Damage Control Thoracotomy: A Systematic Review of Techniques and Outcomes

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Background

Damage control surgery is the practice of delaying definitive management of traumatic injuries by controlling hemorrhage in the operating room and restoring normal physiology in the intensive care unit prior to definitive therapy. Presently, damage control or "abbreviated" laparotomy is used extensively for abdominal trauma in an unstable patient. The application of a damage control approach in thoracic trauma is less established and there is a paucity of literature supporting or refuting this practice. We aimed to systematically review the current data on damage control thoracotomy (DCT), to identify gaps in the literature and techniques in temporary closure.

Methods

An electronic literature search of Pubmed, MEDLINE, and the Cochrane Database of Collected Reviews from 1972-2018 was performed using the keywords "thoracic," "damage control," and "thoracotomy." Studies were included if they reported the use of DCT following thoracic trauma and included survival as an outcome.

Results

Of 723 studies, seven met inclusion criteria for a total of a 130 DCT operations. Gauze packing with temporary closure of the skin with suture was the most frequently reported form of closure. The overall survival rate for the seven studies was 67%. Survival rates ranged from 42-77%. Average injury severity score was 30, and 64% of injuries were penetrating in nature. The most common complications included infections (57%; pneumonia, empyema, wound infection, bacteremia), respiratory failure (21%), ARDS (8%), and renal failure (18%).

Conclusion

DCT may be associated with improved survival in the critically injured patient population. Delaying definitive operation by temporarily closing the thorax in order to allow time to restore normal physiology may be considered as a strategy in the unstable thoracic trauma patient population. The impact an open chest has on respiratory physiology remains inconclusive as well as best mechanisms of temporary closure. Multi-center studies are required to elucidate these important questions.

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INTRODUCTION

Damage control surgery delays definitive surgical management until restoration of normal physiology in the intensive care unit; it is frequently used in the care of severely injured trauma patients in hemorrhagic shock[1–4]. The concept of damage control stems from observations that definitive operations on acutely ill patients in the setting of metabolic exhaustion leads to increased risk of mortality[5–10]. This strategy was first described in the early 1900's, before World War I[1].

Presently, damage control laparotomy, or "abbreviated laparotomy" is a well-accepted practice in the setting of abdominal trauma. Its efficacy is supported by years of experience and demonstration of improved outcomes [4,11–13]. The same principles have been applied to the thoracic cavity, damage control thoracotomy (DCT), but evidence for improved survival in DCT, complication rates, and optimal technique for temporary chest closure is sparse[14,15]. A major tenant of damage control surgery is packing the cavity to promote clot formation and stabilization; however, with the thoracic cavity, there is potential for packing to induce cardiorespiratory compromise, and the appropriate duration to avoid infectious complications is unknown.

The purpose of this article was to conduct a systematic review of the literature on DCT techniques and outcomes in order to summarize experiences with the use of this procedure and assess its utility and safety in unstable trauma patients requiring thoracotomy for thoracic trauma.

MATERIALS and METHODS

Data Sources and Search

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines were followed for our review[16]. An electronic literature search of Pubmed, MEDLINE, and Cochrane Database of Collected Reviews from 1972-2018 was performed by a trained medical

librarian using a combination of keywords and MeSH terms. Our search protocol included identifying articles based on search terms to include: "Thoracic" "Damage Control" and “Thoracotomy”. The studies gathered from this search were thoroughly examined along with their reference section to identify any other relevant studies on damage control thoracotomy.

Study Selection

All titles and abstracts were reviewed independently by two reviewers (AD, TP). Papers selected for full review were analyzed by three reviewers (AD, TP, PM) and consensus used for final inclusion. We included studies meeting the following criteria: patient age greater than 18, written in English, and reported on patient survival. Studies with less than three patients (case reports), conference abstracts, those who failed to describe damage control operations, and resuscitative/ED thoracotomy were excluded from the study (Figure 1). Resuscitative or ED thoracotomies are conducted in the trauma bay or emergency department and are typically reserved for the most severely ill patients with no signs of life. Practice management guidelines for this operation have been well-described and therefore excluded from this analysis.

Data Extraction and Quality Assessment

A detailed review of each study was performed and extracted data included study year(s), study design, sample size, and thoracotomy location. We extracted outcome measures including survival and complication rates. Survival was defined as patient alive at discharge from acute hospitalization. A planned meta-analysis was unable to be performed due to the study types, variation in quality of studies and small sample sizes.

We assessed study quality using the Downs and Black quality appraisal tool for nonrandomized trials and observational studies[17]. Study quality assessment was completed independently by two reviewers (AD and TP) and a third (PM) providing consensus for any disagreements (Figure

1). Each study was scored on the quality of reporting, both external and internal validity, and study power, and the combined scores determined overall quality (Table 1; scale: poor, ≤ 14; fair, 15 to 19; good, 20 to 25 and excellent, 26 to 28)[17].

RESULTS

The literature review returned 723 papers after removal of duplications, 12 underwent full review, and 7 met final inclusion/exclusion criteria (Figure 1). The studies included were limited to retrospective cohorts or case series (Table 2). The average age range between the studies was 20 years to 40 years. Mechanism of injury was predominantly penetrating (64%). The average injury severity score (ISS) across studies was 30 (range 26 -36). Four out of 7 studies included information regarding admission physiology. The average pH 7.14 (SD = 0.1), the average temperature 34.9 Celsius (SD = 1.2), and average INR 1.48 (SD = 0.18). The average units of red blood cells transfused was 17 (SD = 11).

Temporary closure technique varied across the studies. The most frequently reported form of closure was packing with gauze or laparotomy pads, with temporary closure of the skin and placement of chest tubes. Other forms of closure included vacuum assisted devices, surgical towel packing covered with adherent surgical draping, and silastic bag application with or without packing. Of the 5 studies that reported complications, 74 (57%) patients developed an infection (pneumonia, empyema, bacteremia, wound infection), 27 (21%) developed respiratory failure, 24 patients (18%) developed acute renal failure, and 11 (8%) developed Acute Respiratory Distress Syndrome.

Overall, 130 patients underwent DCT, 87 survived to discharge for a survival rate of 67% (Figure 2). Survival rates ranged between 42-77% (Table 3).

A single study compared DCT to definitive management and found no significant difference in survival (47% DCT vs 57% Definitive), thoracic infectious (24% DCT vs. 25% Definitive) or hemorrhagic complications (18% DCT vs. 14% Definitive)(14). This same study compared positive inspiratory pressures before and after closure of DCT and definitive thoracotomy and found inspiratory pressures decreased in damage control closure (DCT 20 cm H_2O vs. Definitive 32.5 cm H_2O). O'Connor et al. demonstrated temporary closure has no impact on respiratory physiology by similarly measuring airway pressure before and after temporary closure and finding no significant difference (Before Closure 27.2 cm H_2O vs. After Closure 24 cm H_2O)[4]. However, Moriwaki et al. in their retrospective review of 12 patients undergoing intrathoracic gauze packing as a mechanism of temporary closure, found half of their patient population who achieved successful hemostasis suffered from respiratory distress, desaturation, and high airway pressure after packing[18].

DISCUSSION

Based on a limited number of studies, damage control thoracotomy seems to be a viable procedure for patients in extremis following thoracic trauma. Only a single study compared survival between DCT and definitive surgery and no difference was identified. The wide variety of packing and closure methods suggest the optimal method has not been established.

The earliest application of damage control concepts for the thoracic cavity was not described until the late 1990's and early 2000's[1]. Since that time there has been little published on this topic. Despite a lack of evidence, the use of DCT for thoracic trauma to control hemorrhage and establish normal physiology in the ICU has gained validity as a management strategy. Of the seven studies identified, containing a total of 130 damage-control thoracotomy operations, the survival rate was 67%, ranging from 42 to 77%. The survival rates reported in this review are much greater than the 0-30% average survival rates reported in resuscitative thoracotomy (RT)

literature[19–22]. This difference likely can be attributed to the morbidity of RT procedures, severity of injury and subsequent inability to transfer to a more controlled operating room environment.

Unlike damage control laparotomy, when temporizing the thoracic cavity one must consider normal respiratory mechanics and the impact temporary closure of the thorax has on physiology. Lang et al,[14]. addressed this issue in their comparison of airway pressure in DCT and definitive thoracotomy chest wall closure (DCT 20 cm H_2O vs. Definitive 32.5 cm H_2O). The rationale is an open chest, with increased subcutaneous space, is less restricting to the lungs and counteracts the decrease volume caused by packing. In the small case series by Caceres and his colleagues, they attributed the tolerance for packing observed in the thoracic cavity is due to the youth of the patient population[15]. While objective data would suggest DCT is safe and has limited effect or might even improve respiratory mechanics, not all authors have reached the same conclusions. Moriwaki et al. in their study concluded that the viscera of the thorax has less capacity to expand in comparison to the viscera of the abdomen, and therefore temporary closure increases the risk for cardiorespiratory compromise[18]. Nonetheless, based on our summary of the DCT literature, DCT appears to be an effective strategy. Less clear is the 'best' method for temporary closure.

Within each individual study multiple strategies were employed to temporarily close the chest. Wound vacuums, chest tubes with pleura drains and adhesive dressing, and skin only suture closure, with or without gauze packing for each approach, are some of the strategies that future research should compare. Based on respiratory mechanics, great care should be placed on strategic placement of hemostatic gauze and laparotomy pads. Areas suitable for packing and for minimizing cardiorespiratory compromise risk include the boundaries of the chest, upper

mediastinum, hilum of the lung, near the diaphragm, and vertebrae[10]. In addition, the use of fewer gauze packs and limiting the duration of time the thorax is packed may reduce cardiorespiratory compromise.

A major concern regarding damage control techniques are complications, specifically infection, secondary to an open chest. With respect to damage control laparotomy, it is well established that patients are at increased risk for post-operative hernias, enterocutaneous fistulas, and dehiscence[23–25]. Previous studies have reported a relationship between duration of packing and bacterial infections in damage control laparotomy[2,26,27]. Many of these studies authors impress upon the readers to remove gauze packing as soon as possible to prevent infectious complications. Moriwaki et al. suggest that gauze packing should be removed within 72-96 hours to avoid complication. Others emphasize the importance of prophylactic antibiotics for such procedures that leave the incision site open[18]. Studies describing damage control thoracotomy identified various forms of infection (e.g. pneumonia, empyema, wound infection) as the most common complication (Table 4). With the current body of literature, largely lacking a comparison group, it is impossible to conclude whether these complications are due to the intervention alone or the nature of the injury. Lang et al. in their retrospective study found no significant difference in thoracic infectious complication rates between DCT and definitive thoracotomy[14]. This remains the only comparison of DCT to definitive management and is underpowered to properly test hypotheses related to complications. Overall, the complications of DCT appear to be comparable to that of definitive thoracotomy in trauma[28].

Limitations

This is a systematic review of a relatively uncommon operation; therefore, the sample size of the studies reporting on this procedure is limited. The literature that does exist has been limited to

case series and retrospective reviews, as this life-saving intervention is unlikely to ever be prospectively studied. As such, most of these reports describe experiences with this operation but fail to offer a control group for comparison to definitive management or other interventions. Currently, the alternative to DCT is definitive thoracotomy. However, DCT may be appropriate for a different, more critically ill patient group. Data to support this thought has not yet been reported. Similarly, RT patients have a heterogeneous pattern of injuries in which some have very severe thoracic injuries or truly do not have a thoracic injury at all. We elected to exclude studies involving RT from this analysis due to the fact that many of the RT publications were ambiguous in their description of the procedure, leading to uncertainty whether these were truly damage control for thoracic injuries. We specifically wanted to evaluate DCT as a strategy for thoracic trauma and thus we excluded those with RT from analysis. Lastly, inconsistency in reported data and outcomes between studies made it challenging to make conclusions. Due to these inconsistencies, we were unable to report the frequency in which strategies to temporize the chest were employed, nor their associated outcomes and complications.

CONCLUSIONS

Damage control thoracotomy appears safe and may have survival benefit for patients with thoracic trauma and aberrant physiology. The most common mechanisms of temporary closures used are packing with gauze pads or commercial vacuum assisted devices. Negative physiologic effects while using this technique are questionable and complication rates appear similar to definitive techniques. Further studies, including coordinated multi-center trials, are needed to assess the best procedure for damage control thoracotomy, particularly focused on patient selection and temporary closure techniques. Standardized reporting of patient inclusion, indications for damage control and closure technique is required.

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