88	Planned relook (32)* Abdominal compartment syndrome (26) Contamination (29) Necrotizing fasciitis (15) Ischaemic bowel (14) Haemodynamic instability (10)	–
Tadlock <i>et al.</i> <sup>26</sup>	2010	Retrospective comparative series	III	13	Ruptured abdominal aortic aneurysm	Non-randomized concurrent patients
Kafka-Ritsch <i>et al.</i> <sup>27</sup>	2012	Prospective series	IV	51	Perforated diverticulitis	–
Khan <i>et al.</i> <sup>28</sup>	2013	Retrospective series	IV	42	Bowel ischaemia (13) Haemorrhage (13) Peritonitis (10) Physiological instability (6)	–
Goussous <i>et al.</i> <sup>29</sup>	2013	Retrospective series	IV	99	Bowel ischaemia (25) Bowel perforation (21) Haemorrhage (15) Anastomotic leak (10) Abdominal compartment syndrome (7) Incarcerated hernia (6) Ruptured abdominal aortic aneurysm (5) Enterocutaneous fistula (3) Necrotizing pancreatitis (2) Necrotizing fasciitis (2) Other (3)	–

\*Several patients had multiple indications. POSSUM, Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity; P-POSSUM, Portsmouth predictor equation for POSSUM; APACHE, Acute Physiology And Chronic Health Evaluation.

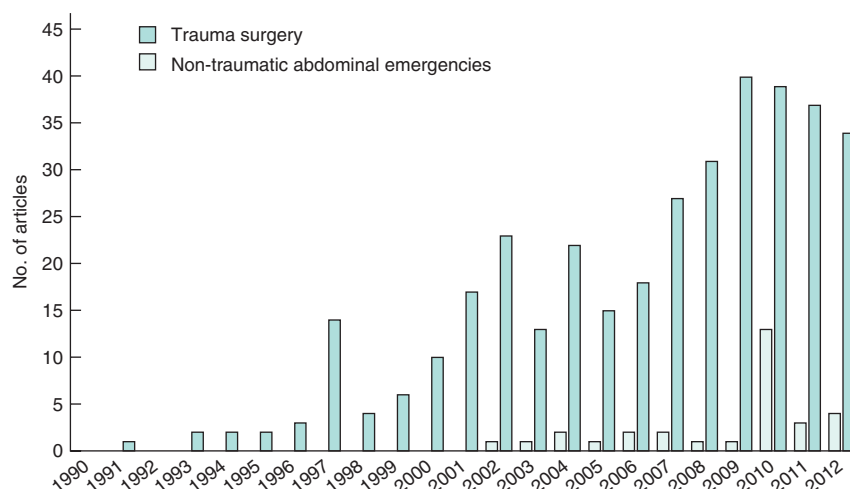


Fig. 1 Articles with 'damage control' in the title by year of publication

evidence to substantiate this application of damage control to the non-trauma setting, the concept has been promulgated widely by acceptance in recent reviews and editorials<sup>1,10,11,30,31</sup>.

Three case series<sup>14,18,21</sup> compared the observed outcomes in patients receiving damage control surgery with those predicted by outcome prediction scores (Acute Physiology And Chronic Health Evaluation (APACHE) II; and Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM)). The total of 38 patients reported in these three studies showed a lower than predicted mortality, and in one series<sup>14</sup> this observation achieved statistical significance. The pathologies undergoing a damage control treatment strategy comprised a mixture of septic and haemorrhagic shock, including gastrointestinal perforations, bowel ischaemia, intraoperative and postoperative bleeding in elective operations, and emergency ruptured aortic aneurysms (Table 2).

Given the largely retrospective nature of these studies, discrepancies in definitions of damage control strategies, and poor documentation of the extent of physiological derangement, as well as almost certain publication bias favouring a positive outcome from damage control, these data can be used only cautiously to advocate damage control strategies in general surgery. Regardless of their limitations, the general trend towards adoption of damage control strategies for abdominal general surgical emergencies is similar to that in the literature reporting damage control experiences in trauma surgery during the early 1990s, at the time of its spread into routine practice (Fig. 1).

### Application to intra-abdominal bleeding or severe sepsis

Despite the lack of high-level evidence, the translation of damage control principles for abdominal emergencies is straightforward in terms of practical application. The same five phases of response (Table 1) may be used to standardize the surgical strategies, although slightly different approaches are proposed depending on the type of shock and abdominal pathology when either bleeding or sepsis is the main problem. An additional phase (phase 0) has been included to relay the importance of preoperative resuscitation – this represents so-called 'damage control resuscitation'.

For haemorrhagic shock, the process is essentially the same as in trauma. Haemorrhage control is paramount and cannot wait. In these patients, the lack of major generalized tissue injury in association with a usually well defined, single area of bleeding provides a tempting opportunity for primary definitive care; however, if the patient is already injured physiologically (acidotic, hypothermic and/or coagulopathic), a staged approach appears safer. This is of particular relevance when vascular control has been associated with intestinal ischaemia–reperfusion injury, and/or vascular repair requires cross-clamping of major vessels with resulting tissue ischaemia.

For septic shock, the clinical presentation and inflammatory aetiology of the shock is fundamentally different from that of traumatic or haemorrhagic shock. There is growing evidence that these patients benefit from a period of resuscitation before surgical intervention and sepsis source control<sup>4,13,31–34</sup>. The damage control procedure is thereby delayed for a short period until cardiac

contractility, preload and afterload are optimized, intravascular volume is restored, and broad-spectrum antibiotics are administered. To achieve these goals, this initial resuscitation phase should utilize goal-directed methods to guide treatment<sup>33,34</sup>. Central venous pressure, mean arterial pressure, urine output and central or mixed venous oxygen saturations are measured, and acted on in real time to titrate crystalloid boluses for intravascular volume resuscitation, and vasopressor dosing. This resuscitation phase is complex, invasive and resource intensive, and is typically conducted in an intensive care environment. To assist clinicians in various aspects of treatment, the different components of this resuscitation phase may be grouped together as bundles, as advocated by the Surviving Sepsis Campaign<sup>33</sup>. These protocolized treatment bundles minimize omission of critical therapies during busy clinical resuscitations. Use of such modern resuscitative strategies may decrease the frequency of circulatory collapse during surgery, and further contribute to improved outcomes<sup>13,32</sup>.

### Patient selection

Correct patient selection is crucial for the benefit from a damage control strategy to be maximized; not applying the strategy to critically ill patients will increase their risk of death, although its overuse will expose patients to the risks of multiple operations, open abdomen management and prolonged intensive care stay, negating the potential benefits of the concept<sup>1,3</sup>. Recent investigation<sup>35</sup> has demonstrated the potential for harm if the damage control strategy is overused. Fewer than 30 per cent of civilian trauma laparotomies typically benefit from a damage control strategy in modern trauma surgery, although this number varies greatly depending on the mechanism of injury and population affected<sup>1,3,35</sup>. The authors estimate that an even lower number, perhaps not more than a few per cent, of all non-traumatic abdominal emergencies would benefit from this strategy. This prediction reflects the fact that most of these abdominal emergencies will not reach the critical level of physiological compromise at which a damage control strategy is indicated. Insufficient data exist to define the precise incidence accurately.

Although selection of the right patient for the right treatment (damage control *versus* primary definitive surgery) is critical, it is important to highlight that these treatment modes may be interchanged depending on the improvement or deterioration of the patient's condition and should not be followed rigidly once indicated; constant re-evaluation is essential.

The indications for damage control surgery in trauma scenarios may be grouped as: patient factors (compromised

**Table 3** Factors to consider for damage control strategy in abdominal emergencies

Patient factors	Medical and surgical history Concurrent illness Medication
Injury/disease factors	Nature of pathology Severity of pathology Expected natural history
Physiological factors	Hypothermia Coagulopathy Organ dysfunction Haemodynamic instability Severity of inflammation/sepsis
Treatment factors	Magnitude and quality of resuscitation Duration and physiological effect of surgery Magnitude of definitive surgery

physiological reserve owing to co-morbidities, anticoagulation, etc.); local/general injury severity/pattern (blunt polytrauma, multiple penetrating torso trauma, severe contamination, major bleeding sources in other regions); physiological parameters (hypothermia, acidosis, coagulopathy, early organ dysfunction); and treatment/iatrogenic factors (magnitude and quality of resuscitation, time spent in surgery, requirement for major vessel cross-clamping)<sup>1–5</sup>. None of these indications is absolute in isolation, but many of them tend to present simultaneously to identify the physiologically compromised severely injured patient. These four categories can be well applied to general surgical catastrophes (Table 3), where patient factors, such as co-morbidities, are frequently more dominant in decision-making than in injured patients. The disease type (malignancy, inflammatory disease, etc.) can be varied and the local pathology can be due to processes of varying aetiology.

Specific trigger points to indicate damage control surgery for injured patients have been published<sup>2</sup>, but validated variably. Similar trigger points may be used for non-traumatic abdominal emergencies<sup>31</sup>, such as hypothermia (temperature below 35°C), metabolic acidosis (pH less than 7.20, base excess below –8.0), or a demonstrable coagulopathy, to name a few. However, there are insufficient published data to validate these parameters in absolute terms, or currently to establish clinical rules. This difficult situation is further complicated by the variable time frame of presentation (particularly in the case of septic shock), and by the great diversity in the pathologies and types of shock causing non-traumatic abdominal emergency. Therefore, until further research becomes available, the correct patient selection for damage control surgery in non-traumatic abdominal emergencies will remain a complex, multifactorial decision, representing a critical clinical challenge that calls on the judgement of the treating clinician and team. Challengingly, the correct



decision may vary in identical patients, but who have been resuscitated or are being operated on by different teams.

### Open abdomen after emergency surgery

Laparostomy was described intermittently in the surgical literature during the last century. However, this idea was not discussed widely until the late 1980s, when larger case series reporting survival benefits from this technique in patients with severe abdominal sepsis became available<sup>36–39</sup>. Before this, surgical techniques focused on mass closure of the tense abdomen, with multiple drains in the peritoneal recesses, and tension sutures in the abdominal wall. This strategy can lead to abdominal compartment syndrome, a fatal condition in critically ill and injured patients<sup>34,40–43</sup>.

The laparostomy forms an integral step in most patients with abdominal trauma managed by a damage control strategy<sup>1–5</sup>. This should be the same in abdominal general surgical catastrophes<sup>34,40–43</sup>. Tissue inflammation may directly preclude a definitive closure without tension and a resulting abdominal compartment syndrome. Furthermore, the evolving inflammatory process places these patients at high risk of developing abdominal compartment syndrome during the next days<sup>42,43</sup>. The actual incidence of abdominal compartment syndrome in current practice is difficult to define owing to the absence of recent published cohorts. However, the incidence has reduced markedly since the late 1990s (when up to 15 per cent of trauma intensive care admissions were diagnosed with the condition). This is likely to be the result of advances in modern damage control resuscitation strategies. Even so, injured and acute surgical patients admitted to intensive care remain at risk<sup>44,45</sup>.

The high morbidity and mortality rates associated with an abdominal compartment syndrome<sup>43,45</sup> suggest that a low threshold should be applied to pre-empt this complication, leaving an abdomen open to avoid the syndrome altogether. The practical aspects of easy abdominal re-entry required in staged operations serve further to make this practice attractive. However, damage control surgery does not equate to, or mandate, a laparostomy. The frequent association exists owing to the positive correlation between this surgical strategy and the presence or risk of abdominal compartment syndrome<sup>44</sup>.

To decide which patients will benefit from a laparostomy requires the same clinical judgement as that used to identify patients who may benefit from the damage control strategy in the first place. The strategy should be applied to the patients at highest risk of abdominal compartment syndrome. Unfortunately, there is little other

direct evidence to guide this decision. Individual patient factors, the degree of tissue injury from the haemorrhagic and/or septic shock, the nature of the pathology (such as severe acute pancreatitis or visceral obstruction), the severity of the physiological effects, and the quality of the resuscitation and treatment, are all critical determinants of the overall risk<sup>44,45</sup>. Further research is required to guide this difficult decision.

Several medical appliances are now available to allow effective and efficient temporary abdominal closure. These devices provide relatively straightforward control of the laparostomy wound between procedures. Apart from facilitating reopening, they aim to protect the abdominal contents from the external environment (minimizing bacterial contamination, heat exchange and evaporation), drain the abdominal cavity, minimize acute adhesions between the intestine and the abdominal wall, and prevent the development of abdominal compartment syndrome<sup>41</sup>.

Major complications linked to the management of an open abdomen are infection, fistula formation and failure to obtain fascial closure<sup>34,40,46,47</sup>. All of these complications are challenging to prevent and manage. Potentially they may be minimized by judicious intravenous fluid management, early enteral nutrition, strategically planned returns to theatre, and dynamic and continuous tension on the fascial layers<sup>45</sup>.

### Damage control in abdominal haemorrhagic shock

#### Bleeding duodenal/gastric ulcer

Endoscopic control of bleeding ulcers has minimized the role of laparotomy; in only a minority of these patients does endoluminal treatment fail, necessitating a duodenotomy for gastroduodenal artery ligation or gastric resection<sup>48,49</sup>. Some patients in this subgroup have experienced a large physiological insult owing to protracted haemorrhagic shock. These patients are typically acidotic, hypothermic and coagulopathic, and it is in these situations that a damage control strategy is recommended. The aim at this initial operation is only to stop the bleeding: by direct suture, by resection, or even by direct packing on the luminal surface. An extensive surgical reconstruction should not be attempted, but instead deferred until after a period of resuscitation. The abdomen may be left open temporarily to avoid abdominal compartment syndrome, and facilitate re-exploration, if required. The definitive anatomical restoration and abdominal closure may then be performed when the patient's physiology has normalized, usually not later than 48 h after initial surgery<sup>50</sup>.

## Uncontrollable venous bleeding during pancreatic surgery

Accidental injury to the portal or retroperitoneal venous structures during elective pancreaticoduodenectomy is difficult to control surgically, and is associated with a high mortality rate<sup>20,23</sup>. Initial control is best achieved with local compression. From an anatomical perspective alone, the ideal repair is facilitated by rapid division of the pancreas, adequate exposure with proximal and distal control, and a primary repair or interposition graft. However, the operation should shift from the elective approach to a damage control strategy as the patient's physiology will rapidly deteriorate from this insult. As a damage control alternative to the definitive repair suggested above, the venous bleeding may be packed, or controlled by direct ligation. Both of these strategies have been reported successfully in the recent literature<sup>20,23</sup>. Furthermore, the elective procedure is then aborted, and anatomical reconstruction deferred until a subsequent laparotomy is performed, after physiological stabilization and resuscitation. Enteric and vascular continuity may be established days later. The bowel oedema secondary to acute portal hypertension can cause abdominal compartment syndrome, emphasizing the role of open abdomen with a temporary abdominal closure.

## Damage control for severe abdominal sepsis

### Gastrointestinal perforation with generalized peritonitis

Prompt diagnosis of gastrointestinal perforation usually allows definitive surgery, aimed at primary repair or resection of the pathology and final closure of the abdominal wall<sup>13,31,49</sup>. However, in the most severe instances, when generalized peritonitis and septic shock dominate the clinical phenotype, the patient's compromised physiology may preclude a safe primary definitive surgical strategy<sup>31</sup>. An anastomosis or large anatomical reconstruction performed in this clinical situation would probably fail owing to the severe physiological compromise. Furthermore, it is unlikely that this failure would be tolerated in this already critical situation. In these extreme situations, the patient may benefit from a damage control strategy.

The patient is brought to the operating theatre after appropriate, intensive, goal-directed resuscitation and administration of broad-spectrum antibiotics, as standardized by the Surviving Sepsis Campaign<sup>33</sup>. Once in theatre, the aim of the damage control procedure is to control the source of the sepsis; the anatomical reconstruction and abdominal closure are a secondary goal, and are deferred to

the secondary procedure after physiological normalization. The precise technical procedure used to achieve source control of the sepsis will vary greatly depending on the situation and pathology encountered. For example, if faeculent peritonitis has developed from perforated sigmoid diverticulitis in a severely shocked individual, the patient may best be served by peritoneal lavage and transection of the immediate upstream descending colon, with a view to delaying the definitive resection and/or reconstruction (with or without stoma) until after physiological normalization. On the other hand, if a small duodenal ulcer is the source of sepsis, a definitive suture repair with omental patch may be adequate<sup>49</sup>. The intraoperative pathological findings need to be incorporated into the intraoperative reassessment of whether or not to continue with the damage control strategy. It should be noted that peritoneal contamination by itself is not an indication for a planned relook/debridement, and an on-demand relook laparotomy strategy should be used instead<sup>40</sup>. The need for, and role of, a damage control strategy is dependent on the primary pathology and its physiological manifestations. Damage control procedures for acute diverticulitis have been reported successfully by several authors<sup>24,27,31</sup>. The abdomen is typically left open to avoid abdominal compartment syndrome, and to facilitate a non-traumatic re-entry. However, as discussed above, the reduced incidence of this syndrome, in association with modern resuscitation practices, may make this step less important in the future.

### Acute mesenteric ischaemia

Among the abdominal surgical catastrophes, acute mesenteric ischemia has one of the highest rates of misdiagnosis owing to its often non-specific clinical presentation and frequently inconclusive investigation findings<sup>51,52</sup>. The possible delays in diagnosis compound the already severe physiological insult associated with the primary pathology. The treatment involves resection of infarcted bowel and revascularization. Because of the deranged physiology, a long procedure with vascular repair and immediate bowel resection is not advisable; a staged procedure adhering to damage control principles is recommended<sup>15</sup>. At the first laparotomy, gangrenous bowel is resected, with the ends stapled off, and the abdomen closed with a temporary closure. A diagnostic angiogram is then performed, with the intention of endovascular reperfusion. Following a period of resuscitation, the peritoneal cavity is re-explored, with a view to re-establishing bowel continuity and definitive closure of the abdominal wall. On occasion more bowel resection may be required; there may be a need for further delayed laparotomies<sup>15</sup>.

## Toxic megacolon

Standard surgical resection of a toxic megacolon is normally limited to a subtotal colectomy, with the remaining distal sigmoid colon and rectum left *in situ*<sup>53–55</sup>. This approach evolved as significantly increased mortality was observed if total proctocolectomy was carried out during the acute phase of illness. This is a damage control strategy, although it has not been labelled as such in the colorectal literature; the subtotal colectomy does not remove the entire diseased organ or attempt to re-establish gut continuity (this combination would be a primary, definitive procedure), but it is sufficient to control the inflammatory stimulus and arrest the inflammatory cascade that may lead to multiple organ failure. The remaining colon/rectum may then be dealt with after recovery from the acute illness, as may the possible enteric anastomosis.

## Acute cholecystitis

The current standard of emergency cholecystectomy for acute cholecystitis is based largely on experiences from physiologically normal patients who typically make up the participants in trials<sup>56,57</sup>. However, in the subset of patients with acute cholecystitis who have associated physiological compromise, an operative approach is unattractive owing to the additional stress associated with the procedure. A percutaneous cholecystostomy offers an alternative treatment, which in its widest use of the definition can be termed a damage control strategy before definitive repair. This bedside drainage procedure, performed under local anaesthetic, removes the septic source with minimal physiological stress to the patient<sup>58,59</sup>. Efforts may then focus on physiological restoration, and definitive surgical resection of the gallbladder may be deferred to a later date.

Subtotal cholecystectomy may also offer an abbreviated procedure to minimize the additional physiological stress of a total cholecystectomy<sup>60</sup>. However, this operation is usually performed for severe inflammation encountered unexpectedly about Calot's triangle, rather than being required owing to physiological exhaustion of the patient. By definition, this technique can be considered a damage control strategy only when undertaken as a result of the physiological compromise.

## Future directions

The clinical applications of damage control principles are well ahead of the available clinical evidence. Unfortunately, it is hard to conduct randomized trials in situations where the accepted practice is already in place before high-level evidence exists. Thus, the best

way forward may be to categorize patients based on their physiological derangement (from haemorrhage or sepsis) and clinical diagnosis category (intestinal obstruction, perforation, vascular occlusion, etc.) in prospective cohorts. Observational studies can then generate hypotheses for groups of patients for whom randomization may be deemed potentially ethical and feasible, and for which a trial can be designed. To facilitate this, standardization of terminology and definitions regarding the clinical syndromes affecting critically ill patients will be required.

Current understanding of the basic science of septic shock is incomplete. Recent advances in understanding the sepsis syndrome, in addition to advances in critical care, imaging and minimally invasive procedures, have already altered the clinical phenotype of inflammation from sepsis. The persistent inflammation-immunosuppression catabolism syndrome has been proposed recently as the most common clinical expression of these inflammatory syndromes in patients who fail to recover from multiple organ failure in intensive care<sup>12</sup>.

Trauma surgeons have become the leaders of traumatic and haemorrhagic shock research in both clinical and laboratory sciences<sup>1,5,12</sup>. Emergency general surgeons should take leadership in surgical sepsis research and translate that knowledge to everyday clinical practice, including treatment strategies such as damage control in abdominal emergencies. The role of damage control surgery for non-traumatic abdominal emergencies will continue to evolve as further research into the precise indications, timing and techniques of resuscitation and surgery becomes available.

## Disclosure

The authors declare no conflict of interest.

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