Notable Grand Rounds
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Michael & Marian Ilitch
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MANAGEMENT OF THE OPEN ABDOMEN

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About Notable Grand Rounds

These assembled papers are edited transcripts of didactic lectures given by mainly senior residents, but also some distinguished attending and guests, at the Grand Rounds of the Michael and Marian Ilitch Department of Surgery at the Wayne State University School of Medicine.

Every week, approximately 50 faculty attending surgeons and surgical residents meet to conduct postmortems on cases that did not go well. That “Mortality and Morbidity” conference is followed immediately by Grand Rounds.

This collection is not intended as a scholarly journal, but in a significant way it is a peer reviewed publication by virtue of the fact that every presentation is examined in great detail by those 50 or so surgeons.

It serves to honor the presenters for their effort, to potentially serve as first draft for an article for submission to a medical journal, to let residents and potential residents see the high standard achieved by their peers and expected of them, and by no means least, to contribute to better patient care.

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Management of the Open Abdomen

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November 30, 2022

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Introduction

This paper is about the open abdomen and will discuss its evolution mostly as it relates to changes in resuscitation paradigms over the last 20 years and will also include a discussion of the management of the open abdomen from a technical standpoint. It concludes with some brief comments concerning planned ventral hernia.[1]

It should be noted, up front, that institutional history can have a particularly powerful influence on the techniques used at the institution, and an appendix describes the history of his institution, Grady Memorial Hospital.

Goals

Specifically, we will describe the history of abbreviated laparotomy and open abdomens and their evolution into the modern era; describe changes in resuscitative paradigms in critically injured patients that have occurred in the last two decades; and, finally, discuss technical aspects

Fig. 1. An open abdomen.

[1] Abdominal compartment syndrome (ACS) is perhaps the biggest single concern of open abdomens but is not covered in this paper since the Grand Rounds presentation on which the paper is based immediately followed an M&M Conference case of ACS, therefore the topic had already been throughly discussed.

of open abdominal management and techniques to optimize early closure.

More colloquially, it boils down to answering three questions: Why would surgeons ever subject a patient to what is really a very morbid technique? Having chosen to subject them to it, what management paradigm will allow us to navigate the morbidity and render the technique life saving instead? What are the specific techniques, technologies, and logistics?

Global Indications

Indications for an open abdomen are:

- Abdominal compartment syndrome
- Intra-abdominal hypertension
- Severe intra-abdominal infection
- Post-traumatic and non-trauma hemorrhage
- Sepsis
- Peritonitis
- Pancreatitis
- Bowel edema or ischemia
- Hypothermia
- Acidosis
- Re-exploration after trauma or abdominal sepsis

In most cases, if an operation cannot be finished, for whatever reason, an abbreviated laparotomy will be performed, followed by temporary abdominal coverage (at Grady, currently, coverage is usually an Abthera wound vac), followed by ICU care until the patient is well enough to be re-operated upon and the fascia is closed—or not: The patient will be discharged either with a closed abdomen or a big ventral hernia.

Some Key Concepts

1. A surgeon should not hesitate to leave the abdomen open if—but only if—necessary. The technique should not be overused.
2. An open abdomen means the underlying procedure is not yet complete, therefore a sense of urgency is needed. Domain may be lost and many adverse things may happen.
3. These are very sick patients, so decision making is complex and needs to be nuanced and oriented to the long term, especially as it relates to preserving fascia when things aren't going well.

History of the Open Abdomen

Ogilvie (1940)[2] seems to have been the first physician to address management of open abdomens in the literature, in the context of devastating abdominal war wounds in World War 2. He used a "double sheet of light canvas or stout cotton cut rather smaller than the defect in the muscles and sutured into place with interrupted catgut sutures…. Vaseline-impregnated gauze swabs [were placed] over exposed viscera, their edges tucked well under those of the defect" with the sides of the incision brought together with Elastoplast or stitches.

In post-war civilian practice, Ogilvie used the same techniques several times in septic abdomens, attempting closure one to four days after the operation. He compared the septic abdomen to any other septic wound—it should be left open to drain and the abdominal wall should be saved by not suturing it, to allow closure at a later date.

After Ogilvie, the open abdomen pretty much disappeared from the literature for 30 years, until abbreviated laparotomies began in the 1970s, A study by Steinberg in 1979 looked at 14 patients with generalized peritonitis who had gauze packs placed on the viscera. They were removed at 48-72 hours and the abdomen was closed with wires that had been place at the first operation. The outcomes—one death and one post-op abscess—were relatively good.

In the 1980s, planned re-laparotomy became a treatment of last resort for heavily contaminated

[2] Ogilvie WH. The late complications of abdominal war-wounds. *Lancet.* 1940;**2**:253–256. doi: 10.1016/S0140-6736(01)08769-4.

abdomens and for patients with severe acute pancreatitis. However, mortality rates were high (40-60%) because these were very sick patients with multiple complications: evisceration, entero-atmospheric fistulae, and significant fluid loss.

Today's practice of using open abdomens in trauma patients predominantly, rather than septic patients, began in the 1990s. Our bodies are not designed to survive the devastating injuries seen daily in the modern trauma center. The surgeon must try to manage these injuries in what is an extremely dysregulated organism that is fighting against the surgeon's efforts.

At the same time, the resuscitative techniques available to the surgeon are imperfect. They are better than they used to be but there remain significant gaps in our understanding of the body's dysregulation and the tools to treat it..

Tools for Resuscitation

Resuscitative tools include a variety of balanced electrolyte solutions—saline, lactated ringers, plasmalyte, and others; and colloid products—whole blood and blood components including (questionably) albumin.

Intravenous (IV) fluids were introduced in the cholera epidemics in the 1840s. To prevent death from dehydration, apothecaries gave small boluses of a variety of solutions mixed in the back chambers of their apothecaries. Indeed, the origins of some of the balanced electrolyte solutions in use today remain obscure.

For example, normal saline is thought to have emerged in 1896 from the laboratory of Hartog Jakob Hamburger, a Dutch chemist who was conducting *in vitro* experiments to find the freezing point of various warm-blooded animals. He found that normal saline was isotonic with the frozen blood of warm-blooded animals.[3]

Normal saline's use spread ubiquitously because it was and remains cheap (currently 65 cents a liter), easy to make, and relatively hyperosmolar (OSM 308); contains no calcium, potassium, dextrose, or lactate; and can be bolused. On the negative side: It is heavy, requires large volumes, is surprisingly acidotic (pH 5,5— patients with significant saline toxicity and hyperkalemic metabolic acidosis are not uncommon) and has no oxygen-carrying capacity.

Colloids have many advantages over crystalloid solutions. Fresh whole blood, which was used as far back as World War 1 and is still used in the military today, has an HCT level of 38-50%, 150-400 k/.mL of platelets, and100% of coagulation factors.

Stored whole blood was added to Grady's massive transfusion protocol 5-7 years ago. It has a shelf life of three to five weeks. It lacks platelet or granulocyte function and gradually loses its labile coagulation Factors V and VIII, but it is a very good tool for resuscitation.

The components transfused in a blood transfusion are chiefly these:

- PRBC (335 mL, 55-60% Het, shelf 42 days)
  - "storage lesion"
- FFP (275 mL, 80% Factor activity, shelf: 1yr)
  - Thawed plasma (shelf: 5 days, Factor V/VIII 65% act)
- Platelets (50 mL random donor)
  - Random donor (5 × 1010; doom temp; shelf: 5 days)
  - Apheresis (equivalent to 6-10 random donors)
- Cryoprecipitate (15mL unit, 150 mL 10 pk)
  - Concentrated fibrinogen, Factor VIII, VWF, Factor XIII

Trauma centers tend to use the oldest packed cells in the Red Cross's inventory before they expire, but an old unit of of blood is not nearly as

[3] Awad et al. The history of 0.9% saline. Clinical Nutrition 27: 179-88, 2008

good a resuscitative tool as a new unit of blood because it loses 2,3-**DPG** in storage and an increased cytokine in plasma.

Fresh frozen plasma (FFP) is used ubiquitously. It has a long half life. For a massive transfusion protocol, FFP can be thawed up to about five days prior with a gradual loss of labile coagulation factors.

Platelets are often scarce because they are a room temperature product so their shelf life is short, plus almost all the blood supply now is in apheresis units which are more difficult to donate. There is a chronic shortage of platelets everywhere.

The last two decades of the 20th century saw significant improvements in trauma systems, improvements in critical care, and more rapid access to accurate, detailed imaging. As a result, more patients with worse injuries were surviving for longer periods of time.

Resuscitation strategies, however, were slow to evolve. Surgeons were seeing injuries the body was not designed to survive and the understanding of how the body reacts was incomplete. The cellular mechanisms were not well known.

A classic article from Dr. Lucas at Wayne State shed fresh light on the patterns associated with with crystalloid resuscitation.[4] Understanding these patterns contributed to the excellent training in precision resuscitation I and others received at Wayne State that was not then available in many residency programs. It illustrates the key role of institutional influences in developing both surgeon and surgery (discussed further in the appendix).

While fluid uptake was obligatory, it was proportional and reversed only in patients who were improving. Unrestrained use of crystalloid, which occurred at many institutions, led to resuscitation-associated coagulopathy or the vicious cycle of crystalloid combining with hypothermia and acidosis, leading to dilutional coagulopathy and more acidosis and more bleeding, and the cycle repeated.

Damage Control Surgery

This then led to the mainstreaming of damage control surgery, which had been practiced at the DMC and at Grady since the 1970s. Dr. Rotundo at the University of Pennsylvania published an article about damage control surgery in 1993.[5] He advocated halting an operation in severely injured, mostly penetrating abdominal trauma, cases to avoid the physiologic exhaustion concomitant with massive crystalloid resuscitation. The open abdomen was back at the forefront again.

This article lead to the stratification of damage control into five phases:

1. Early Diagnosis
2. Initial abbreviated operation
   - Control contamination
   - Stop surgical hemorrhage: ligation/ shunt/packing
3. Restore physiology (ICU)
4. Definitive surgical management
5. Reconstruction of the abdominal wall (may be delayed)

In other words, the surgeon must think about it early, then perform an initial abbreviated operation enabling contamination control and the stopping of surgical hemorrhage with ligation shunting or packing, then bring the patient to the ICU for restoration of their physiology, then (once they are better) bring them back to the OR for definitive surgical management, with the open abdomen at the forefront.

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[4] Lucas CE. Resuscitation of the Injured Patient: Three Phases of Treatment. Surg Clinics NA, 1977. 57(1): 3-15.

[5] Rotondo et al: "Damage Control": An approach for improved survival in exsanguinating penetrating abdominal injury. J Trauma 35: 375, 1993.

Specific Indications

In the early 2000s, surgeons looked for three indications for open abdomen: First, a need for massive resuscitation, which was then imprecise and led to significant visceral edema and oftentimes worsening endpoints despite apparently adequate resuscitation. It often led as well to diffuse coagulopathy and resulting bleeding from all orifices and surfaces—not of blood, but of dilute crystalloid. That was the main indication for an open abdomen at the time.

The second indication was a planned re-look at patients who had shunted vascular structures or if there was concern about visceral viability over time. The third indication was in mass casualty situations where inexperienced surgeons were comfortable doing an operative intervention.

Ideal temporary abdominal coverage was easy, quick to place, inexpensive, non-damaging to tissues, allowed domain maintenance (a real problem), and provided a view of the underlying viscera. Unfortunately, severe shock and massive resuscitation at that time begat significant edema.

Temporary Abdominal Covers

Temporary abdominal covers included skin only/towel clips, "Bogota" bag/silo, temporary non-absorbable and absorbable mesh, early negative pressure dressings, and the Wittmann patch. *Towel clips* (Figure 2) were applied to shut the skin at 1 cm intervals. The technique did not work very well, causing herniation of the bowel between the clips and abdominal compartment syndrome, and of course the clips made radiologic imaging problematical.

Because of these complications, many surgeons turned from towel clip closure to skin-only closure with whip stitching of the skin with heavy suture.

Bogota Bags/silos (Figure 3) (at Grady they took the form generally of a sterilized GU irrigation bag) were popular in the early 2000s. Sewn to the skin with running suture, they allowed redundancy and allowed significant visceral edema without compartment syndrome.

Fig. 2. Towel clips used for temporary abdominal coverage.

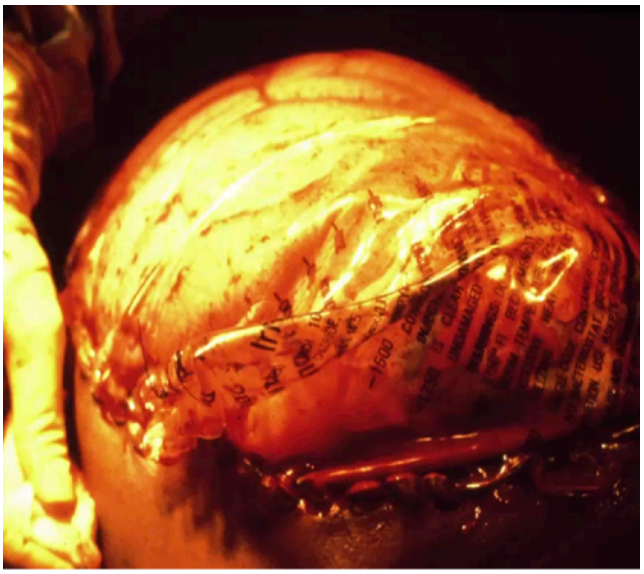
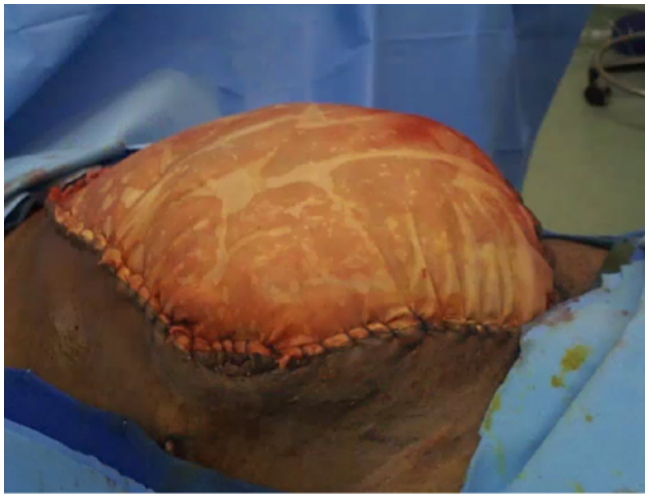


Fig. 3. A silo.

Mesh placement closures include non-absorbable mesh, which can cause intestinal fistula



Fiig. 4. Vicryl mesh temporary cover.

formation. At Grady we always used an absorbable Vicryl mesh (Figure 4), which facilitates planned ventral hernia and is associated with lower rates of fistula formation especially if double-layered. However, Vicryl mesh is used only if the fascia is clearly not gong to be able to close—because it facilitates planned ventral hernia. If closure may still be attempted, Vicryl temporary coverage is not a good idea.

Visceral packing was described in the early 1990s although it may have been practiced in the 1970s. Bender (another former Wayne State/DMC resident) described using rayon or parachute silk (still used today), covering that with fluff gauze, and placing widely spaced retention sutures through the fascia to keep the fluff gauze below the level of the fascia to try to maintain domain. An outer layer of burn gauze is changed as it saturates. As the edema resolves, retention sutures are replaced and the fascia is gradually closed.[6]

Figure 5 shows how damaging that is to the skin and to the fascia. It worked well in Bender's study—17 patients who could not have primary closure had no abdominal compartment syndrome, no renal failure, no enteric fistula, and a

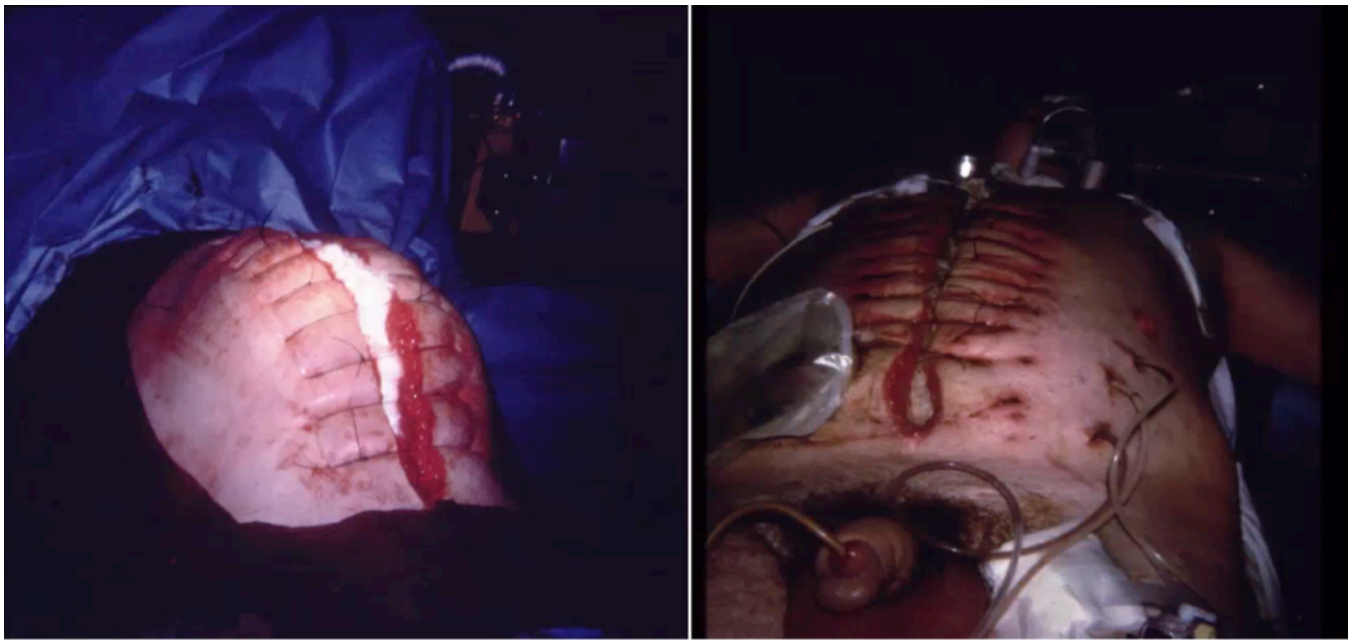


Fig. 5. Visceral packing.
Source: See note 8.

[6] Bender et al. "The Technique of Visceral Packing: Recommended Management of Difficult Fascial Closure in Trauma Patients' J Trauma 36(2): 182-85, 1994.

relatively low mortality rate for this sick patient population; and all the survivors had their fascia closed at a maximum of five repeat operations. The biggest problem with this technique was the damage it could cause to the fascia if it failed. Still, the technique was used relatively regularly at Grady at that time, as a result of significant institutional influence from Wayne State.

An early *negative pressure* technique (known as the *Diebel dressing* at Wayne/DMC) modified visceral packing to create negative pressure. There is a variety of other vacuum pack dressings, mostly homemade. The Barker wound vac is probably the most described in the literature.

Fig. 6. Wittmann patch.
Source: Tieu et al. (See note 9).

The key components of a homemade wound vac are an inner layer of non-adherent dressings, suction at the fascial level, an outer layer of dressings, and then adherent drapes. The great advance of this dressing was that it facilitated quantification of fluid losses while protecting the fascia by keeping it dry.

The Wittmann patch[7] (Figure 6) was very popular in the early 2000s. It was basically a hook and loop sheet with two sheets sewn to the fascia on either side with a non-adhesive barrier underneath. It can be pulled together at the bedside. It had a good closure rate (82%) in Tieu's 2008 study involving 22 patients between 2002-2006 (see note 7).

Choice of Technique
With so many choices, which is best? At Grady, in the era prior to damage control resuscitation:

- At the time of the index operation, if the patient has massive bowel edema with loss of domain but bleeding is not a concern, silo is used.
- If a patient is packed and coagulopathic (generally the case with bad liver injuries), a partial skin-only closure with a silo underneath it to avoid abdominal compartment syndrome is used.
- If the patient needs a second book, for whatever reason, but otherwise is doing okay, a negative pressure dressing is used.

Eventually all of these patients are converted to a negative pressure dressing if repeat operations cannot close them.

Tremblay et al.'s 2001 study[8] of 181 patients evaluated several of these techniques at Grady:

[7] Tieu BH, Cho SD, Luem N, Riha G, Mayberry J, Schreiber MA. The use of the Wittmann Patch facilitates a high rate of fascial closure in severely injured trauma patients and critically ill emergency surgery patients. J Trauma. 2008 Oct;65(4):865-70. doi: 10.1097/TA.0b013e31818481f1. PMID: 18849804.

[8] Tremblay et al. "Skin Only or Silo Closure in Critically Ill Patients with an Open Abdomen", Am J Surg 182: 670-75, 2001.

Skin only/towel clip (93); silo (75); mesh (12); and visceral pack (1). That study found significant morbidity associated with this management paradigm. 23 patients still got abdominal compartment syndrome, despite the open abdomen; 26 developed devastating GI fistulas; and the closure rate was only 52%, mainly because resuscitative techniques were inadequate.

However, resuscitative techniques started improving even as the Tremblay study was being published, for two main reasons: First, a more nuanced understanding of the coagulopathy associated with severe trauma was developed; and second, a much more regimented system was developed to deliver more appropriate up-front resuscitation.

Acute traumatic coagulopathy (ATC) was traditionally thought to be a resuscitation-associated secondary phenomenon (dilutional), but there was increasing evidence from retrospective and later prospective studies that acute traumatic coagulopathy was actually a primary event in severely injured patients.

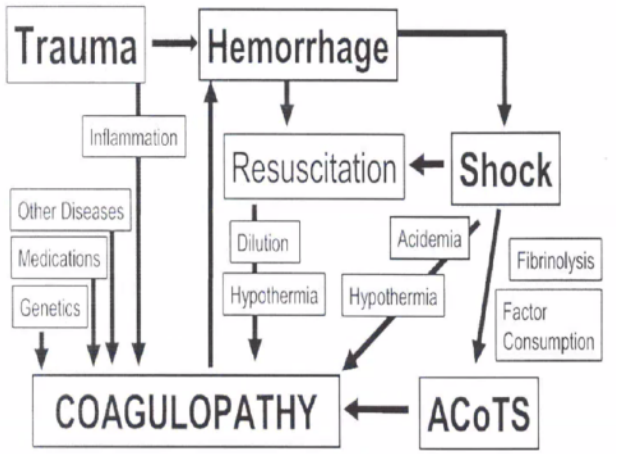


Fig. 7. Pathophysiology of ATC.
Source: Hess et al. (See note 12 below).

Multiple potential pathophysiologic mechanisms with multiple other names such as ETIC (early trauma induced coagulopathy)[9], all incredibly complex, were described. Figure 7 shows Hess et al. (2008)'s pathophysiology, the chief mechanisms being tissue trauma, shock, hemodilution, hypothermia, acidemia, and inflammation. All probably play a role.[10]

There is lots of evidence that the shock state itself playa a central role. As noted earlier, the body is not designed to survive these injuries, and it gets severely dysregulated.

Package	PRBC	FFP	Platelets	Cryo
Initiation #	6 units	6 units *		
1	6 units	6 units	1 apheresis	
2	6 units	6 units		20 units $
3	6 units	6 units	1 apheresis	
4	6 units	6 units		10 units
5	6 units	6 units	1 apheresis	
6	6 units	6 units		10 units

Consider Tranexemic Acid (1 g over 10 min then 1 g over 8 hrs)

* 6 units Thawed FFP in Blood Bank $ Changed to 10 units December 1, 2008

Table 1. Grady Massive Transfer Protocol

In an attempt to avoid physiologic exhaustion, Spinella and Holcomb (2009) looked at the third of Rotundo's five phases of damage control surgery described earlier (phase 3 was to restore the physiology in the ICU) and determined that administering massive crystalloid while a patient was actively bleeding was not a good idea.[11] The massive transfusion protocols—the 1:1:1 high empiric fixed ratio resuscitation—came out of

[9] See e.g. MacLeod JB, Winkler AM, McCoy CC, Hillyer CD, Shaz BH. Early trauma induced coagulopathy (ETIC): prevalence across the injury spectrum. Injury. 2014 May;45(5):910-5. doi: 10.1016/j.injury.2013.11.004. Epub 2013 Nov 20. PMID: 24438827.

[10] Hess et al. The Coagulopathy of Trauma: A Review of Mechanisms. J Trauma 65: 748-54, 2008.

[11] Spinella and Holcomb. Resuscitation and transfusion principles for traumatic hemorrhagic shock. Blood Reviews 23: 231-40, 2009

this strategy. They also pushed Factor VIIa, but that never really worked out.

At Grady, actively bleeding patients are given empiric high fixed ratio resuscitation until they get to the ICU, where they are switched to a massive transfer resuscitation, with good results. Dr. Jeff Nicholas (another Wayne State graduate) and I were the primary drivers for the Grady massive transfusion protocol instituted in 2007, which shoots for one a roughly 1:1:1 ratio. (Table 1 refers.)

In its first year (2006-7) the protocol was activated 116 times, for a mix of blunt and penetrating trauma—really sick patients—and met with considerable success compared to historic controls, showing marked improvements in 24-hour (17.6%, Historic Cx: 36%) and 30-day (38.4%, Historic Cx: 50%) mortality. Good ratios (average FFP: PRBC 1:1.9; average Plt: PRBC 1:1.48) were a result of the blood bank changing the way it processed blood samples and thawed fresh frozen plasma, among other things.[12]

From 2007-2009 we had 217 activations and 132 trauma MT patients. The high line on Figure 8 indicates the correct empiric ratios and a very high survival rate. The ratios were a significant risk factor in terms of outcomes.

A 2009 study by Snyder et al. from the University of Alabama pointed to a potential survival bias related to the resuscitation. Survival at 24 hours (fixed value) had a low ratio (> 1:2) = 42%, a high ratio (< 1:2) = 60%, and RR death in high ratio = .37 (.22-.64). But for survival at 24 hours (time varying covariate) the RR death in high ratio = .84 (.47-1.5).

The conclusion was that oftentimes empiric high fixed ratio resuscitation did not have the desired effect; it was just that the patients who survived did so long enough to get catch-up plasma.

That led to the two major prospective studies on resuscitation: The PROMMTT (Prospective Multicenter Major Trauma Transfusion) study, which enrolled 1245 adult trauma patients in 10 Level I centers in 2009-2010 to measure outcomes after

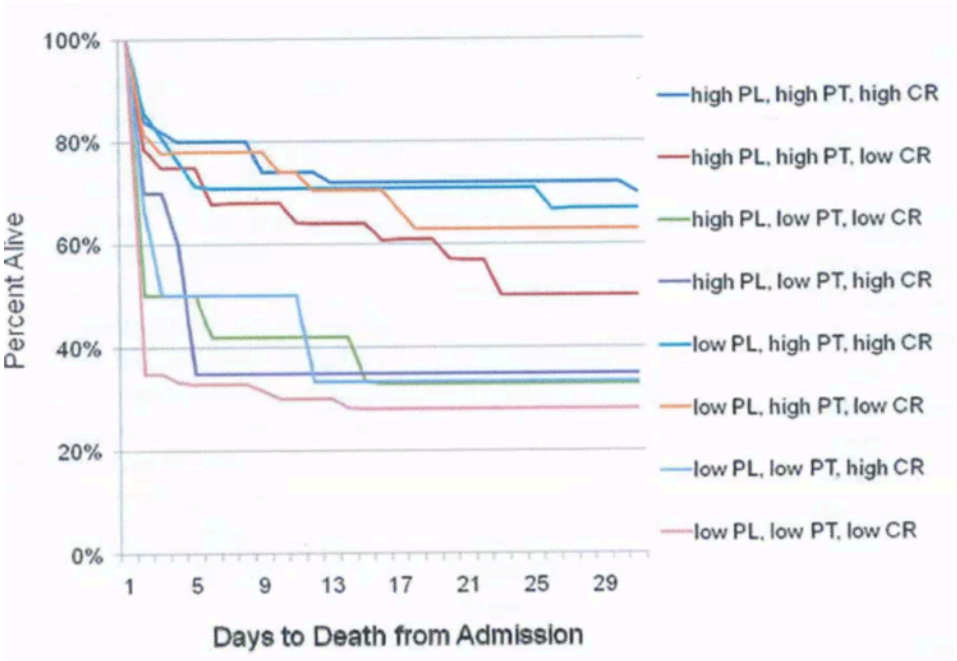


Fig 8. Survival curve.
Source: Shaz et al. Increased number of coagulation products in relationship to red blood cell products transfused improves mortality in trauma pts. Transfusion 50: 493-500, 2010.

[12] Dente et al. Improvements in Early Mortality and Coagulopathy are sustained better in pts with blunt trauma after institution of a MTP J Trauma 2009; 66: 1616-24.

a high fixed ratio resuscitation. The study found:[13]

- A median time to death from hemorrhage of 2.6 hrs.,
- Improved plasma:RBC ratios in early resuscitation led to better outcomes, and
- Time to plasma/cryo delayed > 3 hrs in many centers

The second study—PROPPR (Prospective Multicenter Major Trauma Transfusion)—found no difference between a 1:1:1 and a 1:1:2 ratio.[14]

Damage Control Resuscitation Today

Damage control resuscitation significantly changed the management of open abdomens. There is significant less need to abort operations for coagulopathy and significantly less bowel edema in the vast majority of patients. Nevertheless, not everyone believes in open abdomens. One surgeon of my acquaintance has called open abdomen ”a fallacy."

As of 2022, the specific indications for open abdomen are the need for massive resuscitation, with worsening endpoints (base deficit, etc.); planned re-look (shunted vascular structures, visceral viability); and Lack of surgical expertise in mass casualty situations. But the need for significant visceral edema and diffuse coagulopathy really have gone away.

Of course there are still patients who are sick, have worsening endpoints, and who need planned ventral hernia operations. Unfortunately, many surgeons today, especially junior faculty, are not comfortable doing all the things I think they should be comfortable doing. The result is more open abdomens than are necessary.

New Tools

Resuscitative strategies, such as new blood components, increasing use of TEG (thromboelastography)-guided resuscitation, TXA, and whole blood in civilian centers have evolved as discussed earlier. So have negative pressure techniques, which clearly have appeal—they facilitate fluid loss quantification and make patient management easier. Patients on negative pressure do not lie in puddles of resuscitative fluid. According to the vendors, they even prevent fascial retraction.

Over the years there have been a variety of homemade wound vacs. The Barker wound vac is amongst the most well described. A very cheap dressing consisting of a non-adherent drape, gauze, JP, and Ioban, it was reported by Barker et al. in 2006[15] that of 258 trauma/vascular patients with 717 changes, 68% had fascial closure, 15% had complications (5% fistula), and the in-hospital mortality rate was relatively low at 26%.

Commercially, KCI sells wound vac products which I have used with success. The second generation of wound vac is the Abthera, which is in ubiquitous use at Grady. It is hard to say the commercial systems are any better than homemade wound vacs but the vendors claim their have more uniform negative pressure, enhanced fluid removal from the parabolic gutters, medial traction on the fascia without sutures, and improved visceral protection.

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[13] J Trauma ACS, Supplement to July 2013 (Vol 75, Issue 1) editio.

[14] Holcomb et al. Transfusion of Plasma, Platelets and BC in a 1:1:1 vs. 1:1:2 Ratio and Mortality...The PROPPR RCT., JAMA. 2015, 313(5): 471

[15] Barker et al. Experience with Vacuum-Pack Temporary Abdominal Wound Closure... J Trauma 2006.

Kirkpatrick[16] et al. (2015)[17] compared home-made the Barker wound vac versus the Abthera in 45 randomized patients (23 Abthera, 22 Barker) and found no significant difference in closure rates or any other inflammatory markers, although they did note a (possibly spurious) improved 90 day mortality rate in the Abthera patients that they could not explain.

Olina et. al (2015)[18] also compared standard wound vac (WV) with Abthera, prospectively, in 73 patients (46 WV, 27 Abthera). The primary fascial closure rate with the Abthera was better 41% vs. 12%) but the fistula rate was unchanged and days-to-closure was also better.

So, some have come to the conclusion that Abthera might be a step forward. However, negative pressure in cases where there are intestinal suture lines is not without problems. Lindstedt et al. (2013) found significant decreases in intestinal wall blood flow in both a Barker wound vac and an Abthera. In a pig model, they demonstrated two thirds blood flow at just -50 mHg pressure, falling even further to about 40% at -125 mmHg. Therefore caution is necessary in using negative pressure on patients who have intestinal suture lines.

There have been further evolutions in the wound vac, including a fascial traction system, a wound vac plus fascial sutures (basically a modified visceral packing technique) that had 100% fascial closure rate. Balancing fascial preservation while aggressively trying to close the open abdomen and avoiding a planned ventral hernia is the ultimate aim.

Planned Ventral Hernia (PVH)

At some point, in many patients the fascia just will not close. It may have retracted, it may have been lost to debridement, or the patient may have persistent and ongoing multi-system organ failure and persistent bowel edema. PVH must then be performed, but junior surgeons tend, in my experience, to be very reluctant to do them.

The PVH technique involves four phases:

1. Apply Vicryl mesh,
2. Let it granulate,
3. Do a skin graft in the abdominal wall, and
4. Definitively reconstruct after six to 12 months.

Fabian et al.(1994)[19] showed in a study of 88 ADA patients a low (9%) fistula rate and no wound-related deaths. While it was very morbid (the patients were discharged with massive ventral hernias) it did allow them to leave the hospital.

A few pointers for the surgeon to bear in mind are:

- Sew to the skin, not to the fascia, so as preserve the fascia.
- Use a double layer of Vicryl mesh to lower the risk of fistula.
- Vicryl mesh has almost no tensile strength so it should be relatively loosely applied and it will stick down on the bowel mass; otherwise, the mesh may pull away.

In Phase 2 (granulation), some patients will granulate through the mesh while others will form a separate interface and the mesh will pull

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[16] Dr. Kirkpatrick was a trauma fellow on Lucas and Ledgerwood's service at Wayne State when I was a fourth year resident. He is now a senior surgeon in Calgary, Canada.

[17] Kirkpatrick et al. Acute Neg Pressure RCT. Annals of Surgery 2015

[18] Olona et al. Comparative study of open abdomen treatment... Hernia 2015.

[19] Fabian TC, Croce MA, Pritchard FE, Minard G, Hickerson WL, Howell RL, Schurr MJ, Kudsk KA. Planned ventral hernia. Staged management for acute abdominal wall defects. Ann Surg. 1994 Jun;219(6):643-50; discussion 651-3. doi: 10.1097/00000658-199406000-00007. PMID: 8203973; PMCID: PMC1243212.

off over time, with the granulation bed underneath it. The former takes a lot longer than the latter. Covering the mesh with a wound vac until 24 hours prior to skin grafting, then replacing it with a sloppy wet Sulfamylon slurry, will help reduce the bacterial count and result in a fairly good take for a split thickness skin graft.

The granulation bed should be secured to the edge of the normal skin, the bowel being underneath. A 100% take is unlikely but 90-95% is a good take.

Any urge to do early reconstructions on open abdomens should be resisted. Component separations and big mesh closures may burn a surgical bridge, and patients who have reached the planned ventral hermia stage are not in good shape—they are nutritionally ill, repleted, and deconditioned. At that stage, a patient discharge is a win.

Recap of Key Concepts

1. Open abdomens are very morbid and while there should be no hesitation in leaving them open if necessary, but it should be necessary—open abdomen should not be overused.
2. A sense of urgency is important around an open abdomen.
3. Decision making is complex and needs to be nuanced
4. Long-term thinking is important in relation to preserving the fascia.

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Appendix

A Note on Institutional Influences

Unlike most surgical procedures and techniques, the management of the open abdomen is in some ways institution specific, so knowing something about the institutions that have influenced a surgeons's approach to open abdomens can have explanatory value.

Wayne State University School of Medicine and the Detroit Medical Center together constitute one of the iconic healthcare institutions in the United States, and I had the good fortune to have been trained here.

I have also had the good fortune to spend my subsequent career in another iconic institution: Emory University and Grady Memorial Hospital. Like WSU and the DMC, Emory and Grady have a long and storied history beginning in the 19th century.

Grady was named after Henry Woodfin Grady, an Atlanta philanthropist who died of pneumonia in 1889 at the young age of 39. The original hospital, built in 1892, is still standing.

One of Grady's claims to iconic fame is that it boasts the oldest hospital-based EMS system in the country. The hospital's first patient, Mr. Allen Kimball, became the ambulance driver. Grady EMS covers most of the city of Atlanta and, since Grady is the only level one trauma center in the city, with 12,000 activations and 8,000 admissions, it is extremely busy.

Less to its credit, Grady was a segregated hospital until as recently as the 1960s. The modern building was built as an H shape, with African American patients in one wing of the H and Caucasian patients in the other.

Grady has also seen its share of disasters, including the Centennial Olympic Park bombing[20] and most recently the the Bluffton bus crash.[21]

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[20] A domestic terrorist pipe bombing attack on July 27, 1996, during the Summer Olympics.

[21] March 2, 2007, on Interstate 75 in Atlanta. A bus carrying 36 passengers crashed through a bridge parapet, killing seven.

Fig. A-1 Grady Hospital. The original (1892) building on the left is flanked by the modern current hospital on the right.

Fig. A-2. Grady's first ambulance, driven by its first patient, was hit by a train in its first week of operation.