# Damage Control Resuscitation

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# DAMAGE CONTROL?

The term damage control comes from the US Navy and was described in the 1940s for control of battle damage to ships.

**Rapid repairs to keep the ship afloat,**

**Return to port,**

**and finally definitive repairs.**

# HISTROY

- **Idea originated from major hepatic trauma.**

Pringle JH. **V. Notes on the Arrest of Hepatic Hemorrhage Due to Trauma.** Ann Surg. 1908 Oct;48(4):541-9.

**NOTES ON THE ARREST OF HEPATIC HEMORRHAGE DUE TO TRAUMA.**

BY J. HOGARTH PRINGLE, F.R.C.S.,

OF GLASGOW,

Lecturer on Surgery in Queen Margaret College, Surgeon to the Glasgow Royal Infirmary.

RUPTURE of the liver is fortunately an accident not often met with, but one which, when it is seen, may be associated with a condition of the patient as serious as any one can meet with in surgical practice. While small lacerations of the liver substance may be, and, no doubt are, recovered from without surgical interference; if the laceration be extensive and vessels of any magnitude are torn, hemorrhage will, owing to the structural arrangement of the liver, go on continuously, and by the time such a patient comes under the care of a surgeon the general state is almost invariably bound to be extremely grave, from the hemorrhage alone or from hemorrhage and shock combined, and this is perhaps specially the case in that class of injury due to contusing violence in which there is often gross injury inflicted on parts other than the liver and when shock is liable to be more severe than in localized injuries caused by sharp instruments.

# Lethal Triad

**“bloody vicious cycle”** - unattended core **hypothermia** and persistent **metabolic acidosis** as key events promoting a lethal **coagulopathic state.**

Elerding SC, Aragon GE, Moore EE. Fatal hepatic hemorrhage after trauma. Am J Surg. 1979;138:883-888.

Kashuk JL, Moore EE, Millikan JS, Moore JB. Major abdominal vascular trauma-a unified approach. J Trauma. 1982;22:672-679.

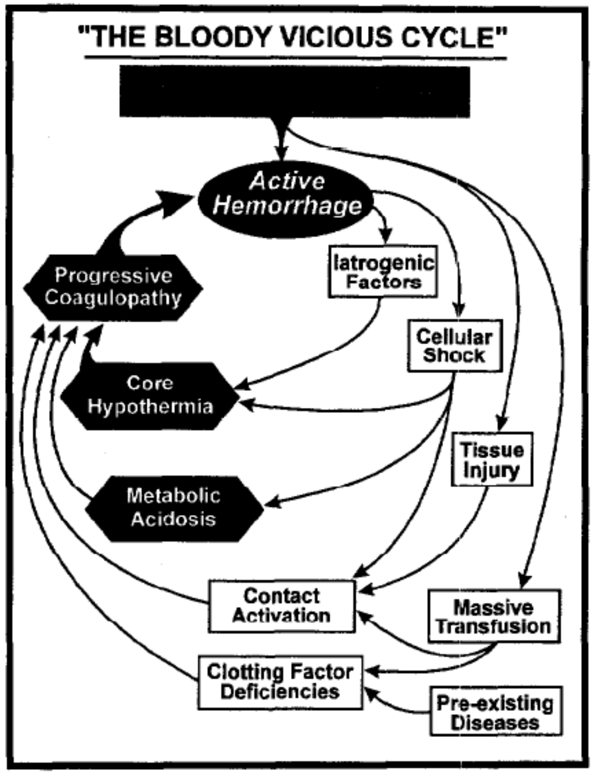


**Figure 1.** The pathogenesis of the bloody vicious cycle following major torso injury is multifactorial, but usually manifests as a triad of refractory coagulopathy, progressive hypothermia, and persistent metabolic acidosis.

Am J Surg. 1996;172:405-410.

# *Management of the Major Coagulopathy with Onset during Laparotomy*

H. HARLAN STONE, M.D., PRISCILLA R. STROM, M.D., RICHARD J. MULLINS, M.D.

**An experience with 31 patients who developed major bleeding diatheses during laparotomy was reviewed. Management of the initial 14 patients was by standard hematologic replacement, completion of all facets of operation, and then closure of the peritoneal cavity, usually with suction drainage; only one patient survived.**

**The subsequent 17 patients had laparotomy terminated as rapidly as possible to avoid additional bleeding. Major vessel**

*From the Department of Surgery, Emory University School of Medicine, Atlanta, Georgia*

Throughout the centuries of recorded medicine, direct pressure has been the most reliable means of gaining

The bleeding diathesis was controlled in only two

**This technique of initial abortion of laparotomy, establishment of intra-abdominal pack tamponade, and then completion of the surgical procedure once coagulation has returned to an acceptable level has proven to be lifesaving in previously nonsalvageable situations.**

wound in a patient whose blood will not clot and cannot be made to clot. By far the most extreme example is a bleeding diathesis complicating laparotomy. This event is an all-too-common occurrence in the patient who has sustained a major intraabdominal injury or who has a disease process or operation which has been attended by a massive hemorrhage. The coagulopathy can seldom be reversed satisfactorily. Thus, the usual outcome is continued bleeding and thereby death through exsanguination.

Presented at the Ninety-Fourth Annual Meeting of the Southern Surgical Association, December 6–8, 1982, Palm Beach, Florida.

Reprint requests: H. Harlan Stone, M.D., Department of Surgery, University of Maryland Hospital, 22 South Greene Street, Baltimore, Maryland 21201.

Submitted for publication: January 3, 1983.

Between July 1, 1976, and June 30, 1982, a major coagulopathy developed during laparotomy in 31 patients on the Trauma Surgical Service at Grady Memorial Hospital. During the first three years of review, 14 patients were managed by standard procedures directed toward reversal of the bleeding diathesis plus completion of all details in the operative procedure. In the ensuing three years, once a coagulopathy was noted in the following 17 patients, operation was immediately aborted, abdominal tamponade was effected through packing and closure under tension, and later, reexploration was performed, once the patient's blood adequately clotted, to complete the initial operative procedure.

Patient ages ranged from 17 to 67 years, with an average of 28 years. There were 22 blacks and nine whites, 25 men and six women.

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# In 1993, Rotondo et al.

0022-5282/93/3503-0375$03.00/0
THE JOURNAL OF TRAUMA


'DAMAGE CONTROL': A
IN EXSANGUINATING P

Michael F. Rotondo, MD, C. William Sch
Gordon R. Phillips, III, MD, Todd M. Fruc
and Peter A. Angood, MD

Definitive laparotomy (DL) for penetrating a
vascular and visceral injury is a difficult sur
derangements such as dilutional coagulopa
preclude completion of the procedure. "Dar
control of hemorrhage and contamination fo
rapid closure, allows for resuscitation to no
and subsequent definitive re-exploration. T
the damage control technique with definitiv
patients with penetrating abdominal injuries
transfusion of greater than 10 units packed
Medical records were retrospectively review
probability of survival, actual survival, trans
and postoperative phases, resuscitation an
temperature, pH, and $HCO_3$. No significant
and 24 DC patients and actual survival rate
However, in a subset of 22 patients with ma
visceral injuries (maximum injury subset), c
survival was markedly improved in patients
77%*) vs. DLM (1 of 9, 11%) (Fisher's exac
to the operating room, DC survivors averag
transfused and 10.3 units fresh frozen plasma over a mean ICU stay of 31.7 hours.
Resolution of coagulopathy (mean prothrombin time/partial thromboplastin time 19.5/70.4 to 13.3/34.9), normalization of acid-base balance (mean pH/$HCO_3$ 7.37/20.6 to 7.42/24.2), and core rewarming (mean 33.2°C to 37.7°C) were achieved. All patients had gastrointestinal procedures at reoperation (mean operative time, 4.3 hours). We conclude that damage control is a promising approach for increased survival in exsanguinating patients with major vascular and multiple visceral penetrating abdominal injuries.

**Table 6**
**Injury scoring and survivorship for patients with one or more major vascular injury and two or more visceral injuries—the maximum injury subset (n = 22)**

| | DLM (n = 9) | DCM (n = 13) |
|---|---|---|
| RTS | 5.29 ± 2.8 | 6.22 ± 2.6 |
| ISS | 23.8 ± 10.8 | 22.9 ± 6.2 |
| Ps | 0.670 ± 0.396 | 0.810 ± 0.295 |
| PATI | 40.9 ± 12.4 | 43.6 ± 11.0 |
| Actual Survival | 1 (11%) | 10 (77%) |

Reported as mean ± standard deviation.
* Fisher's exact test, $p < 0.02$.

abdominal injury

# Damage Control Resuscitation

| Damage Control Resuscitation |
| --- |
| *Minimize crystalloids during early resuscitation* |
| *Permissive hypotension (palpable pulse or SBP~90 mmHg)* |
| *Transfusion of blood products in ratios similar to whole blood (1:1:1)* |

**Figure 1.** The 3 tenants of damage control resuscitation.

+

**Damage Control Surgery(immediate control of hemorrhage)**

# Large volume crystalloid resuscitation

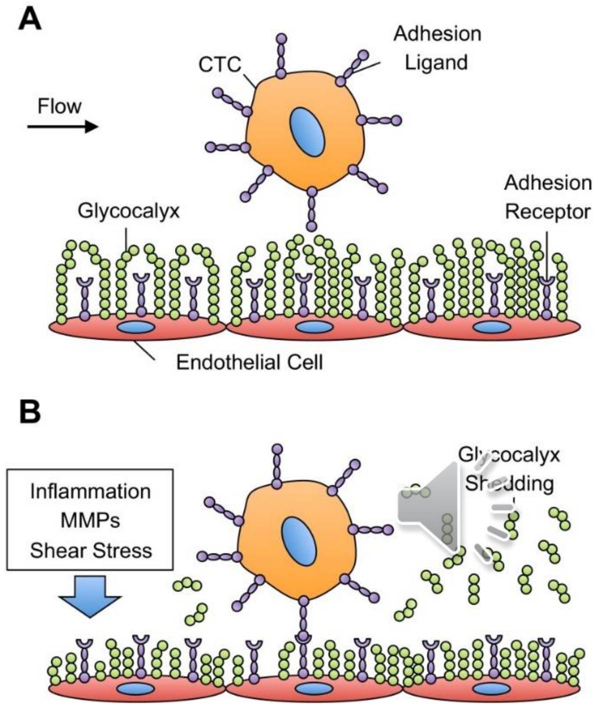
- Macrophage release of tumor necrosis factor ά ↑ ↑ & proinflammatory cytokines ↑ ↑

⇒ **Capillary leak ↑ ↑**

⇒ **endothelial glycocalyx thinning ↑ ↑ =>** third space fluid losses and intravascular volume depletion.

- Pulmonary edema, cardiac dysfunction, bowel edema

- Dilusional coagulopathy



# HEMODILUTION

- Overzealous crystalloid resuscitation can exaggerate an existing coagulopathy.

- Interestingly, acute hemodilution to 50% in vitro does not impair clot formation, but this magnitude of hemodilution **enhances the sensitivity to tPA** due to the dilution of endogenous antifibrinolytics.

# PERMISSIVE HYPOTENSION

- become hemostatic on their own as  become more hypotensive
- **clot disrupted by the increased pressure**

**Table 1** **Relationship of Punch Size with Initial Hemorrhage Volume**

| Punch size (mm) | All pigs including non resuscitated | | No NE | | NE | |
|---|---|---|---|---|---|---|
| | Hem. Vol. (ml/kg) | n | Rebleed MAP (mmHg) | n | Rebleed MAP (mm Hg) | n |
| 1.5 | 10.5 ± 1.1* | 14 | 62 ± 5 | 9 | 126 ± 13 | 3 |
| 2.0 | 16.6 ± 0.8 | 38 | 66 ± 3 | 20 | 134 ± 8 | 12 |
| 2.8 | 19.3 ± 1.4 | 10 | 61 ± 5 | 9 | (none) | |

NE, norepinephrine.

made by Cannon from WWI and Beecher from WWII. There-fore, we recommend that patients without definitive hemor-rhage control should not be resuscitated beyond a MAP of 60 mm Hg or a systolic pressure of 80–90 mm Hg.

*J Trauma*. 2003;54:S110 –S117

The New England
# Journal of Medicine



Volume 331 OCTOBER 27, 1994 Number 17

## IMMEDIATE VERSUS DELAYED FLUID RESUSCITATION FOR HYPOTENSIVE PATIENTS WITH PENETRATING TORSO INJURIES

William H. Bickell, M.D., Matthew J. Wall, Jr., M.D., Paul E. Pepe, M.D., R. Russell Martin, M.D., Victoria F. Ginger, M.S.N., Mary K. Allen, B.A., and Kenneth L. Mattox, M.D.

*Methods.* We conducted a prospective trial comparing immediate and delayed fluid resuscitation in 598 adults with penetrating torso injuries who presented with a prehospital systolic blood pressure ≤90 mm Hg. The study setting was a city with a single centralized system of prehospital emergency care and a single receiving facility for patients with major trauma. Patients assigned to the im-

Table 2. Systemic Arterial Blood Pressure and Laboratory Findings on Arrival at the Trauma Center in Patients with Penetrating Torso Injuries, According to Treatment Group.*

| Variable | Immediate Resuscitation (N = 309) | Delayed Resuscitation (N = 289) | P Value |
|---|---|---|---|
| Systolic blood pressure (mm Hg) | 79±46 | 72±43 | 0.02 |
| Hemoglobin (g/dl) | 11.2±2.6 | 12.9±2.2 | <0.001 |
| Platelet count ($\times 10^{-3}$/mm$^3$) | 274±84 | 297±88 | 0.004 |
| Prothrombin time (sec) | 14.1±16 | 11.4±1.8 | <0.001 |
| Partial-thromboplastin time (sec) | 31.8±19.3 | 27.5±12 | 0.007 |
| Systemic arterial pH | 7.29±0.17 | 7.28±0.15 | 0.46 |
| Serum bicarbonate concentration (mmol/liter) | 20±10 | 20±11 | 0.82 |

*Plus–minus values are means ±SD. To convert values for hemoglobin to millimoles per liter, multiply by 0.62.

Table 4. Total Volumes of Fluids Administered to Patients with Penetrating Torso Injuries, According to Treatment Group.*

| Variable | Immediate Resuscitation (N = 309) | Delayed Resuscitation (N = 289) | P Value |
|---|---|---|---|
| Before arrival at the hospital | | | |
| Ringer's acetate (ml) | 870±667 | 92±309 | <0.001 |
| Trauma center | | | |
| Ringer's acetate (ml) | 1608±1201 | 283±722 | <0.001 |
| Packed red cells (ml) | 133±393 | 11±88 | <0.001 |
| Operating room† | | | |
| Ringer's acetate (ml) | 6772±4688 | 6529±4863 | 0.31 |
| Packed red cells (ml) | 1942±2322 | 1713±2313 | 0.07 |
| Fresh-frozen plasma or platelet packs (ml) | 357±1002 | 307±704 | 0.45 |
| Autologous-transfusion volume (ml) | 95±486 | 111±690 | 0.76 |
| Hetastarch (ml) | 499±717 | 542±696 | 0.41 |
| Rate of intraoperative fluid administration (ml/min) | 117±126 | 91±88 | 0.008 |

*Plus–minus values are means ±SD.

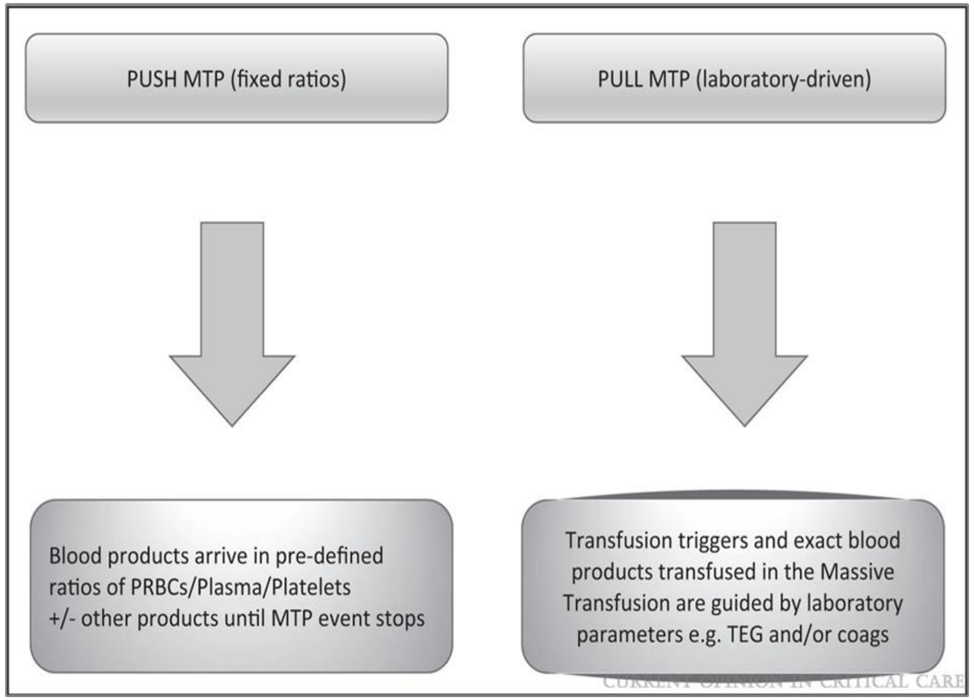
†For these analyses there were 268 patients in the immediate-resuscitation group and 260 patients in the delayed-resuscitation group.

Table 5. Outcome of Patients with Penetrating Torso Injuries, According to Treatment Group.

| Variable | Immediate Resuscitation | Delayed Resuscitation | P Value |
|---|---|---|---|
| Survival to discharge — no. of patients/total patients (%) | 193/309 (62)* | 203/289 (70)* | 0.04 |
| Estimated intraoperative blood loss — ml‡ | 3127±4937 | 2555±3546 | 0.11 |
| Length of hospital stay — days§ | 14±24 | 11±19 | 0.006 |
| Length of ICU stay — days§ | 8±16 | 7±11 | 0.30 |

# Massive Transfusion Protocols

- The development and implementation of massive transfusion protocols (MTPs) have been associated with a reduction in mortality and overall blood product use in trauma centers.
- **The optimal goal is early communication to the blood bank of the urgent need of a large volume of blood products**.
- The content of MT protocols should be based on the principles of damage control resuscitation.
- As such, they should provide for ratio-based blood products that are empirically delivered (hemostatic resuscitation) and have a process for the immediate availability of RBC, plasma, and platelets.
- Protocols should also include standardization of the assessment of coagulopathy and include assessment and treatment of acidosis, hypothermia, and hypocalcemia.



ORIGINAL ARTICLE

ONLINE FIRST

# The Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) Study

**Objective:** To relate in-hospital mortality to early transfusion of plasma and/or platelets and to time-varying plasma:red blood cell (RBC) and platelet:RBC ratios.

**Design:** Prospective cohort study documenting the timing of transfusions during active resuscitation and patient outcomes. Data were analyzed using time-dependent proportional hazards models.

**Setting:** Ten US level I trauma centers.

**Patients:** Adult trauma patients surviving for 30 minutes after admission who received a transfusion of at least 1 unit of RBCs within 6 hours of admission (n=1245, the original study group) and at least 3 total units (of RBCs, plasma, or platelets) within 24 hours (n=905, the analysis group).

**Main Outcome Measure:** In-hospital mortality.

**Results:** Plasma:RBC and platelet:RBC ratios were not constant during the first 24 hours ($P < .001$ for both). In a multivariable time-dependent Cox model, increased ratios of plasma:RBCs (adjusted hazard ratio=0.31; 95% CI, 0.16-0.58) and platelets:RBCs (adjusted hazard ratio=0.55; 95% CI, 0.31-0.98) were independently associated with decreased 6-hour mortality, when hemorrhagic death predominated. In the first 6 hours, patients with ratios less than 1:2 were 3 to 4 times more likely to die than patients with ratios of 1:1 or higher. After 24 hours, plasma and platelet ratios were unassociated with mortality, when competing risks from nonhemorrhagic causes prevailed.

**Conclusions:** Higher plasma and platelet ratios early in resuscitation were associated with decreased mortality in patients who received transfusions of at least 3 units of blood products during the first 24 hours after admission. Among survivors at 24 hours, the subsequent risk of death by day 30 was not associated with plasma or platelet ratios.

*JAMA Surg. 2013;148(2):127-136. Published online October 15, 2012. doi:10.1001/2013.jamasurg.387*

Research

Original Investigation

# Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma
## The PROPPR Randomized Clinical Trial

John B. Holcomb, MD; Barbara C. Tilley, PhD; Sarah Baraniuk, PhD; Erin E. Fox, PhD; Charles E. Wade, PhD; Jeanette M. Podbielski, RN; Deborah J. del Junco, PhD; Karen J. Brasel, MD, MPH; Eileen M. Bulger, MD; Rachael A. Callcut, MD, MSPH; Mitchell Jay Cohen, MD; Bryan A. Cotton, MD, MPH; Timothy C. Fabian, MD; Kenji Inaba, MD; Jeffrey D. Kerby, MD, PhD; Peter Muskat, MD; Terence O'Keeffe, MBChB, MSPH; Sandro Rizoli, MD, PhD; Bryce R. H. Robinson, MD; Thomas M. Scalea, MD; Martin A. Schreiber, MS; Deborah M. Stein, MD; Jordan A. Weinberg, MD; Jeannie L. Callum, MD; John R. Hess, MD, MPH; Nena Matijevic, PhD; Christopher N. Miller, MD; Jean-Francois Pittet, MD; David B. Hoyt, MD; Gail D. Pearson, MD, ScD; Brian Leroux, PhD; Gerald van Belle, PhD; for the PROPPR Study Group

| | 1:1:1 | 1:1:2 | |
|---|---|---|---|
| Mortality at 24 hours | 12.7% | 17% | P=0.12 |
| Mortality at 30 days | 22.4% | 26.1% | P=.26 |
| Exsanguination | 9.2% | 14.6% | P=0.03* |
| Hemostasis achieved | 86% | 78% | p=0.006* |

# Trauma Induced Coagulopathy(TIC)

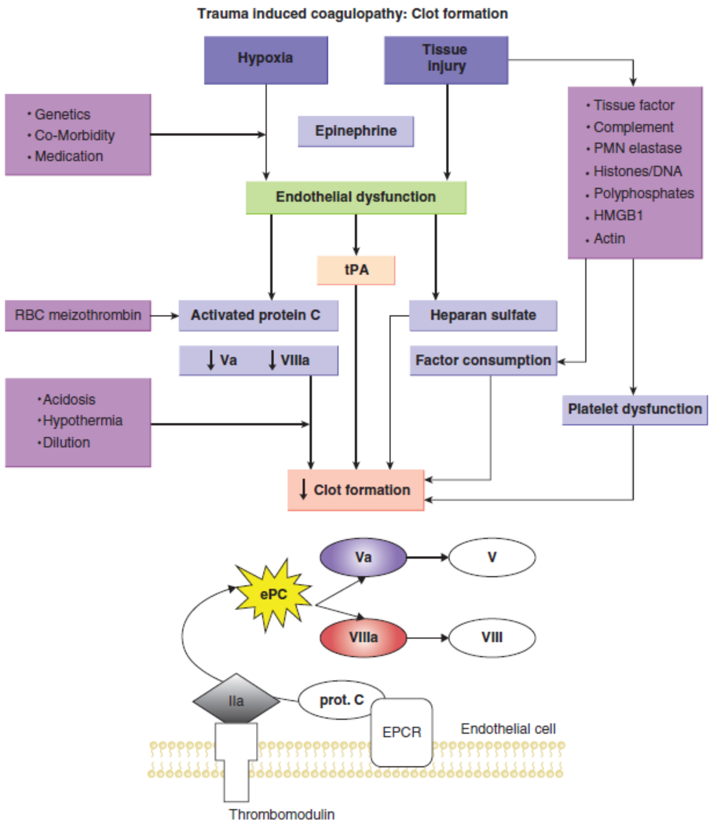



**FIGURE 13-3** Ineffective clot formation is the dominant manifestation of TIC. Hypoxia and tissue injury provoke endothelial dysfunctions which activates protein C and releases anticoagulants from the glycocalyx. Platelet dysfunction, factor consumption, and acidosis further impair thrombin generations and clot formation.

# HYPOTHERMIA

- The effects of hypothermia include altered platelet function, impaired coagulation factor function, enzyme inhibition and fibrinolysis.
- **1 °C drop** in temperature is associated with a **10% drop in function**
- Hypothermia **below 34 °C** inhibits the initiation phase of clotting.
- Most of the coagulation enzymes are **slowed** by hypothermia.
- **While moderate hypothermia delays the onset of thrombin generation, the total amount of thrombin generation is unaffected.**

# ACIDOSIS

- A reduction of pH from 7.4 to 7.0 has been shown in vitro to reduce

- **FVIIa activity by 90%,**
- **prothrombin complex (Xa/Va) activity by 70%**
- **FVIIa-TF complex activity by 55%.**

- **pH 7.1** -> a pronounced inhibition of the propagation phase of thrombin generation

-> **clot strength ↓ & fibrinogen degradation two-fold ↑**

- **pH <7 -> impaired platelet aggregation and adhesion**

**-> the correction of pH with bicarbonate or trishydroxymethylaminomethane (THAM) does not restore platelet function.**

# Damage Control Surgery

DCS

**Severely injured patients**

↓

Control **hemorrhage** and **contamination**

DCR

↓

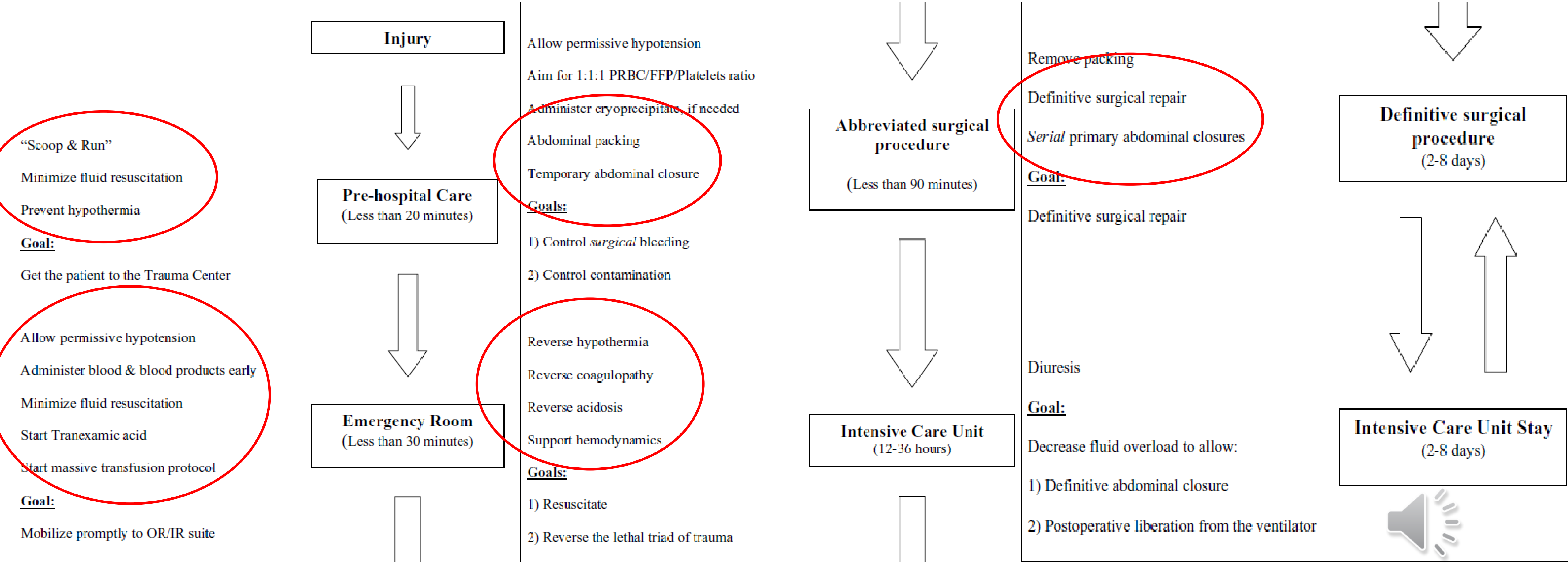
**continued resuscitation** and **aggressive correction** of their **coagulopathy, hypothermia, and acidosis in the ICU**

↓

**returning to the operating room**

**;definitive repair of their injuries**

# Damage Control Resuscitation




Scandinavian Journal of Surgery 103: 81–88, 2014

# Damage Control Surgery = Only Staged Laparotomy?

Originally implemented for injured patients with “ metabolic failure” or “physiologic exhaustion”(hypothermia, metabolic acidosis, coagulopathy), damage control surgery quickly became a technique used by multiple surgical specialties including the following : **general surgery, thoracic surgery, vascular surgery, orthopedic surgery, gynecologic surgery**, etc.

- Trauma 8th ed. -

# Indication
# for Damage Control Surgery

# Indication for Damage Control

## Staged Laparotomy for the Hypothermia, Acidosis, and Coagulopathy Syndrome

Ernest E. Moore, MD, *Denver, Colorado*

**The recent history, indications, physiologic objectives, and technical aspects of staged laparotomy are discussd in this overview. While postinjury refractory coagulopathy is the most common scenario for this life-saving concept, there are many other potential applications during both emergency and elective procedures in the neck, chest, pelvis, and extremities as well as the abdomen.**  ***Am J Surg.* 1996;172:405–410.**

"disasterous hemorrhage, abscesses, and hepatic necrosis" coupled with increasing success at direct operative control of hepatic bleeding led Madding and Kennedy[4] to censor packing during World War II. This military doctrine prevailed throughout the Korean and Vietnam conflicts, and extended to civilian practice as reflected in the statement of a recognized authority in liver trauma that "there is virtually no place in modern surgery for gauze packing of the liver as sepsis and recurrent bleeding are almost inevitable sequelae" (*Annals of the Royal College of Surgical Engineers*,

1) **inability to achieve hemostasis** due to a recalcitrant coagulopathy, ie, the bloody vicious cycle

(2) **inaccessible major venous injury**, eg, retrohepatic vena caval disruption

(3) **anticipated need for a time-consuming procedure**, eg, pancreaticoduodenectomy, in the patient with a suboptimal response to resuscitation

(4) **Demand for nonoperative control of extra-abdominal life-threatening injury**, eg, ruptured pelvic fracture hematoma requiring selective arterial embolization;

(5) **Inability to approximate the abdominal incision due to extensive splanchnic reperfusion induced visceral edema**, eg, following protracted shock requiring massive fluid administration;

(6) **desire to reassess abdominal contents**, eg, compromised intestinal blood supply due to extensive mesenteric wound.

**Degree of physiologic insult in the pre- or intraoperative setting**

Persistent systolic BP <90 mm Hg or a successfully resuscitated cardiac arrest during transport to hospital

Persistent systolic BP <90 mm Hg in the preoperative setting or during operation

Preoperative core body temperature <34°C, arterial pH <7.2, or INR/PT >1.5 times normal (with or without a concomitant PTT >1.5 times normal)

Core body temperature <34°C and arterial pH <7.2 at the beginning of operation

Persistent core body temperature <34°C or persistent arterial pH <7.2 during operation

INR/PT and PTT >1.5 times normal during operation

Clinically observed coagulopathy during operation

Core body temperature <34°, arterial pH <7.2, and laboratory-confirmed (INR/PT and/or PTT >1.5 times normal) or clinically observed coagulopathy in the preoperative setting, at the beginning of operation, or during the conduct of operation

**Estimated blood loss and amount or type of resuscitation provided**

Estimated blood loss >4 L in the operating room

>10 units of PRBCs were administered to the patient in the preoperative or preoperative and intraoperative settings

# No Definite Selection Criteria

- Too Liberal -> Unnecessary staged operation -> complication ↑
- Too Strict -> Adverse physiological outcome -> Too late to salvage

# Impact of Closure at the First Take Back Burden and Potential Overutilization Control Laparotomy

Quinton M. Hatch, MD, Lisa M. Osterhout, BS, Jeanette Podbielski, BSN, Charles E. Wade, PhD, John B. Holcomb, MD, and Bryan A.

**Background:** Damage control laparotomy (DCL) is a lifesaving technique initially employed to minimize the lethal triad of coagulopathy, hypothermia,

directed at achieving bot
appropriate indications fo

**Key Words:** Trauma, La
failure.

auma. 2011;71: 1503

**TABLE 3.** Logistic Regression Model Predicting the Development of Abdominal Infections (Intra-Abdominal Abscess, Retroperitoneal Abscess, and Pelvic Abscess)

| | Odds Ratio | 95% Confidence Interval | p |
|---|---|---|---|
| Age, yr | 1.00 | 0.98–1.03 | 0.461 |
| Male gender | 1.06 | 0.46–2.40 | 0.891 |
| ISS | 0.97 | 0.95–1.00 | 0.061 |
| Large bowel injury | 1.88 | 0.96–3.67 | 0.063 |
| Intraoperative transfusions, units | 0.99 | 0.97–1.02 | 0.975 |
| Closed at initial take back | 0.28 | 0.12–0.66 | 0.004* |

* Statistical significance at $p < 0.05$.

admission.
**Conclusion:** Early fascial closure is an independent predictor of reduced complications in DCL patients. One in five patients closed at initial take back did not meet any of the traditional indications for DCL upon initial ICU admission. This may represent an overutilization of this valuable technique, exposing patients to increased complications. Further efforts should be

Management of changed marke Surgery, followi ondo et al.[1,2] Bef ial closure were rdless of the pa e, however, ten ised popularity a rauma continues ection of physic nage control lapa revent (or at lea , coagulopathy, ent. During the i is performed a trol of contamin normal physiolog nporary abdomin ond-look operati npartment syndro s at the next o increasing knowledg in the resuscitation employed quite freq

Several authors DCL is employed fo tients.[1,16,17] Furtherm ing the sequelae of D in mortality when co been postulated tha improved intensive experience with the many new techniqu are being overutiliz

Although the may be an accepta

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From the Department of Surgery and The Center for Translational Injury Research, The University of Texas Health Science Center, Houston, Texas.
Presented in oral form at the 41st Annual Meeting of the Western Trauma Association, February 27-March 5, 2011, Big Sky, Montana.
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DOI: 10.1097/TA.0b013e31823cd78d



**TABLE 4.** Logistic Regression Model Predicting the Development of Noninfectious Abdominal Complications (Ileus, Bowel Obstruction, Ischemic Bowel, and Anastomotic Breakdown)

| | Odds Ratio | 95% Confidence Interval | p |
|---|---|---|---|
| Age, yr | 0.99 | 0.97–1.02 | 0.867 |
| Male gender | 1.68 | 0.67–4.22 | 0.266 |
| ISS | 0.96 | 0.93–0.98 | 0.006* |
| Large bowel injury | 1.27 | 0.63–2.53 | 0.493 |
| Intraoperative transfusions, units | 1.00 | 0.97–1.03 | 0.760 |
| Closed at initial take back | 0.23 | 0.09–0.56 | 0.001* |

* Statistical significance at $p < 0.05$.

**TABLE 5.** Logistic Regression Model Predicting the Development of Abdominal Wound Complications (Surgical Site Infection, Incisional Hernia, and Dehiscence)

| | Odds Ratio | 95% Confidence Interval | p |
|---|---|---|---|
| Age, yr | 0.98 | 0.96–1.01 | 0.281 |
| Male gender | 0.62 | 0.28–1.33 | 0.219 |
| ISS | 0.98 | 0.96–1.01 | 0.362 |
| Large bowel injury | 1.87 | 0.96–3.66 | 0.065 |
| Intraoperative transfusions, units | 0.99 | 0.97–1.02 | 0.848 |
| Closed at initial take back | 0.31 | 0.13–0.72 | 0.007* |

* Statistical significance at $p < 0.05$.

**TABLE 6.** Logistic Regression Model Predicting the Development of Pulmonary Complications (Ventilator-Dependent Respiratory Failure, Ventilator-Associated Pneumonia, and Empyema)

| | Odds Ratio | 95% Confidence Interval | p |
|---|---|---|---|
| Age, yr | 1.01 | 0.99–1.02 | 0.282 |
| Male gender | 1.05 | 0.54–2.04 | 0.870 |
| Chest AIS | 1.20 | 1.03–1.40 | 0.014* |
| Urgent thoracotomy/sternotomy | 1.38 | 0.57–3.31 | 0.473 |
| Intraoperative transfusions, units | 0.97 | 0.91–1.04 | 0.484 |
| Closed at initial take back | 0.35 | 0.20–0.62 | <0.001* |

* Statistical significance at $p < 0.05$.

# Opinions of Practicing Surgeons on the Appropriateness of Published Indications for Use of Damage Control Surgery in Trauma Patients: An International Cross-Sectional Survey

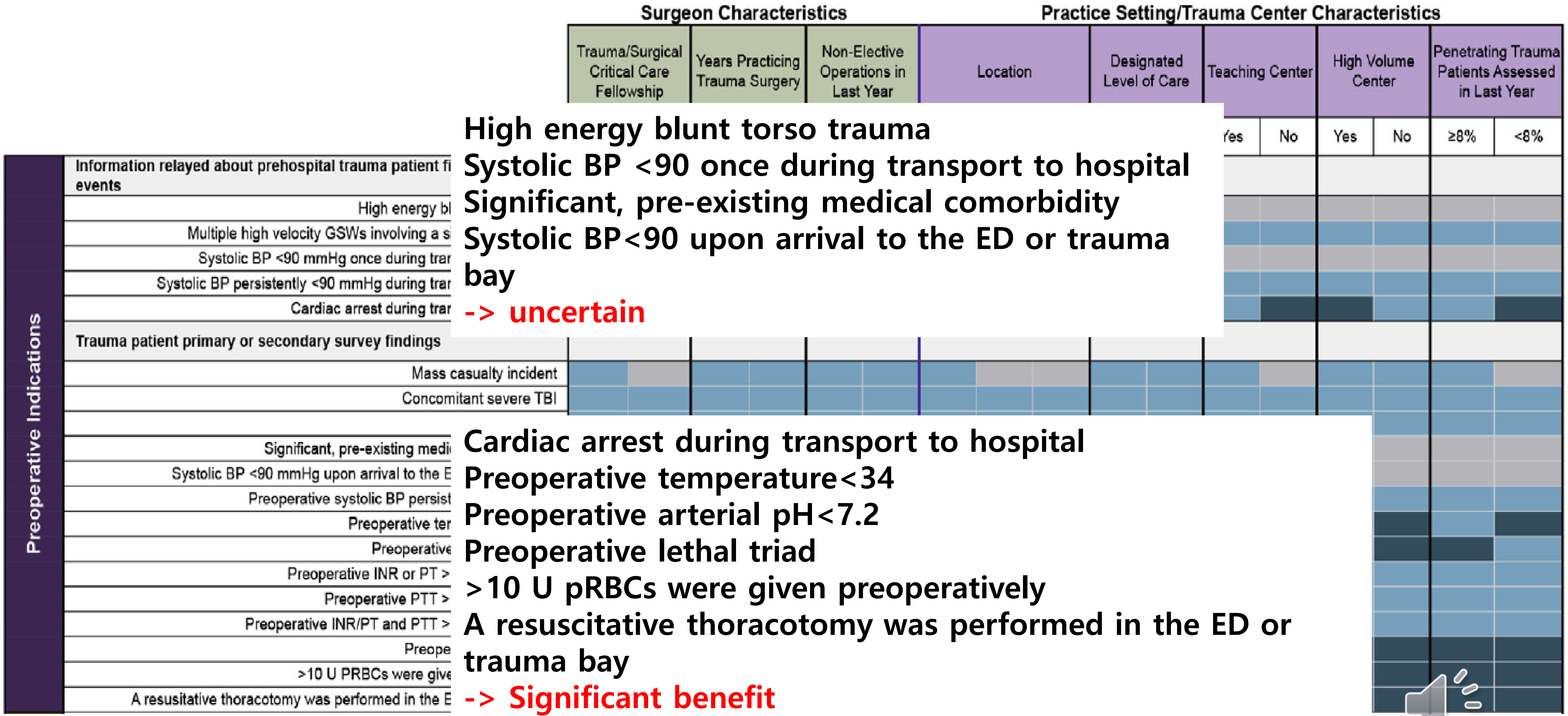
Derek J Roberts, MD, PhD, David A Zygun, MD, MSc, Peter D Faris, PhD, Chad G Ball, MD, MSc, FACS, Andrew W Kirkpatrick, MD, MHSc, FACS, Henry T Stelfox, MD, PhD, Indications for Trauma Damage Control Surgery International Study Group

**BACKGROUND:** Variation in use of damage control (DC) surgery across trauma centers may be partially driven by surgeon uncertainty as to when it is appropriately indicated. We sought to determine opinions of practicing surgeons on the appropriateness of published indications for trauma DC surgery.

**STUDY DESIGN:** We asked 384 trauma centers in the United States, Canada, and Australasia to nominate 1 to 3 surgeons at their center to participate in a survey about DC surgery. We then asked nominated surgeons their opinions on the appropriateness (benefit-to-harm ratio) of 43 literature-derived indications for use of DC surgery in adult civilian trauma patients.

**RESULTS:** In total, 232 (64.8%) trauma centers nominated 366 surgeons, of whom 201 (56.0%) responded. Respondents rated 15 (78.9%) preoperative and 23 (95.8%) intraoperative indications to be appropriate. Indications respondents agreed had the greatest expected benefit included a temperature $<34^\circ C$, arterial pH $<7.2$, and laboratory-confirmed (international normalized ratio/prothrombin time and/or partial thromboplastin time $>1.5$ times normal) or clinically observed coagulopathy in the pre- or intraoperative setting; administration of $>10$ units of packed red blood cells; requirement for a resuscitative thoracotomy in the emergency department; and identification of a juxtahepatic venous injury or devascularized or destroyed pancreas, duodenum, or pancreaticoduodenal complex during operation. Ratings were consistent across subgroups of surgeons with different training, experience, and practice settings.

**CONCLUSIONS:** We identified 38 indications that practicing surgeons agreed appropriately justified the use of DC surgery. Until further studies become available, these indications constitute a consensus opinion that can be used to guide practice in the current era of changing trauma resuscitation practices. (J Am Coll Surg 2016;223:515–529. © 2016 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

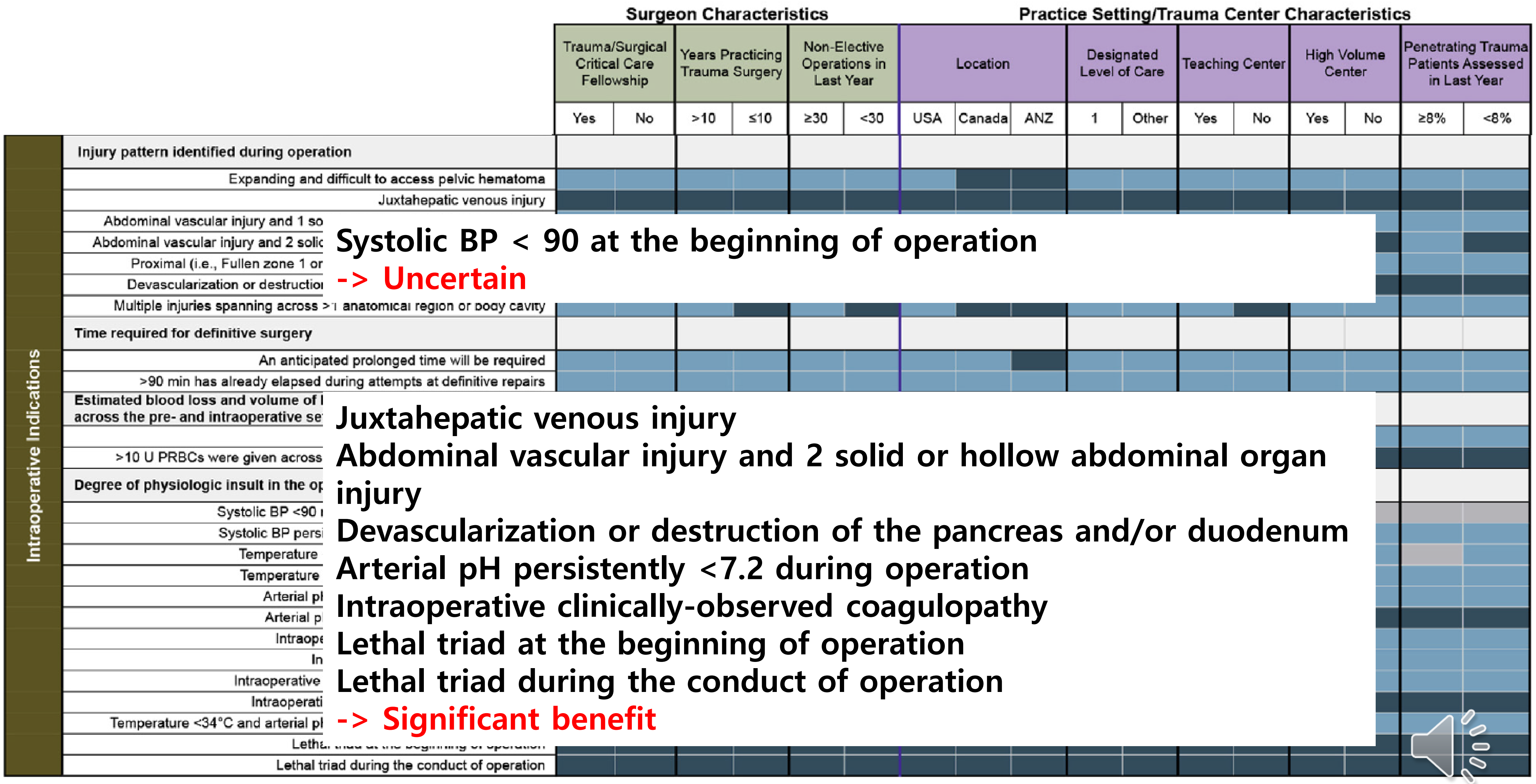



**High energy blunt torso trauma**
**Systolic BP <90 once during transport to hospital**
**Significant, pre-existing medical comorbidity**
**Systolic BP<90 upon arrival to the ED or trauma bay**
**-> uncertain**

**Cardiac arrest during transport to hospital**
**Preoperative temperature<34**
**Preoperative arterial pH<7.2**
**Preoperative lethal triad**
**>10 U pRBCs were given preoperatively**
**A resuscitative thoracotomy was performed in the ED or trauma bay**
**-> Significant benefit**

**Key to Color Coding of Appropriateness Ratings**

| | |
|---|---|
| Significant benefit (median Likert scale rating=5, without disagreement) | |
| Benefit (median Likert scale rating=4, without disagreement) | |
| Uncertain (median Likert scale rating=3, without disagreement) | |




Systolic BP < 90 at the beginning of operation
-> Uncertain

Juxtahepatic venous injury
Abdominal vascular injury and 2 solid or hollow abdominal organ injury
Devascularization or destruction of the pancreas and/or duodenum
Arterial pH persistently <7.2 during operation
Intraoperative clinically-observed coagulopathy
Lethal triad at the beginning of operation
Lethal triad during the conduct of operation
-> Significant benefit

**Key to Color Coding of Appropriateness Ratings**

| | |
|---|---|
| Significant benefit (median Likert scale rating=5, without disagreement) | (dark blue) |
| Benefit (median Likert scale rating=4, without disagreement) | (light blue) |
| Uncertain (median Likert scale rating=3, without disagreement) | (gray) |

# Thoracic Damage Control Surgery

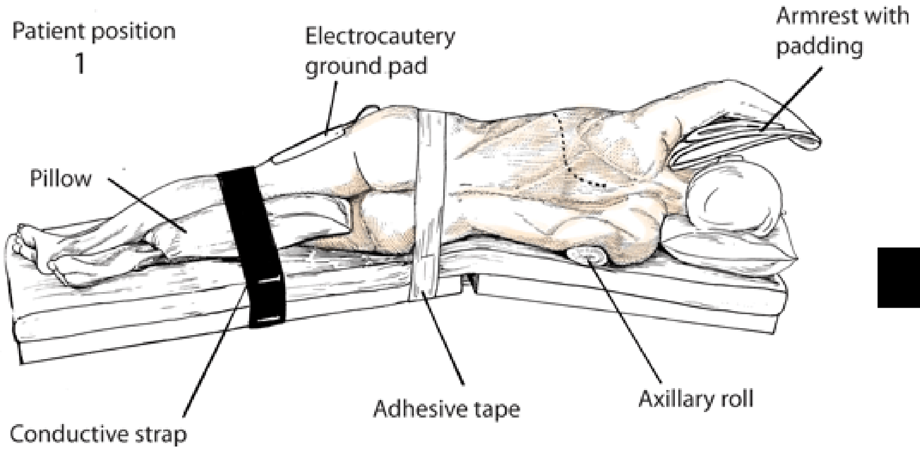
# Thoracic Damage Control Surgery

- **Abdominal damage control surgery**
  - hemorrhage & immediate infection exposed by the GI tract

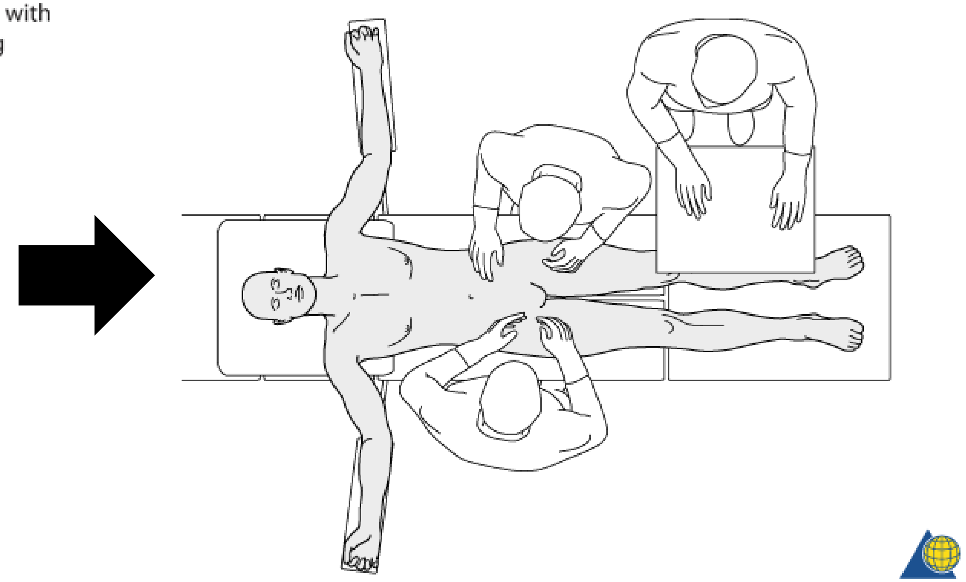
- **Thoracic damage control surgery**
  - exsanguination
  - space occupying and lung-compression events

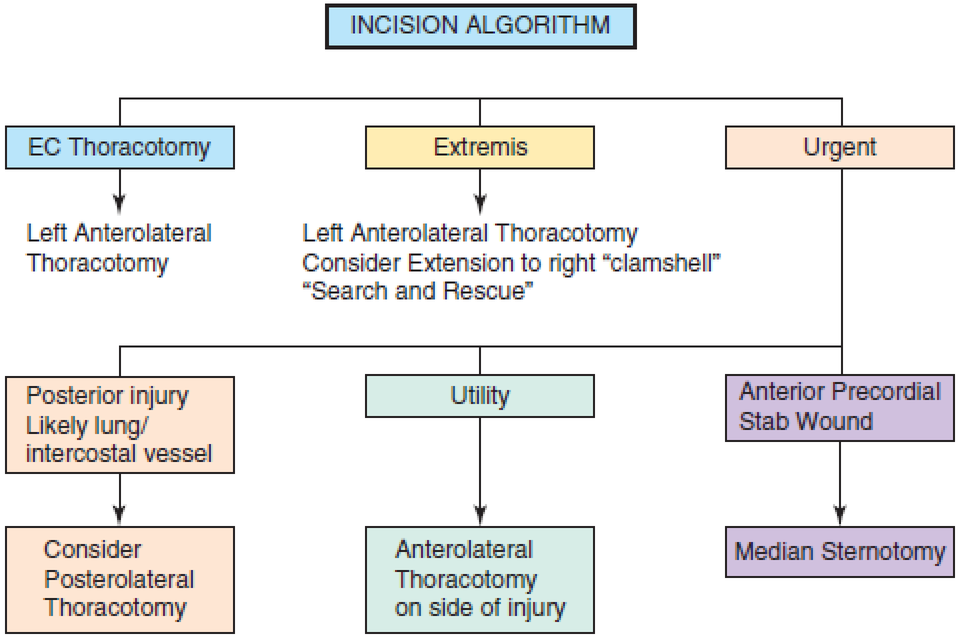
=> **Arrest of hemorrhage and maintaining oxygenation by relieving intrathoracic positive pressures.**

# POSITION?




Source: Zollinger RM, Ellison EC: *Zollinger's Atlas of Surgical Operations, 9th Edition*:
http://www.accesssurgery.com

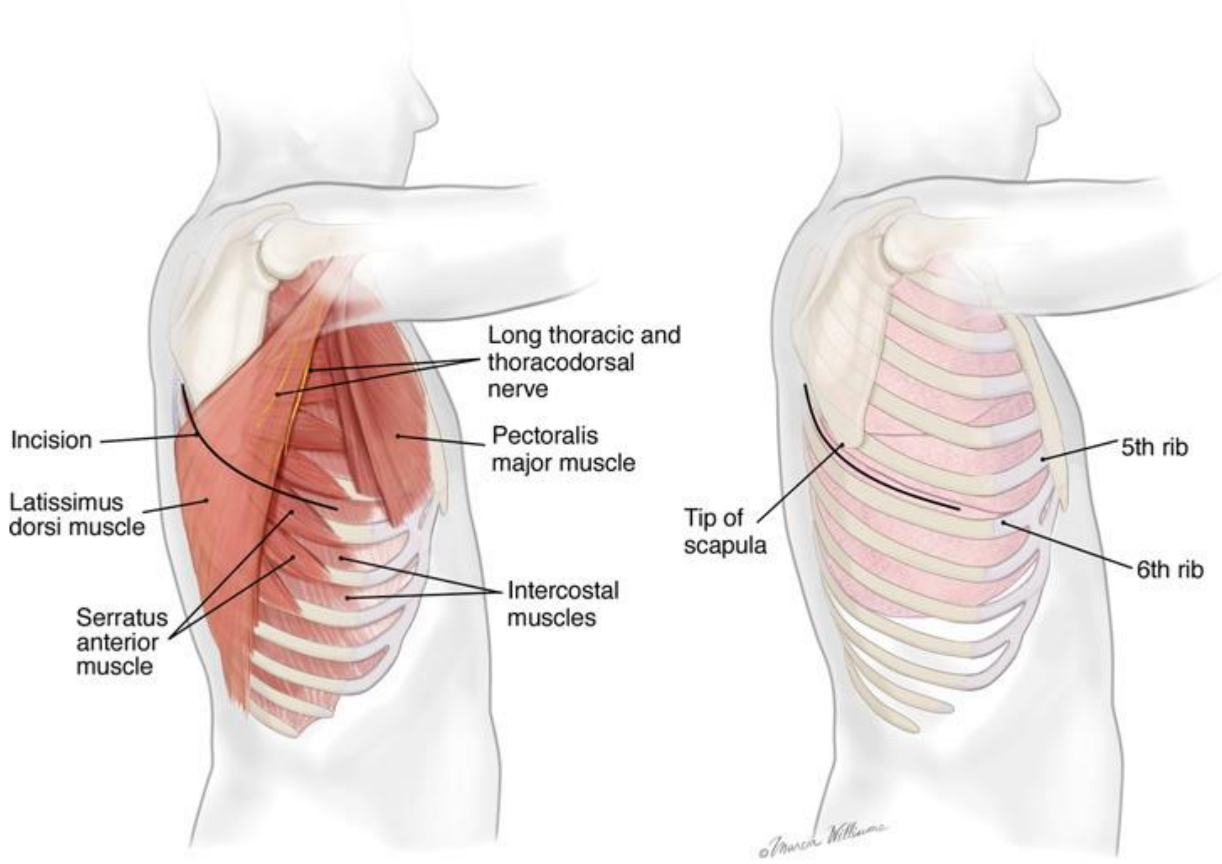






Incision algorithm.

Trauma 7th ed chapter 24

# Posterolateral Thoracotomy

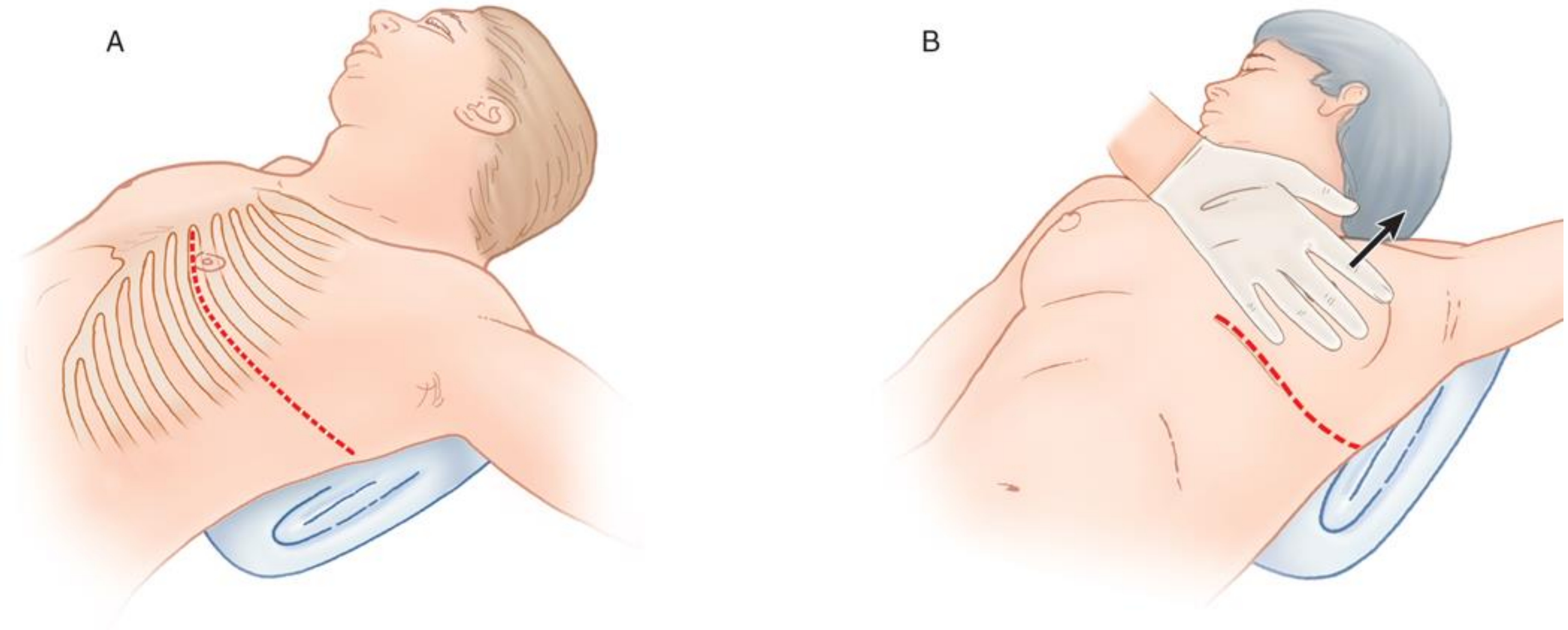



Source: Sugarbaker DJ, Bueno R, Krasna MJ, Mentzer SJ, Zellos L: *Adult Chest Surgery*: http://www.accesssurgery.com



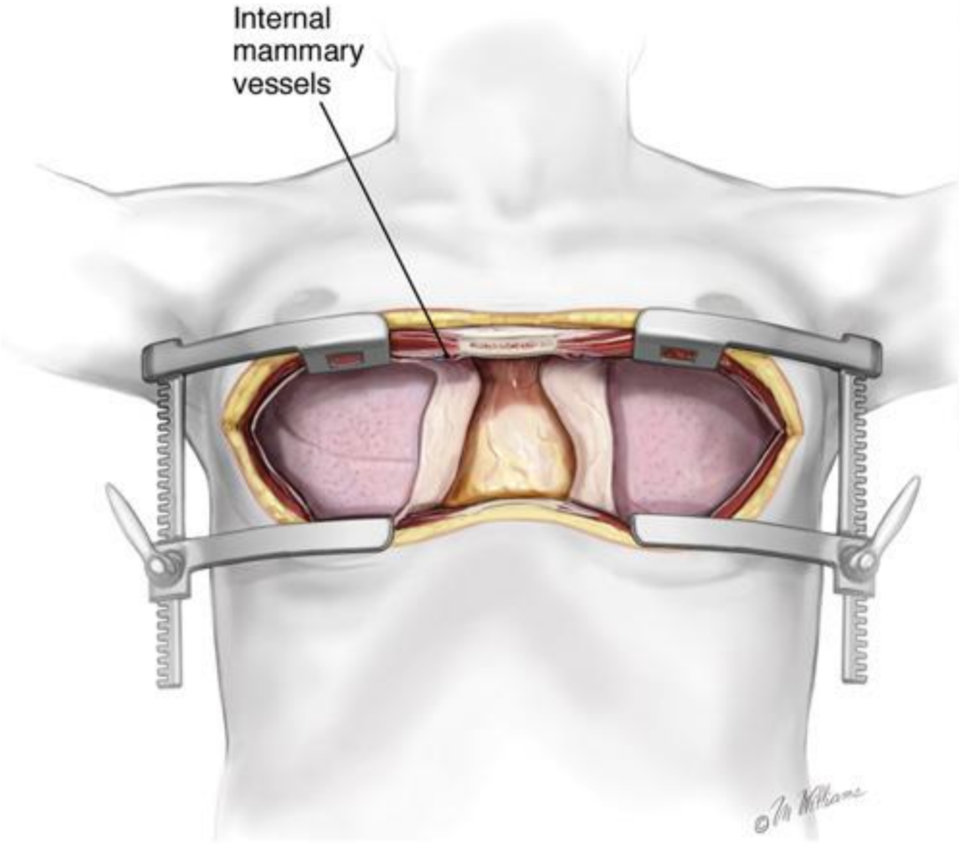
**descending thoracic aorta, esophagus, azygous vein, and the mediastinal trachea and bronchi**

# Anterolateral Thoracotomy



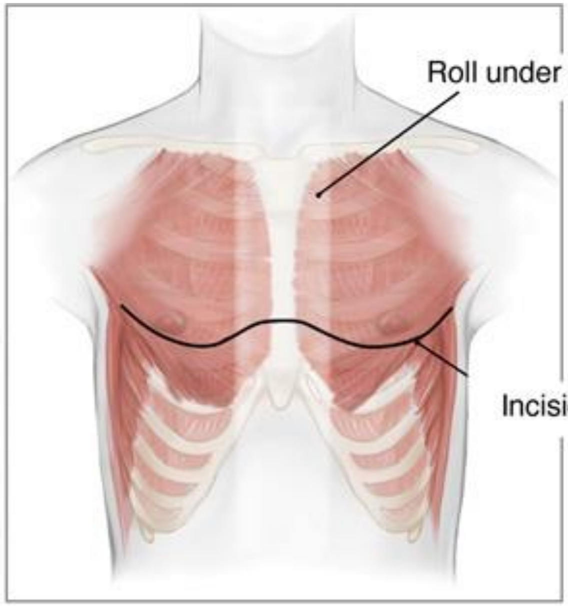

Source: Reichman EF: *Emergency Medicine Procedures, Second Edition:* www.accessemergencymedicine.com

# Transverse Thoracosternotomy (Clamshell)

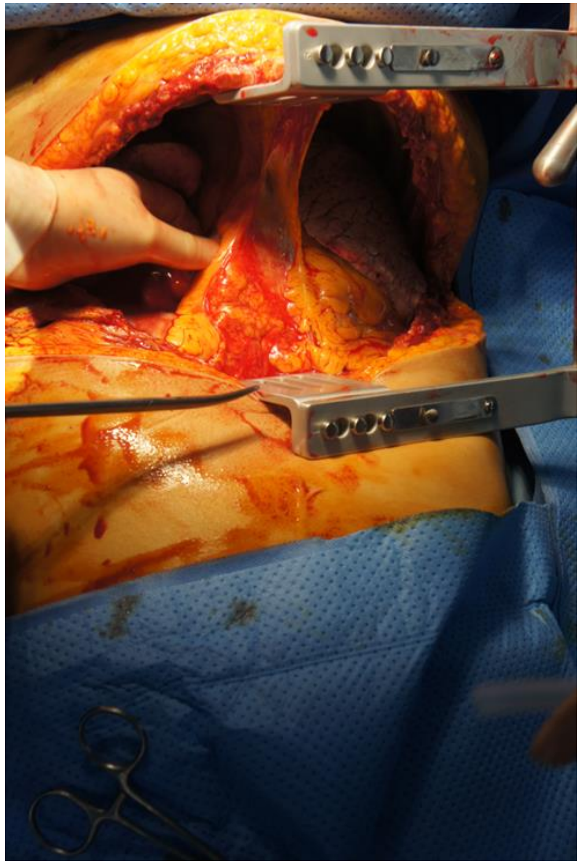


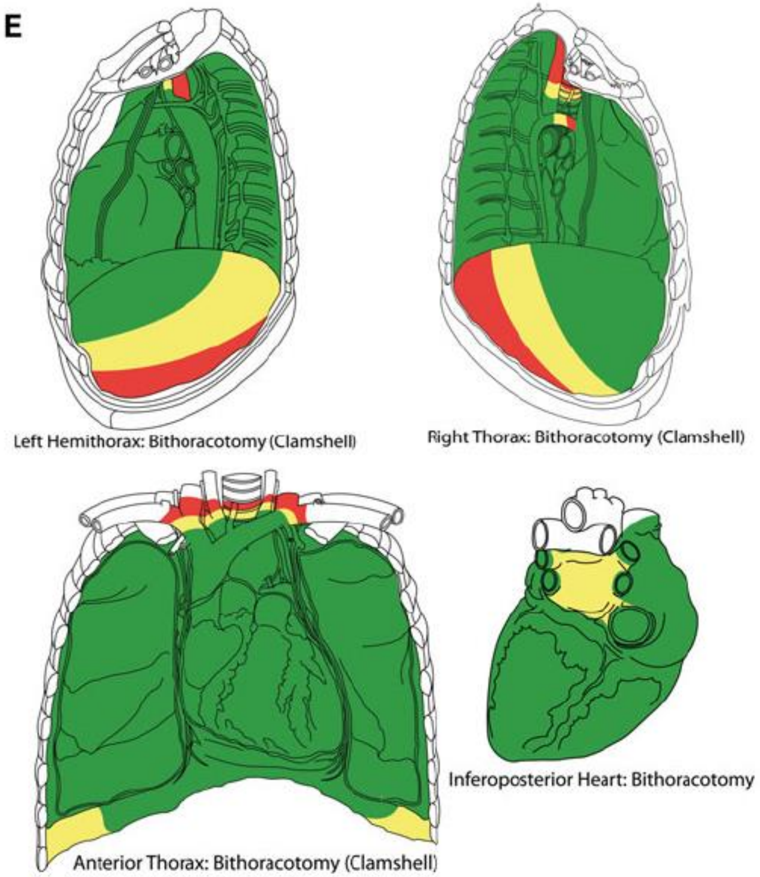

Source: Sugarbaker DJ, Bueno R, Krasna MJ, Mentzer SJ, Zellos L: *Adult Chest Surgery:*
http://www.accesssurgery.com





# Clamshell Thoracotomy






**Bilateral Anterior Thoracotomy (Clamshell Incision) Is the Ideal Emergency Thoracotomy Incision: An Anatomic Study**

Eric R. Simms · Alexandros N. Flaris ·
Xavier Franchino · Michael S. Thomas ·
Jean-Louis Caillot · Eric J. Voiglio

*Conclusions* In severe thoracic trauma, specific injuries are unknown, even if they can be anticipated. The best incision is therefore one that provides the most rapid and definitive access to all thoracic structures for assessment and control. While the right and left anterolateral incisions may be successfully employed by surgeons with extensive experience in ET, the clamshell incision remains the superior incision choice.

World J Surg (2013) 37:1277–1285

# Thoracic Damage Control Surgery Technique

# HILAR CONTROL

**Fig. 3.** *Manual control of right pulmonary hilum by primary surgeon.*

**Fig. 4.** *Lower lobe retraction and inferior pulmonary ligament division by first assistant.*

**Fig. 5.** *Hand-over-hand transfer of manual hilar control from first assistant back to primary surgeon, with preparation for hilar cross clamping by the primary surgeon.*

**Fig. 6.** *Noncrushing clamp securely across right pulmonary hilum.*

# PULMONARY HILUM TWIST

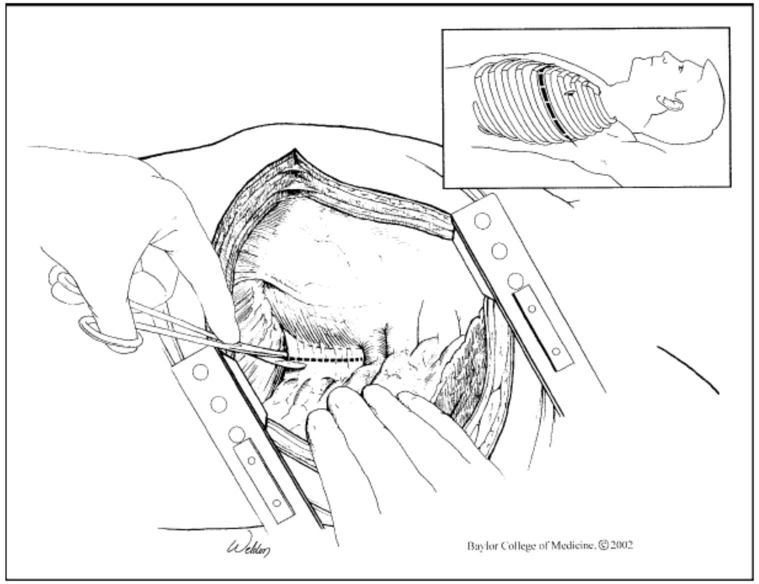



Fig. 1. Sharply divide the inferior pulmonary ligament. The ligament should be divided to the level of the inferior pulmonary vein.

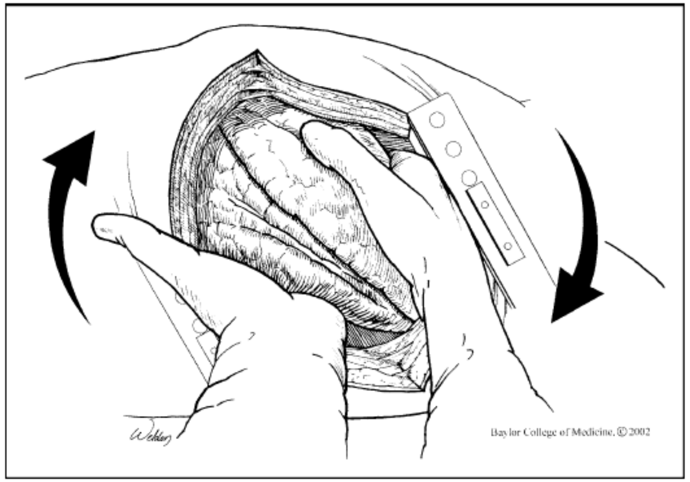



Fig. 2. Place one hand on the anterior aspect of the upper lobe and the other hand on the posterior aspect of the lower lobe. Rotate the lower lobe anteriorly and the upper lobe posteriorly 180 degrees.

Wilson A, Wall MJ Jr, Maxson R, Mattox K. The pulmonary hilum twist as a thoracic damage control procedure. Am J Surg. 2003 Jul;186(1):49-52.

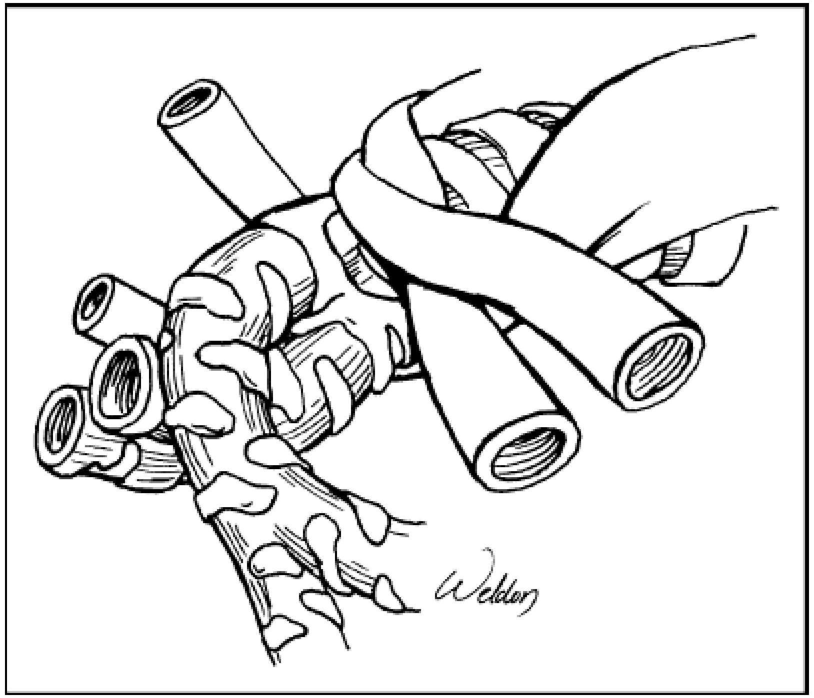


Fig. 4. The vascular structures will be twisted around the bronchus with effective occlusion.

Wilson A, Wall MJ Jr, Maxson R, Mattox K. The pulmonary hilum twist as a thoracic damage control procedure. Am J Surg. 2003 Jul;186(1):49-52.

# Lung Sparing Technique

# Stapled pulmonary tractotomy

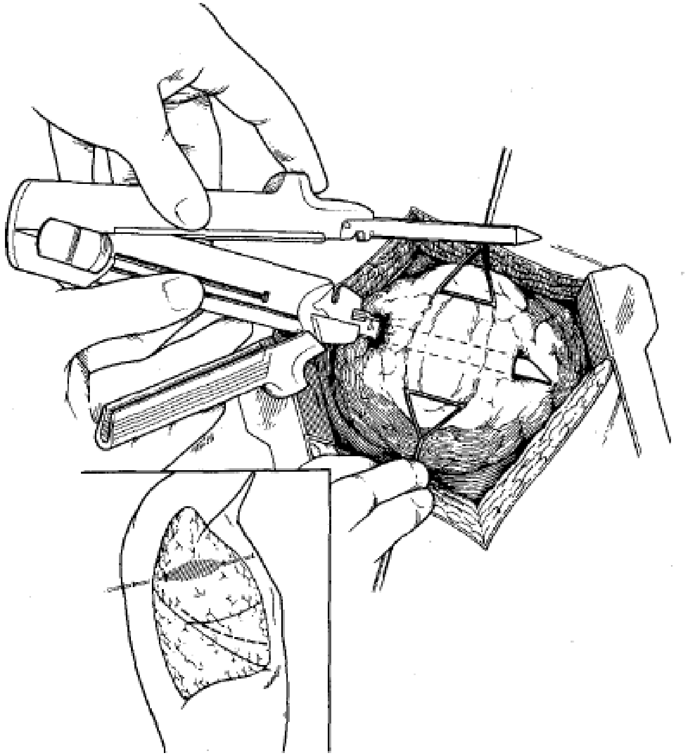


FIG 1. Missile penetrating the pulmonary parenchyma, creating description of pulmonary tissue and deep intraparenchymal bleeding. Stapling device is placed into the orifices of the entrance and exit wounds.

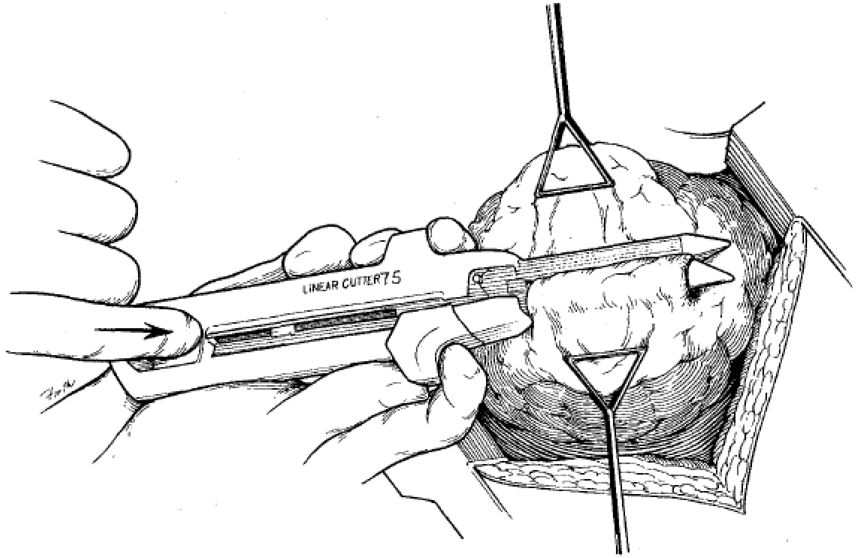



FIG 2. Stapling device is closed and fired to create the tractotomy.

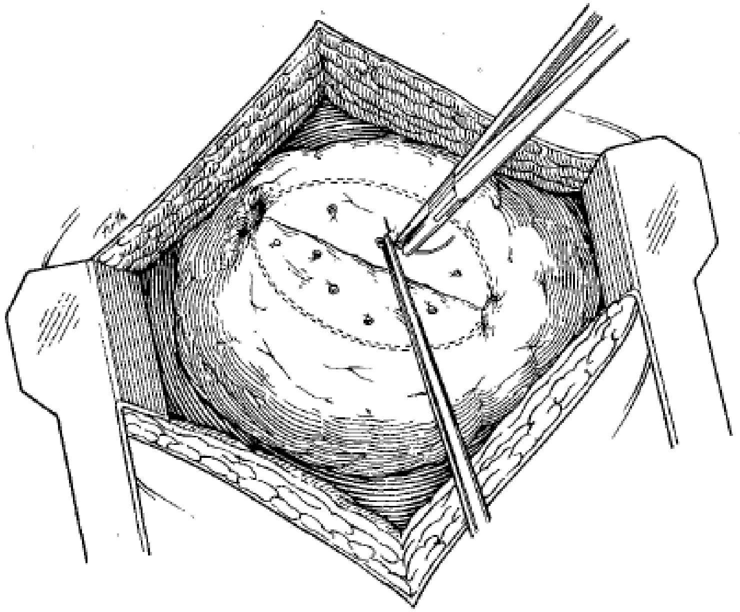
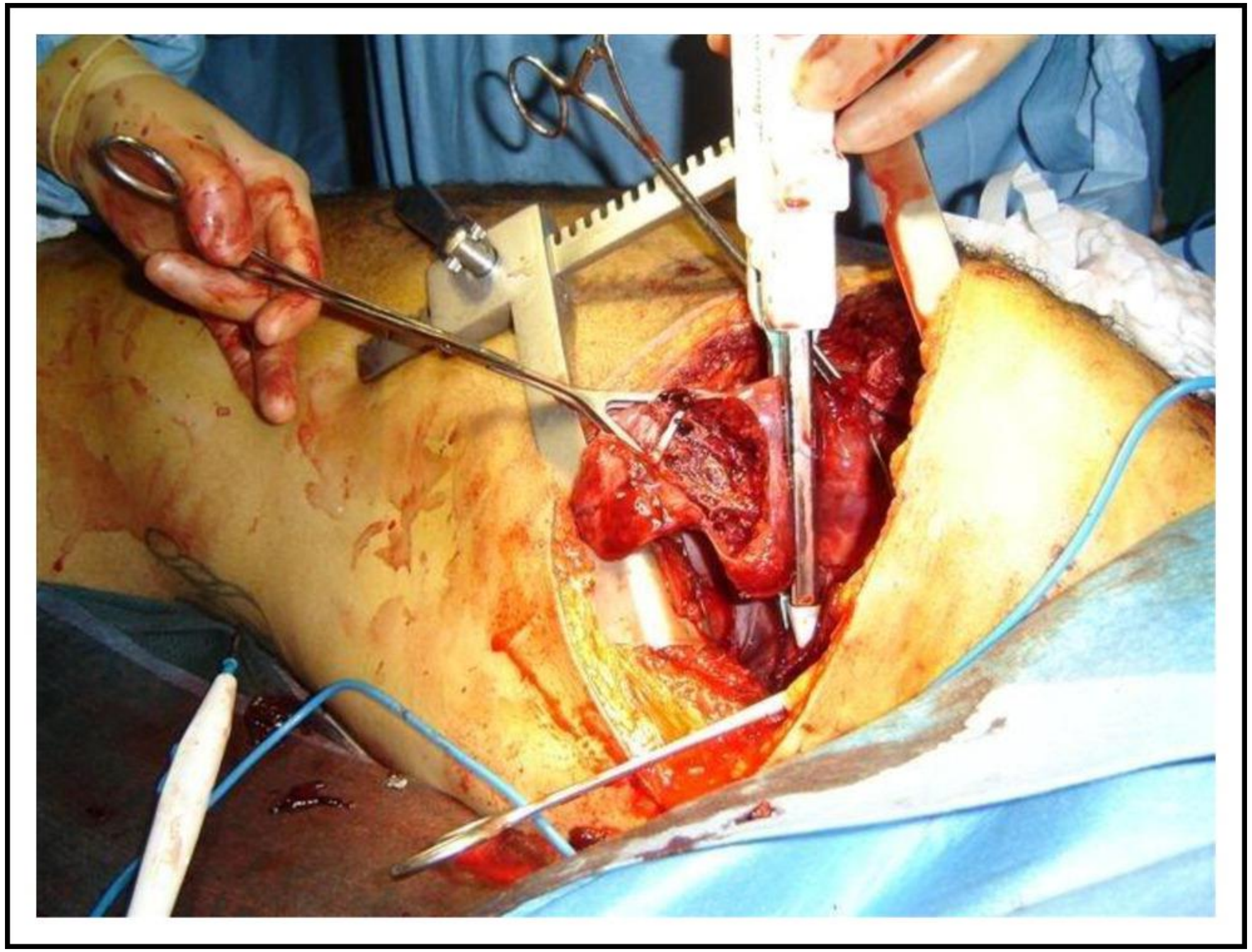


FIG 3. Tractotomy exposes the bleeding vessels, which are then selectively ligated.

# Wedge resection



Y Moriwaki, H Toyoda, N Harunari, M Iwashita, T Kosuge, S Arata, N Suzuki
Gauze packing as damage control for uncontrollable haemorrhage in severe thoracic Trauma.
*Ann R Coll Surg Engl* 2013; 95: 20–25

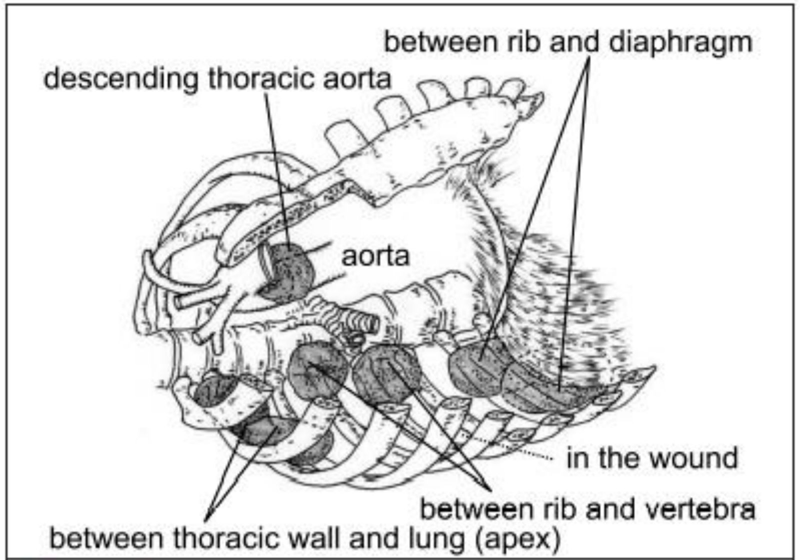



Figure 1 Schema of the packing site in the thoracic cavities of the six successful cases

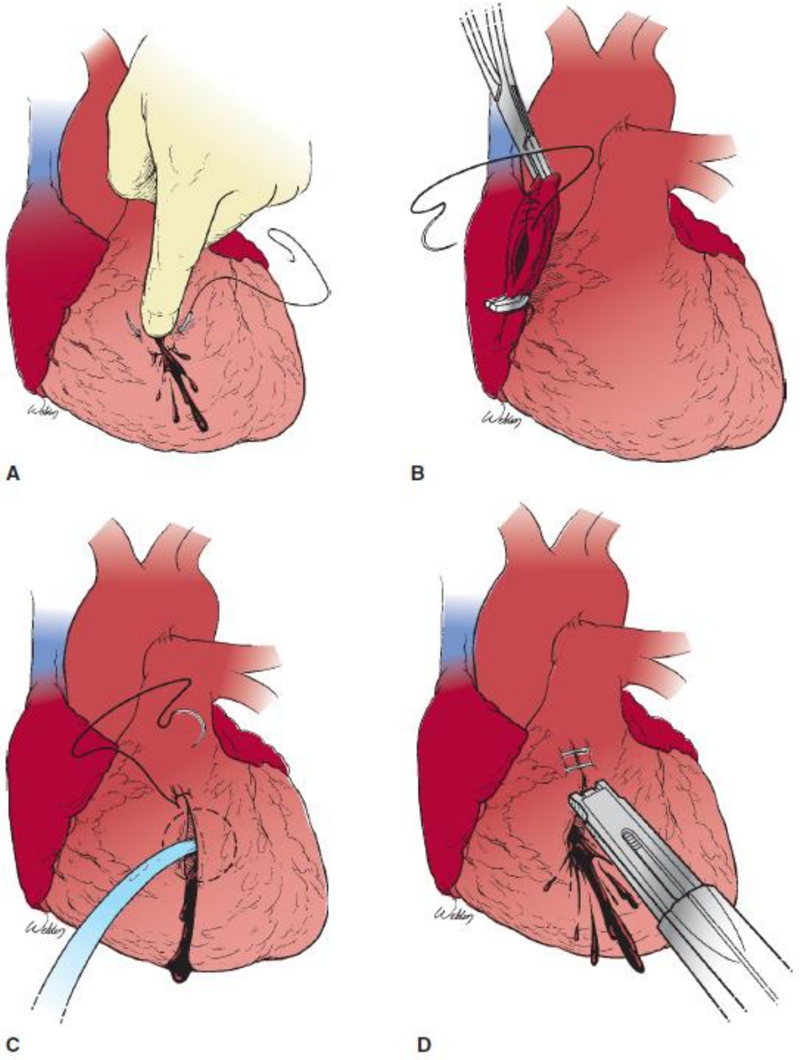



**FIGURE 26-3** Temporary techniques to control bleeding. (**A**) Finger occlusion; (**B**) partial occluding clamp; (**C**) Foley balloon catheter; (**D**) skin staples. (*Copyright © Baylor College of Medicine, 2005.*)

# Damage-control techniques in the management of severe lung trauma

**Alberto Garcia, MD, Juan Martinez, MD, Julio Rodriguez, MD, Mauricio Millan, MD, Gustavo Valderrama, MD, Carlos Ordoñez, MD,** *and* **Juan Carlos Puyana, MD,** *Cali, Colombia*

DCT mortality in pulmonary trauma was 6 (24%) of 25 because of coagulopathy, or persistent bleeding in 5 patients and multiorgan failure in 1 patient.

**RESULTS:** A total of 840 trauma thoracotomies were performed. DC thoracotomy (DCT) was performed in 31 patients (3.7%). Pulmonary trauma was found in 25 of them. The median age was 28 years (interquartile range [IQR], 20–34 years), Revised Trauma Score (RTS) was 7.11 (IQR, 5.44–7.55), and Injury Severity Score (ISS) was 26 (IQR, 25–41). Nineteen patients had gunshot wounds, four had stab wounds, and two had blunt trauma.

Pulmonary trauma was managed by pneumorrhaphy in 3, tractotomy in 12, wedge resection in 1, and packing as primary treatment in 8 patients. Clamping of the pulmonary hilum was used as a last resource in seven patients. Five patients returned to the intensive care unit with the pulmonary hilum occluded by a vascular clamp or an en masse ligature. These patients underwent a deferred resection within 16 hours to 90 hours after the initial DCT. Four of them survived.

Bleeding from other intrathoracic sources was found in 20 patients: major vessels in nine, heart in three, and thoracic wall in nine.

DCT mortality in pulmonary trauma was 6 (24%) of 25 because of coagulopathy, or persistent bleeding in 5 patients and multiorgan failure in 1 patient.

**CONCLUSION:** This series describes our experience with DCT in severe lung trauma. We describe pulmonary hilum clamping and deferred lung resection as a viable surgical alternative for major pulmonary injuries and the use of packing as a definitive method for hemorrhage control. (*J Trauma Acute Care Surg*. 2015;78: 45–51. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

**LEVEL OF EVIDENCE:** Epidemiologic study, level V.

**KEY WORDS:** Thoracic injuries; lung injury; penetrating; damage control; deferred pneumonectomy.

# THANK YOU FOR YOUR ATTENTION