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TRAUMA

Rounds

## Mass Casualties — A Call for Preparation, Triage Training, and Coordination

by Alan D. Murdock, Col., USAF, MC

As the one-year anniversary of the Boston Marathon bombings has just passed, one can't help being astounded at the high survival rate despite the severity of the injuries, due to the application of sound field triage, rapid transport, and coordinated care of the receiving trauma hospitals. On April 15, 2013, at 2:49 p.m. EST, two improvised explosive devices (IED) were detonated near the finish line of the Boston Marathon, immediately killing three and injuring 264 people. Of the 264 injured, 164 patients were rapidly assessed, triaged and transported to local trauma centers, with adult trauma centers receiving an average of 31 patients within an hour of the bombing. Remarkably, all survived their injuries.

### Preparation

Although many of the actions on that day were fortuitous, due to timing and location of the bombings (i.e. no elective operations scheduled due to Patriots' Day, six Level 1 trauma centers (5 adult and 1 pediatric) located within short distances, and emergency medical operations located at finishing line), deliberate actions stemming from September 11, 2001 led to its success. In November 2002, the city of Boston, with the coordination of emergency medical services (EMS) and 10 hospitals, cooperated in a large-scale disaster drill with stimulated explosion of dirty bombs. After the exercise, hospitals and agencies continued to work to refine the response, with many in-hospital and citywide exercises over the next 10 years. Additionally, Boston hospitals analyzed the timeline and nature of injuries by the University of Colorado Health System Center's response to the Aurora, Colorado theater shootings revealing the need to perform further incident command training. Finally, in an effort to improve communication and team performance, trauma surgery and emergency medicine worked to provide team training with the help of simulation centers. All the efforts resulted in an increasingly well-prepared system to coordinate and provide care for a large number of injured patients.

### Triage

Besides preparation, triage is arguably the most important element in mass casualty management. Due to the marathon's medical operations, patients had a short time from injury to medical attention. Based on lessons learned from wars in Iraq and Afghanistan, EMS technicians and physicians at medical tents and ambulances had tourniquets which

*(Continued on Page 2)*

## Mass Casualties — A Call for Preparation, Triage Training, and Coordination *(Continued from Page 1)*

controlled extremity bleeding. This maneuver contributed most to immediate survival, since over 50% of pre-hospital deaths related to blast injuries are secondary to exsanguination. Patient transport to local trauma system was then coordinated through a number of operations centers, including the Boston Medical Intelligence Center (MIC) and Massachusetts State Emergency Operation Center (SEOC). The MIC is a high-technology communications and information sharing facility that allows Boston EMS, first responder agencies, hospitals, public health departments, community health centers, long-term care facilities, state and federal as well as public and private partners to share information and work collaboratively in response to large-scale incidents. On this day, MIC notified trauma centers within minutes of the event and allowed them to immediately clear emergency departments, open operating rooms, and “reverse” triage (safely discharging or transferring inpatients and diverting hospital resources to those patients who need it most). The SEOC consistently updated hospitals with information on the number of patients en route and what injuries to expect via the WebEOC system, an incident management software platform, which also provided real-time data on each hospital’s equipment and staff availability. Hospitals remained in communication with coordination centers during the aftermath of the event exchanged information, including patient identification information so patients and families could be reunited.

After field triage and transport, trauma centers had to perform in-hospital triage. Numerous strategies have been advocated, including early discharge of patients from intensive care units, cancellation of elective admissions and operations, appropriate use and reuse of resources, and integration of stockpiles. Previous bombing experiences demonstrated instances of “overtriage,” which has been associated with increased mortality. Overtriage is defined as the immediate care of patients who don’t have critical injuries in a mass casualty setting, thus overloading the medical facility and delaying care of the most severely injured.

### **Blast Injury and Management**

The morbidity and mortality of blast injuries are related directly to the victim’s distance from ground zero. The primary injury from the shock wave is due to rapid pressure changes concentrically from the blast site and affects gas- and fluid-filled organs (i.e. ears, lungs, intestines). Secondly, projectiles from IED and nearby materials (i.e. dirt, metals, clothing, human) penetrate soft tissues, bone and organs. These injuries are usually limited to the blast’s line of sight. Finally, victims might experience tertiary blast effect resulting in blunt injuries from being propelled by the blast wave. In the Boston bombing, the small size and ground position of the IEDs were primarily responsible for lower-extremity injuries, including multiple primary amputations as well as secondary amputations due to extensive tissue damage.

Hospitals receiving 20-30 patients at one time requires employing crisis standards of care including re-triage of patients into immediate intervention (control of airway, control of hemorrhage), delayed interventions (i.e. stable patients with open fractures or perforated bowel) and even expectant (no intervention, comfort measures only) if resources are completely overwhelmed. In an effort to optimize patient flow, hospitals created a team of a nurse, trauma surgeon, and scribe who took inventory of the number of patients, including demographics, vital signs, and injuries, with a surgical resident assigned to each patient to provide proper ATLS protocol was followed. Communication with incident commanders and operating room staff was constant.

Many hospitals borrowed techniques from the military, marking vital signs and injuries directly on the patient with an indelible marker. Hemodynamically unstable patients were taken immediately to the operating room, which accounted for approximately 30% of injured patients. Ultimately 50% of the patients presenting required some type of operation, including management of traumatic amputation and open fractures, fasciotomies, extensive debridement and foreign body removal, and completion amputation with reconstruction. Patients who did require surgical intervention averaged 5-6 operative procedures, with patients undergoing staged lower-extremity salvage and staged below-knee amputation salvage accounting for nearly half of all procedures.

Unique aspects of blast injury management included heavy contamination of wounds (i.e. nails, metallic BBs, pieces of clothing and human bone/soft tissue); infectious disease assessment for empiric antibiotic therapy; possible viral disease transmission from human remains; multiple debridements with extensive use of vacuum-assisted closure dressing; and wound closure with reconstructive salvage efforts (i.e., skin grafts, nerve repair, local tissue advancement, pedicle muscle flaps, free flap). Regardless of which primary services operated on the patient, trauma surgery, plastic surgery, vascular surgery, and orthopaedics staff surveyed all mass casualty patients to assess for any service specific needs. Additionally, new outpatient clinics were established for follow-up including trauma surgery, plastic surgery, orthopaedics, infectious disease, social work, and psychologists to provide a full multidisciplinary approach to the care of mass casualty injured patients.

### **Conclusion**

Preparation via wide-scale training, design of triage strategies, controlled patient flow, and proper resource use is the key to the highest survival during mass casualty events. Preemptive communication and coordination are mandatory for the success of a future crisis management.

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### Additional Reading

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UPMC prints *Trauma Rounds* with an eye toward helping emergency medicine professionals improve their preparedness and practice. To this end, each issue includes a Pennsylvania Department of Health-accredited continuing education test for one hour of credit for FR and EMT-B, EMT-P, and PHRN. This issue's test can be accessed online at **[UPMC.com/TraumaRounds](http://UPMC.com/TraumaRounds)**.

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# Chest Wall Reconstruction: Surgical Management of Flail Chest

by Graciela Bauzá, MD

## Introduction

Blunt thoracic trauma accounts for 20-25% of trauma related deaths, with rib fractures occurring in more than 2/3 of patients with chest trauma. Morbidity and mortality from rib fractures are significant and are associated with respiratory complications such as pulmonary contusions, pneumonia, respiratory failure, and sepsis. The incidence, morbidity, and mortality of rib fractures are rising as the population ages. Mortality is doubled and the incidence of pneumonia is significantly higher in patients older than 65.

Bony chest trauma can range from a single rib fracture to multiple rib fractures. Two or more ribs fractured in two or more places, resulting in the paradoxical movement of a section of the chest wall, is known as flail chest. This is often associated with other injuries, such as pulmonary contusion, pneumothorax, hemothorax, and tracheobronchial injuries.

Flail chest is associated with respiratory distress because the chest wall is unable to assist in proper respiratory mechanics and underlying lung contusion leads to pulmonary shunting and worsening hypoxemia. In addition to affecting the mechanics of breathing, pain from fractured ribs leads to splinting, with inadequate chest expansion, decreased tidal volume, weak cough, and poor pulmonary toileting. These patients often require immediate intubation in the field or trauma bay. Despite significant trauma, only 10-15% of thoracic injuries require operative intervention.

The management of rib fractures has been centered on pain control and pulmonary toileting. Patients with flail chest or severe chest trauma are best managed in a trauma center and are often admitted to the intensive care unit for close observation, gas



Plated ribs

exchange monitoring, respiratory therapy with incentive spirometry, and attention to pain control. Various modalities are combined to address pain receptors including acetaminophen, NSAIDs, opioids, anticonvulsants, and regional analgesia (e.g., paravertebral nerve blocks, epidural, subcutaneous infusion pumps, lidocaine patches). Pain control is of the utmost importance in the successful management of these patients. Mechanical ventilation is used when a patient has exhausted their pulmonary reserve and is unable to maintain adequate saturation or protect their airway. Of patients with multiple rib fractures, a majority endure chronic pain and approximately 60% are permanently disabled and never return to work.

More recently, the surgical management of chest wall trauma has become more popular amongst trauma, thoracic, and orthopaedic surgeons.

## Indications for chest wall stabilization

### Chest wall defect or lung herniation

- Segmental bone defect with lung herniation through rib cage
- Crush injury with collapse of the structure of the chest wall and loss of thoracic volume

### Flail chest, non-flail rib fractures

- Significant chest wall collapse or deformity with/without paradoxical wall motion
- Impalement of lung or other solid organs (e.g., liver, spleen) by fractured ribs
- Diaphragmatic injury from rib fracture
- Displaced rib fractures of at least one rib width, overriding segments
- Symptomatic fracture movement (i.e., "clicking")

### Acute or chronic pain

- Severe pain with splinting resulting in respiratory insufficiency, failure to wean from pain medication/oxygen, or failure to tolerate physical activity while in-hospital
- Disabling pain with inability to return to activities of daily living, work

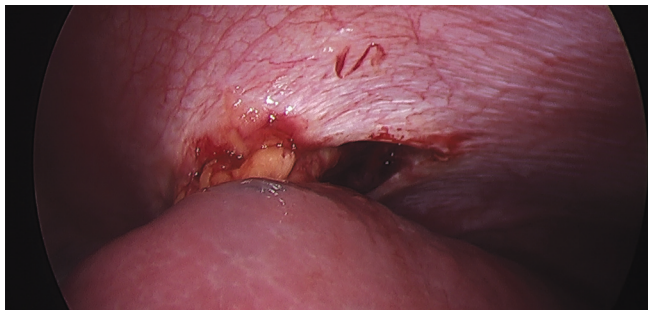
### Thoracotomy for other indication

- During closure of thoracotomy for other indication after trauma with rib fractures (i.e., "on the way out")

### Rib fracture nonunion

- Chronic pain after rib fractures ( $\geq 2$  months) with evidence of nonunion on computed tomography

The indications for chest wall reconstruction are often a source of debate and vary from institution to institution. The success of this operation is contingent upon the correct indication. Hypoxemia or respiratory insufficiency secondary to pulmonary contusion will



Diaphragm laceration on laparoscopy.

not be improved by rib fixation. Operative fixation of patients with pulmonary contusions may be performed when associated with the above indications. Most importantly, surgical stabilization of rib fractures should not be undertaken if other severe or life-threatening injuries exist (i.e., head trauma, spine injury, hemodynamic instability).

### Procedure

Open reduction with internal fixation of rib fractures has recently been popularized at multiple trauma centers. Rib fracture repair, however, has been performed for more than 50 years. Historically, severely displaced rib fractures and flail chest underwent closed reduction, external fixation, traction, and/or simple bed rest. Many patients succumbed to respiratory failure until the advent of positive pressure with mechanical ventilation. Given the success of mechanical ventilation, the development of internal fixation has been slow.

**Patient Selection** Rib fixation has been studied in adults on/off mechanical ventilation. Exclusion criteria are: Abbreviated Injury Score < 3, severe traumatic brain injury, spinal cord injury (as it precludes positioning), severe pulmonary contusion, hemodynamic instability, open chest wound with contamination of rib fractures, sepsis, empyema, and osteoporotic bone. Preoperative CT scan of the chest is obtained with 3D reconstruction to aid in operative planning.

**Timing of Operation** Early intervention (<5 days post injury) is preferable. Late repair may be done for nonunion.

**Technique** The current surgical technique for rib fixation involves open fracture reduction with splinting of ribs using a variety of plates and screws or intramedullary nails. Anterior and lateral ribs 3-10 are fixed preferentially, because ribs 1 and 2 are non-mobile and difficult to access, as are posterior ribs beneath the scapula. Lung isolation may be used if thoracoscopic assistance is used to localize ribs, free impaled lung tissue,



CT 3-D reconstruction of flail chest

evacuate hemothorax, and evaluate the diaphragm for lacerations. A thoracotomy incision is performed with the patient in the lateral decubitus position. Ribs are reduced and realigned. Care is taken not to injure the neurovascular bundle of each rib. The plates are applied to the external cortical surface and fixed with screws traversing both the inner and outer cortex of the ribs. The number of ribs fixed remains controversial. Some believe all fractures should be repaired while others focus attention on severely displaced or symptomatic fractures.

### Conclusion

Several studies have demonstrated advantages to chest wall stabilization. The beneficial effects of this procedure include fewer days on mechanical ventilation, decreased rates of pneumonia and tracheostomy, decreased length of stay (LOS) in the intensive care unit, and overall decreased hospital LOS. In addition, some studies have shown earlier return to work, decreased disability, maintenance of lung function, and earlier freedom from opioid use and reduction in pain.

Surgical stabilization of ribs comes with risks. Multi-trauma patients are exposed to general anesthesia as well as further trauma to the chest wall to achieve rib fixation, despite careful technique to optimize tissue preservation. Implanted foreign bodies can become infected or dislodged over time, requiring reoperation and hospitalization.

Larger studies with attention to specific patient injury pattern, technique, functional outcome, pulmonary status, and pain control are needed to further define the optimal patient in need of rib fixation surgery. Rib fixation systems are evolving into the field of minimally invasive surgery, which should increase the focus and influence of this procedure.

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# Diverticulitis: Medical and Surgical Management

by **Brian Scott Zuckerbraun, MD**

Diverticulitis refers to inflammation of acquired outpouchings in the wall of the colon. These diverticula are typically about 0.5 to 1 cm in size and most commonly located in the sigmoid colon. The inflammation of the colon can range from mild with abdominal pain to free perforation with spillage of fecal material into the abdominal cavity and the development of sepsis. Colonic diverticulum can also be associated with bleeding, but this article will focus on inflammation and diverticulitis.

Colonic diverticulosis refers to the presence of diverticulum without inflammation. It is common and the incidence increases with age. Diverticulosis is rarely seen in individuals younger than age 30. However, in Western society the prevalence increases to 40% by the age of 60 years and 60-80% by the age of 80 years. The formation is thought to be associated, with increased intraluminal pressure in the sigmoid colon. Several hypotheses to explain the generation of high intracolonic pressures include a low fiber diet as well as altered colonic motility. Additional risk factors for the development of diverticulosis include increasing age, geographic factors, cigarette smoking, nonsteroidal anti-inflammatory use, obesity, decreased physical activity, and caffeine ingestion.

10-25% of patients with diverticulosis will go on to develop diverticulitis. The number, size, or extent of diverticula do not seem to correlate with the risk of developing diverticulitis. The incidence of diverticulitis has been increasing over the past several decades in the U.S., but this may be in part secondary to the increased availability and use of CT scans.

The etiology of diverticulitis is thought to be similar to the development of acute appendicitis, in which obstruction of the diverticulum can lead to bacterial overgrowth, distention, and tissue ischemia. This results in localized inflammation and possibly contained perforation with a peridiverticular abscess or free intraperitoneal perforation with peritonitis. It is also possible for the inflammatory process to fistulize (erode into and connect to) adjacent structures, most commonly the bladder. When the inflammation or perforation occurs, this process is associated with infection.

## Symptoms

The symptoms of diverticulitis range from mild abdominal pain to peritonitis with sepsis. The most common symptom complex during acute diverticulitis involves left lower-quadrant pain and fever. Depending on the location of inflammation and the redundancy

of the sigmoid colon, pain may be midline or in the right lower quadrant. Bleeding per rectum is usually not associated with diverticulitis and would suggest other etiologies of colitis, including inflammatory bowel disease or ischemia. Nausea or vomiting may be present secondary to an associated ileus, a small bowel or large bowel obstruction secondary to phlegmon (inflammatory mass) formation or strictures. Physical examination most often reveals tenderness with or without an associated mass. Laboratory evaluation will often demonstrate a leukocytosis.

Most often symptoms will resolve after treatment with antibiotics and decreasing oral intake; however, some patients will have “smoldering” disease that only partially improves and is marked by continued symptoms of left-sided abdominal pain and low-grade fevers. Patients with smoldering disease often have crampy pain associated with a partial obstruction secondary to a continued phlegmon or stricture. Other patients have more elusive symptoms of pain without fever or leukocytosis or imaging findings, and this may be difficult to differentiate from irritable bowel syndrome.

When diverticulitis is associated with a colovesicular fistula, the infection or abscess is essentially drained by decompressing into the bladder, and symptoms are marked by cystitis, pneumaturia, pyuria, or fecaluria. Laboratory evaluation often reveals an abnormal urinalysis and polymicrobial urine culture. Likewise, colovaginal or uterine fistulas may present with vaginal discharge, passage of air or stool per vagina.

## Diagnosis

The differential diagnosis for patients with diverticulitis includes appendicitis, colorectal cancer, bowel obstruction, inflammatory bowel diseases, ischemic colitis, gynecologic disease, and irritable bowel syndrome. Other diagnoses may include pyelonephritis, ureteral calculi, endometriosis, stercoral ulcer, or colonic volvulus.

Although multiple imaging modalities are of potential use to diagnose suspected diverticulitis, none is as useful as CT scanning. CT scanning is both widely available and accurate. Most surgical practitioners feel comfortable reading CT scans of the abdomen and pelvis; thus, there is also a comfort level with this as a diagnostic test. CT scanning can accurately determine the diagnosis of diverticulitis as well as determine other diagnoses that will often top the differential. The importance of endoscopy to exclude an underlying malignancy cannot be underscored following the initial presentation of diverticulitis. Colonoscopy is

most often performed at least six weeks after the episode of diverticulitis due to the risk of exacerbating microperforations secondary to intraluminal insufflation.

### Management

Uncomplicated diverticulitis is treated with antibiotic therapy. Most isolates are polymicrobial. The most common aerobic gram negative is *E. coli*. Aerobic gram positive is *Enterococcus*, and anaerobe is *Bacteriodes fragilis*. Antibiotic regimens for the treatment of diverticulitis should have: 1) activity against these common bacteria, 2) good tissue penetration, 3) minimal toxicity, and 4) clinical efficacy.

Patients with minimal symptoms and mild clinical findings on exam are often treated as outpatients on oral regimens for 7-14 days. Patients who present with more severe tenderness, fever, systemic symptoms, or inability to tolerate oral intake are most often hospitalized. These patients most often will undergo laboratory evaluations as well as CT scanning. Patients with uncomplicated disease are most often treated with bowel rest and intravenous antibiotics and are then transitioned to an oral regimen following clinical improvement.

Diverticular abscesses are present in approximately 15% of patients with diverticulitis who have undergone CT scanning. These abscesses can be mesocolic or pericolic, or pelvic or retroperitoneal. Patients with diverticular abscesses that are larger are most often treated with percutaneous drainage as a means of source control in addition to antibiotic therapy. Clinical response is followed after drainage. If patients fail to improve or their clinical condition worsens, repeat CT scanning to evaluate for recurrent or persistent abscesses is often performed, or surgical therapy is recommended. Although the role and timing for elective surgical resection can be debated, ideally patients can be acutely treated with antibiotics with or without percutaneous drainage and elective surgical resection can be offered in the future if indicated. Indications for elective surgical resection have evolved over time, but in general terms include the development of multiple recurrent episodes of diverticulitis in relationship to the frequency of these episodes, as well as ongoing symptoms from stricture formation.

Patients who present acutely with free perforation and the development of purulent peritonitis or feculent peritonitis should be treated with surgery. Only 1% of patients will develop free perforation, and this is most often the initial attack of diverticulitis. The mainstay of surgical treatment for perforated diverticulitis or complicated diverticulitis requiring urgent operation has been the Hartmann procedure. This involves resection of the involved disease segment, end colostomy and a blind pouch towards the rectum. This procedure eliminates the septic focus, but has

the disadvantage of requiring a second major operation. Studies have demonstrated that a high number of patients (up to 35%), particularly those of advanced age or with severe comorbidities, never undergo reversal of their colostomy. Retrospective review has illustrated that Hartmann's procedure was associated with a 18.8% mortality, a wound infection rate of 24.2%, and stoma complications in 10.3%.

There is increased interest in alternative surgical treatments other than a Hartmann procedure. Several studies have suggested that in select patients, resection with primary colorectal anastomosis, with or without upstream fecal diversion (usually loop ileostomy), is superior to Hartmann resection. Several contraindications to this approach include hemodynamic instability, diffuse peritonitis, significant bowel wall edema, ischemia, immunocompromised state, and ischemia.

Colovesical fistulas often require surgical treatment; however, an urgent operation is rarely required as the fistula usually serves to "drain" or decompress the infection. If a patient is highly symptomatic with symptoms of cystitis, then suppressive antibiotics are utilized. Management of a colovesical fistula at the time of operative exploration infrequently requires resection of the bladder. The fistula is usually "pinched off" the colon, and the fistulous tract may not be identified. A suture repair is necessary in few cases. We advocate indwelling foley catheter with a cystogram prior to removal, usually after 7-10 days, when a colovesical fistula is managed in this fashion. When managed electively, as in all cases of diverticulitis, colonoscopy or sigmoidoscopy should be performed preoperatively to rule out a malignancy, in addition to cystoscopy to rule out a primary bladder neoplasm.

### Summary

In summary, diverticulitis is quite common and refers to inflammation of diverticulum of the colon, which can range from mild to associated diverticular perforation. Acute management is escalated based upon severity, and almost uniformly involves bowel rest and antibacterials. Associated diverticular abscesses should be drained if possible, and patients with peritonitis, sepsis, or failure to improve or worsening symptoms should undergo urgent operative management, which most commonly involves resection of the affected segment with creation of an end colostomy. For patients who improve without initial surgery, elective surgery, usually without ostomy creation, is based upon the presence of chronic associated symptoms or the history of recurrent episodes over shorter periods of time. Additionally, patients who are diagnosed with diverticulitis should increase dietary fiber, which may decrease the likelihood of future episodes.

## UPMC MEDICAL TOXICOLOGY

### Staying One Step Ahead of New Synthetic and Designer Drug Abuse

Over the last several years, our region has witnessed the emergence of a multitude of new synthetic drugs of abuse. These drugs have included the likes of “bath salts” (synthetic cathinones) and “spice” (synthetic marijuana). In addition, surrounding areas have been experiencing the emergence of other synthetic stimulants, such as “Molly,” and synthetic hallucinogens, such as “2Ci.”

With so many new synthetic drugs now available, and others currently in development, the UPMC Division of Medical Toxicology and the Pittsburgh Poison Center are staying ahead of the curve in order to provide the most effective treatments with these emerging drugs of abuse.

As many more designer drugs become available, identifying the specific drug involved

will become more difficult. However, the drug’s exact identity is less concerning than knowing the appropriate symptomatic treatments, such as:

- Use adequate sedation (particularly benzodiazepines) for agitation.
- Use cooling methods for hyperthermia.
- Use IV fluids for the treatment of dehydration and rhabdomyolysis.

Patients who are extremely agitated may require intubation and sedation as a means to keep both the patient and hospital staff safe.

Contact the UPMC Division of Medical Toxicology or the Pittsburgh Poison Center for any additional treatment recommendations.

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