REVIEW ARTICLE

Damage control: a light at the end of the tunnel

Controle de danos: uma luz no fim do túnel

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ABSTRACT

The concept of "damage control" is established in the management of severely traumatized patients. This strategy saves lives in delaying definitive repair of anatomic lesions and focus on restoring physiology. The purpose of laparotomy in damage control is stopping bleeding and infection in patients with severe hemorrhagic shock who are exhausting their physiological reserves. Subsequently, these patients will be submitted to CPR and correction of coagulopathy, hypothermia, and acidosis in intensive treatment center before returning to the operating room. Such approach has achieved high survival rates, better than expected for abdominal trauma, and its application has been extended to include thoracic and orthopedic trauma.

Key words: Wounds and Injuries; Laparotomy; Shock, Hemorrhagic; Ressuscitation.

RESUMO

O conceito "controle de danos" está estabelecido no manejo de pacientes gravemente traumatizados. Essa estratégia salva vidas ao adiar o reparo definitivo das lesões anatômicas e concentrar-se na restauração da fisiologia. O objetivo da laparotomia no controle de danos é interromper a hemorragia e a contaminação em pacientes, com choque hemorrágico grave, que estejam exaurindo suas reservas fisiológicas. A seguir, esses pacientes serão submetidos à ressuscitação e correção de coagulopatia, hipotermia e acidose no centro de tratamento intensivo, antes de retornarem à sala de cirurgia. Tal abordagem tem alcançado taxas de sobrevida melhor que o esperado para o trauma abdominal e sua aplicação tem sido estendida para incluir o trauma torácico e ortopédico.

Palavras-chave: *Ferimentos e Lesões; Laparotomia; Choque Hemorrágico; Ressuscitação.*

INTRODUCTION

The treatment of patients severely poly-traumatized presented considerable change in recent decades due to factors related to the technological development of aggressor agents and optimization of services for victims. Thus, there was an increase in the magnitude of trauma mechanisms from the spread of weapons of high energy and use of more powerful vehicles. In turn, victims of these aggressors who, by the severity of cases, did not even arrive at hospitals alive because they died at the accident scene or during transportation, are now assisted with structured pre-hospital care services capable to keep them alive until admission in trauma centers.

Therefore, patients with severe shock associated with imminent metabolic repercussion and lesions in various organs, which would require hours for surgical correction, raised an urgent need for a paradigm shift to the forefront of this issue. The

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experience shows that the attempt of definitive treatment of all lesions in patients critically unstable leads inexorably to death, still in the peri-operative period or some hours later, by exsanguination resulting from coagulopathy or multiple organ and system failure.

Facing the need to facilitate a rapid control strategy for bleeding and contamination caused by trauma, so that the patient can be properly resurrected, a tactical proposal labeled as damage control arose in the beginning of the 90s (DC).[1]

Since then, DC became the standard treatment of severely traumatized patients with massive hemorrhage in North America, Israel, and South Africa, as well as in many other countries.[2]

DEFINITION

The goal of DC, at first, is to preserve the life of the individual, gaining time for intensive therapeutic resources to restore its physiology, thus enabling the final surgical correction of lesions in a second moment.

It is known that lesions triggered by traumas, such as lacerations of organs and tissues and fractures, here called the first strike, act in such a way as to release pro-inflammatory and anti-inflammatory substances. In turn, respiratory insufficiency (hypoxia), bleeding with cardio-circulatory instability, ischemia/reperfusion and tissue contamination act early as a second strike, and, at this time as an endogenous strike.[3]It is still possible that inadequate resuscitation, whether in the pre-hospital care and/or admission to the trauma center, can act as a third strike triggering adverse events that may lead to metabolic-physiological exhaustion and death.

The combination of the first and second strikes and, eventually, the third one, acts causing the emergence of hypothermia, coagulopathy, and acidosis (the lethal triad). From there, each component of this triad can exacerbate the others, contributing to a vicious cycle that, if not promptly reversed, will culminate in irreversible cell failure.

In its own way, prolonged surgical procedures, with the aim of definitive repair of multiple lesions, lead to constant heat and blood loss, worsening acidosis, hindering patient's compensation, and prominently contributing to the installation of the lethal triad, and can be considered part of the third strike.

Therefore, DC is based on five stages:

- **stage 1 (indication):** the crucial moment of the correct use of the DC strategy is the recognition of patients who should be assisted, based on the trauma mechanism and clinical condition at hospital admission. The judgment based on experience in the assistance of seriously traumatized patients might be the main determining factor for the success of this complex approach. Patients with indication of DC should remain in the resuscitation room just enough to establish control of airways, decompress pneumothorax, stabilize the pelvic ring, start heating, perform chest x-rays and ultrasound (FAST) when necessary, and blood collection for exams and cross examinations. Resuscitation is initiated preferably with the administration of blood products (whole blood and fresh frozen plasma) at the expense of crystalloids, rapidly transferring the patient to the operating room. It should be noted that patients with no precise indication, and inappropriately submitted to DC, will suffer morbidity-mortality resulting from this tactic. Table 1 shows clinical situations that may require DC;

Table 1 - Clinical situations that may require damage control

Thoracic trauma
Penetrating injury and PAS < 90 mmHg;
Pericardial effusion in blunt or penetrating trauma;
Emergency thoracotomy.
Abdominal and pelvic trauma
Penetrating abdominal trauma and PAS < 90 mmHg;
Blunt abdominal trauma, free intraperitoneal liquid and PAS < 90 mmHg;
Closed pelvic fracture, PAS < 90 mmHg, free intraperitoneal fluid;
Open pelvic fracture.
Trauma of extremities
Injury by firearm in the femoral triangle;
Mutilated limb by blunt injury.
Other situations
Emergency laparotomy will be followed by decompression craniotomy;
Trauma in multiple sites;
Lesions in several hollow viscera associated with parenchymatous organs;
Necessity of embolization for hemostasis in pelvic fracture and associated intra-abdominal lesions;
Need for massive blood transfusions (> 10 CH units);
Severe metabolic acidosis (PH < 7.30);
Hypothermia (T < 35° C);
Coagulopathy diagnosed by exams, thromboelastogram, or non-surgical bleeding;
Need for operative time greater than 90 minutes.

SBP: systolic blood pressure.

- **stage 2 (abbreviated laparotomy):** swift operation to control bleeding and contamination, using simple techniques, quick and temporary measures in order to neutralize lesions that lead to imminent death, keeping the abdomen in laparotomy to prevent compartmental syndrome and allow re-assessment of the definitive treatment of lesions while preserving the aponeurosis for the definitive closure of the peritoneal cavity when possible;
- **stage 3 (damage control resuscitation):** use of anesthetic technique that focuses on the permissive hypotension, patient warming, infused solutions, and use of blood products to the detriment of crystalloid solutions, followed by transfer to the Intensive Care Unit (ICU) for the correction of metabolic disorders. It must be initiated at stage 1, in the resuscitation room, and continue until normal physiology is re-established in the ICU.
- **stage 4 (definitive treatment of lesions):** the return of the patient to the surgical center for the definitive treatment of lesions and closure of the abdominal wall as soon as clinical conditions for re-intervention are observed. It is necessary, as it occurs in the trauma surgery service of the João XXIII Hospital, in Belo Horizonte-MG, that a surgeon is present and responsible for the longitudinal follow-up of patients in order to determine the best time for this re-assessment;
- **stage 5 (rehabilitation):** physical and psychological therapy, adaptation of limb prostheses are frequently required in patients submitted to DC.

Figure 1 shows the longitudinality of the procedures involved in DC.

THE DEADLY TRIAD

The establishment of hypothermia, acidosis, and coagulopathy, known as the lethal triad (LT) in severely traumatized patients undergoing massive hemo-transfusions leads to mortality as high as 90% as described by Ferrara et al.[4] Accordingly, the set of tactics involved in DC aims to avoid triggering such a condition. Figure 2 shows the pathophysiological components of the LT.

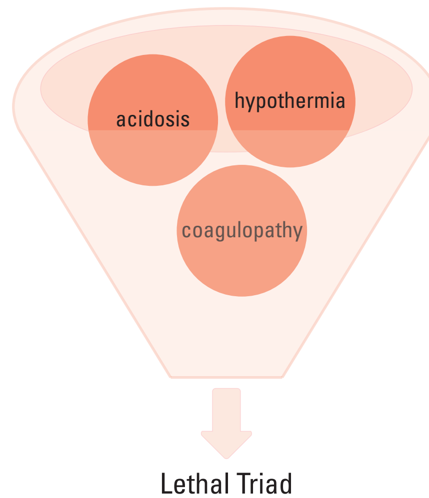

Figure 2 - Pathophysiological components of the lethal triad.

Hypothermia

The heat loss begins at the moment of trauma, being exacerbated by low peripheral perfusion that is secondary to shock and exogenous factors such as patient exposure to the environment, intravenous infusion of unheated solutions, and opening of body cavities (thoracotomies, laparotomies).

Generally, the prognosis is directly related to the degree of hypothermia, with 100% mortality rate observed at temperatures below 32.8° C.[5,6] Hypothermia causes and exacerbates bleeding by affecting platelet function, reducing enzymatic activity of coagulation factors, and changing fibrinolysis.[5,7]

Thus, severely traumatized patients should receive special attention for the prevention and treatment of hypothermia (Table 2).

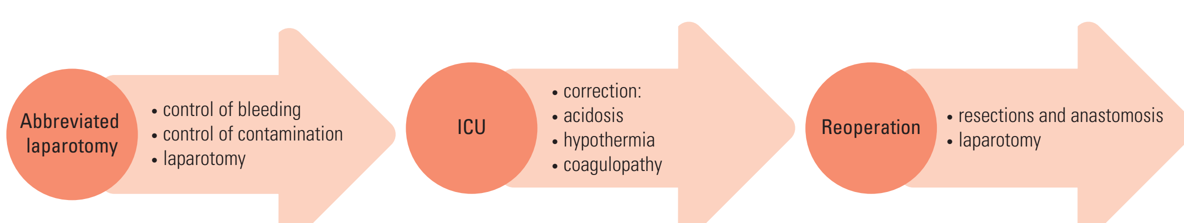

Figure 1 - Longitudinality of procedures in DC.

Table 2 - Treatment and prevention of hypothermia

Cover the patient in the emergency room;
Raise the temperature of the operating room;
Reheat infused solutions;
Use thermal mattress and heaters in the peri-operative and ICU;
Irrigate the thoracic and/or abdominal cavities with heated saline solutionin the peri-operative period.

Acidosis

Metabolic acidosis is the predominant phenomenon resulting from cell hypo-perfusion, secondary to hemorrhagic shock. Patients with pH < 7.2 present reduced myocardial contractility and cardiac output, vasodilation, hypotension, bradycardia, arrhythmias, renal /liver blood flow reduction, and decreased response to endogenous and exogenous catecholamines.[8] Moreover, acidosis acts synergistically with hypothermia to determine alterations in the coagulation cascade aggravating bleeding.

Coagulopathy

Coagulopathy in trauma is one of the factors, in isolation, most accurate for the prediction of a patients' prognosis and the biggest challenge in severe cases submitted to DC due to non-mechanical bleeding that often cannot be stopped with surgical techniques suitable for hemostasis. As pointed out, it is aggravated by hypothermia and acidosis.

The interconnection of cause and effect between the LT components causes the prevention and reversal of each factor to be crucial in the prophylactics of physiological-metabolic exhaustion that results in death.

Its approach involves the correct hemodynamic resuscitation as well as management of factors involved, such as hypothermia and metabolic acidosis.

DAMAGE CONTROL RESUSCITATION

The current approach of patients with indication for DC evolved into a set of strategies that contemplates all aspects involved in the pathophysiology of severely traumatized patients, previously discussed, in an integrated manner towards surgical procedure using key concepts such as: permissive hypotension; use of blood products to the detriment of crystalloids for volume replacement; rapid correction of coagulopathy based on the transfusion of components (plasma, platelets, cryo-precipitation), hemostatic resuscitation; and, more recently, the use of tranexamic acid. The association of these conducts with the fighting measures and correction of hypothermia and acidosis, and abbreviated laparotomy, is what is conventionally called damage control resuscitation (DCR).[9]

Permissive hypotension

The discussion about risks and benefits of permissive hypotension still lacks attention as for its clinical application due to the absence of conclusive studies, and the following aspects can be considered: how low is the pressure tolerated by severely poly-traumatized patients? For how long? How is the reperfusion lesion? At what pressure level clots are displaced from vessels? In addition, most studies treated patients with penetrating trauma. How does it behave in of the case of blunt trauma? And how is it when there is associated traumatic brain injury?

Given these issues to be resolved by appropriate studies, it is likely that attitudes to avoid excessive use of fluids and vasoactive amines, elevating blood pressure levels in excess and emphasizing the maintenance of systolic blood pressure around 90 mmHg, are beneficial in the DC scenario.

However, traumatic brain lesion patients, pregnant women, and the elderly, using beta-blockers, should not be submitted to permissive hypotension.

Hemostatic resuscitation

The hemostatic resuscitation (HR) based on the administration of crystalloids is the cornerstone in the treatment of patients with mild to moderate hemorrhagic shock. However, for the subgroup of patients with massive exsanguination, in which are included candidates for RDC, there is a need for more discussion. In time, the fact that in spite of isotonic fluids helping reducing oxygen debt by increasing flow and, consequently, slightly raising the availability of oxygen in the cellular context, does not increase the ability of oxygen transport and does not act correcting the coagulopathy present in these patients. On the contrary, there are studies showing the negative potential of infusion of large volumes of isotonic fluids compared to the activation of the immune system as well as the worsening of acidosis (hyperchloremic) and coagulopathy (dilutional), increasing the possibility of installation of adult respiratory distress syndrome, systemic inflammatory response syndrome, subsequently, multiple organ and system failure.[10]

Hewsonet al.[11] in 1985, retrospectively analyzed patients massively resuscitated and suggested that coagulopathy was more common in those who received crystalloids in excess. At that time, these authors suggested that red blood cells should have been used as a concentrate (CH) with fresh frozen plasma (PFC) in the ratio of 1:1 in patients with severe hemorrhagic shock.

More recently, studies conducted in military and civilian scenarios showed that the administration of whole blood and transfusion of components to the detriment of crystalloids improves survival of patients who are victims of severe hemorrhage.[12-14]However, Duscheneat al.[15] analyzed patients receiving more than ten units of CH at a level 1 trauma center in a retrospective study. The mortality rate was 26% in the CH:PFC ratio of 1:1 and 87.5% in the ratio of 4:1 ($p = 0.0001$). Such data suggest that, in trauma cases requiring massive transfusions (above 10 CH units), the ratios of CH:PFC that were close to 1:1 confer an advantage in survival.

The PROMMT study prospectively assessed hemo-transfusions performed in 10 American level 1 trauma centers concluding that greater proportions of plasma and platelets administered early during volume resuscitation to patients who have received at least three units of CH, in the first 24 hours after admission, were responsible for mortality reduction.[16]

Therefore, the current trend in trauma centers is to use CH and PFC with more liberality in cases of DCR.

Although most DCR scholars agree about the need for early and sustained administration of PFC, there is still plenty of debates regarding the use of platelets (PLT). Some studies report the use of CH:PFC:PLT in the ratio of 1:1:1 claiming that platelets are easy to administer, and produce readily measurable effects on coagulation by immediately increasing absolute count in the circulating blood.[9]

Research conducted by Gunter et al.[17] and Holcomb et al.[18] demonstrated increased survival of 30 days in groups of patients who received larger ratios of PLT with respect to CH. However, one should consider the possibility of an increase in the occurrence of adult respiratory distress syndrome and multiple organ failure associated with the transfusion of blood products, especially platelets.[19,20]The PROPPR study is underway in the United States with the objective to verify the survival in two groups: CH:PFC:PLT 1:1:1 and CH:PFC:PLT 2:1:1 to evaluate the best relationship between components to be transfused in voluminous bleeding.[21]

Similarly, there is no consensus on the use of cryoprecipitate, from the beginning of resuscitation, in order to maintain fibrinogen levels above 100 mg/mL. It is known that the liver produces large amounts of fibrinogen during traumatic hemorrhage, and patients rarely arrive in the emergency room with a fibrinogen deficit.

Therefore, the use of fixed ratios of platelets and cryoprecipitate in the early stages of HR is still not consensual and should be administered according to a clinical and laboratory (including the thromboelastography when available) assessment, or in research massive blood transfusion protocols.

Regarding HR, the early intravenous administration of tranexamic acid, still in the resuscitation room, is gaining prominence in the literature. This drug increases clot stability, slowing fibrinolysis and acting after the step involved in the coagulation cascade.[21-23]

Abbreviated laparotomy

The abbreviated laparotomy is an essential step in DC and needs to observe certain principles in order to be properly conducted:

- the decision to perform DC must occur quickly, already in the patient's primary assessment in the emergency room, and according to criteria previously discussed or during the first 10 minutes of operation. To opt to interrupt an operation that is ongoing for hours and perform DC in a patient already in the lethal triad represents unrecoverable delay in the operative moment;
- the length of stay in the emergency room will be the time required to only guarantee definitive airway, treatment of hypertensive pneumothorax, pelvis stabilization, chest x-ray, FAST, blood collection, and control of external bleeding;
- the rapid transfer to the surgical center is needed because the greatest commitment is to control the bleeding that is ongoing in any body cavity. Therefore, the protocol named red wave was created at the João XXIII Hospital. Thus, as soon as the surgical team evaluates the patient and provides DC, a bell rings in the resuscitation room alerting the blood bank and surgical block. The patient is immediately transferred to the surgical block, which features a specially mounted and reserved room to provide

this type of procedure. In turn, the blood bank sends bags of universal blood and plasma to the surgical block while blood typing is being performed.

Once DC is indicated, the surgical team should follow the steps:

- xyphopubic median laparotomy;
- initial buffering of quadrants with compresses;
- careful inventory of the cavity for operation planning;
- temporary control of bleeding using simple and rapid hemostatic techniques;
- temporary control of contamination with techniques that preserve tissues and are timely;
- irrigation of the celomic and/or thoracic cavity with a heated saline solution;
- tamponade of bloody areas with compresses, in a parsimonious way, in opposite vectors, avoiding the abdominal compartment syndrome resulting from excessive compresses;
- laparotomy with a Bogotá bag avoiding sutures in the aponeurosis that will be preserved for the further definitive closure of the abdominal wall.

Table 3 shows the most commonly used procedures for the control of bleeding and contamination during DC.

Table 3 - Temporary control techniques of bleeding and contamination

Bleeding
Ligation of vessels;
Temporary arterial Shunt with probe;
Tamponade with compresses;
Tamponade with balloon (Foley probe, Fogarty catheter);
Resections (e.g. total splenectomy, total nephrectomy).
Contamination
Ligation of intestinal handles with cardiac tape;
Choledochostomy and ureterostomy with probe;
Simple continuous suture of hollow viscera (one plan): esophagus, stomach, duodenum, rectum;
Intestinal ostomies without maturation (avoid them whenever possible).

After the operation, the patient will be transferred to the intensive care unit (ICU) for resuscitation and treatment of hypothermia, acidosis, and coagulopathy. Later, under appropriate conditions, he will return to the operating room and receive the definitive treatment of visceral lesions (resections, vascular and gastrointestinal anastomoses). However, due to edema in the intestinal loops and lateral retraction of the surgical wound, and maintained in laparotomy, in certain cases it is possible that laparorrhaphy is not feasible. For this purpose, alternative techniques for abdominal wall synthesis, such as fatty skin closure as proposed by Drumond[24], allow the coverage of the granulation tissue and intestinal loops enabling the late treatment of incisional hernia.

Figures 3 and 4 represent the 5 Hs of death (related to great voluminous losses) and the 4 Ts of life (signaling the importance of transfusions of blood products in the hemostatic resuscitation, preoccupation with body temperature control, speed of time for the indication and performance of abbreviated laparotomy, and teamwork (time) including all professionals (surgeons, anesthesiologists, ITU specialists, nurses, and physical therapists) involved in this complex approach.

Finally, patients should be rehabilitated and reintegrated into society in the best functional conditions that can be offered.

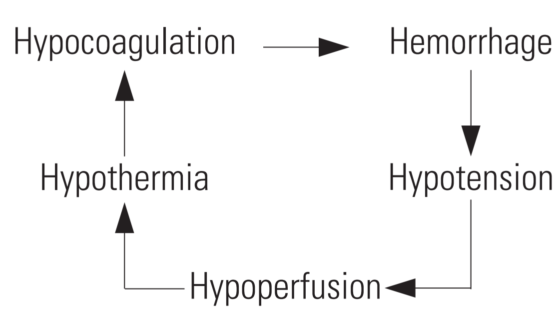

Figure 3 - The 5 Hs of death.

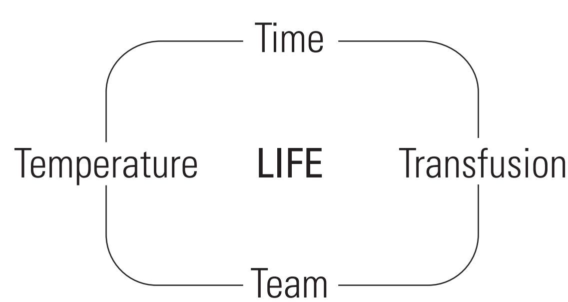

Figure 4 - The 4 Ts of life.

CONCLUSION

The goal of DC is the rapid surgical interruption of the critical hemorrhage associated with resuscitative measures specific to this group of patients in order to interrupt the course of pathophysiological alterations that will culminate with the perpetuation of the LT and, consequently, death.

The attempt in definitely treat lesions in patients with voluminous hemorrhages and critical conditions, in prolonged operations, invariably ends in death, during the procedure or in the first postoperative hours, whether due to uncontrollable bleeding resulting from irreversible coagulopathy, whether due to multiple organ and systems failure.

The damage control resuscitation performed prematurely may reduce the need for damage control surgery by maintaining physiological stability in patients.[22,23]

The available evidences in the literature and experience of specialized services assisting poly-traumatized patients indicate that damage control resuscitation, when well-conducted in all its stages, reduce mortality if properly indicated. Brenner et al.[25] published a prospective study evaluating 88 patients undergoing DC and reported 72% survival in this group of patients of the utmost gravity.

However, because of its high morbidity and cost, it should not be performed in cases that do not meet the criteria established in the literature.

The future development of new agents and tactics that can reverse coagulopathy in voluminous bleeding may reduce the need for DC.

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