Damage control surgery and the abdomen at the dawn of the 21st century

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ABSTRACT: Damage control is not a modern concept, but the application of this approach is the result of the constantly raising need to care for patients sustaining multiple high-energy injuries.

A Medline search was performed to locate English language articles relating to damage control procedures in trauma patients. The retrieved articles were manually cross-referenced, and additional academic and historical articles were identified.

Damage control surgery, sometimes known as «damage limitation surgery» or «abbreviated laparotomy», is best defined as creating a stable anatomical environment to prevent the patient from progressing to an unsalvageable metabolic state. Patients are more likely to die from metabolic failure (hypothermia, metabolic acidosis and coagulopathy) than from failure to complete organ repairs. Is damage control surgery going to have the decaying luck of truncal vagotomy and gastrectomy in the treatment of peptic ulcer disease, for example? Probably yes, since it won't be long before thorough knowledge of the pathophysiology of the trauma patient will result in the development of effective procoagulants, safe rewarming techniques and successful circulatory assist techniques, which will provide the surgeon an ideal surgical field, in order to proceed with the reparative surgery.

Key Words: Damage control surgery, Abbreviated laparotomy, Damage limitation surgery, Hypothermia, Metabolic acidosis, Coagulopathy, Trauma patient.

INTRODUCTION

Damage control (DC) is a surgical strategy that sacrifices the completeness of the immediate repair in order adequately to address the combined physiological impact of trauma and surgery[1]. The term damage control originates from the US Navy, with reference to the capacity of a ship to absorb damage and maintain mission integrity. Such a strategy allows a rapid assessment of the damaged hull and sufficient temporary repair to enable expedient return to a controlled environment in port[2]. In the early 1900s two groups discussed abbreviated laparotomy, describing planned re-exploration for hepatic trauma[3,4]; it was then that packing with occlusion of the porta hepatis to control liver bleeding was described[5]. The concept was formally reintroduced for control of hepatic hemorrhage in 1978[6], and rapidly gained wide support (describing liver packing and programmed re-operation[7,8]). The term «damage control surgery» was first described in trauma by Rotondo and Schwab, who in 1993 outlined a three-phase approach to patients with major abdominal injuries[9]. Damage control concepts evolved somewhat further with Moore, who expanded the whole strategy plan in five stages[10], and with Johnson in 2001 who named the initial phase «ground zero»[11].

In essence, damage control surgery equates with abbreviated surgery and restoration of near normal physiology, in a staged approach to a life-threatening injury.

Pathophysiology

Trauma patients are often admitted to hospital with hypotension, hypothermia or both. Moreover, meta-

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Table 1. Considerations for damage control surgery.

- Penetrating abdominal injury with systolic blood pressure < 90 mmHg
- High velocity gunshot or abdominal blast injury
- Multi-system trauma with major abdominal injury
- Compound pelvic fracture with associated abdominal injury
- Multiple casualties with definite surgical requirement and limited resources
- Military environment

(Modified from: Sugrue M, D'Amours SK, Joshipura M. Damage control surgery and the abdomen. Injury, Int. J. Care Injured 2004;35:642-648).

Table 2. Key parameters utilized in decision making for damage control surgery.

- Hypotension (systolic blood pressure <90 mmHg)
- Hypothermia(<34˚C)
- Coagulopathy (APPT< 60 sec)
- Acidosis (pH< 7,2) and base deficit > 8
- Major intra-abdominal vascular injury
- Associated need for management of extra abdominal life-threatening injury

(Modified from: Sugrue M, D'Amours SK, Joshipura M. Damage control surgery and the abdomen. Injury, Int. J. Care Injured 2004;35:642-648).

bolic acidosis and progressive coagulation defects are also present. This triad of hypothermia, acidosis and coagulopathy constitute the so called «death - triad»[6,8,12] and are the most important indicators for a staged operative procedure.

Hypothermia is associated with sympathetic a-adrenergic overdrive, peripheral vasoconstriction and end-organ hypoperfusion, resulting in conversion from aerobic to anaerobic metabolism and metabolic acidosis. Aggressive fluid resuscitation, especially with normal saline, exacerbates the situation, predisposing to impairment of the coagulation cascade. The patient remains cold, becomes acidotic, and bleeds. Hypothermia is an independent risk factor[13], with a direct correlation to injury severity[14]. Mortality rates of 100 per cent have been reported in trauma patients with core temperatures of less than 32˚C undergoing laparotomy[13,15].

Coagulopathy has two underlying causes. The dilution component, invariably secondary to aggressive fluid resuscitation, and the consumption component, due to the natural physiologic response of the body. The two components become intertwined and, compounded by the associated hypothermia, accelerate the patient into a vicious cycle. If coagulopathy is prevented and transfusion needs are decreased, then the risk of hypothermia is in turn lessened and the vicious cycle is interrupted.

Indications of damage control surgery in the abdominal trauma

Damage control is indicated only in a highly selected group of trauma patients. While ATLS teaches the early management of trauma, it makes little reference to damage control as a concept. The Definitive Surgical Trauma Course, however, has identified the fundamental importance of the principles of damage control, particularly in the abdomen[16,18]. Consideration for damage control should be made under the circumstances as shown in Table 1.

Awareness of potential triggers to initiate damage control is vital. It should be fairly obvious that high

Table 3. Pitfalls in damage control surgery.

- Delayed recognition of need for damage control
- Procrastination and failure to make decisions in the emergency room
- Poor communication with anesthetic, nursing and critical care teams
- Failure to monitor intra-operative temperature
- Failure to perform blood gases either in the ER or OR
- Inadequate monitoring of volume of fluid resuscitation
- Surgical ego
- Performing unnecessary investigations immediately after damage control procedure

(Modified from: Sugrue M, D'Amours SK, Joshipura M. Damage control surgery and the abdomen. Injury, Int. J. Care Injured 2004;35:642-648).

Table 4. Potential tools required during stage one of damage control surgery.

- Large abdominal packs and vascular clamps
- Intra-arterial shunts and ligation
- Balloon tamponade devices
- Hemostatic agents including factor VIIa
- Staplers

(Modified from: Sugrue M, D'Amours SK, Joshipura M. Damage control surgery and the abdomen. Injury, Int. J. Care Injured 2004;35:642-648).

velocity abdominal gun shot wounds are more likely to need damage control principles[19]. Key clinical and laboratory parameters that should act as triggers for damage control are shown in Table 2.

It is important to differentiate between damage control abdominal surgery and surgery for the prevention of abdominal compartment syndrome (ACS), which in essence is really temporary abdominal closure. In damage control surgery time is critical, which is different from a planned decision to leave the abdomen open to prevent the ACS.

Lastly, in terms of decision making, it is vital that pitfalls in damage control technique or decision making do not occur. Some of these potential pitfalls are listed in Table 3.

The five-stage approach of damage control surgery

- Stage 0 - «Ground zero» - Decision to perform damage control (Figure 1).

For maximum benefit, this decision should be made within minutes of starting the procedure, if not in the emergency room. Experts emphasize the concept of injury pattern recognition[20] (Table 1), rather than adherence to physiological measurements, although both should be used in conjunction. The predictors described above, in conjunction with a systemic lactate concentration greater than 5 mmol/l together with an appropriate injury pattern (Table 1), should prompt aggressive institution of damage control.

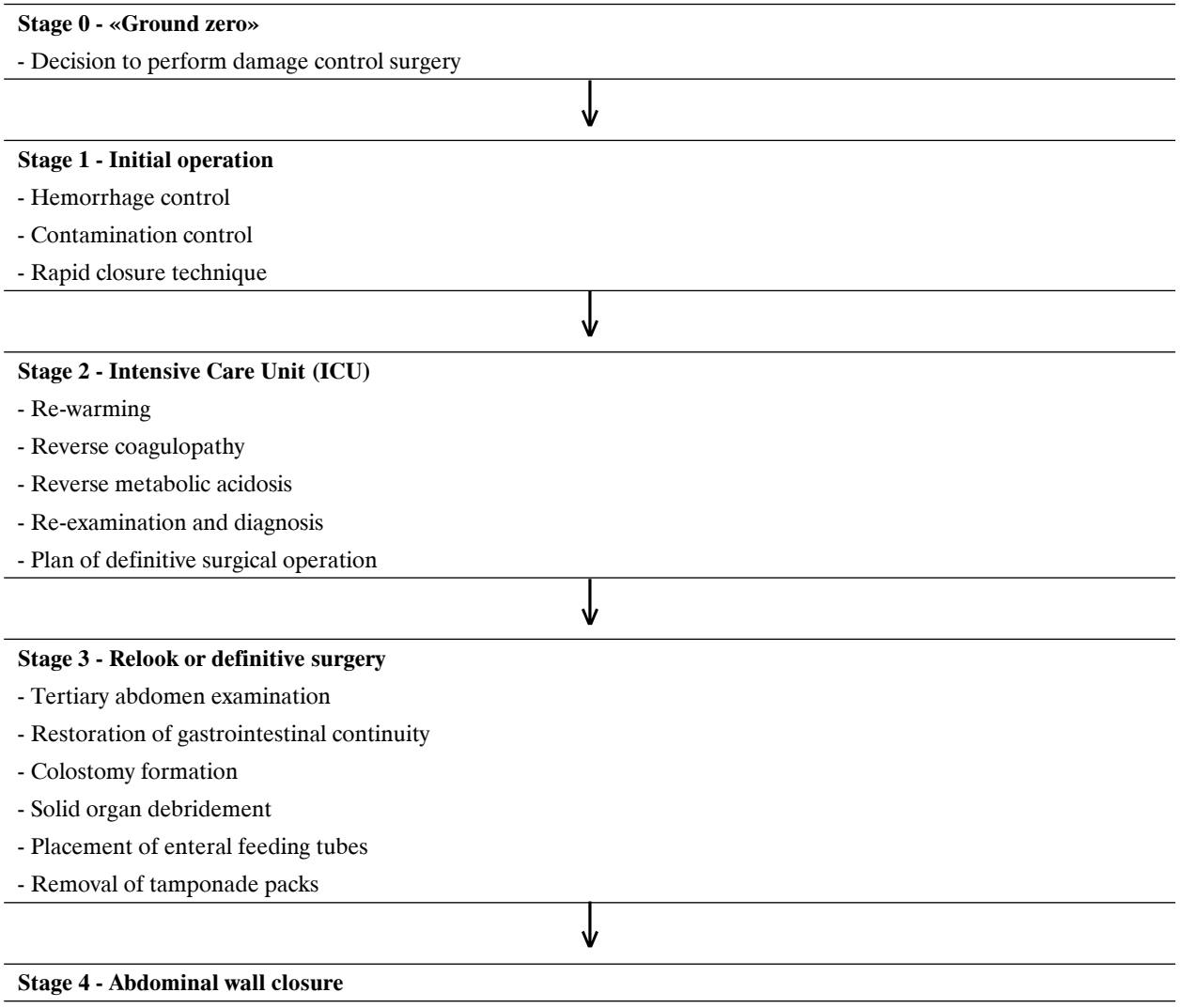
- Stage 1 - Initial operation

Initial operation goals include hemorrhage control, contamination limitation and temporary abdominal closure. Before proceeding with a particular incision and surgical approach, it is important that steps are taken to anticipate and avoid pitfalls, when possible. This should include:

1. Warming of operating theatre to 27°C.

2. Advising nursing staff of anticipated major blood loss.

3. Organizing sponge packs and tools (Table 4) before incision is made.



(Modified from: Loveland JA, Boffard KD. Damage control in the abdomen and beyond. Br J Surg 2004;91:1095-1101).

Figure 1. Damage control surgery stages.

4. Avoiding use of suction in the early stages of laparotomy.

5. Avoiding over-resuscitation before surgical hemorrhage control.

6. Recognizing and treating coagulopathy, even before its laboratory confirmation, especially when it is multifuctorial in origin (hypothermia, hemodilution, consumption of clotting factors, acidosis), which applies in a trauma patient.

The patient should be prepared from the chin to thighs with a warm antiseptic. A long complete midline incision is essential, ideally with the use of diathermy on high coagulation setting to reduce blood loss. Self-retaining retractors should not be used in the initial phase of damage control laparotomy.

The principles of damage control in controlling hemorrhage include the immediate recognition and restriction of major hemorrhage with packing (a life-saving technique), followed by control of all arterial and venous hemorrhage from visible vessels. Packing of all four abdominal quadrants (in essence, three «quadrants», the left and the right upper quadrant

and the pelvis) is usually done with the use of four to five packs, which are inserted in a systematic fashion to the upper quadrants first, followed by the pelvis. On a probability basis, in blunt trauma the spleen, the liver and the major vessels are the most likely source of hemorrhage, in that order, while in penetrating trauma in the shocked patient, major vessel injury is the obvious potential source of instability. If after the first round of pack removal hemorrhage appears continuous, a second set of packs should be rapidly inserted and rapidly removed. Definitive techniques to achieve hemorrhage control should be undertaken at this point including splenectomy, clamping of major mesenteric vessel bleeding, nephrectomy and packing of the liver. Splenectomy should be performed in less than two minutes and nephrectomy through a lateral approach in less than five minutes. In the event of uncontrolled hemorrhage in the profoundly hypotensive patient the next step is digital control of the aorta, followed by aortic cross-clamping. There has been a significant deviation from tradition with respect to management of renal tract injuries. The current trend is to proceed directly with nephrectomy in the presence of an actively bleeding kidney or expanding haematoma. In the absence of such features, renal injuries should be observed initially and if necessary dealt with definitively later. Similarly, the resected ureter is either ligated, exteriorized or stented. Lastly, in the presence of irrepressible pelvic hemorrhage, packing should be also immediately performed.

During hemorrhage control, time should not be spent on micro hemorrhage from tissue surfaces, as this should be packed, if possible. On the other hand, consideration should be given for maximum replacement of coagulation factors with platelets, fresh frozen plasma, cryoprecipitate and Factor VIIa[21]. Elective angiography and embolization, even in compound pelvic and liver injuries[22], should be postponed, until the patient's handover to the ICU and his/her stabilization there.

The second principle in damage control strategy is to control contamination. This will require the use of staplers with linear staplers transecting bowel ends, occlusion with umbilical tape, suture or towel tag ligation. Resection and anastomosis should be limited or delayed. Shunts can be used successfully and in crisis large bore IV tubing can be used, although preferentially a vascular shunt such as a Javid shunt should be used[10,23].

The final stages of abdominal damage control initial operation lie in abdominal closure. As a general principle, the abdomen should be left open to avoid the abdominal compartment syndrome, and allow ease of return to theatre without damage to the fascia. Leaving the abdomen open will not affect tamponade of the liver or the pelvis. Several techniques have been suggested for abdominal closure[24-26]. The simplest option for abdominal closure is a rapid whip-stitch to the abdominal wall using a large nylon suture or the use of towel clips. It is not, however, the preferred technique as it results in tissue tension and intra-abdominal hypertension and towel clips are radio-opaque and interfere with radiologic examination. A sandwich technique using a steri-drape and a green sterile surgeon's hand towel wrapped in a sandwich between the steri-drape is ideal. It is important to have the drape large enough to ensure it goes laterally under the abdominal wall. Drains should then be placed between the sandwich and the covering steri-drape to ensure adequate drainage of intra-abdominal fluid to help firstly monitor blood loss and secondly prevent accumulation of fluid, which may result in the ACS. Very occasionally there will be massive oedema of the intestine and this will require a silo. It is important to prevent evisceration; therefore it is necessary to suture the prosthetic material to the fascia. Suturing to the fascia tends to damage and cause oedema, hence the preferential technique of avoiding suture placement when able. When suturing the prosthetic material for a silo the use of PTFE is preferable as it retains its strength beyond that of a Bogota bag. On subsequent stages a VAC pack can be used, as this offers other advantages.

- Stage 2 - Patient transfer to the ICU for restoration of homeostasis

After initial surgery, patients are transferred to the ICU for further resuscitation, reversal of acidosis, correction of coagulopathy and rewarming. The ICU team is given full details of the trauma, initial resuscitation and surgical intervention. Normothermia is paramount for efficient functioning of enzymes in-

trinsic to the coagulation cascade and metabolic pathways; unless core temperature exceeds 35°C, normal coagulation will not occur, despite aggressive component replacement[15]. Passive warming techniques include use of warm air blankets, warmed fluids and humidified ventilator gases. Active options available include lavage of anatomical cavities and continuous arteriovenous rewarming[27], etc. The decision to transfuse is initially arbitrary, but later is guided by haemoglobin levels and clotting profiles. These variables may be misleading in the presence of hypothermia. Crystalloid transfusion should be minimized to restrict further oedema of the bowel and the ensuing ACS. Endpoints include a systemic lactate concentration of less than 2-5 mmol/1, base deficit greater than -4 mmol/l, core temperature greater than 35°C and an international normalization ratio of less than 1,25 times the normal value.

During hospitalization in the ICU, it is vital that the patient is transferred to radiology only for hemorrhage control procedures, such as elective angiography and embolization of an ongoing hemorrhage. This approach of urgent post-operative angiography should be considered for patients with complex hepatic injury, when intrahepatic arterial bleeding or an AV fistula can be embolized/occluded. Angiography should also be considered for patients with significant retroperitoneal, pelvic or deep muscle injuries identified at surgery.

- Stage 3 - Re-look or definitive surgery

A planned re-operative procedure should be considered once there is an improvement in temperature, base deficit and coagulation profile, usually between 24-48 hours after the initial operation. Compromising and returning to the OR before adequate resuscitation will leave the patient less likely to withstand the prolonged procedure of definitive surgery. Two important issues should be pre-decided: a) the definitive or not abdominal closure, and b) the patient's feeding with either a nasojejunal tube or a feeding enterostomy. During a planned re-operation, definitive procedures should be performed before pack removal, as the latter may induce bleeding requiring re-packing, and so prevent completion of the intended operation. Such procedures include restoration of gastrointestinal continuity, colostomy formation, solid organ debridement and placement of enteral feeding tubes. It is important to perform a «tertiary» survey, as an incidence of missed injuries of 17 per cent has been described under these circumstances[28].

- Stage 4 - Abdominal wall closure

If bowel oedema has resolved, the abdomen can be closed formally. However, mobilization of such interstitial fluid may not be complete and temporary closure may still be necessary. Definitive closure should be achieved as soon as possible thereafter.

Complications

The most common condition that results directly from damage control is intra-abdominal hypertension or acute compartment syndrome (ACS), with an incidence of 15%. A fine line exists between sufficient packing to achieve tamponade and increasing the risk of ACS as a result. For this reason the abdomen is only partially (or temporarily) closed. Despite this, ACS may still occur, because of increasing visceral swelling, expanding haematomata and the use of abdominal packs. Signs of a distended abdomen, increased ventilator inspiratory pressure requirement, raised intracranial pressure, oliguria progressing to anuria[29], a decreased cardiac output and hypotension may occur insidiously and can also be associated with other pathologies than intra-abdominal hypertension and ACS. An objective assessment of intra-abdominal pressure is therefore required[30]. Intra-abdominal pressure can be estimated most conveniently from the transduced pressure of an indwelling urinary catheter. This is usually done by intermittent measurement but it is also possible to monitor continuously using a three-way irrigation catheter. A pressure >30mmHg confirms ACS and requires return to OR for initial or further decompression. Decompression should lead to improved visceral perfusion, cardiac function and ventilatory mechanisms.

Another described complication, which appears to be independent of hollow viscus injury, but rather associated with packing itself as well as selective hepatic artery ligation, is the intra-abdominal abscess formation[31,32].

The open abdomen and its management is fraught with difficulty for the surgeon, ranging from problems of closure to complications resulting directly from ex-

posure of enteric contents, including exudative fluid loss, fistula formation and adhesive obstruction.

Re-operation. When?

Resent literature suggests a period of 8 hours to 10 days, during which the re-operation should be performed[6,10,31], once there is a reverse in the «death triad». In general, though, the planned re-operation is performed between 12 and 24 hours from the initial operation. A lactate level below 4 mmol/l is presently one of the indicators of return of tissue perfusion, in conjunction with a base excess greater than -4 mmol/l and a normalized coagulation profile. Ideally the patient should be monitored in the operating room for the first 2-3 hours following damage control laparotomy, in order to ensure there is non need for early re-operative surgery, as this would be required if there were ongoing major blood losses. Two points should be emphasized:

a) The differentiation between planned and emergency re-look procedures. Ongoing uncontrolled surgical bleeding and/or the development of ACS require an unscheduled re-laparotomy. This means an emergency return to the operating room or urgent decompression in the ICU. Other scenarios that may encourage earlier re-operation are limb ischemia after arterial ligation or stenting, and closed loop obstruction after multiple bowel resections. Ideally, however, re-look operations should be carried out at the surgeon's discretion, as long as the patient is stabilized. The planned re-operation has a significantly lower mortality rate[28].

b) At a re-look operation only procedures that the patient can tolerate should be performed. It may be necessary to leave the abdomen open. Ostomies required at this stage should be brought as lateral as possible. The same applies for feeding jejunostomies.

The future of damage control surgery

The challenge of envisioning the future of damage control surgery is intriguing[33]. Is damage control surgery going to have the decaying luck of truncal vagotomy and gastrectomy in the treatment of peptic ulcer disease, for example, in the sense that as more understanding of the biology and the pathogenesis of peptic ulcers became known, vagotomy and resection waned? Probably yes, since it won't be long before thorough knowledge of the pathophysiology of the trauma patient will result in the development of effective procoagulants, safe rewarming techniques and successful circulatory assist techniques, which will provide the surgeon an ideal surgical field, in order to proceed with the reparative surgery. Perhaps in the next decade, rather than arguing why, how and when to perform damage control surgery, we will be discussing how to avoid the need for damage control in the first place.

Η χειρουργική ελέγχου της βλάβης στην αυγή του 21ου αιώνα

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ΠΕΡΙΛΗΨΗ: Η χειρουργική ελέγχου της βλάβης (Damage Control Surgery - DCS) δεν είναι μια πρόσφατη θεωρία, αλλά η εφαρμογή στην πράξη αυτής της προσέγγισης γεννήθηκε από την διαρκώς αυξανόμενη ανάγκη αντιμετώπισης ασθενών που υπόκεινται σε πολλαπλά τραύματα υψηλής ενέργειας.

Διενεργήθηκε βιβλιογραφική έρευνα στην ιατρική βάση δεδομένων MEDLINE, προκειμένου να εντοπιστούν άρθρα στην αγγλική γλώσσα που να σχετίζονται με τις διαδικασίες της χειρουργικής ελέγχου της βλάβης σε πολυτραυματίες. Επιπλέον, εντοπίστηκαν άρθρα ακαδημαϊκού και ιστορικού ενδιαφέροντος σχετικά με το θέμα.

Η χειρουργική ελέγχου της βλάβης, αλλιώς γνωστή και ως «χειρουργική περιορισμού της βλάβης» ή «σύντομη λαπαροτομία», ορίζεται καλύτερα ως η χειρουργική στρατηγική που σκοπό της έχει να δημιουργήσει ένα σταθερό ανατομικό περιβάλλον, προκειμένου να εμποδιστεί η μετάπτωση του πολυτραυματία ασθενούς σε μια μη αναστρέψιμη μεταβολική κατάσταση. Κι αυτό, γιατί οι πολυτραυματίες πιθανότερα καταλήγουν εξαιτίας της μεταβολικής τους αστάθειας (υποθερμία, οξέωση και διαταραχές του πηκτικού μηχανισμού), παρά εξαιτίας της αποτυχίας να ολοκληρωθεί η άμεση χειρουργική αντιμετώπιση των τραυμάτων τους.

Άραγε, θα έχει η χειρουργική ελέγχου της βλάβης την φθίνουσα τύχη, για παράδειγμα, της στελεχιαίας βαγοτομής και γαστρεκτομής στην αντιμετώπιση του γαστρικού έλκους; Πιθανώς ναι, μια που δε θα αργήσει ο καιρός που η πλήρης γνώση της φυσιοπαθολογίας του πολυτραυματία θα οδηγήσει στην ανάπτυξη αποτελεσματικών φαρμακευτικών παραγόντων που θα αναστρέφουν άμεσα τις διαταραχές της πήξεως, και τεχνικών επαναθέρμανσης και υποστήριξης του κυκλοφορικού που θα επαναφέρουν τη θερμοκρασία του σώματος και θα παρέχουν στο χειρουργό το ιδανικό χειρουργικό πεδίο, προκειμένου να αντιμετωπίσει σε δεύτερο χρόνο τις τραυματικές βλάβες του ασθενούς.

Λέξεις Κλειδιά: Χειρουργική ελέγχου της βλάβης, Υποθερμία, Οξέωση, Διαταραχές Πηκτικού μηχανισμού, Πολυτραυματίας.

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