Taking Control Early:
Best Practices in Managing Patients with an Open Abdomen

Learning Objectives

• Employ early intervention for managing open abdominal wounds
• Review nontrauma surgical scenarios with an open abdomen, including sepsis, peritonitis, transplant, appendicitis, and abdominal aortic aneurism repair
• Implement best practices to reduce the occurrence of fistula

Faculty

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Albert Einstein Medical Center
Philadelphia, Pennsylvania
Open Abdomen

“The open abdomen technique is one of the greatest advances in recent times and has enormous application in the daily management of the critically ill or injured patient.”

– RR Ivatury

We just made a mess of it until now

Management Goals

• Planning—is the key element in managing a patient with an open abdomen
• Management of IAH/ACS
• Resuscitation—of crystalloids/MTP adoption
• Adoption of Damage Control Mentality
• Early enteral nutrition
• Effective temporary abdominal closure techniques
The Problem

- Open abdomen use has increased because of risks of abdominal hypertension and abdominal compartment syndrome
- Studies have clearly shown that without adequate stabilization and control of systemic derangements, prolonged time in the operating room has negative effect on outcome
- Therefore, damage control was developed to increase outcomes based on rapid evaluation and stabilization
- Significant morbidity with this procedure including: fistulas, renal failure, acute respiratory distress syndromes, ACS, and giant abdominal wall hernias

ACS = abdominal compartment syndrome.

Paradigm Change in Managing the Open Abdomen

- Stopping the intestines from falling to the floor is not a goal of therapy
- To minimize complications and improve outcomes, the entire local and systemic effects of the open abdomen must be treated
- The goal is a change from TAC to TMOA

TAC = temporary abdominal closure; TMOA = total management of the open abdomen.

Elements in Managing the Open Abdomen

- Understanding the concepts of ACS/IAH
- Understanding the intra-abdominal inflammatory response
- Concepts in managing sepsis and trauma
- Concepts in TAC/TMOA

IAH = intra-abdominal hypertension.
Most significant pitfall in managing the open abdomen is the lack of understanding of the pathophysiology, treatment, and prevention of ACS/IAH.

Considerations with the Open Abdomen

IAP

“IAP is the steady-state pressure concealed within the abdominal cavity.”

- Elevated IAP is a common finding in the ICU
- IAP increases and decreases with respiration
- IAP is directly affected by:
  - Solid organ or hollow visera volume
  - Space occupying lesions
  - Ascites, blood, fluid, tumors
  - Conditions that limit expansion of the abdominal wall
  - Burn eschars, third-space edema

IAP = intra-abdominal pressure; ICU = intensive care unit.

APP

“APP = MAP minus IAP = MAP – IAP”

• The critical IAP that leads to organ failure varies by patient
• A single threshold IAP cannot be globally applied to all patients
• Analogous to cerebral perfusion pressure, APP assesses not only the severity of IAP, but also the relative adequacy of abdominal blood flow
• APP is superior to IAP, arterial pH, base deficit, and arterial lactate in predicting organ failure and patient outcome
• Failure to maintain APP >60 mm Hg by day 3 predicts survival

IAH

“IAH is defined by a sustained or repeated pathological elevation in IAP ≥12 mm Hg”

• Not a new concept and was recognized 150 years ago
• Graded clinical pressure change
• The definition of IAH has varied over the years with thresholds as high as 40 mm Hg being previously advocate
• Most clinicians are therefore concerned only when IAP exceeds 20 mm Hg to 25 mm Hg; this is well above the IAP that can cause organ dysfunction and failure
• Failure to intervene when IAP rises above 25 mm Hg is associated with poorer outcome

Key Elements of IAH

• There is a direct correlation between IAH and outcome
• Sugrue et al showed that IAP >18 mm Hg was an independent predictor of renal failure
• Ivatury et al showed intervention to reduce IAH/ACS leads to a reduction in death, ranging from 36% to 11%
• Joseph et al showed a direct correlation with intractable ICP and elevated IAP
Impact of IAH on Outcomes

- IAH is the engine that leads to ACS; it is an important graded clinical entity
- There is a direct effect on outcomes using IAH as a physiologic monitor of organ hypoperfusion and exacerbation of the post-injury inflammatory state
- Lower grades can be managed nonoperatively, but pressures over 25 mm Hg need decompression

IAH Grading

- IAH is graded as follows:
  - Grade I  IAP 12 mm Hg to 15 mm Hg
  - Grade II  IAP 16 mm Hg to 20 mm Hg
  - Grade III  IAP 21 mm Hg to 25 mm Hg
  - Grade IV  IAP >25 mm Hg
- Grade III strong consideration for decompression
- Grade IV decompression essential to prevent permanent organ damage

Realization of the Risks of IAH/ACS

Real-World Mentality
Risk Factors For IAH

“Despite a diverse range of associated conditions...the unifying feature of IAH appears to be the presence of shock requiring aggressive resuscitation with crystalloid fluids”


ACS

“ACS is defined as a sustained IAP >20 mm Hg (with or without an APP <60 mm Hg) that is associated with new organ dysfunction/failure.”

- ACS = IAH + organ dysfunction
- The most common organ dysfunction/failure(s):
  - Metabolic acidosis despite resuscitation
  - Oliguria despite volume repletion
  - Elevated peak airway pressures
  - Hypercarbia refractory to increased ventilation
  - Hypoxemia refractory to oxygen and positive end-expiratory pressure
  - Intracranial hypertension


Conclusions from Malbrain as Far Back as 2004

“Our study suggests that there is no specific type of patient or disease or treatment that reliably indicates when IAP needs to be measured, or when measurement is not necessary in a mixed ICU population. Indeed, it seems that...IAP should be routinely measured.”

**Recommendations: Risk Factors and Surveillance for IAH/ACS**

- Patients should be screened for IAH/ACS risk factors upon ICU admission and in the presence of new or progressive organ failure (Level I evidence).
- Independent risk factors for IAH/ACS include:
  - Large volume fluid resuscitation (>3.5 L/24 hours)
  - Acidosis
  - Hypothermia
  - Coagulopathy/polytransfusion
  - Pulmonary, renal, and hepatic dysfunction
  - Ileus
  - Abdominal surgery/primary fascial closure


**Post-Traumatic Inflammatory State**

- Growing body of evidence to show that the post-traumatic inflammatory state plays an important role in outcomes in trauma patients.
- Secretion of cytokines and other inflammatory substances are stimulated by the over use of crystalloid; over use of blood leads to edema, decreased blood flow, ischemia, worsening of the inflammatory state and as a result:
  - Compartment syndromes develop in any part of the body with potential systemic effects if not controlled locally.

Critical Values in IAH/ACS
Monroe-Kellie Doctrine

- Pressure/volume relationship:
  - At a critical volume, pressure rises dramatically with any additional edema
- Result
  - Reduced perfusion pressure
  - Reduced blood flow
  - End-organ ischemia


Risk Factors for IAH/ACS

1. Diminished abdominal wall compliance
   - Acute respiratory failure, especially with elevated intrathoracic pressure
   - Abdominal surgery with primary fascial or tight closure
   - Major trauma / burns
   - Pneumoperitoneum
   - Hypercapnia
2. Increased intra-luminal contents
   - Gastroparesis
   - Ileus
   - Colonic pseudo-obstruction
3. Increased abdominal contents
   - Hemoperitoneum / pneumoperitoneum
   - Ascites / liver dysfunction
4. Capillary leak / fluid resuscitation
   - Acidosis (pH < 7.2)
   - Hypotension
   - Hypothermia (core temperature < 33°C)
   - Hyperfusion (>10 units of blood / 24 hrs)
   - Coagulopathy (platelets < 50,000 / mm³)
   - Sepsis
   - Pancreatitis
   - Oliguria
   - Massive fluid resuscitation (>5L / 24 hrs)
   - Hypernatremia
   - Hypoglycemia
   - Sepsis
   - Major Trauma / burns
   - Central obesity
   - Damage control laparotomy


So How Is the Pathophysiology of IAH Related to Current Resuscitation Guidelines?
The Unifying Feature of IAH

- Shock requiring aggressive resuscitation with crystalloid fluids
- Crystalloid-based, preload driven, goal-oriented shock resuscitation is the standard of care in North America
  - Sepsis – Surviving sepsis guidelines
  - Trauma – advanced cardiac life support guidelines
  - Burn – Parkland formula
  - Major abdominal surgery – Preoperative loading

Incidence and clinical effects of intra-abdominal hypertension in critically ill patients


- 83 patients admitted to the ICU
- 31% had IAH on admission
- 33% developed IAH during their stay
- 64% occurrence for the whole group
  - 43% mortality
- 12% developed ACS
  - 80% mortality

Fluids–Independent Risk Factor for IAH

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Volume predicting IAH (or ACS)</th>
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<tbody>
<tr>
<td>Malbrain 2005</td>
<td>Mixed ICU</td>
<td>3.5 Liters /24 hours</td>
</tr>
<tr>
<td>Balogh 2003</td>
<td>Trauma</td>
<td>&gt;3 Liters in emergency room &gt;7.5 Liters by ICU (IAP&gt;25)</td>
</tr>
<tr>
<td>Daugherty 2007</td>
<td>Medical ICU</td>
<td>+5 Liters/24 hours</td>
</tr>
<tr>
<td>Vidal 2008</td>
<td>Mixed ICU</td>
<td>+3 Liters/24 hours</td>
</tr>
</tbody>
</table>

Where Does Resuscitation Fluid Go?

Right Here!

Clinical Reality

With the clinical information available about the relationship of IAH and organ failure to allow a patient to progress to ACS is the equivalent of finding a tension pneumothorax on a chest x-ray.

Compartment Syndromes

- There is a clear relationship to over aggressive fluid resuscitation with crystalloids and the development of compartment syndromes.
- While there may be isolated development of compartment syndromes; "multiple compartment syndromes can occur as a result of a futile attempt to optimize circulation with preload driven resuscitation with crystalloids."
- Poly-compartment syndrome

Compartment Syndromes

- There is a clear relationship to over aggressive fluid resuscitation with crystalloids and the development of compartment syndromes.
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Fluid Resuscitation and IAH

- Goal: Balanced resuscitation
  - "Enough but not too much"
- Utilizing both IAP and volume measurements allows judgment of when "enough" has been given
  - Once IAP and central venous pressure/pulmonary capillary wedge pressure starts to rise, total body fluids are sufficient (or excessive) and you need to try something else -- step out of the futile crystalloid preloading cycle
- Still proceed towards early, goal-directed treatment, but utilize IAP to assist in decision making
Pitfall: Lack of a Resuscitation Protocol

- Establish a protocol to include:
  - Minimize use of crystalloids with increased use of 1:1:1; Blood: FFP:PLTS
  - Use of end points of resuscitation as a guide to fluid management: BD, SVO2, Lactate, RVEDVI
- Mandatory serial bladder pressure monitoring in high-risk patients
- Indiscriminate use of crystalloids in resuscitation is the leading cause of IAH/ACS

Back to the Question: When Is Decompression TOO Late

- When ACS develops:
  - ACS is preventable and is due to uncontrolled IAP or lack of monitoring
  - Not recognizing at-risk patients for IAH
  - Patients that have had large volumes of crystalloid with a rapidly increasing IAP that require decompression before the consequences of ACS
  - Not monitoring patients at risk for secondary ACS and allowing progression to organ failure

Management Failures in ACS/IAH

- The reasons for failure of management is an out of control inflammatory response that is “self-sustaining”
- Current practices exacerbate the inflammatory/pressure state
- Established an equilibrium between inflammation and maintenance of organ perfusion

Inflammatory Response

- Key to understanding the inter-relationship of IAH/ACS
- Root cause of most complications seen in septic and traumatic states
- Minimizing the effect of IAH/ACS and control of sepsis and minimizing crystalloid is the goal of TMOA

Effects of Increased IAP

- Increased IAP produces
  - Decreases in bowel submucosal TPO$_2$ without similar changes in extra-abdominal TPO$_2$
  - Severe intestinal ischemia
  - Decreases in cardiac index
  - Increases in pulmonary artery occlusion

TPO$_2$ = bowel tissue oxygenation.

Ischemia/Reperfusion Injury

Hemorrhagic Shock

Resuscitation

Global Ischemia/Reperfusion Injury

Increased Capillary Permeability

Hydrostatic Edema

Mesenteric Venous Hypertension
(Secondary to Abdominal Packing)

Increased Hydrostatic Pressures and Decreased Oncotic Pressures

Hydrostatic Intestinal Edema

Pathophysiology of ACS

Inflammation

Δ MicroQ

Injury

↑ Vas Perm

Edema & Ascites

↑ IAP

ACS

More Edema & Ascites

↓ LymphQ

IAP

Vas Perm

Edema & Ascites

ACS

More Edema & Ascites

LymphQ

Edema & Ascites
Are Lymph and Ascites Toxic?

- Toxic lymph
  - Ligate mesenteric lymph duct
    - Lung injury
    - Neutrophil activation
    - Mortality
  - Mesenteric lymph \(\rightarrow\) EN apoptosis and ...perm

- Toxic ascites
  - Peritoneal NPT (remove ascites)
  - Reduced systemic inflammation
  - Reduced organ injury (MODS)
  - Reduced mortality

NPT = negative pressure therapy; MODS = multiple organ dysfunction syndrome.

Peritoneal and Systemic Inflammation

Plasma TNF


NPT vs PD Survival

### IAH, MOF, and Mortality

<table>
<thead>
<tr>
<th></th>
<th>No IAH (n = 47)</th>
<th>IAH (n = 23)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>4 (8.5%)</td>
<td>10 (43.5%)</td>
<td>.006</td>
</tr>
<tr>
<td>MODS</td>
<td>0.8 ± 1.9</td>
<td>4.3 ± 3.7</td>
<td>.0001</td>
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</tbody>
</table>


### ACS, MOF, and Mortality

<table>
<thead>
<tr>
<th></th>
<th>No ACS (n = 49)</th>
<th>ACS (n = 28)</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>12%</td>
<td>43%</td>
<td>.01</td>
</tr>
<tr>
<td>MOF</td>
<td>8%</td>
<td>32%</td>
<td>.01</td>
</tr>
</tbody>
</table>


### Prevention of ACS

- ACS and complications of the open abdomen is potentially preventable in most cases can be minimized by:
  - Closely monitoring of abdominal pressure
  - Using an open abdomen technique in high-risk patients
  - Controlling IAP in the open abdomen
  - Early decompression with trends of IAP leading to ACS
Monitoring IAP:
The Key to Early Intervention

IAP Monitoring

• Clinical judgment
• Homemade pressure transducer technique
• Standard IAP monitoring kit

Clinical Judgment for Detecting Elevated IAP

• Prospective, blinded trial – Staff physician judgment
• Results: <50% of the time was the clinician able to determine when IAP was elevated
• “…findings suggest that more routine measurements of bladder pressure…”

**Pitfalls in IAP Monitoring**

- Improper placement of the transducer: zeroed at midaxillary line
- Over distention of the bladder
- When using manometric fluid measurements, mm H$_2$O need to be converted to mm Hg for readings consistent with guidelines

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**Pitfall IAH/ACS Management: Positioning**

![Graph]

- Stretch out Head-of-Bed Elevation (degrees)
- Overweight
- Obese
- Normal

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**Pitfall: Over Distention of Bladder**

"The reference standard for intermittent IAP measurement is via the bladder with a maximal instillation volume of 25 mL sterile saline."
Standard IAP Monitoring Kit

- Closed system in-line with the foley catheter
  - Once attached, it is left in place during entire time IAP is measured
  - 30 seconds to measure IAP
  - Standardized measurement
  - No reproducibility errors

AbViser: Reproducibility Study

- Nursing driven study with 89 different nurses participating
- Excellent intra- and inter-observer reproducibility


Effective Management of the Open Abdomen
Use of an Effective TAC Protocol

- Low trigger to leave abdomen opened
- Planned early closure
- Use of an effective TAC device that will
  - Effectively reduce cytokines
  - Minimize IAP to physiologically acceptable levels
  - Minimize abdominal retraction
  - Minimize bowel fixity

Evolution In Management of the Open Abdomen

- Initially used to control intra-abdominal contents and were static
- Evolution of devices that are more dynamic with recognition that multiple factors must be controlled while an abdomen is opened
- Including: inflammatory fluid, minimize IAH, and preserve the abdominal wall
- Early closure has been shown to decrease complications and improve overall outcomes
- A standardized approach is the key to controlling the physiology

TMOA

- Various techniques achieve temporary closure
- TMOA manages complex biologic factors observed in the open abdomen
  - Inflammatory response
  - Wound healing/mechanics of the abdominal wall
  - Improve closure and decrease complications
  - Resuscitation (minimizing crystalloid)
- Cornerstone of an integrated approach incorporating a comprehensive management guideline
**Damage Control Paradigm**

<table>
<thead>
<tr>
<th>Traditional Resuscitation</th>
<th>Damage Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggressive crystalloid</td>
<td>Balanced resuscitation</td>
</tr>
<tr>
<td></td>
<td>• Crystalloid/colloid</td>
</tr>
<tr>
<td></td>
<td>• Vasoactive medications</td>
</tr>
<tr>
<td>Surgical management only</td>
<td>Comprehensive medical and surgical management</td>
</tr>
<tr>
<td>IAP measurements only to predict decompression</td>
<td>IAP-guided therapy</td>
</tr>
<tr>
<td>Emergent decompression</td>
<td>Prophylactic decompression</td>
</tr>
<tr>
<td>Decompression for IAP &gt;30 mm Hg to 40 mm Hg</td>
<td>Decompression for IAP &gt;25 mm Hg</td>
</tr>
<tr>
<td>Late closure</td>
<td>Early closure</td>
</tr>
</tbody>
</table>

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**Types of TAC**

- Bogota Bag
- Absorbable mesh – Vicryl®
- Nonabsorbable – Marlex®, Gortex®
- "Vac Pac" closure
- ABThera™ Open Abdomen NPT System
Methods of TAC

Desired Goal

Keys To Successful Management

1. Open early to avoid IAH/ACS
2. Prevent visceral adherence to the abdominal wall
   - Prevention starts at the first operation!
   - Maintain your options for subsequent closure
3. Prevent lateralization and loss of abdominal domain
   - Actively combat fascial retraction
4. Avoid enteric fistula formation
   - Resuscitate early and properly
   - Avoid elevated IAP!
5. Start closing as soon as physiologically reasonable
Vacuum Pack Technique (Barker VAC Pac)

- 4-year experience from University of Tennessee College of Medicine in 1997; reviewed 93 patients with vacuum assisted abdominal closure with ultimate STSG
- Reviewed the experience with 112 trauma patients in 2000
- 55% had primary closure

STSG = split-thickness skin graft.

Open Abdomen

Hydrostatic Bowel Edema
Inflammation Toxic Ascites

ACS IAH

Barker “Vacuum-Pack”: Uneven Distribution of Negative Pressure

APPLIED SUCTION = -125 mm Hg

Actual Intra-abdominal Suction

ABThera™
Even Distribution of Negative Pressure

APPLIED SUCTION = -125 mm Hg

Actual IAP


Pressure at the Bowel Surface during Topical NPT of the Open Abdomen

• Porcine model to study pressure at bowel surface with ABThera™
• Pressures at -50,-75,-100,-125, and -150 mm Hg
• Pressures at outer foam corresponded with applied pressure
• Median pressure at the bowel surface was between -2 mm Hg and -10 mm Hg regardless of the surface pressure


Are Commercial Negative Pressure Systems Worth the Cost in Open Abdomen Management?

• Retrospective review
• 74 patients treated with a TAC
• 37 patients with Barker Vacuum Pack Technique (2009-2010)
• 37 patients with ABThera™ NPT (2010-2011)
• Age and BMI higher ABThera™, all other variable same
• 33/37 (89%) successful midline closure with ABThera™
• 22/37 (59%) successful midline closure with Barker
• P < .05, odds ratio 7.97 favoring ABThera™

Components

- Nonadherent polyurethane fenestrated inner
  - Prevents bowel from adhering to the abdominal wall
  - Allows for fluid drainage (improved with ABThera™ Dressing)
  - Prevents V.A.C.® GranuFoam™ Dressing from sticking to bowel

Components

- Blue foam – V.A.C.® GranuFoam™ Dressing
  - Open cell hydrophobic dressing
  - Negative pressure manifold
  - Manifolds negative pressure, thus facilitating the closure of the abdominal wall

Components

- ABThera™ SensaT.R.A.C.™ Open Abdomen Dressing Compatible with InfoV.A.C.® and V.A.C.ATS® Therapy System
  - To maintain constant negative pressure at the wound site not in the canister
- Interface pad is used with ABThera™ open abdomen NPT system
- Adherent drape—water tight seal
- Use of the adherent drape is key to a negative pressure environment
Placement of Visceral Protective Layer

- Full deployment to all gutters
- Can be placed without cutting
- Use of a blunt instrument to help placement

Cutting and Sizing of VPL

- Cut plastic VPL to place around colostomies and feeding tubes
- If cutting the VPL is needed, cut in the center of the square foam and pull off

VPL = visceral protective layer.

Proper Placement of the VPL
Placement of Foam

- Fig. 1 Placement of entire piece of foam over the VPL and under the fascia
- Fig. 2 Place the second piece of foam to conform to the skin
- Fig. 3 Applied adhesive to skin, place the trac pad and apply suction

Placement of Adhesive Layer

- 2-person placement
- Placed transversely and not pulled tight
- Place in a shingled pattern

Personal Clinical Experience with ABThera™ Open Abdomen NPT

- Simpler than the Barker “vacuum-pack”
  - Placement in the gutters is easier
  - “VPL” stays in place
  - Fixity is less
- The limbs of the ABThera™ nonadherent polyurethane fenestrated inner can be cut to reach specific areas of concern
- The open abdomen is much drier with better fluid removal
- The suction pump is much simpler
Abdomen Allowed to Granulate with Skin Graft

Facilitating Fascial Closing

“If you fail to plan, you plan to fail.”

Begin planning your closure as soon as you open the abdomen

Enteric Fistulas

• The dreaded complication of the open abdomen
• Most likely a complication of
  – Inadequate resuscitation
  – Visceral malperfusion
  – Incorrect TAC management
  – Exposed anastomoses and tubes
Enteric Fistula Complication

• Recent studies suggest that TAC is NOT the culprit
  - Prospective, 5-year study of NPT
    - 4.7% fistula rate
  - Prospective, 6-year study of various TACs
    - 5.0% fistula rate
    - Fistula rate correlates with
      - Timing of abdominal decompression
      - Closure type
      - Resuscitation algorithm


Total Open Abdomen Management

Comprehensive abdominal management significantly decreases complications and increases patient survival

<table>
<thead>
<tr>
<th>Year</th>
<th>APACHE 2</th>
<th>Days to Closure</th>
<th>Fistula</th>
<th>Primary Closure</th>
<th>STSG</th>
<th>Survival</th>
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<tbody>
<tr>
<td>2002</td>
<td>23 ± 9</td>
<td>22 ± 21</td>
<td>16%</td>
<td>59%</td>
<td>13%</td>
<td>50%</td>
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<tr>
<td>2003</td>
<td>20 ± 8</td>
<td>17 ± 19</td>
<td>13%</td>
<td>72%</td>
<td>23%</td>
<td>57%</td>
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<tr>
<td>2004</td>
<td>22 ± 8</td>
<td>17 ± 16</td>
<td>3%</td>
<td>69%</td>
<td>15%</td>
<td>53%</td>
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<tr>
<td>2005</td>
<td>22 ± 8</td>
<td>16 ± 17</td>
<td>9%</td>
<td>72%</td>
<td>19%</td>
<td>63%</td>
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<tr>
<td>2006</td>
<td>20 ± 9</td>
<td>13 ± 16</td>
<td>8%</td>
<td>76%</td>
<td>12%</td>
<td>70%</td>
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<tr>
<td>2007</td>
<td>20 ± 9</td>
<td>10 ± 10</td>
<td>3%</td>
<td>81%</td>
<td>3%</td>
<td>72%</td>
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</table>

Open early, close early!


Financial Implications of Closure

Earlier intervention = decreased resource utilization

<table>
<thead>
<tr>
<th></th>
<th>Primary</th>
<th>Staged</th>
<th>Mesh</th>
<th>Skin Only</th>
<th>STSG</th>
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<tbody>
<tr>
<td>ICU days</td>
<td>11 ± 12</td>
<td>21 ± 14</td>
<td>24 ± 14</td>
<td>23 ± 14</td>
<td>32 ± 19</td>
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<tr>
<td>Hospital days</td>
<td>25 ± 21</td>
<td>42 ± 21</td>
<td>44 ± 20</td>
<td>49 ± 22</td>
<td>70 ± 39</td>
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<tr>
<td>Ventilator days</td>
<td>9 ± 10</td>
<td>19 ± 12</td>
<td>23 ± 16</td>
<td>20 ± 16</td>
<td>31 ± 23</td>
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<tr>
<td>Days to Closure</td>
<td>5 ± 4</td>
<td>19 ± 9</td>
<td>16 ± 11</td>
<td>21 ± 14</td>
<td>39 ± 23</td>
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<td>Fistula (%)</td>
<td>1.3</td>
<td>1.3</td>
<td>20</td>
<td>11</td>
<td>36</td>
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<tr>
<td>Charges ($1000)</td>
<td>$227</td>
<td>$376</td>
<td>$491</td>
<td>$450</td>
<td>$598</td>
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<tr>
<td></td>
<td>± 206</td>
<td>± 209</td>
<td>± 279</td>
<td>± 274</td>
<td>± 335</td>
</tr>
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</table>

Philadelphia Bag

- There are clinical situations, because of loss of domain, in which packing and severe bowel edema will not allow the full ABThera™ Open Abdomen NPT system to be applied.
- A modification of the system can be used to place only the VPL sutured to the skin with suction applied.
- This allows for the application of NPT without exacerbating the extreme bowel and abdominal wall edema.

Transabdominal GSW

- GSW abdomen
- Hypotensive
- GCS 10
- BP 90 systolic
- Lactate 5.0

GSW = gun shot wound; GCS = Glasgow Coma Scale; BP = blood pressure.
Injuries

Combined grade 4 colon injury, grade 3 liver injury, grade 4 pancreaticoduodenal injury

Damage Control and ABThera™

Traumatic Whipple Resection

Patient was taken back to the OR for serial explorations and had a colectomy with ostomy, Whipple resection and primary closure of the abdomen in one week.
Shot Gun Blast Abdomen

- Point blank shot gun blast
- Eviscerated bowel on presentation
- Damage control procedure

Initial Procedure: Damage Control

Injuries right colon, blast and tissue loss abdominal wall

Blast Effect Silver Foam
Return to OR Closure Midline Incision

Patient had midline closed with interrupted sutures and Alloderm underlay to close abdominal wall defect. Silver foam placed over the repair.

Creation of Skin Flaps and Closure

Secondary ACS
Bowel Ischemia with Increased IAP

48 Hours ABThera™

Patient had 48 hours of AbThera™ placement that reduced the edema and allowed for primary closure of the fascia

Grade 4 Liver Laceration, DCL, Packing
Closure Abdominal Wall

Summary

• Management of an open abdomen is complex
• Just “keeping the bowel in” is not reflective of the biology of an open abdomen
• The open abdomen is the engine for systemic complications: systemic inflammatory response syndrome, MODS
• TMOA is designed to manage the patient