A New Look at Criteria for Damage Control Surgery

Hisashi Matsumoto12, Kunihiro Mashiko2, Yuichiro Sakamoto2.
Noriyoshi Kutsukata2, Yoshiaki Hara2 and Hiroyuki Yokota1

1Department of Emergency and Critical Care Medicine, Graduate School of Medicine, Nippon Medical School
2Shock and Trauma Center, Nippon Medical School Chiba Hokusoh Hospital

Abstract

Background: Several reports have validated the criteria for damage control surgery (DCS). However, although metabolic acidosis and body temperature can be measured quickly, tests for predicting the severity of coagulopathy require special laboratory equipment and take 15 to 30 minutes. Such delays could be life-threatening for patients requiring DCS. The aim of this study was to establish simplified and practical criteria to enable rapid decision-making regarding the need for DCS.

Methods: Thirty-four consecutive patients with unstable hemodynamics after initial fluid resuscitation who had undergone DCS for severe abdominal or pelvic injuries were retrospectively analyzed. The patients’ characteristics, clinical courses, laboratory data, and outcomes were reviewed using the data contained in their medical records.

Results: The overall survival rate was 55.9% (survivors group: n=19; nonsurvivors group: n=15), which was similar to the calculated mean probability of survival (Ps=0.5671). At the start of surgery, the systolic blood pressure (SBP) was less than 90 mm Hg in all cases in which surgery failed, and the mean SBP in the nonsurvivors group (69.6 ± 14.8 mm Hg) was significantly lower than that in the survivors group (93.2 ± 22.9 mm Hg, p=0.006). Except in two cases, the value of the base excess in the nonsurvivors group was less than -7.5 mmol/L, and the mean base excess (-11.5 ± 5.3 mmol/L) in the nonsurvivors group was significantly less than that in the survivors group (-5.5 ± 4.9 mmol/L, p=0.008) at the start of surgery. The core temperature at the start of surgery was less than 35.5°C in all cases in the nonsurvivors group. On the basis of these results, three indicators (SBP less than 90 mm Hg, base excess less than -7.5 mmol/L, and core temperature less than 35.5°C at the start of surgery) were identified. The success rate of DCS in patients who possessed all three indicators (28.6% ) was significantly lower than that in patients who did not possess all three indicators (75.0%; p= 0.014).

Conclusion: Our results indicate that surgeons should decide to perform DCS when only one or two criteria defined in this study are met and should not wait for all three criteria. Although our proposed criteria are not strict and may broaden the indications for DCS, leading to an increase in the number of DCS procedures, saving the lives of patients who have sustained severe torso trauma must be the priority; ‘over-triage’ may be acceptable in situations where an appropriate decision-making protocol has been followed.

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Key words: trauma, damage control surgery, coagulopathy, hypothermia, acidosis
Introduction

The conventional indications for damage control surgery (DCS) in patients with exsanguinous torso trauma are the well-known “deadly triad” of metabolic acidosis, hypothermia, and coagulopathy, and several reports have shown the effectiveness of DCS\textsuperscript{3,4}. In an emergency, the level of metabolic acidosis can be quickly determined by means of blood gas analysis, and the patient’s body temperature can be determined with a simple measurement. However, coagulation tests, such as determinations of the prothrombin time (PT) and the activated partial thromboplastin time (APTT), which are needed to determine the severity of coagulopathy, require special laboratory equipment and 15 to 30 minutes. Furthermore, PT and APTT are determined at 37°C, not at the patient’s actual body temperature, and might not accurately reflect the coagulation abnormality in patients with hypothermia.

Therefore, surgeons may hesitate to perform DCS when information about the severity of coagulopathy is unavailable, even if metabolic acidosis and hypothermia are present. Such delays could be fatal if the patient does indeed require DCS. Shapiro et al.\textsuperscript{5} have reported that the results of thromboelastography can simplify the diagnosis of coagulopathy and might serve as an early predictor of the need for transfusion in patients who have sustained blunt-force injuries. However, simpler criteria are needed to avoid delays in performing DCS. The aim of the present study was to establish simplified and practical criteria for deciding whether to perform DCS.

Materials and Methods

Clinical Series

From April 2000 through March 2008, 34 consecutive patients underwent DCS for the treatment of severe abdominal organ or pelvic injuries at the Shock and Trauma Center of Chiba Hokusoh Hospital, Nippon Medical School, which corresponds to a Level 1 trauma center in the United States. Patients who had sustained severe head injuries or had died in the emergency department (ED) were excluded. Patients judged as “nonresponders” or “transient responders” according to the criteria described below were considered to be candidates for DCS, although the decision to perform DCS was ultimately made by the surgeon.

On the basis of the Advanced Trauma Life Support course of the American College of Surgeons\textsuperscript{6}, the Japan Advanced Trauma Evaluation and Care program has developed criteria that classify patients with hemorrhagic shock into three types according to the response to initial fluid resuscitation (2,000 mL of warm Ringer’s solution in adults): “responders,” who respond well to an initial infusion and do not require “additional” crystalloid infusion or blood transfusion to maintain a systolic blood pressure (SBP) greater than 90 mm Hg; “transient responders,” who respond well initially but require additional fluids or blood to maintain a SBP greater than 90 mm Hg; and “nonresponders,” who have an SBP that remains less than 90 mm Hg after initial fluid resuscitation.

Damage control techniques, including suturing, selective vascular repair and ligation, and gauze and towel packing at the injured sites for uncontrolled hemorrhage, were performed with a direct approach in cases of solid organ, mesenteric, or retroperitoneal hemorrhage. Also, hollow viscus injuries were closed using a single-layer, full-thickness closure. Towel clip closure was usually selected for temporary abdominal wall closure, but some patients underwent silo closure to reduce the risk of abdominal compartment syndrome.

A high-flow blood fluid warming device (Level 1 System1000; Smiths Medical, London, UK) was used for fluid resuscitation and transfusion to avoid hypothermia in the ED and the operating room (OR). All 34 patients were transported to the intensive care unit and were rewarmed with warm blankets. Blood components, including fresh frozen plasma and platelets, were administered appropriately to correct the coagulopathies and normalize the values of hemoglobin, platelets, and PT (international normalized ratio). Reoperation was planned once the hemodynamics, acid-base balance, body temperature,
and coagulation had normalized. The outcomes of DCS were survival or death of the patients.

The patients’ clinical characteristics, including age, sex, injuries, injury severity score (ISS), probability of survival (P), operating procedures, laboratory data, and outcome, were reviewed by using medical records (Table 1). The patients were 25 men and 9 women, ranging in age from 11 to 90 years (mean ± SD, 51.9 ± 20.5 years). The mechanism of injury was blunt trauma in 33 cases and stabbing in 1 case. The mean ISS was 35.6 ± 13.5 (range, 9 to 66), and the mean P was calculated using the Trauma Score-Injury Severity Score method was 0.5671.

Sixteen patients underwent ED laparotomy to control intraperitoneal hemorrhage. The remaining 18 patients were transported to the OR. The primary DCS procedure for controlling hemorrhage was hepatotomy in 15 cases, pancreateotomy in 2 cases, splenectomy in 2 cases, splenectomy in 2 cases, aortotomy in 1 case, and suture repair of the inferior vena cava in 2 cases. An ED thoracotomy with aortic cross-clamping was performed in 9 of these cases. Cardiopulmonary bypass for cardiac injury was performed in 2 cases, suturing of lung lacerations was performed in 2 cases, and pulmonary hilar clamping was performed in 1 case. Planned reoperations were performed 1.5 ± 0.7 days after the initial operation. The primary procedure utilized in the planned reoperations was reperfusion; other procedures included hepatotomy in 1 case, non-anatomical hepatectomy in 1 case, pancreaticoduodenectomy in 4 cases, distal pancreatectomy in one case, intestinal repair in 3 cases, nephrectomy in 2 cases, and colostomy in 1 case.

**Physiologic Variables**

Three variables (SBP, base excess, and core temperature) were examined at the time of ED arrival and at the start of thoracotomy or laparotomy; these variables were investigated as predictors of patient outcome.

Characteristics were compared between survivors and nonsurvivors by means of the chi-square test or the Wilcoxon signed-rank test, as appropriate. Statistical significance was inferred when the p value was less than 0.05. Values are expressed as the mean ± standard deviation.

**Results**

The overall survival rate was 55.9% (survivors group: n=19; nonsurvivors group: n=15), which was similar to the calculated mean Ps. Patient characteristics, including age, sex, ISS, Ps, and mechanism of injury, were not related to outcome (Table 2). The survival rate was 50.0% among the “nonresponders” (9 of 18 patients) and 62.5% among the “transient responders” (10 of 16 patients); no significant relationship between the response to initial fluid resuscitation and the results of DCS was observed.

In the survivors group, the mean SBPs at the time of ED arrival (89.9 ± 21.3 mm Hg) and at the start of the surgical procedure (93.2 ± 22.9 mm Hg) were similar. In contrast, in the nonsurvivors group the mean SBP at the start of the surgical procedure (69.6 ± 14.8 mm Hg) was slightly but not significantly lower than that at the time of ED arrival (84.6 ± 21.8 mm Hg). At the start of the surgical procedure, the SBPs in all cases in the nonsurvivors group was less than 90 mm Hg, and the mean SBP in the nonsurvivors group was significantly lower than that in the survivors group (p=0.006). In the survivors group, the levels of base excess were not significantly different at the time of ED arrival (−7.2 ± 5.1 mmol/L) and at the start of surgery (−5.5 ± 4.9 mmol/L). In the nonsurvivors group, however, the levels of base excess were greater at the start of surgery (−11.5 ± 5.3 mmol/L) than at the time of ED arrival (−7.6 ± 6.4 mmol/L, p=0.013). At the start of surgery, the base excess in the nonsurvivors group (with the exception of two cases) was less than −7.5 mmol/L; this value was significantly lower than that in the survivors group (p=0.008). The core temperature at the start of surgery was less than 35.5°C in all cases in the nonsurvivors group (Fig. 1).

On the basis of these results, three indicators (SBP less than 90 mm Hg, base excess less than −7.5 mmol/L, and core temperature less than 35.5°C at the start of surgery) were identified. The survival
## Table 1 Demographics and Clinical Characteristics of 34 Patients Who Underwent DCS

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age</th>
<th>Gender</th>
<th>Injuries</th>
<th>ISS</th>
<th>Ps</th>
<th>DCS</th>
<th>Planned re-operation</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>M</td>
<td>Pancreas, L-Kidney, L-rib fx</td>
<td>29</td>
<td>0.9116</td>
<td>packing</td>
<td>DP, Lt-nephrectomy</td>
<td>Alive</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>M</td>
<td>Liver, T-SAH, DAI</td>
<td>18</td>
<td>0.8692</td>
<td>EDT/EDL, heparorrhaphy, packing</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>M</td>
<td>Pancreas, SMV</td>
<td>16</td>
<td>0.9963</td>
<td>pancreorrhaphy, packing</td>
<td>depacking</td>
<td>Alive</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>M</td>
<td>Pancreas, Cerebral contusion</td>
<td>43</td>
<td>0.3121</td>
<td>packing</td>
<td>PD</td>
<td>Alive</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>F</td>
<td>Liver</td>
<td>25</td>
<td>0.9684</td>
<td>heparorrhaphy, packing</td>
<td>depacking</td>
<td>Alive</td>
</tr>
<tr>
<td>6</td>
<td>57</td>
<td>M</td>
<td>Liver, Heart (RV, LA)</td>
<td>42</td>
<td>0.0864</td>
<td>EDT/EDL, cardiorrhaphy, heparorrhaphy, packing</td>
<td>depacking</td>
<td>Alive</td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>M</td>
<td>Rt-Kidney, Spleen</td>
<td>45</td>
<td>0.9116</td>
<td>splenectomy, packing</td>
<td>Rt-nephrectomy</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>80</td>
<td>F</td>
<td>Liver, Flail chest, Pulmonary contusion</td>
<td>50</td>
<td>0.2147</td>
<td>EDT/EDL, packing</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>F</td>
<td>Pancreas, Liver, Spleen, L-pneumothorax, R-open patella fx</td>
<td>38</td>
<td>0.9650</td>
<td>splenorrhaphy, packing</td>
<td>PD</td>
<td>Alive</td>
</tr>
<tr>
<td>10</td>
<td>67</td>
<td>M</td>
<td>Liver, Flail chest, Pulmonary contusion, Bil. femur fx, R-open tibia fx</td>
<td>41</td>
<td>0.1998</td>
<td>heparorrhaphy, packing</td>
<td>depacking</td>
<td>Alive</td>
</tr>
<tr>
<td>11</td>
<td>63</td>
<td>M</td>
<td>Liver, Mesenterium, Small intestine</td>
<td>9</td>
<td>0.9665</td>
<td>heparorrhaphy, packing</td>
<td>depacking</td>
<td>Alive</td>
</tr>
<tr>
<td>12</td>
<td>33</td>
<td>M</td>
<td>Pancreas, Spleen</td>
<td>25</td>
<td>0.9827</td>
<td>splenorrhaphy, packing</td>
<td>PD</td>
<td>Alive</td>
</tr>
<tr>
<td>13</td>
<td>64</td>
<td>M</td>
<td>Liver, Pancreas, PV, Skull base fx, R-forearm fx, R-acetabular fx, R-tibia fx</td>
<td>38</td>
<td>0.0538</td>
<td>EDT, heparorrhaphy, packing</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>14</td>
<td>64</td>
<td>M</td>
<td>Liver, Spleen, Pulmonary laceration</td>
<td>41</td>
<td>0.2875</td>
<td>EDT/EDL, heparorrhaphy, packing, suturing for pulmonary laceration</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>15</td>
<td>27</td>
<td>M</td>
<td>Liver, Spleen, IVC, Pulmonary contusion</td>
<td>50</td>
<td>0.8912</td>
<td>EDT, heparorrhaphy, packing</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>16</td>
<td>55</td>
<td>M</td>
<td>Pancreas</td>
<td>25</td>
<td>0.9177</td>
<td>pancreorrhaphy, packing</td>
<td>PD</td>
<td>Alive</td>
</tr>
<tr>
<td>17</td>
<td>90</td>
<td>M</td>
<td>Liver, Flail chest, Pulmonary laceration, R-open tibia fx</td>
<td>43</td>
<td>0.2617</td>
<td>EDT/EDL, heparorrhaphy, packing, suturing for pulmonary laceration</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>18</td>
<td>54</td>
<td>F</td>
<td>Mesenterium, Small intestine, Pulmonary contusion, C1/2 dislocation</td>
<td>50</td>
<td>0.1325</td>
<td>EDTL, repair, packing</td>
<td>Anastomosis</td>
<td>Alive</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>M</td>
<td>Liver, Spleen, L-forearm fx, R-femur fx</td>
<td>27</td>
<td>0.6425</td>
<td>EDT/EDL, packing</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>20</td>
<td>37</td>
<td>M</td>
<td>Liver, HV, Heart (RV), R-pneumothorax</td>
<td>41</td>
<td>0.8997</td>
<td>EDT/EDL, cardiorrhaphy, heparorrhaphy, packing</td>
<td>heparorrhaphy</td>
<td>Alive</td>
</tr>
<tr>
<td>21</td>
<td>62</td>
<td>M</td>
<td>Mesenterium, Pulmonary contusion</td>
<td>25</td>
<td>0.3432</td>
<td>EDTL, repair, packing</td>
<td>Anastomosis</td>
<td>Alive</td>
</tr>
<tr>
<td>22</td>
<td>84</td>
<td>M</td>
<td>Small intestine, Pelvic fx</td>
<td>25</td>
<td>0.6938</td>
<td>EDT, repair, packing</td>
<td>—</td>
<td>Dead</td>
</tr>
<tr>
<td>23</td>
<td>62</td>
<td>M</td>
<td>Rectum, Bladder, Pelvic fx, L-open femur fx, L-open tibia fx</td>
<td>50</td>
<td>0.1417</td>
<td>EDTL, packing</td>
<td>colostomy</td>
<td>Dead</td>
</tr>
<tr>
<td>24</td>
<td>70</td>
<td>M</td>
<td>Liver, Flail chest, Pulmonary contusion, Skull fx, pneumoencephalus, L-open tibia fx</td>
<td>41</td>
<td>0.2133</td>
<td>heparorrhaphy, packing</td>
<td>depacking</td>
<td>Alive</td>
</tr>
</tbody>
</table>
New Criteria for DCS

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>Mechanism of injury</th>
<th>ISS</th>
<th>Ps</th>
<th>Survivors group</th>
<th>Non-survivors group</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.7 ± 16.3</td>
<td>13/6</td>
<td>18/1</td>
<td>322 ± 130</td>
<td>0.70 ± 0.36</td>
<td>55.6 ± 24.3</td>
<td>12/3</td>
<td>15/0</td>
</tr>
</tbody>
</table>

ISS, injury severity score; Ps, probability of survival

D, damage control surgery; ISS, injury severity score; Ps, probability of survival; fx, fracture; EDT, emergency department thoracotomy; EDL, emergency department laparotomy; D P, distal pancreatectomy; PD, pancreatoduodenectomy; T-SAH, traumatic subarachnoid hemorrhage; DAI, diffuse axonal injury; SDH, subdural hematoma; RV, right ventricle; LA, left atrium; IVC, inferior vena cava; PV, portal vein; SMV, superior mesenteric vein; SPV, splenic vein; HV, hepatic vein

Discussion

Our results show that the presence of all three indicators—a systolic blood pressure of less than 90 mm Hg, a base excess of less than −7.5 mmol/L, and a core temperature less than 35.5°C at the start of surgery—suggests a poor prognosis. The indications for DCS are based on the physiologic status of the patient and technical issues related to the surgical procedure. Moore et al. and Shapiro et al. have suggested the following indications for DCS: 1) an inability to achieve hemostasis as a result of coagulopathy, 2) inaccessible major venous injury, 3) a time-consuming procedure in a patient with a suboptimal response to resuscitation, 4) the management of extra-abdominal life-threatening injury, 5) the need to readdress the intra-abdominal contents, and 6) the inability to reapproximate the abdominal fascia as a result of visceral edema. Coagulopathy is the most common reason for performing DCS, although many reports have shown that the survival rate is lower after DCS once coagulopathy or a metabolic disorder has developed.

The generally accepted indications for DCS include a core temperature at the time of laparotomy <35°C, a pH <7.2, a base excess <−15...
mmol/L (age <55 years) or <6.0 mmol/L (age >55 years), and PT and APTT <50% of normal. Moore et al. have reported that severe coagulopathy (PT > twice normal and APTT > twice normal), massive rapid blood transfusion (10 units/4 hours), and persistent cellular shock (oxygen consumption index <110 mL/min/M² and lactate >5 mmol/L) were predictors of death. Rotondo and his colleagues² have reported that DCS may be triggered by the transfusion of 10 or more units of packed red-blood cells (estimated blood loss > 4 liters). Therefore, DCS should be performed before the patient’s condition deteriorates to this degree, and readily accessible data are essential during resuscitation and surgery. However, several problems exist with these criteria. For example, the oxygen consumption index

is not always immediately available. Results of coagulation tests, including determinations of PT and APTT, may not always accurately reflect the coagulation abnormality in patients with hypothermia, because such tests might be performed at 37°C, not at the patient’s actual body temperature. Massive blood transfusion and crystalloid infusion themselves lead to hemodilution and severe coagulopathy⁵,¹¹,¹²,¹³; consequently,
New Criteria for DCS

knowing the amount of blood loss during primary resuscitation would be ideal. Accurately determining blood loss is difficult, however, because the amount of blood lost before the patient’s arrival at the hospital is rarely available. Therefore, we felt that the criteria for deciding to perform DCS should be simplified; thus, the objective of this study was to establish a practical and reliable standard for emergency physicians and surgeons.

Among several recorded vital signs and laboratory data, we selected three variables: SBP, base excess, and core temperature at the time of ED arrival and at the start of surgery. In particular, SBP is a new factor that has not been described in previous reports. Although our data showed no relationship between the response to initial fluid resuscitation and the outcome of DCS, there is a significant statistical difference in SBP at the start of surgery between survivors and nonsurvivors.

Persistent hemodynamic instability typically leads to excessive fluid administration. As mentioned above, massive crystalloid infusion and blood transfusion can contribute to coagulopathy and increase blood loss. Hess and his coworkers\(^9\) have described that Acute Coagulopathy of Trauma-Shock (ACoTS) is altered by subsequent events and treatments, in particular acidemia, hypothermia, and dilution. The coagulopathy of trauma is the result of multiple independent but interacting mechanisms, including tissue trauma, shock, hemodilution, hypothermia, acidemia, and inflammation. It is also proposed the new concept of “ACoTS”, in which initiation, of coagulation occur with activation of anticoagulant and fibrinolytic pathways. These mechanisms may contribute to traumatic coagulopathy.

However, coagulopathy can be understood classically as the result of metabolic acidosis, hypothermia, and hemodilution induced by administration of large volumes of fluids and blood; therefore, hemodynamic instability requiring administration of such volumes should be recognized before coagulation tests are performed. Thus, we suspect that SBP at the start of the surgical procedure, which reflects hemodynamic instability and the need for additional fluid resuscitation, might predict coagulopathy and be an important variable in deciding whether to perform DCS.

The base excess and core temperature can be readily determined in an emergency. The diagnosis of acidemia is based on the arterial blood pH. However, pH might not accurately reflect the severity of metabolic acidosis in a patient because of the effects of respiratory compensation; therefore, we focused on the value of the base excess rather than the pH. Our study did not show a significant difference in the mean core temperature at the time of ED arrival and at the start of surgery in the two groups. However, core temperature is a classic, important, and simple variable for determining the need to perform DCS and can be measured easily and quickly in an ED or OR.

We feel that the decision to perform DCS should not be made according to strict criteria, because once coagulopathy has passed the “point of no return,” any efforts to achieve hemostasis will be unsuccessful\(^8\). Because the DCS success rate among cases in which all three criteria were met (28.6%) was significantly lower than that among cases in which they were not (75.0%), the presence of all three indicators might mark the “point of no return.” Consequently, we concluded that surgeons should decide to perform DCS before all three indicators are present. Mikhail\(^5\) has similarly suggested that the injury-incision time should be shortened to ensure that the operation is started before the patient’s physiologic limit is reached, defined as the onset of the triad of hypothermia, acidosis, and coagulopathy.

Recognizing when all three indicators are present is the key point. If the decision to perform DCS is made too early, too many unnecessary DCS procedures will be performed. On the other hand, our results suggest the decision to perform DCS should be made when only one or two criteria are fulfilled at the start of surgery. Although our proposed criteria are not strict and may broaden the indications for DCS, leading to an increase in the number of DCS procedures, saving lives must be the priority, and ‘over-triage’ may be acceptable when an appropriate decision-making protocol has been followed.
The limitations of this investigation include its retrospective design, the small number of subjects, the uncontrolled examinations, and the fact that the final decision to perform DCS depended largely on the surgeon. Further study involving a larger numbers of patients is needed, even if such studies are also retrospective, because attempting a randomized controlled study would be difficult given the small number of trauma cases treated at our center.

In conclusion, we suggest that surgeons should decide to perform DCS when only one or two following criteria are fulfilled: a systolic blood pressure less than 90 mm Hg, a base excess less than −7.5 mmol/L, and a core temperature less than 35.5°C at the start of the surgical procedure. With this concept in mind, we believe that achieving a high survival rate in patients who have sustained severe torso trauma requires a high rate of DCS, even if the number of unnecessary DCS procedures may increase.

References


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