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Damage Control in Surgery-An Expanding Concept

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Patients with multiple injuries suffer severe Physiological insult by single overwhelming hit or secondary hits leading to development of fatal triad namely Coagulopathy, Hypothermia and Acidosis. Without prompt corrective measures the patient will be pushed towards Systemic Inflammatory Response Syndrome, Organ failure and finally Death.

The concept of damage control surgery developed in order to prevent secondary hits due to magnitude of surgery and involves doing the minimal in the shortest possible time followed by stabilization in ITU before definitive surgery. Since then the concept has expanded.

The expansion of the concept of DCIS can be considered in four stages. First Stage involved Establishment of the Damage control Surgery (DCS) in severe abdominal trauma. Stage Two saw establishment of Damage control Resuscitation with DCS as a component. DCR, a systematic approach to exsanguinating trauma, incorporating several strategies to reduce morbidity and mortality is achieved by wide range of efforts to minimize fatal triad. Stage Three the concept encompassed other regions such as thorax, limbs and brain. Stage four extended it beyond Trauma in to critical surgical illnesses across a vast range which includes cholecystitis, bleeding

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peptic ulcers, intestinal obstructions and pyonephrosis.
DCIS has become a key component in trauma care saving many severely injured. Since origins in Abbreviated laparotomy, DCIS has evolved in to concepts of DCR and branched off to cover other areas and systems and also engulfed care of non-trauma surgical emergencies. More conceptual, technical and technological developments are expected in the future care of injured and ill.

Keywords: Damage control surgery; damage control resuscitation.

1. INTRODUCTION

In multiple severe injuries resulting severe Physiological Insult by single overwhelming hit, two major hits or sometimes serial hits lead to development of fatal triad of internal derangements namely Coagulopathy, Hypothermia and Acidosis [1]. If corrective measures were not taken promptly and aggressively the patient will be pushed towards Systemic Inflammatory Response Syndrome, Sepsis, Organ failure and finally Death. This is the dreaded path clinicians look to avoid at any cost in severe trauma. Reversal of the effects of first hit and prevention of subsequent hits provide the conceptual background to damage control in surgery.

Until few decades ago patients who sustained severe multiple injuries succumb to them with in few hours or days. Improvements in Trauma surgery in 1970s and 80s much thanks to Vietnam War led to their survival after initial surgery. However significant proportion subsequently developed SIRS, ARDS, MOF and Sepsis while in ITUs and perished there in few days or weeks. The said conditions requiring survival from initial severe injury as a prerequisite made appearance among enemy ranks against critically ill relatively recently and therefore called by some as “diseases of progress in medicine”.

The concept of damage control surgery developed in 1980s in order to circumvent severely injured dying in ITUs after initial injury. Damage control is a Navy term defined as “the capacity of a ship to absorb damage and maintain mission integrity’’ [2]. Since first described by Rolendo et al. in 1993 increase in military and civilian trauma along with development of trauma centers and dedicated research units manned by bold innovative surgeons and scientists have expanded the concept both linearly and laterally [3,4].

The expansion of the concept of DCS can be considered in four stages although in reality there is some degree of overlapping of time periods.

2. FIRST STAGE-ESTABLISHMENT OF THE PRACTICE OF DAMAGE CONTROL SURGERY (DCS) IN SEVERE TRAUMA

DCS aimed to do minimum, least time consuming maneuvers to minimize effects of injury and initial surgery on the patient thus facilitating restoration of physiology than correction of disrupted anatomy [5]. The recorded sporadic practice of Damage control surgery dates back to American civil war (1861-1865) and employed by some surgeons since in many conflicts and when handling civilian trauma. Pringle described use of packing for hepatic trauma in 1908 for which modifications were made by Halstead in 1913 [6]. But until Late 1970s DCS was often dismissed as unsafe surgery performed when nothing else can be done [3,6]. Introduction of the concept of abbreviated laparotomy by Stone in 1983 and coining of the term Damage Control Surgery (DCS) in a landmark paper by Rolando and Schwab in 1993 saw revalidation of DCS which has since stayed and expanded. Since inception, DCS mostly fell within forte of general surgeons particularly military surgeons performing trauma work [3]. As a result only 10% of US soldiers wounded during 2003-2009 period died compared to 24% in Vietnam War [3].

2.1 Indications for DCS

Not every trauma patient warrant DCS as limited scale of injuries, early arrest of bleeding and prompt resuscitation give many of them time to undergo a definitive procedure at the initial operation. Those who continue to experience the sequel of tissue shock that manifests as persistent hypothermia, metabolic acidosis and non-surgical non-mechanical bleeding become candidates for DCS. It is also indicated on proactive basis and sometimes when early warning signs of above derangements make appearance. Although indicators for DCS are numerous and still not defined in entirety there are widely agreed upon ones. The Mechanism, anatomical injuries, physiological and

biochemical derangements as well as miscellaneous considerations such as mass disasters are among them. Some of the indicators are preoperative while others enable decision making both pre and intra-operatively.

Penetrating abdominal injury with SBP less than 90 mmHg, high velocity Gunshot or abdominal blast injury, multi-system trauma with major abdominal injury, Combined visceral injury with major vascular injury, compound pelvic fractures with associated injuries are among anatomical considerations.

Physiological DCS triggers include hypothermia, coagulopathy and acidosis. Core temperature less than 35℃, pH less than 7.2, base deficit greater than –8 and significant coagulopathy are among end points in decision making.

Operative time over 90 mins and SBP under 90 mmHg for 4 or more hours is considered as cut-of values [7].

In military or disaster situations deficiency in time, expertise, facilities as well as need to do best for the most may push a surgeon towards DCS.

2.2 Phases of DCS

At the inception DCS was divided in to three phases-Initial operation, ICU based resuscitation and re-operation [4]. Fourth phase coming before others in time scale was added in 2001 by Johnson et all who termed it 'ground Zero' [8]. It included assessment and resuscitative measures taken during rapid transport from point of injury via emergency department to operating theatre. This also had laid foundations for next stage in development, the Damage Control Resuscitation (DCR). Later a fifth phase coming at the end termed 'closure of the abdomen' was added with the understanding of the difficulties encountered in decision making and process of closing the abdomen following definitive surgery or sometimes after initial surgery due to increase in intra-abdominal contents hematoma, packing, oedema [8].

2.3 Techniques of DCS in Abbreviated Laparotomy

The Aim of abbreviated laparotomy in context of DCS is to stop bleeding and contamination. Rapid access using diathermy all the way from skin disregarding the effects on subsequent healing is in line with principals of DCS. In Liver Injury packing above and below has been in use for many years. However hepatic artery ligation and angio-embolization too may be required for Control of bleeding. Bleeding from pelvic injury can be controlled with benefit of external Fixation, External splinting, Internal iliac ligation which can be unilateral and gauze packing [7,9]. Contamination from bowels can be prevented by simply tying off the open ends or by cross stapling if the establishment of continuity is not rapidly possible. This will stop contamination allowing continuity to be established at re-operation. Pancreatic bleeding can be packed for submission and irritant secretions from lacerated pancreatic or biliary ducts can be drained to safety of exterior at the initial surgery. Except in blunt trauma usually enabling hands-off management of lateral haematoma associated with renal injury, Nephrectomy is quicker over attempted preservation. Similarly splenectomy is preferred over unpredictable and time consuming preservation efforts. Temporary closure of abdomen using Opsite sandwich, Bogota bag, over and over suture closure of skin, towel clips or improvised techniques with sheets from Uri bags or collapsible saline packs provide answers to closing of the abdomen with sufficient laxity to prevent Abdominal compartmental syndrome [10,11].

2.4 Stage Two–Establishment of Damage Control Resuscitation with DCS as a Component

It is said that medical science is the only field benefited from warfare. The concept of DCR which has emerged over last 10 years is an offshoot of recent war experiences in Middle East by armed forces of United States and United Kingdom [12]. This evolved naturally from the concept of DCS which is now considered a component of DCR. DCR can be defined as "A systematic approach to patients with exsanguinating trauma, incorporating several strategies to reduce morbidity and mortality" [10]. This objective is achieved via wide ranging efforts over wider time scale to minimize the occurrence of fatal triad of Hypothermia, Acidosis and coagulopathy.

Hypothermia is multi factorial in a trauma patient. It can be due to exposure to cold at scene, during transport or in the operating theatre. Administration of cold Fluids and Blood products as well as effects of drugs for sedation and

anesthesia also contributes to this. Hypothermia increases bleeding by impeding Platelet adhesion, deregulation of coagulation factors and by interfering with fibrinolysis. Core temperature of 35C is associated with poor prognosis while core temperature of 32C is associated with 100% mortality [13]. Countermeasures include external rewarming such as use of blankets as well as internal rewarming strategies including warming of IV fluids and cavity irrigation.

Acidosis is again multi factorial. Hypoxia, inadequate tissue perfusion, lactic acidosis as well as the use of excessive Normal saline resuscitation with its supra physiological Chloride content all contribute. Acidosis decreases activity of coagulation factors. Clinically the degree of base deficit and lactate level on admission tend to strongly correlate with worsened patient mortality. Correction of hypoxia and restoration of circulation is the best countermeasure against acidosis.

Coagulopathy in a trauma patient which was termed trauma induced coagulopathy (TIC) by Brohi et al. [14] is caused by multiple independent but interacting mechanisms. Acute Traumatic coagulopathy (ATC), the endogenous component of TIC is initiated within minutes of injury and has an association with magnitude of trauma and shock. This is characterized by isolated factor V inhibition, impaired platelet function, dysfibrinogenemia, hyper fibrinolysis and systemic anticoagulation [15,16]. Exogenious causes of TIC include acidosis, hypothermia, and dilution by hypocoagulable fluid. INR of 1.3 and above is a recognized indicator of coagulopathy [17]. As coagulopathy appears to be the main enemy of a patient trying to recover from the effects of major trauma, much research has been directed towards rapid diagnosis and early direct interventions. Point of care techniques such as thromboelastogram provides answers to above [18].

In the wake of above findings with the realization that DCS is not much successful in isolation, DCS has now become a component of DCR. Other components of DCR are:

A) Permissive Hypotension, maintain systolic blood pressure around 90 in case of head injury around 100 until hemorrhage control has much recognized benefits [19].
B) Haemostatic resuscitation including early stopping measures such as tourniquets, temponading balloons as well as tranexemic acid [20].
C) Limited Use of crystalloids and colloids to avoid dilutional coagulopathy. Colloids are avoided and crystalloids usually hartmans is limited to 1.5 litres. Resuscitation in Advanced shock (Class III and IV) are initiated with blood and blood products. They are best administered according to MTP guided by coagulation parameters and massive transfusion protocol but in practice 1'1'1 protocol of Packed cells, FFP and platelets are used in most centres [21].
D) Warming of all fluids including blood components to body temperature.

2.5 Stage Three-Damage Control beyond Abdominal Trauma

Since the use of DCS in the forms of Abbreviated Thoracotomy the concept has been extended to other anatomical areas and systems.

2.6 Damage Control Thoracic Surgery

The requirement of abbreviated thoracotomy may occur in an emergency department (EDT) specially in the event of Penetrating trauma. Fast, simple relevant access is obtained with initial left antero-lateral thoracotomy which if necessary extends across midline to ipsilateral chest finally enabling clam-shell thoracotomy. Technically minor surgical procedures of Needle Thoracocenticis and Pericardiocentesis normalize physiology for a short time until the insertion of chest drain or thoracotomy, a secondary procedure. In order to shorten time peripheral laceration of lungs can be stapled. For a bleeding cavity laceration not involving hilum, a linier stapler along the wall of the tract will keep the length of the cavity widely open and amenable to haemostatic maneuvers.This procedure is known as pulmonary tractotomy [22-25].

In Hilar leisions cross clamping will temporarily abort bleeding and prevent air embolism. Pneumonectomy with an application of a stapler across hilum is quicker than an anatomical or segmental resection but carries variable mortality between 0 to 50% and therefore best avoided [26-29]. Less than 50% diameter Oesophagial lesions can be directly repaired and more extensive injuries can be managed with gastrostomy and exclusion of the proximal end. Unilateral internal jugular or subclavian artery injuries can be tied off. Balloon temponade using 30 ml bulb foley catheter is employed in bleeding

root of neck injuries as an initial maneuver. In lower Tracheal injuries through wound intubation is an option. While smaller laceration can be directly repaired. Temporary closure of chest wall can be achieved with over and over interlocking stich but towel clips are employed for the purpose at times.

2.7 Damage Control Orthopaedics

Damage control orthopedics using either external fixators or Thomas splint plays an important role in management of fracture shaft of femur, a facture with fatal outcome in the past. Tibial plafond fractures need gentle and minimal handling of coveted soft tissue and any factures with associated sever brain injury need minimal initial intervention giving latter the priority in management. In general, splinting of long bones as well as POP casts are valuable in immediate stabilization of long bone fractures [30,31].

Posterior fixation of unstable vertebral fractures is followed by ICU stabilization and time consuming anterior fixation. Slings and external fixation devises such as C –Clamps are used to achieve immediate stabilization and haemostasis of unstable pelvic fractures. This may need internal iliac artery ligation, packing and even angioembolization as an initial procedure.

Initial Fasciotomy in a limb with compromised vascular supply reduce the urgency of vascular repair. Minimum essential debridement is beneficial in a limb soft tissue injury in multiple trauma scenario and Amputations over salvage may be the hard choice offered to the patient if the stakes on life are high. Life over limb and limb over fracture is the order of battle for optimal outcome.

2.8 Damage Control Vascular Surgery

While some vessels can be simply tied off as an acceptable alternative to repair Aorta and IVC injuries can be managed at initial surgery with stents, sometimes improvised ones such as chest drains. Vascular bridging for limb injuries with improvised or commercial devises can maintain blood supply to limbs for a period. Tourniquet on a bleeding limb is accepted as an initial intervention in a exsanguinating patient. Temporary Intravascular shunts (TIVS) when used for common and external lilac injuries with comparable injury and patient characteristics showed improvement in amputation rate from 47% to 0% in 22 patients with penetrating trauma. TIVS are simple, rarely clot and effective provided both arterial and venous tracts are patent [32].

2.9 Damage Control Neurosurgery

Management of a traumatic brain injury commence with resuscitation correcting hypoxia, coagulopathy, anemia and $PaCO_2$. Control of Core temperature specially brain temperature as well as administration of epilepsy prophylaxis are important to prevent permanent damage. Devises to obtain direct measurements of mileu interior of brain and for induction of therapeutic cerebral hypothermia are under evaluation In order to exploit them for DCNS [33-35]. Arrest of bleeding, evacuation of intracranial haematomas and decompressive craniotomy with removal of bone are increasingly employed in DCNS particularly in children [36]. Insertion of emergency room ICP bolt for monitoring and therapeutic drainage is valuable as an initial measure [3]. DCNS Courses are designed and operated for Doctors and assisting staff leaving for middle eastern duties by US Army for some time [37].

2.10 Stage Four-Damage Control Concepts beyond Trauma in to Critically Ill Surgical Patients

Irrespective of the differences in initial insult, physiological derangements seen in critically ill as well as the trauma patients and the sequel are similar. This finding has led surgeons to extend DCS to patients who are critically ill with non-traumatic causes with reduction in mortality [38-43]. Instead of 24 to 72 hour ICU in trauma, stabilization phase of longer time duration may be acceptable in critically ill.

Bleeding duodenal or Gastric ulcers are managed with simple over sawing but sometimes extra-luminal or even intraluminal packing becomes necessary. Ill patients with Acute cholecystitis are managed with Cholecystectomy or when required with Subtotal cholecystectomy which saves time. Uncontrolled bleeding during pancreatic surgery can respond to packing. Acute Mesenteric ischemia will favour resection of bowels with stapled closure and second surgery to restore intestinal continuity once patient had ITU stabilization. Perforated viscus and peritonitis will respond to minimally time consuming procedures such as hartmanns after peritoneal washing. Toxic mega colon will benefit from rapid stapled Subtotal colectomy and

ileostomy over time consuming procto-colectomy [44]. Endoscopic stenting as an initial procedure to relieve Acute Large bowel obstruction due to malignancy will allow stabilization of patient's physiology and subsequent definitive surgery [45]. Drainage of empyema, Intra-abdominal abscess and pyonephrosis via percutaneous guided catheters and cholangitis via ERCP will buy time for a definitive procedure. Trans-Ureteric stenting is also an minimally interventional procedure for pyonephrosis. Postpartum hemorrhage and other pelvic bleeding in Gynecology and obstetrics l benefit from DCS with packing and internal iliac artery ligation which has been in use for many years.

3. SUMMARY AND CONCLUSION

Damage Control in Surgery has come to stay as a key component in trauma care after a long journey through trauma and conflict ridden world. With proper patient selection it can make a significant difference in saving lives of severely injured. Since abdominal trauma origins, original DCS has evolved in to concepts of DCR and branched off to cover fields such as thoracic surgery, orthopedics, vascular surgery and neurosurgery. It has also invaded the care of critically ill patients who suffer from non-trauma surgical emergencies with promising results. Considering the exponential increase in volume and quality of research running on Damage Control in Surgery More conceptual, technical and technological developments are expected in the future care of injured and ill.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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