First To Cut

Trauma Lessons Learned In The Combat Zone

First To Cut

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The information in this book are the personal opinions of the authors and do not necessarily reflect the official views of the department of defense.

The medical vignettes do not identify any individual and are fictitious in the composite.

This book is a gift to the military medical personnel who take care of our soldiers, airmen, sailors, and marines who volunteer to go into harm's way to defend our way of life. Thank you for your service.

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Dedication

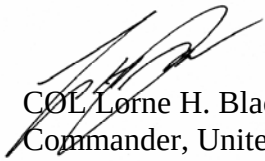
This book is dedicated to the living memory of
U.S. Army General Surgeon Major Mark Taylor
and
US Army Orthopedic Surgeon Colonel Brian Allgood.

COL Brian Allgood, MD

MAJ Mark Taylor, MD
(Second from left)

Introduction

The first goal of this book is simple; to save lives. As all deployed combat surgeons know combat trauma is not your parent's civilian trauma. There is no equivalent to a patient with 100 fragmentation holes, above the knee amputation and a 10% burn in the civilian world. Being faced with these unique wounding patterns for the first time often results in mistakes that are not repeated due to experiencing it. We will document these experiences in a rapid format – in a conversational tone - so that combat surgeons can hopefully benefit from our mistakes and pearls of wisdom. To paraphrase Winston Churchill, these lessons can only be "forged in the fires of battle".



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"What is Combat Damage Control Surgery?"

Damage control has been devised to stop the physiologic derangements of severe hemorrhage seen in trauma patients known as the "lethal triad" or the vicious bloody cycle" of hypothermia, acidosis, and coagulopathy. Civilian damage control surgery has been well defined. Damage control is the trilogy defined as:

1. *Abbreviated operation*
2. *ICU resuscitation*
3. Return to the O.R. for the *definitive surgery.*

The abbreviated operation has 2 main goals:

1. *Stop bleeding*
2. *stop soilage* of stool and succus.

The ICU resuscitation has the goal of fluid resuscitation to correct acidosis, coagulopathy and hypothermia. The definitive operation is where definitive surgical procedures are performed after correction of physiologic parameters to close to normal, these procedures include definitive vascular (e.g. vein interposition grafts), GI procedures (e.g. small bowel anastomosis, colostomy maturations, etc) and definitive hemostasis (e.g. packing removal, etc).

While civilian damage control trilogy is performed within the confines of a single building moving the patient a few hundred meters- combat damage control surgery is undertaken over a global evacuation moving the patient through several hospitals. This need for global evacuation results in the civilian paradigm of a damage control trilogy being replaced with a multiple stage surgical and resuscitative process – (see figure 1). The Combat surgeon also has to deal with limited supplies and lack of blood component availability – especially far forward. These challenges are often magnified by mass casualty situations.

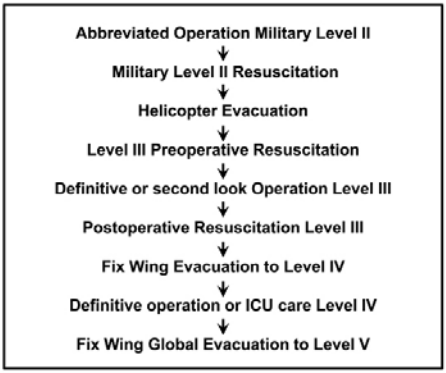

Fig 1. Combat Damage Control Stages of Surgical and Resuscitative Care.

Fig 2. Two tables with five board certified general surgeons performing two damage control laparotomies at a CSH.

Combat Injury Distribution

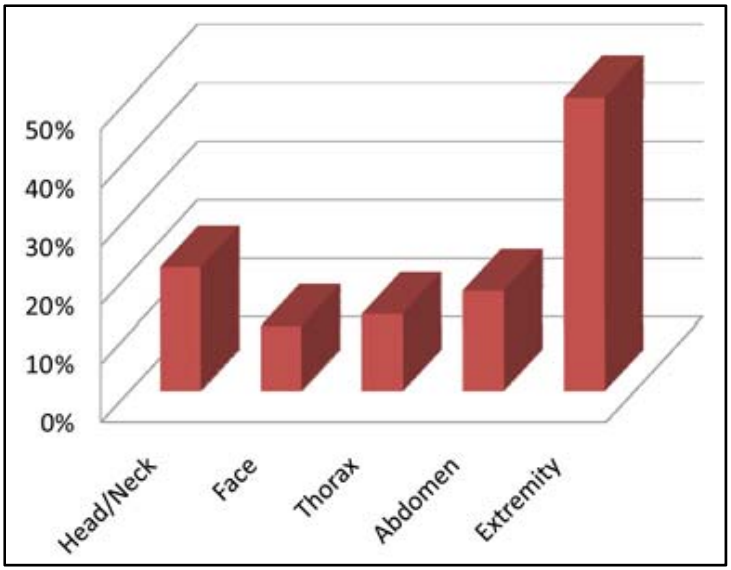

Fig 3. Combat injury distributions have not changed since the Civil War. The extremities are still the most commonly injured anatomic region accounting for over half of all injuries.

Fragmentation Wounds

"Bleeding under the drapes"

"25 y.o. male suffers a total body fragmentation injury and arrives with SBP of 70. I placed bilateral chest tubes, I wrapped Kerlix around all the LE frag wounds which were not bleeding in the E.R. I took him directly to the O.R. for ex lap, ex lap reveal kidney injury which is easily controlled with nephrectomy, the patient was unstable during the case and received 10 u of blood, 6 FFP and neosynephrine by anesthesia. After the abd is closed I then removed the drapes and to my horror there was over 2 liters of blood on the table – the patient fell into the vortex of the lethal triad and died as I stood over him helpless as he bled from every hole."

Fig 4

The patient with multiple full body fragmentation wounds has NO equivalent in civilian trauma. Always be aware that fragmentation wounds that are initially not bleeding can and often do resume bleeding with resuscitation and return of a normal systolic blood pressure. Always be vigilant of the possibility of "bleeding under the drapes" and if unexplained hypovolemia /unstable vitals take several checks for un-visualized fragmentation injuries under the drapes.

Lessons Learned:

- Fragmentation wounds often do not bleed with hypotension
- Fragmentation wounds often re-bleed with resuscitation
- Check areas of fragmentation wounding not visualized (covered with drapes) during the O.R. case

"He had fragments all over his abdomen and the fast was negative."

"30 y.o. male involved in an Explosion and came in with a SBP of 130. CXR was normal and his FAST exam was negative for intraperitoneal fluid. I did not know if I should ex lap him or not"

Fig 5. Multiple fragment wounds over the abdomen

Fragmentation wounds from explosions are an injury pattern unique to combat – there is no civilian equivalent. These fragments are often of low velocity. A negative FAST exam is of no value as it does not rule out small bowel injury - the most common injury with abdominal fragmentation wounds. A positive FAST exam should require ex lap. The CT scanner has been shown to be extremely sensitive for evaluating for intraperitoneal penetration – if it is available- and mandates ex lap A CT

scan that rules out intraperitoneal penetration can allow for safe observation even with global evacuation. At a level II – especially in a MASCAL – give IV antibiotics and consider transfer to a level III in the patient with abdominal frag wounds, normal hemodynamics and a negative FAST exam.

Lessons Learned:

- A negative FAST exam is of no value with abd frag wounds
- A POSTIVE FAST exam should require ex lap
- CT scan negative for intraperitoneal penetration can allow for safe observation
- CT scan POSITIVE for intraperitoneal penetration mandates ex lap
- At level II Consider IV antibiotics and transfer to level III in the stable patient with abdominal frag wounds and negative FAST exam

Reference:

Beekley A, Blackbourne LH, Sebesta J, McMillan N, Mullenix P, Holcomb JB. Selective non-operative management of penetrating torso injury from combat fragmentation wounds. J Trauma. 2008;64:S108-S117.

"Massive facial frag wounds and bleeding"

"23 y.o. male involved in an explosion with massive facial injury – arrives to CSH coherent with significant arterial and venous bleeding…

Facial fragmentation wounds are a unique combat military wound. The first concern with these injuries is the airway – intubate ASAP. The next concern is bleeding – most often

manual pressure will stop the bleeding – if the bleeding does not stop significantly with pressure bring the patient to the O.R. emergently and call for you OMFS or ENT colleagues to join you. Arterial bleeders are best controlled at the bleeding point and avoid proximal artery ligation except in life threatening bleeding as the flap blood supply is very important for reconstruction. IF the bleeding is control with simple pressure measures the patient should be brought to the CT scanner for brain – eye – and facial scans – many patients with facial frag wounds will have intraocular or intracranial fragments. One can ligate the external carotid artery to stop life threatening hemorrhage.

Lessons Learned:

- With massive facial trauma secure the airway ASAP
- Apply manual pressure to any bleeding areas
- Massive bleeding is best addressed in the O.R.
- Obtain CT scan of brain and eyes as soon as feasible
- Obtain ophtho and OMFS/ENT consultation ASAP
- Control bleeders at the end point of bleeding not by proximal arterial control unless absolutely necessary
- Ligation of the external carotid can be life saving

"Creative wound vacs 101"

"21 y.o. male patient with left leg fragmentation wounds about 1-3 cm in diameter. Strong pulses and no fractures on x-ray. I was thinking how in the world do I wound vac all of these holes without a million of those suction connectors."

Most surgeons would agree that wound vacs make life easier for the medical staff and patients. I would say they even lower pain and remove the need for BID painful dressing changes. They also appear to close wounds quicker than traditional wet to dry dressings. A simple technique to connect the suction from a single source to many fragment holes is to pack all the holes with sponge – tack in place with a few staples then role up kerlix and connect the sponges by the kerlix "bridges" then wrap with IOBAN or the wound vac sealing drape and the suction will be applied to all of the holes. Wound vacs have been placed after the initial debridement of soft tissue wounds with no increase in infections (actually 0% infections of one series from a level III facility).

Lesson Learned:

- Wound vacs can make everyone happy
- Kerlix and be used to connect multiple sponges in multiple fragmentation holes
- Woud vacs can be used safely after initial debridement

Reference:

Leininger B, Rasmussen T, Smith D, Jenkins D, Coppola C. Experience with wound vac and delayed primary closure of contaminated soft tissue injuries in Iraq. J Trauma. 2006;61:1207-1211.

"Wrong fragment projection"

"30 y.o. male involved in an explosion. Multiple Entrance wounds – large one over left pectoralis muscle – placed chest tube 200 cc of blood and air – three days later we got a CT to look for a retained hemothorax –

found a frag next to his spleen – took him for ex lap – found a 2 cm hole in the diaphragm…"

"27 y.o. male involved in a explosion with multiple frag wounds – profuse bleeding from left subclavian hole – took him to the O.R. for exposure of left subcalvian artery – had proximal control but still bleeding – he had a left pulmonary artery injury not a subclavian artery injury…"

Fragmentation wounds are an injury unique to the combat wounded. They are of various size and velocities and can project anywhere based on the patient body position on impact. The unstable patient does not give you the luxury of an extensive preop radiologic evaluation. A quick look at the heart and abd with the FAST may reveal blood in one of these compartments, a chest tube can monitor bleeding from the pleural cavities, ex lap with pericardial window can be helpful to evaluate for abd injury or heart wound. If the patient has continued bleeding and is unstable always consider another compartment or organ injury. A simple on table x-ray may give clues to fragment projection as well. If unstable always leave the abdomen open for easy re-exploration.

Lessons Learned:

- Fragments take many routes through the body
- If the patient continues to bleed and is unstable *consider involvement of another body cavity, organ or vessel*
- Chest tubes can monitor the pleural cavities
- The FAST and pericardial window will evaluate the heart
- FAST, DPL and ex lap will evaluate the peritoneal cavity for blood

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"Explosion frags, blunt trauma and burn injury"

"23 y.o. male s/p attack in a high speed MVC with fire – arrived to the CSH hypotensive, frag wounds all over trunk and neck, right leg traumatic amputation, burns to face, arms and trunk – I am thinking 'where do I start'…"

The combat injured can have the combination of blunt and penetrating trauma which can also be further complicated by an amputation topped off with a significant burn injury. This constellation of injuries can be very challenging. First priority is to rule out life threatening bleeding. The first question you have to ask yourself is 'should this patient be in the ED or the O.R.?' and then 'is the hypotension continuing hemorrhage or blood loss from the amputation or burn injury hypovolemia ?'. CXR or bilateral chest tubes will evaluate for pleural bleeding. DPL or FAST (and repeated delayed FAST) will evaluate for significant intraperitoneal bleeding with ex lap reserved for definitive evaluation with the patient who does not respond to resuscitation. FAST (and repeated FAST) vs. Pericardial window will eval for cardiac injury. Two windlass tourniquets or a pneumatic tourniquet will assure hemostasis in a major extremity injury/amputation. Pelvic fracture vs. penetrating pelvic injury is a hard call – x-ray will evaluate for significant bony disruption – but if the patient has penetrating fragments and a pelvic bony disruption the patient should have an ex lap to rule out major vessel injury in the pelvis due to the penetrating frags and then pelvic packing. All of these diagnostic measures can be obtained in the O.R.

Lessons Learned:

- The safest place for the hypotensive multiple trauma patient is the operating room
- Rule out life threatening hemorrhage as your first priority
- CXR or bilateral chest tubes will evaluate for pleural bleeding
- Consider pneumatic tourniquet for all major extremity injuries
- FAST, pericardial window will evaluate for cardiac injury
- FAST (repeated FAST) or DPL will evaluate for significant intraperitoneal bleeding
- Ex lap is the definitive rule out for intraperitoneal bleeding
- X-ray, physical exam and ex lap will eval for pelvic fracture and pelvic bleeding
- The patient with blunt and penetrating pelvic trauma should have an ex lap to rule out major pelvic vascular injury
- In the multiple trauma patient in extremis with penetrating and blunt trauma consider bilateral chest tubes, ex lap with pericardial window to rule out all major cavities for major bleeding

"Frag wounds head to toes – Which cavity first"

"25 y.o. female involved in a mortar blast arrives at the FST hypotensive – she has frag wounds literally from her head to her toes. – the neck has a stable nonexpanding hematoma, she is talking with decreased breath sounds on the left –I place a left Chest tube and we start PRBCs – now - where do I start?"

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Total body fragmentation wounds are a truly unique injury of the combat wounded. If the patient is hypotensive the best and safest place to be is the O.R. ABCs – intubate, bilateral chest tubes. Abdominal injury can be ruled out with an EX Lap, the heart can be evaluated with a pericardial window – if positive for blood then median sternotomy. The 2 pleural cavities can be evaluated by the amount of blood draining from the chest tubes- with the caveat that a chest tube can become clotted with blood – if any doubt: place a second chest tube. If the neck is not actively bleeding it can wait for exploration until after life threatening bleeding is ruled out in the more likely cavities (i.e. abdomen, chest). If you have exsanguinating subclavian or neck injuries you must start there – if a second surgeon is available simultaneous dissections can be carried out but be wary of heat loss from opening up any body cavity especially if you open up more than one area – going to 2 operating teams is a judgment call - warm the room, warm the blood, start whole blood or FFP/platelets, consider Factor VIIa if the patient is massively bleeding or is coagulopathic. Always think "life over limb" and re-examine the extremities after life threatening cavitory bleeding has been ruled out – leave tourniquets up until major cavitory bleeding has been sorted out. Examine the patient during the O.R. case for "bleeding under the drapes" from fragmentation wounds after blood resuscitation.

Lessons Learned:

- The safest place for a hypotensive patient with total body fragmentation wounds is the Operating Room
- The pleural cavities in the hypotensive pt can be evaluated with bilateral chest tubes

- The abdomen can be evaluated in the hypotensive patient with abd frag wounds by EX LAP
- The heart can be evaluated for pericardial blood by FAST exam
- The heart can be evaluated in the O.R. by pericardial window and median sternotomy if the window is positive for blood
- The neck can be evaluated in the hypotensive pt with neck frag wounds by neck exploration
- Examine the patient during the O.R. case for "bleeding under the drapes" after resuscitation
- After ruling out major cavity bleeding re-examine the patient from head to toe

"Antibiotics and frag wounds"

"25 y.o. male involved in an explosion – arrives to the CSH normotensive with frag wounds up and down his legs. Started UnasynIV and took him to the O.R. and irrigated all of his wounds and removed any clothing in the wounds – obvious bacterial wound inoculation – how long should I continue the IV antibiotics? – no one seems to know I just kept them going until he transferred out 2 days later"

Multiple wounds from fragments from an explosion are a unique wounding pattern seen only in combat. The fragments are of differing size and velocity and almost all traverse clothing often bringing cloth and other foreign bodies with them in to the subQ and muscle. The most important aspect of treating these wounds is removal of all visible foreign material, debridement of dead tissue, and irrigation – along with leaving the wounds open. IV

antibiotics should be given for at least 24 hours after injury and some would continue therapy for 72 hours. Broad spectrum coverage for resistant pathogens such as *Acinetobacter, Pseudomonas,* and *Klebsiella* are typically not needed at the time of injury; therefore a first generation cephalosporin such as cefazolin (ancef) is adequate. It is important to realize that short course therapy is likely adequate, consider that we give IV prophylactic antibiotics for only 24 hours with colon injuries regardless how massive the stool/bacterial load is.

Lessons Learned:

- Fragmentation wounds should be debrided of necrotic tissue, removal of foreign bodies and irrigation
- Use prophylactic IV antibiotics for typically 24 hours
- Prolonged IV antibiotics are then reserved for the diagnosis of a wound infection

"Thigh fragments just underneath the skin"

"28 y.o. male involved in an explosion – several fragments to leg – no bony involvement – normal distal pulse and ABI. Lots of frags felt just under the skin – do I leave them or make incisions and remove all the superficial ones?..."

Fragmentation wounds are a very unique injury to the combat wounded. The basics include debridement of necrotic tissue and removal of any foreign material (e.g. clothing) from the entrance sites and saline irrigation. Large fragments that will inhibit function should be

removed in the O.R. Small fragments even if superficial should be left in place – they can always be removed at a later date if symptomatic. Criteria for not removing fragments includes no fractures, no major vascular involvement and no break of pleura or peritoneum, wound entry/exit less than 2 cm in maximum dimension, wounds not frankly infected, and exclusion of extremely dirty wounds. Although initial studies evaluated 5 days of antibiotics, it is likely a single dose of a first generation cephalosporin such as cefazolin (ancef) is adequate if the wound is cleaned and bandaged with close clinical monitoring. If an infection develops, the fragment can be removed at that time with bacterial cultures of the wound to direct further therapy although debridement alone is often adequate

Lessons Learned:

- Fragment entrance wounds should be cleared of necrotic tissue, foreign material and irrigated
- Large fragments that will impair function should be removed in the O.R.
- Small superficial frags under the skin should be left in place
- Antibiotics should be given but a single dose is likely adequate

"Packed the wound with kerlix and kept bleeding"

"22 y.o. female involved in explosion – arrives hypotensive with a single frag wound below her distal right clavicle – place a chest tube – no blood – the wound is bleeding dark blood – pack it in the ED with a 4 x 4 and bring her straight to the O.R. – explored the wound with a

large prox- distal control subclavicular incision. The axillary artery and vein were intact and the fragment tract was just below through and through the chest – missed all large vessels – no arterial bleeding just muscle branches but she was cold, coagulopathic- so we packed it with Kerlix – she oozed blood all night getting 10 units of blood and 10 of FFP until the bleeding stopped – she did fine.."

Deep wounds without a major vascular injury can bleed profusely. Correcting coagulopathy is imperative – FFP and PRBCs in a 1:1 ratio, platelets or whole blood, - consider crYO and Factor VIIa if significant bleeding ensues after standard measures. Kerlix often allows for significant wicking of coagulopathic bleeding – try a hemostatic wound agent like chitosan or chtiaflex. A "hemostatic plug" can be constructed with gelfoam (thrombin soaked is best) with avitene wrapped in a surgicel sheet (like a cigarette) can be placed in smaller diameter holes – this can be left in situ. Follow a hemostatic plug by more gelfoam or chitoflex, or alternatively pack over the plug with kerlix or lap pad. Suturing the skin over such a hemostatic dressing allows for tamponade and accumulation of blood that will hopefully form a clot.

Lessons Learned:

- Kerlix by itself can result in significant blood wicking and bleeding
- Consider a "hemostatic plug" in bleeding frag holes without identifiable vessel injury
- Hemostatic plug can be constructed with gelfoam (+/- thrombin), +/- avitene wrapped in a sheet of Surgicel

- Large soft tissue defects can be covered with a chitoflex packing
- Suturing skin over a hemostatic dressing with a large nylon suture to will allow for tamponade

"Full thickness bowel burn"

"23 y.o. male arrives to CSH with multiple frag wounds to abd and flank – normotensive –FAST exam negative- we bring him to the CT scanner – he has multiple intraperitoneal fragments without any free fluid – ex lap no succus but looking at the small bowel he has – no lie – full thickness burns in the small bowel from the hot fragments – we resect the areas and hook him back up…"

Fragments come in different sizes and different velocities depending on the metal, explosive charge and distance from the explosion. Some fragments are extremely hot and can cause thermal injury to tissues– and bowel is no exception. Even without succus soilage run the bowel extremely carefully and more than once with fragmentation wounds to rule out thermal and small fragment injuries. Fragmentation thermal injury is truly a unique injury in combat surgery.

Lessons Learned:

- Fragments from explosions can be extremely hot
- Fragments can cause thermal injury to bowel
- Run bowel very carefully and repetitively with fragmentation wounds

"Local national – frag wounds everywhere- tetanus prohy?"

"27 y.o. local national arrives to the FST with multiple frag wounds to lower extremities in subQ no obvious bony involvement and b/l strong pulses – he has no idea of his past medical history – no idea about tetanus immunizations in the past…"

Tetanus prophylaxis is a common question in combat wounded. All U.S. Service members will have a tetanus prophylaxis immunization checked prior to deployment. Local national tetanus immunization is often unknown and even if given there is no way to know of any quality assurance. All tetanus prone injuries in local nationals need the full court press – immunization and immunoglobulin. If tetanus immunoglobulin is not available at the level II facility – the need for immunoglobulin must be communicated to the accepting facility. U.S. Service members with a tetanus prone injury should receive a tetanus immunization.

Lessons Learned:

- Level II facilities should have tetanus immunizations and immunoglobulin on hand
- Local nationals with a tetanus prone injury should receive both the tetanus immunization and immunoglobulin
- U.S. service members with a tetanus prone injury should receive a tetanus immunization

"Frag wounds – he will never change the dressings"

"27 y.o. local national civilian injured by explosion with multiple large frag wounds to legs – normal pulse and neuroexam –ABI >1.0 bilaterally – started IV antibiotics and took him to the O.R. washout/debridement and packed – brought him back the next day for washout and further debridement – place wound vac – he said he could not even look at the wound let alone change any packing…"

The general rule of combat surgery is to leave all war wounds open due to the risk of massive contamination and high risk of infection that can be life threatening. Utilizing multiple O.R. sessions for irrigation and serial debridement with negative pressure wound therapy (placed after initial O.R. debridement) have resulted in clean wounds that have been successfully treated with delayed primary closure – this is particularly useful in local nationals who will have limited supplies and limited home nursing care. If the wound bed looks clean without any signs of infection in local nationals a delayed primary closure is an excellent option with a wound vac placed in the clean debrided/irrigated wound after the initial operation. Do not use negative pressure dressings with contaminated or infected wounds (i.e. there is no data in these wounds). The safest option for patients going through the evacuation chain should have the wounds packed open or a negative pressure dressing placed with the decision on delayed primary closure made at level IV and level V.

Lessons Learned:

- Large wounds should be treated with serial debridements and irrigation

- A negative pressure dressing should be placed on all clean large wounds
- Delayed primary closure of all clean wounds after serial debridements/irrigations is safe
- Do not use negative pressure dressing with a grossly contaminated or infected wound
- Change negative pressure dressing every 3 days – (remove if signs of infection and inspect the wound)

Reference:

Leininger B, Rasmussen T, Smith D, Jenkins D, Coppola C. Experience with wound vac and delayed primary closure of contaminated soft tissue injuries in Iraq. J Trauma. 2006;61:1207-1211

Damage Control Resuscitation

"We gave him FFP but his INR was over 2 in the ICU"

"28 y.o. with GSW to RUQ. I took him emergently to the O.R. and ex lap. I packed his liver and resected his transverse colon. He received 13 units of PRBCS and 4 u FFP. His INR in the ICU was 2.2 and he continued to ooze significantly until I got 10 more units of FFP in him."

The patient requiring a "massive" transfusion (>10 units of PRBCs) is also bleeding clotting factors at approximately 1 unit of FFP per unit of PRBC bled – not to mention the clotting factors that form clot at the site of injury. Coagulopathy is a part of the "lethal triad" of trauma with acidosis and hypothermia. In civilian trauma the initial ICU INR is directly correlated with mortality. Retrospective data of combat wounded requiring a massive transfusion have shown a MORTALITY benefit from receiving FFP to PRBC at a 1:1 ratio. All pts requiring massive transfusion in the combat zone should receive FFP to PRBCs in a 1:1 ratio as soon as possible.

Lessons Learned:

- Post-operative INR is correlated with mortality
- All combat wounded receiving a massive transfusion should receive FFP to PRBCs in a 1:1 ratio as soon as possible

Reference:

Borgman M, Spinella P, Perkins J, et al. The ratio of blood products transfused affects mortality in patients receiving

massive transfusions at a combat support hospital. J Trauma. 2007;63:805-813

"O Negative whole blood"

"24 y.o. with GSW to lower abd. We took him for ex lap. Small bowel injuries, mesenteric bleeding and significant abd wall muscle bleeding – packed him off – he was cold and coagulopathic. We had PRBCs but no FFP. We gave him some O positive whole blood. His type and cross returned AB neg. we transferred him to the CSH and heard he had a bad acute lung injury…"

Male patients can receive O negative or O positive PRBCs as the universal donor as PRBCs have no or insignificant number of antibodies. Female pts should receive O negative as the universal PRBCs donor. Whole blood on the other hand has approximately 1 unit of FFP worth of antibodies and thus O negative/positive is NOT the universal donor for whole blood. Whole blood should be TYPE SPECIFIC due to the antibodies it contains. Giving O negative/positive whole blood to an A or AB donor can result in transfusion reactions and transfusion related acute lung injury (TRALI). TRALI is treated with supportive care and usually recovers quickly but should be avoided. If the patient is in extremis and the only whole blood available is O neg/pos it has been given successfully in combat situations.

Fig 6. Whole blood transfusion at a CSH

Lessons Learned:

- The PRBC universal donor for male pts is O negative or O positive
- The PRBC universal donor for females is O negative
- There is NO universal donor for whole blood and should be type specific
- Giving O neg/pos whole blood can result in TRALI
- Neg/pos can be given to the patient in extremis if that is the only whole blood available

"Is there an FFP universal donor?"

"28 y.o. male arrived after an explosion with frag holes all over and missing half of his buttock. We packed off the buttock and wrapped all wounds with Kerlix and he was very hypotensive in the E.R. we started O pos PRBCs and ordered some O neg FFP. Then it hit us – is O neg FFP the universal donor?"

Due to antibodies to blood antigens the universal donor FFP is not O neg/pos. The universal donor FFP is AB as the donor will not make antibodies to self. FFP will last 12 months frozen -40^0 and 90 days if frozen to -20^o. FFP is good for 5 days thawed (known as thawed plasma) but must be refrigerated. Room temperature FFP (room temperature thawed plasma) is good for 4 hours. A busy CSH should have thawed AB plasma ready (4 units) and available for the E.R. and O.R. Of note, each unit of FFP has the equivalent of 2 units of cryoprecipitate of fibrinogen.

Lessons Learned:

- The universal donor FFP is AB
- Thawed FFP is known as "thawed plasma" and is good for 5 days in the refrigerator
- Room temperature thawed plasma is good for 4 hours
- Each unit of FFP contains fibrinogen equivalent of 2 units of cryoprecipitate

"Factor VIIa"

"30 y.o. male with multiple GSWs to the abdomen – arrives hypotensive – we take him immediately to the O.R.

and started the ex lap. Tons of blood. Bleeding from shattered liver, mesentery, spleen, small bowel hole, colon holes. Packed everything we could, took out the spleen, anesthesia gave FFP: PRBCs 1:1, platelets but he was becoming cold and more coagulopathic – we gave him recombinant Factor VIIa and the bleeding stopped – it was very impressive."

Factor VIIa is a procoagulant. It should be used in refractory or severe bleeding as an adjunct to FFP: PRBCs in a 1:1 ratio and platelets. It does not work with acidosis and needs adequate platelets for the full effect. Of note, Factor VIIa works with hypothermia in vitro. All prospective randomized trials and retrospective trials on combat wounded have not shown any increase in thromboembolic events. Factor VIIa should not be used unless there is life threatening bleeding and coagulopathy or the clinical judgment that clinically significant coagulopathy will ensue.

Lessons Learned:

- Use individual Physician judgment when using Factor VIIa in the bleeding, coagulopathic patient
- Factor VIIa does not work optimally with acidosis
- Factor VIIa needs adequate platelet levels for max effect
- Factor VIIa can be re-dosed if needed

"Why didn't you tell me you were giving neo?"

"29 y.o. male with total body fragmentation wounds and large buttock/flank soft tissue loss – placed bilateral chest tubes with minimal drainage- packed off the soft tissue injury areas – took him for ex lap – packed his liver – kept

looking at the monitor and saw a SBP >90 at all times – brought him to the ICU and he crumped big-time and needed a massive blood and blood product transfusion – then I found out – unbeknownst to me – that he was receiving large doses of neosynephrine during the O.R. case…"

Pressors in hemorrhagic shock have been demonstrated to increase mortality. The patient is not bleeding neosynephrine but blood and blood products. Bleeding trauma patients should receive blood and blood products and if in extremis with a nonlife supporting blood pressure as a last resort the anesthesia folks often give a dose of neosynephrine to give time for blood products to arrive in the O.R. but the surgeon needs to be informed of all doses given. Communication is the key to the resuscitation of trauma patients. Surgeons must keep the anesthesia personnel informed on surgical hemostasis/bleeding and anesthesia needs to keep the surgeon informed on the ongoing resuscitation/vital signs.

Lessons Learned:

- A pressor in hemorrhagic shock should be given only as a temporary "last resort"
- If a pressor is given to a bleeding patient the surgeon needs to be informed immediately
- If the surgeon encounters significant bleeding the anesthesia personnel need to be informed immediately
- Communication between both anesthesia and the surgeon on status of ongoing resuscitation, vital signs, and how surgical hemostasis is going is paramount

Extremity and Vascular

"Resuscitation and field tourniquets"

"22 y.o. male patient brought into CSH E.R. with initial SPB of 80 with bilateral near complete traumatic above the knee amputations and bilateral windlass type tourniquets applied with complete cessation of bleeding. I started crystalloid and o negative PRBCs. His blood pressure quickly rose to 120 and had significant arterial bleeding from his distal residual limbs. I brought him quickly to the O.R. for ligation of his vessels, debridement and washout. He received 16 total units of PRBCs – several of which he lost on the way to the O.R."

With a traumatic amputation the initial windlass field tourniquet almost always arrives with cessation of residual limb bleeding. With resuscitation and subsequent elevation of the systolic blood pressure the driving force often defeats the tourniquet or "pops the clot". To defeat this, the initial resuscitation should not be too aggressive until you have surgical control of the vessels. Definitive tourniquet cessation of inflow can be obtained by placing a second field windlass tourniquet or rapid placement of an orthopedic pneumatic tourniquet from the operating room. The morbidly obese patient with very large lower extremities can be refractory to tourniquet placement of any kind, these patients will benefit from groin cut down and temporary clamping of the femoral vessels.

Fig 7. Double windlass tourniquet placement by a combat medic

Fig 8. Orthopedic pneumatic tourniquet can be placed in the E.R. or in the operating room

Lessons Learned:

- Significant bleeding often resumes after resuscitation with a field tourniquet in place

- A second field windlass tourniquet can be placed next to the initial tourniquet in the E.R.
- An orthopedic pneumatic tourniquet can be placed in the E.R.
- Utilize minimal resuscitation until surgical control of the vessels
- Groin cut down and temporary clamping of the vessels can provide cessation of inflow in morbidly obese/massive thighs
- If all else fails pre-op – maintain manual pressure on way to the O.R.

"Multiple frag wounds up and down the leg and no pulse"

"27 y.o. female involved in EXPLOSION, arrived hemodynamically stable with a hundred frag wounds to left leg and a windlass field tourniquet in place and no distal pulse. When we took down the field tourniquet we had profuse bleeding from all frag wounds – we quickly replaced the field tourniquet with a pneumatic tourniquet and took her to the O.R. Where to start? I couldn't explore all the holes – too many. I did an on table angiogram and found a complete transection of the distal SFA."

A pulseless leg with multiple frag wounds is similar to a shotgun blast in civilian trauma. One cannot fillet the leg open to visualize the entire vascular tree, this is best evaluated by angiogram. To minimize ischemic time this can be performed in the O.R. by an "on table" angiogram. Proximal control is obtained and injection contrast followed by fluoro or multiple plain x-rays will define the

arterial injury point. After completion of the vein interposition graft check distal pulses and doppler signals - consider obtaining a “completion” angiogram to evaluate your repair as well as rule out additional distal arterial injuries. Prosthetic graft material should NEVER be used in extremity trauma in the combat zone as the grafts either clot or get infected – **use Vein.**

Lessons Learned:

- Multiple frag wounds and arterial injury are best pin pointed by on table angiogram
- After repair with multiple frag wounds perform on table completion angiogram to rule out distal injuries
- Use ONLY vein in all extremity vascular injuries for arterial and venous repairs
- Check distal pulses, Doppler signals and completion angiogram after your repair

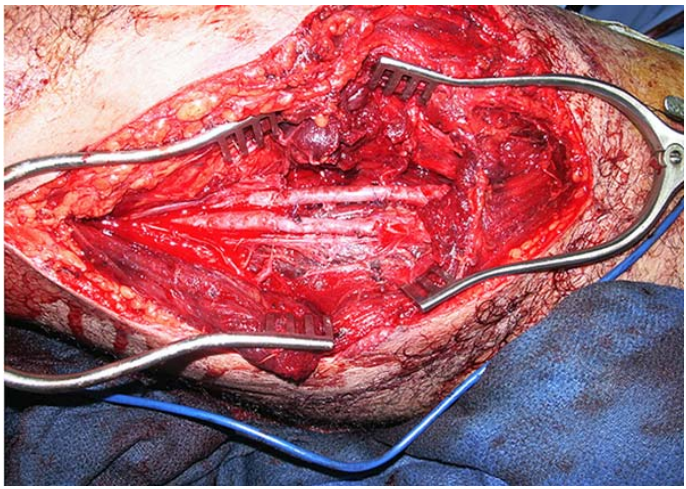

Fig 9. Reversed interposition vein grafts in femoral arterial and venous position in thigh

First To Cut

"A pulseless leg all by yourself -way out"

"I was at a far forward Navy FRSS (level II) and had a 22 y.o. with frag wound to his right popliteal artery and loss of pulse distally. He had a tourniquet placed on his upper thigh. I took him to the O.R. and placed a straight shunt. We did not have any more Fogarty embolectomy catheters but had adequate backflow. He had a Doppler signal before I sent him to the CSH. When he got to the CSH the shunt had clotted off."

The options for far forward surgical facilities should be either ligation or tourniquets employed in the patient *in extremis* and shunts for everyone else. It is important to make sure there is no clot distally with a Fogarty catheter if at possible. Placing the distal shunt in first and then place proximally with ongoing back-bleeding through the shunt. Perform fasciotomy correctly and liberally. Studies have documented that the majority of shunts will stay patent and no reported cases of shunt dislodgement and exsanguinations – but this is a theoretical catastrophe – and the patient should be transported with a tourniquet in place (NOT tightened!).

Lessons Learned:

- Shunt or ligation are the options for far forward surgery for vascular injuries
- Secure vascular shunts with large silk sutures
- Distal thrombectomy with a fogarty catheter will maximize patency
- A tourniquet should be placed loosely (i.e. not employed) proximal to the shunt for transport in case of shunt dislodgement

Reference:
Ritenour A, Dorlac W, Fang R, et al. Complications after fasciotomy revision and delayed compartment release in combat patients. J Trauma. 2008;64:S153-S162.

Chambers LW, Green DJ, Sample K, et al. Tactical surgical intervention with temporary shunting of peripheral vascular trauma sustained during Operation Iraqi Freedom: one unit's experience. J Trauma. 2006 Oct;61(4):824-30.

Fig 10. Temporary interposition vascular shunt in place

Fig 11. Extremity vascular shunt

"We don't need no stinking proximal control"

"A 26 y.o. male with a single fragmentation to mid thigh and a significant hematoma but with palpable pedal pulses. I thought it was going to be just muscle branches or a venous injury due to the palpable pulse so I just dove into the hematoma and was greeted by pulsatile bright red blood all over my mask. I held pressure as my partner got proximal control in the groin. The patient had a 50% transection of his SFA."

Most Combat surgeons do very little vascular surgery in CONUS. For those of us who do not do vascular surgery on a regular basis the basic tenet of safe vascular surgery – Proximal and Distal control of the vessels – are very important. Proximal control can be obtained with an orthopedic pneumatic tourniquet or surgical dissection proximally with placement of a Potts vascular loop. In every vascular case get proximal control.

Lessons Learned:

- Get proximal and distal control of vascular injuries
- Consider "remote" proximal incisions for proximal control
- Pneumatic tourniquet or cut down can afford proximal control
- Maintain manual pressure on way to O.R.

"Four hours of tourniquet time"

"26 y.o. male with foot traumatic amputation and multiple frag wounds to the right leg with a high thigh field tourniquet in place. Arrived to the CSH with SBP of 100 HR of 120. we had no report on duration of the

tourniquet. We took down the tourniquet and he promptly coded. We put the tourniquet back up, intubated him and gave him fluid and bicarb and he came back. We found out later that the tourniquet had been in place for over 4 hours…."

The use of tourniquets – while rare in civilian trauma is very common in combat injuries. Tourniquets are the number 1 instrument that a medic can employ to lower the KIA numbers. The use of tourniquet with application until the absence of a distal pulse by default causes distal ischemia. Release of a functioning tourniquet after several hours can result in the release of acidic fluid and potassium. The patient intubated and without a head injury can be briefly hyperventilated. Before taking down a long duration tourniquet make sure the patient is well hydrated, resuscitated, adding an ampule of sodium bicarbonate or THAM can prophylax against the release of "bad humors", lactic acid, and potassium. Also release the tourniquet slowly – if the rare arrhythmia arises re–employ the tourniquet and retry after further bicarb and fluid. If the leg is necrotic remember "life before limb" and perform an amputation.

Lessons Learned:

- Prolonged tourniquet times can result in the release of acidotic fluid and hyperkalemia
- Perform 4 compartment fasciotomy with all lower extremities with significant tourniquet times

"I do this cool one incision fasciotomy"

"I received a 28 y.o. male with grenade fragments to the calf – no bony injury – but developed a "hemorrhagic

compartment syndrome – the surgeon at the level II did a one incision 4 compartment fasciotomy – I am not joking – the muscles had protruded out and were 2-3 cm above the skin and 12 cm across – I had to skin graft it and it was a huge defect."

You should have a low threshold for performing 4 compartment lower leg fasciotomies. Especially if there is any ischemic time and/or if any question of ischemia and in the patient will undergo global transport where observation is hit and miss and not by the same surgeon. Fasciotomies should be performed with 2 bilateral skin incisions and the skin incision should be the same length as the fascial incisions as the *skin alone can cause compartment syndrome!* This use of 2 incisions will almost always allow for the medial fasciotomy skin incision to be primarily closed at the level III or Level IV facility and often the lateral incision can be closed with serial closure with sutures or sequential tightening of a "Jacob's ladder" made of a vessel loop tacked in place with metallic skin staples. Make absolutely sure that all four compartments are completely released. Doing otherwise has led to documented muscle necrosis. Delay and incomplete fasciotomies is associated with limb loss and death!

Fig 12. Bilateral incision 4 compartment fasciotomy

Lessons Learned:

- Have a low threshold for performing 4 compartment fasciotomies
- Use a long, 2 incision approach every time you perform a 4 compartment fasciotomy
- Ensure that all compartments are completely released as incomplete fasciotomies can cause muscle necrosis

Reference:

Ritenour A, Dorlac W, Fang R, et al. Complications after fasciotomy revision and delayed compartment release in combat patients. J Trauma 2008;64:S153-S162.

"The popliteal artery and vein were transected"

"29 y.o. male with frag wounds around his right knee with pulsatile bleeding. Placed a pneumatic tourniquet and brought him to the O.R. - dissected proximally and distally – both the popliteal artery and vein were transected…"

For some reason, it seems like fragments gravitate to the popliteal fossa. This is not an uncommon vascular injury in combat wounded. If in a level II facility - ligation or shunt of the vein and shunt placement in the artery is optimal with a 4 compartment fasciotomy. Your approach should be medial – this is the easiest approach for the nonvascular surgeon. At the level III vein interposition grafts should be placed in both the venous and arterial injuries. Perform the proximal anastomosis first and let the vein distend with pulsatile blood for optimal approximation of required length. While it used to be a law that you should not ligate the popliteal vein current thinking is that popliteal vein

reconstruction is optimal but it can be ligated. If you have to in a damage control situation perform the vein ligation with a 4 compartment fasciotomy.

Lessons Learned:

- Shunt popliteal artery injuries in a level II facility
- Shunt or Ligate popliteal vein injuries in a level II facility
- Place interposition graft for popliteal venous injuries at a level III if feasible (may need to consider "panel" graft to fit size of vein)
- Ligate popliteal veins if reconstruction is not feasible at a level III facility
- Perform four compartment fasciotomy for all popliteal repairs

"The femoral artery was transected and the femur was in 2 pieces"

"27 y.o. male with GSW to right thigh, large hematoma, tourniquet in place, obvious deformity, on x-ray femur was in 2 pieces. We took down the tourniquet and no distal flow. We took him to the O.R. placed an orthopedic pneumatic tourniquet. Fixed the artery with a reversed saphenous vein interposition graft and then Ortho gents ex fixed the femur. The graft then buckled and we had to redo the graft. Afterwards we did a 4 compartment fascial release."

With vascular injuries with a concomitant unstable fracture most surgeons would much rather have the stability and defining lengthening of the bone with an ex fix before attempting definitive vascular repair. An ex fix can be placed very quickly if the orthopedic surgeon is notified

early and is present in the O.R. The performance of an adequate 4 compartment fasciotomy will be an easy prophylactic measure to ensure muscle viability.

Lessons Learned:

- Use a pneumatic tourniquet as soon as possible with leg vascular injuries or cut down for proximal control
- Notify the Orthopedic surgeon upon arrival of an unstable fracture with a vascular injury
- If an ex fix can be placed quickly do the ex fix *before* the vascular repair
- If the ex fix will delay the vascular repair significantly consider placing a temporary shunt prior to ex fix
- Perform 4 compartment fasciotomy liberally

"GSW transecting the subclavian artery, near death…"

" 25 y.o. male arrived with GSW to the right shoulder under the clavicle – hypotensive with pulsatile bright red blood pulsing out – we applied manual pressure, gave blood, intubated him, placed a chest tube – groin lines, got him ready to the O.R. – he exsanguinated on the way to the O.R."

Subcalvian artery injuries can get your attention quick and can exsanguinate faster. One option in the ED is to place a 30 cc Foley catheter (or more than one) through the skin defect and blow up balloon under the clavicle – placing a Kelly clamp at the skin can maintain tension. The best way to stop bleeding (or to at least diminish it) is to get proximal control as fast as possible. In the patient in extremis with a left subclavian artery injury the fastest way

to get control is to intubate, sedate and perform an E.R. thoracotomy above the nipple (2-3 ICS) - lateral thoracotomy and clamp the left subclavian where it branches off the aorta – it is actually high and under the pleura but can be palpated and seen. If the vessel cannot be clamped a fist up in the upper pleural cavity (cuppula) can limit blood loss. Your options in the O.R are ligation, shunt or interposition graft. The right is more controversial – most textbooks recommend a median sternotomy for proximal control on the right and this is a good option if the patient can survive until the O.R. Another option is to perform a clamshell thoracotomy in the E.R. and get a clamp on. Time is of the essence and lines, etc can be placed in the E.R. just as well as in the O.R. Endovascular options can be entertained where available in the stable patient after imaging.

Lessons Learned:

- Subcalvian artery injures can quickly exsanguinate
- Get proximal control ASAP with exsanguinating subclavian artery injuries
- Perform a left (2-3ICS) lateral thoracotomy for proximal control with a left subclavian injury
- Perform a median sternotomy or clamshell thoracotomy for a actively hemorrhaging right sided subclavian artery injury

"Aortic injury – we tried and tried to put in a graft but then he became coagulopathic…"

"24 y.o. female with frag wounds to back – hemodynamically normal – took her for CT scan – large retroperitoneal hematoma below the kidneys with some

contrast extravasation- took her immediately to the O.R. – ex lap pulled the small bowel up and the hematoma was just above the pelvis got proximal control just below the renal arteries and both iliacs – opened it and had a hole in the very small aorta – tried to primarily fix – no luck then transected and tried to sew in a graft – but lots of bleeding from lumbars – she got cold and coagulopathic…"

Patients with aortic injuries rarely make it alive to a surgical facility. The aorta is actually very small in young healthy patients and the retroperitoneum can allow for a significant tamponade effect at times. Promixal and distal control is paramount with aortic injuries and exposure can be obtained below the renals like a AAA repair – more proximal abd aortic control can be obtained with the left medial visceral rotation (AKA Mattox maneuver) including swinging the left kidney, pancreas, descending colon, and spleen to the middle line. In a level II and during damage control you're the best option is often to place a pediatric chest tube as a shunt and perform bilateral 4 compartment lower leg fasciotomy. In extreme cases ligation of the aorta is an option (with 4 compartment fasciotomy – "life over limb") and reconstruction later when the patient is stabilized. Remember that you can ligate lumbars liberally.

Lessons Learned:

- Proximal and distal control of aortic injuries is mandatory
- Shunting the aorta with a small pediatric chest tube is an option for level II and damage control
- Ligate the aorta below the renal arteries is an option in extreme cases to save life over limb

- Perform 4 compartment lower leg fasciotomy liberally with aortic flow compromise
- Ligate lumbar arteries as needed

"External iliac artery transection, stool everywhere and no long grafts"

"28 y.o. male with GSW to the pelvis. Arrived hypotensive to our FST. Brought him to the O.R. and did an EX LAP. Stool everywhere. Active arterial bleeding from the pelvis – packed it got lots of blood ready then removed packing – the left common iliac was bleeding – transected. Easily clamped both ends. Now-what do I do? Stool all over…"

Iliac artery injuries are not uncommon injuries in combat wounded. The basics of damage control must be followed. Stop bleeding, minimize soilage. The best option at a level II for limb salvage is to place a vascular shunt (and perform a 4 compartment fasciotomy) and staple off the leaking bowel - then ship ASAP. Playing the "worst case scenario" game – consider flying the patient with an intra-abdominal shunt with a surgeon with a vascular clamp. The same procedures can be adhered to in a level III with a cold, coagulopathic patient. In the patient in extremis simple ligation is an option with fasciotomy. When the patient is stabilized and coagulopathy is corrected reconstruction can be entertained. The safest reconstruction options include long ax-fem and fem-fem bypass if the abdomen is hostile with contamination. With minimal contamination and in situ graft can be entertained with retroperitonealization or omental covering. Optimally, a vascular consultation is obtained – cannot hurt…

Lessons Learned:

- Shunt iliac artery injuries at level II and in damage control situations
- Ligation of the iliac artery is an option in the patient in extremis
- Perform 4 compartment fasciotomy with compromised iliac artery blood flow

"Damage control laparotomy in extremis and a transected brachial artery"

"28 y.o. male with multiple GSW to the abdomen – arrives hypotensive, cold, acidotic – we take him immediately to the O.R. pack him off and get warm blood, Factor VIIa – activate the "walking whole blood bank" try to rewarm him remove packs stop some mesenteric bleeders but his pelvis and liver have capillary ooze- repack. We decide to wait in the O.R. to warm him and await the whole blood – during this time we complete a rapid "tertiary" exam and find a GSW to his right upper arm and no distal pulse or Doppler signal- but at least his arm was not bleeding. He is so coagulopathic I did not even think of placing an incision for a shunt placement. I placed a tourniquet so we could have some control if he started to bleed from the arm…"

"Life over extremity." This is a clear case where the patient is in extremis and placing an additional incision and attempt at a vascular shunt and fasciotomy would lead to additional bleeding (with hypotension), and heat loss and would likely worsen the coagulopathy. It is no crime to make a judgment call that attempting to save a limb would jeopardize the attempt to save a life. The bleeding extremity in the patient in extremis can also be sacrificed

with the placement of a tourniquet – if your judgment is that the patient will die if you attempt salvage maneuvers.

Lessons Learned:

- "LIFE OVER EXTREMITY"
- The bleeding or pulseless extremity can be sacrificed to save life with a patient in the extremis of the lethal triad
- Options for the damage control patient with a concomitant extremity vascular injury are observation with pressure bandage, tourniquet, or shunt placement (clinical judgment)

"Exsanguinating axillary artery wound"

"22 y.o. male involved in dismounted explosion with large fragment wound to left axilla – in the arm pit – arrives delirious with active arterial bleeding. Rolled up a kerlix and packed wound and had another surgeon hold pressure – intubated him and got a groin cordis and started blood right away – he went into V tach on the way to the O.R…"

Exsanguinating axillary artery can be seen as a very similar problem to an exsanguinating subclavian artery. Manual pressure is often unable to occlude the artery bleeding under significant tissue mass. Proximal control is the goal and where in the hospital to get is a judgment call. If minimal or if bleeding is slowed with manual pressure the patient may be able to wait until the O.R if it is immediately available. If the patient is exsanguinating in front of you an ED thoracotomy should be employed with a left superior to the nipple anterolateral thoracotomy and clamping of the subclavian artery – on the right a median

sternotomy in the O.R or a clamshell thoracotomy in the ED will allow for proximal right subclavian clamping. After an ED thoracotomy with proximal control the patient is brought immediately to the O.R. for definitive repair. In the O.R. your options for an axillary artery are ligation or shunt if the pt is in extremis. A shunt is preferred over ligation if feasible. In the more stable patient, vein or prosthetic interposition graft placement are options. Most young healthy patients will tolerate axillary artery ligation without limb loss – consider performing UE fasciotomy.

Lessons Learned:

- Patients with an exsanguinating axillary artery injury need proximal control ASAP
- Immediately pack and manually place pressure on all axillary wounds, intubate, groin cordis, start blood
- Perform left above nipple anterolateral thoracotomy for exsanguinating LEFT axillary artery injury for prox control
- Perform clamshell thoracotomy or median sternotomy for prox control of RIGHT exsanguinating axillary artery injury
- If stable and not actively exsanguinating – get proximal control with supraclavicular proximal control of the subclavian artery
- Axillary artery ligation or shunt are options in the patient in extremis
- With axillary artery ligation consider performing a UE fasciotomy (or delay until correction of coagulopathy)

"Land mine injury to lower leg – and pus"

"14 y.o. male arrives at the FST with a mangled foot after stepping on a land mine – we took him straight to the O.R. the foot was obviously unsalvageable and we guillotine amputated above the ankle – then we debrided and irrigated – we left the wound open and started IV antibiotics – 4 days later frank pus was leaking around the bone…"

Land mine injuries are a unique injury that deployed surgeons will see around the world. The first rules of damage control surgery apply – stop bleeding and then debride. At the first operation remove all necrotic or marginal tissue and guillotine amputation at a safe proximal location and leave skin and muscle open to drain– irrigate and start IV antibiotics as soon as possible (preop). Always spare as much healthy tissue as possible. Land mine injuries are unique in that the pathway of least resistance for the explosion with contamination is most often up a bone proximally. A common surgical mistake is not to debride or transect proximal enough resulting in infection and the need to revise the amputation proximally. Do not forget tetanus prophylaxis.

Antibiotic therapy is augmenting adequate surgical debridement at the time of initial care. Although randomized controlled studies have not been undertaken to definitively identify the ideal antimicrobial agents to treat acute combat-related injuries, a recent committee met to discuss which antibiotics should be implemented in this setting. It was decided that a first generation cephalosporin such as cefazolin (ancef) is the ideal therapy.

Although studies have evaluated the use of enhanced gram negative coverage with an aminoglycoside or

fluoroquinolone, there is ongoing concern for selecting more resistant pathogens. If aggressive surgical intervention is carried soon after the injury, then therapy for 24 hours out to 72 hours is likely adequate in this setting. If the wound develops purulent drainage after 4 days, broad spectrum antibiotics should be started after bacterial cultures are obtained with therapy subsequently dictated by those culture results targeting the specific pathogen and its antimicrobial resistance profile.

Lessons Learned:

- At the first operation always use guillotine amputation with muscle and skin open
- With amputations start IV antibiotics ASAP
- A common mistake with landmine amputations is not accounting for proximal bone pathway of contamination
- Multiple washouts and re-debridements may be necessary – do not close until all is healthy
- Remember tetanus prophylaxis as indicated

Abdominal Injury

"Colon frag wounds – blow it up"

"36 y.o. involved in an explosion and fragment holes from foot to his head, normal vitals except for low sats. Intubated, rt chest tube with 300 cc blood and air, on CT fragments seen throughout his abd. Took him to the O.R. for ex lap. 2 small holes in the transverse colon and 30+ hematomas all over his ascending and descending colon, tried to open the majority of blood staining spots. Closed his fascia. Next day, hypotensive and tachycardic – brought him back to the O.R. for re-exlap. I found fecal staining in his descending colon with a small perforation."

The only thing that comes close to a multiple fragment injury to the colon in civilian trauma is a shotgun injury. The classic teaching is to open (unroof) all colon hematomas and blood staining spots looking for a perforation and this should be followed in combat fragmentation wounds to the colon as well – but can be hard if the mesentery is full of fat. One thing that can be very helpful is the "colon squeeze" test. Take a colonic segment between both hands and squeeze the colon to distend it looking for escape of gas. Have a low threshold for a "second look" within 24 hours if any doubt.

Lessons Learned:

- Unroof and open all colonic hematomas and blood staining looking for perforations
- Perform colonic "Squeeze Test"
- Low threshold for second look with multiple colonic fragmentation wounds

"Packed abdomen and no abd wound vacs around"

"27 y.o. male with a RUQ GSW and hypotensive – took him straight to the O.R. and packed his upper quadrant with complete cessation of significant bleeding – he received 12 u of PRBCs – no way to even just close skin – no wound vacs around which I use back home"

The open abdomen is an essential initial condition of damage control surgery. A packed abd will require a second look and if the abd is packed and the patient received a significant resuscitation closing the fascia will be a set up for compartment syndrome. To remove the possibility of compartment syndrome the abd should be left open. A wound vac is a good solution but is not always available. A "field expedient" abd wound vac can be constructed. First layer over the bowel needs to be nonadherent plastic (no lap pads or towels directly on the bowel) a sterile radiology cassette drape or a towel encased by an Ioban works well) – it is also important to keep the bowel separated from the parietal peritoneum so place the plastic down into the gutters. The next layer on top of the plastic is kerlix (again not on the bowel directly) then 2 J-P drains with the tubing exiting superiorly) then more kerlix over the J-Ps then a all encompassing Ioban over the entire abd with small air tight "mesenteries" wrapped around the J-P drains as they exit – some place J-P drains through the skin. Place the J-P drains on suction to remove any excess fluid draining. This will allow for coverage of the bowel and keep heat in and allow for drainage of fluid.

Fig 13. Abdominal dressing over open abdomen

Lessons Learned:

- Keep all damage control abds OPEN
- Always keep plastic over bowel
- Place the plastic down into the gutters to keep bowel and parietal peritoneum separated
- A sterile radiology cassette drape or a blue towel encased in Ioban can provide a first layer
- J-Ps in a Kerlix bed can allow for drainage of fluid
- J-Ps must exit superiorly as the "leaks" of fluid are always inferiorly

"GSW thru the colon and bullet in the psoas muscle"

"28 y.o. male with GSW of the abdomen, brought him to the O.R. for ex lap – moderate stool soilage and significant descending colon tissue injury – stapled and removed the segment - the bullet was lodged in the psoas muscle with significant bleeding…"

The question of what to do with a bullet that has been potentially contaminated by a colon pass is relatively simple for the combat surgeon. While there are civilian case reports and case series that report a higher incidence of peri-bullet abscess formation after a colon pass through the risk of going after a bullet embedded in a muscle is too high. Dissecting a bleeding or non-bleeding retroperitoneal muscle can result in life threatening bleeding. These bleeding muscles should be packed with the first goal of damage control surgery in mind– stop bleeding – and you should consider a hemostatic plug or chitoflex for these injuries. If a retroperitoneal abscess forms - the area can be drained in a CONUS facility.

Lessons Learned:

- Leave embedded fragments or bullets in the retroperitoneal musculature in place – regardless if they pass thru the colon
- Pack off all retroperitoneal bleeding holes and do not dissect out

"IVC injury – we tried to fix it but had to ligate"

"25 y.o. male with frag wound to lower back - talking, SBP around 100, a little tachy, I took him to scanner – a single frag in his retroperitoneum with dye everywhere – took him straight to the O.R. Ex lap, Cattel, Kocher then opened the hematoma over 50% transaction of the lower IVC – controlled with sponge sticks. We tried to run a suture but had a lot of blood loss, and the patient became coagulopathic – had to just ligate the IVC– post-operatively his lower extremity compartments became real tight and when his coagulopathy corrected we took him back for 4 compartment fasciotomies."

Infrarenal Inferior Vena Cava (IVC) injuries can be ligated if primary suture repair is not successful or if you do not have the time to perform a patch graft. Ligation of the suprarenal IVC carried a very high mortality due to renal failure and should not be performed unless as a temporary last ditch effort and to return ASAP for return of flow. If one ligates the IVC a lot of blood will pool in the lower extremities and can result in muscle killing compartment syndrome. In the combat wounded undergoing IVC ligation where they will not be observed at one site or by one individual – all of these patients should undergo prophylactic B/L 4 compartment fasciotomy, leg elevation and leg compression wrapping.

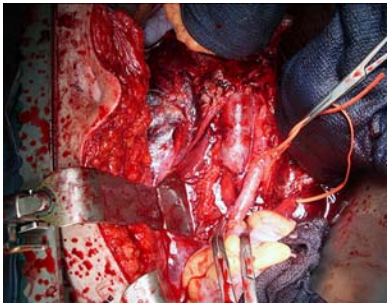

Fig 14. Distal ivc ligated with a prolene suture

Lessons Learned:

- INFRArenal IVC injuries can be ligated
- SUPRArenal IVC injuries should not be ligated due to very high mortality
- Bilateral 4 compartment fasciotomy should be performed for IVC ligation in a combat zone
- If coagulopathic – return to the O.R. for fasciotomy after coagulopathy is corrected
- Sponge sticks can be used to control IVC bleeding, Allis clamps can be applied to iliac vein bleeding points for control

- As blood pools in the lower extremities after IVC ligation, the pt will have significant fluid requirements

"The portal vein was transected – I tried to fix it but the pt became coagulopathic and I had 3 units of blood left…"

"29 y.o. female with GSW to abdomen. Took her immediately to the O.R. and did ex lap found huge hematoma. Clamped the porta hepatitis off prox and distally – opened it and found a complete transaction of the portal vein. We had limited blood supply so we ligated the portal vein and shipped her off to the CSH alive and warm."

All portal vein injuries should be primarily repaired if possible after proximal and distal control of the area of bleeding. If in a damage control mode – placing a shunt is an option and if in extreme physiologic and massive destruction ligation is an option but carries at least a 50% mortality due to the massive fluid sequestration in the gut and the patient will require massive amounts of fluid resuscitation for the first 24-36 hours post-operative – needless to say leave the abdomen open. Always perform "second look" at 24 hours for ischemic bowel. All applies for SMV ligation as well.

Lessons Learned:

- Clamping the porta hepatitis proximally and distally for control of a portal vein injury
- The portal vein can be shunted if enough portal vein is intact
- The portal vein (or SMV) can be ligated if primary repair or shunt is not an option

- Expect massive fluid requirements after ligating the portal vein
- Leave abdomen open with portal vein injury
- Perform second look for bowel ischemia in 24 hours with portal vein ligation, shunt or repair

"Frag right thru the right hepatic artery, cold, coagulopathic…"

"40 y.o. with multiple frag wounds to the abd and hypotensive – took him straight to the O.R. – blood, FFP, - ex lap – he had liver holes bleeding –packed them off – he had a hematoma with active bright red bleeding from his porta hepatis – clamped it prox and distally and then opened it up – his right hepatic artery was transected and he was now cold coagulopathic – I ligated both ends and got out – returned to the O.R in 24 hrs and removed packs and removed his gallbladder – he did fine."

Ligating arteries is a life saving maneuver in damage control – if the artery can be ligated with few complications. The right hepatic artery can be ligated if the portal vein is intact (remember the portal vein provides 75% of blood flow and 50% of the oxygen to the liver) but a cholecystectomy should be performed when the patient is stable and not coagulopathic due to gallbladder ischemia. In damage control many arteries can be ligated, including the left or right hepatic arteries if the portal vein is intact, the celiac axis, splenic artery (perform splenectomy at some point), unilateral renal artery (perform nephrectomy), axillary artery (should have abundant collaterals for limb salvage), in the extremities a shunt and fasciotomy should be performed if at all possible for limb salvage. The SMA cannot be ligated do to high incidence of small bowel

necrosis, if pancreas is also injured perform distal aorta to SMA interposition graft – place shunt in a damage control case. Iliac artery transaction should be treated with shunt in a damage control situation.

Lessons Learned:

- Arterial ligation can be performed as a life saving maneuver in damage control
- Perform cholecystectomy with right hepatic artery ligation
- The right or left hepatic artery can be ligated if the portal vein is intact
- The celiac artery can be ligated
- The SMA cannot be ligated – shunt and repair later
- The renal arteries can be ligated but then perform a nephrectomy
- The splenic artery can be ligated with a splenectomy
- The axillary artery can be ligated
- Perform a shunt and fasciotomy for extremity vascular injury if possible over ligation

"Massive abdominal wall destruction"

"29 y.o. male involved in RPG explosion – close proximity – arrived to the FST hypotensive with massive abd wound and fragments over abd/pelvis – took him to the O.R. ex lap – stopped all bleeding, packed liver and pelvis- had a huge right sided abd wall defect – just covered with an Ioban and shipped…"

A significant abdominal wall defect will get your attention. The same damage control principles are at play – stop bleeding and resuscitate with blood and blood products.

Ligate arterial bleeders from the abd wall after stopping any significant intra-abdominal bleeding – after surgical bleeding has ceased limit GI succus soilage – at this point you have basically an open abdomen familiar to all general surgeons and treat it that way – plastic over bowel – kerlix – +/- J-P drains over kerlix and then cover the entire defect with benzoin on skin followed by a large IOBAN – the alternative is to place a Bogata bag (IV or irrigation bag) sutured to the SKIN for temporary coverage – at the second look at a level III the abd wall is debrided and a wound vac is then placed if available (or replace the Ioban). Abdominal wall reconstruction can be attempted at level IV or above – the fall back position is always to let the bowel granulate (+/- single vicryl mesh coverage) and STSG. Then consideration can be made for definitive repair at 12 months post STSG.

Fig 15. STSG to granulation tissue of open abdomen

Lessons Learned:

- Large abdominal wall defects are treated like an open abdomen
- Place plastic over bowel for all temporary closures to minimize adhesions
- If vicryl mesh is placed over an open abdomen place a single layer to minimize time until granulation
- Wait 12 months before abdominal wall reconstruction after STSG to bowel

"GSW right thru the head of the pancreas and the duodenum"

"34 y.o. male with GSW to mid- epigastrium, went to ex lap and found a hole in the duodenum and head of pancreas with massive destruction. He needed a trauma Whipple but we only had 10 units of blood so we only finished half of the resection and called it quits and sent him to the CSH."

A trauma Whipple (pancreaticoduodenectomy) should NOT be attempted at a level II facility. In these situations go back to the basic principles of damage control: 1. Stop all bleeding 2. Stop succus soilage – Do not attempt resection. Stop all bleeding and soilage and place drains or simply pack off the area with dry laparotomy pads and ship after adequate pre-warming and resuscitation for the trip to the next level. The definitive surgery can be successfully performed at the Level III with adequate blood bank support and ICU care. Enlist the help of the most experienced surgeon.

Lessons Learned:

- Do not attempt a Whipple at a level II facility
- Stop all bleeding and soilage and transfer packed with an open abdomen to a level III

"Ahh – the packing will stop the bleeding"

"27 y.o. male with at least 2 GSW to RUQ – hypotensive – brought emergently to O.R. – ex lap – lots of blood and lots of bleeding from the RUQ. Packed it off – still blood – pringle and packed him off and started massive resuscitation, FFP, PRBCs, platelets, cryo, Factor VIIa, removed pringle and thought packing would hold off bleeding – gave time for correction of coagulopathy while we were waiting he went bradycardic and then asystolic…"

While packing is a very important part of damage control it cannot stop surgical bleeding. A transected portal vein or IVC will not be held off very long with packing – if you still have significant bleeding after packing – you are usually dealing with one of 2 possibilities; major vessel bleeding or massive coagulopathy – in these cases you must remove the packing and reassess to determine what is the culprit. This is true for any region. The one exception is a deep muscle bleeder from the psoas muscle – do not go chasing a vessel in this area – just pack tight and consider hemostatic agents such as fibrin soaked Gelfoam®, surgical®, Avitene®, Chitoflex®, etc. Packing is not a cure all for massive bleeding. If packing stops the bleeding do not remove the packs at that operation.

Lessons Learned:

- Packing will not stop major vessel bleeding

- If significant bleeding after packing consider, surgical bleeding or massive coagulopathy
- If significant bleeding after packing remove packing and reassess the situation
- Do not dissect out psoas muscle bleeders
- Consider hemostatic agents

"The rectum and nec fash"

"43 y.o. male with GSW to the pelvis – arrived to the CSh hypotensive – we took him straight to the O.R. – ex lap – packed his pelvis – had complete transaction of his rectum – stapled off the ends and packed him off – returned 24 hrs later for washout – performed colostomy – did not place presacral drain based on the civilian data – he developed a swollen left thigh took him to the O.R. – he had raging nec fasciitis "

While the classic teachings for a rectal injury from the Vietnam War are proximal diversion (colostomy), presacral drainage, distal rectal irrigation and closure of the rectal injury if easily done – the civilian trend has been to not to irrigate and not to place presacral or other drains. The Vietnam data (with small numbers) suggested a benefit from the addition of distal rectal stool washout in high velocity wounds. Combat high velocity rectal injuries are not civilian injuries and until we have data supporting otherwise a drain is a minor thing that may help and should not hurt – a high rectal injury should be drained with a J-P drain and a distal rectal injury should be drained with a presacral drain (J-P or Penrose). Distal rectal washout should be considered on a case by case judgment. If massive stool soilage and massive pelvic/rectal destruction

having a large stool reservoir may be a source of subsequent infection. Necrotizing fasciitis from a rectal injury often runs down the thighs and should be monitored.

Lessons Learned:

- Perform diverting colostomy for all rectal injuries
- Close rectal defect if accessible
- Place perirectal injury drainage
- Consider distal rectal stool washout with massive injuries

"Pelvic fracture and hypotensive"

"26 y.o. male speeding away from an explosion – which he missed – and ran into a tractor trailer head on – arrived to the FST talking but hypotensive with a SBP of 95. Clear breath sounds and not SOB, FAST negative but unstable open book pelvis fracture by physical exam. We wrapped sheets around his pelvis and spun it and taped it tight with 100 mile tape…"

Blunt trauma is not uncommon with or without penetrating trauma in vehicles especially after exiting a danger zone. Unstable pelvic fractures can often be elicited by physical exam. The commercial pelvic binders work well if applied correctly but often these are not available – in this case a simple sheet can be life saving – place the sheet under the buttocks and bring both ends anteriorly – twist the ends around each other and tighten down to the desired tension and then wrap the twisted ends with tape as close to the skin as possible. The knees should be taped together for extra support. Intraperitoneal bleeding should be evaluated with FAST or SUPRAumbilical DPL. With blunt pelvic fracture FAST is helpful only if positive – a negative FAST

with a blunt pelvic fracture cannot be trusted to rule out intraperitoneal bleeding and DPL should be performed to rule out intraperitoneal bleeding. The role of extraperitoneal pelvic packing with exsanguinating pelvic fracture is gaining popularity in civilian centers and should be considered in the exsanguinating patient with a blunt trauma pelvic fracture – especially with limited blood supply.

Lessons Learned:

- Blunt trauma is seen in the combat zone
- An open book pelvic fracture needs to be closed ASAP
- A sheet wrapped, twisted and taped down around the pelvis will close most pelvic fractures
- Tape the knees together for extra support
- With blunt trauma pelvic fracture the FAST is accurate only if positive
- If FAST is negative in the unstable pelvic fracture patient perform supraumbilical DPL
- Consider extraperitoneal packing in the unstable blunt trauma pelvic fracture patient

"Transpelvic GSW and interventional radiology… NOT"

"34 y.o. with transpelvic GSW arrives at the CSH hypotensive – bring him straight to the O.R. – ex lap – iliac vein and arteries are intact – he has a small entrance hole on the right pelvic wall and a large hole on the left pelvic wall with profuse bleeding. – I packed the small hole with surgical and lap pads. I tried to pack the large hole and placed lap pads but had continued bleeding – he

is now getting coagulopathic - I tried the left hypogastric with a zero silk and packed – it stopped bleeding"

Transpelvic GSWs can present with massive pelvic wall destruction and a combination of arterial and venous plexus bleeding. Small holes can be plugged with a "hemostatic plug" made up of thrombin soaked fibrin, avitene all rolled up like a cigarette in Surgicel – this plug can be placed in small holes followed by lap pads. Large holes are harder to pack off for hemostasis but a hemostatic dressing such as chitoflex or surgicel/fibrin followed by lap pads often works or consider Foley catheter. If life threatening coagulopathic bleeding continues consider excluding arterial inflow – in civilian practice embolization is an option but at most level III this not available or is rudimentary. The option to the surgeon is tying off the hypogastric or by injecting avitene into the hypogastric artery– this tolerated if unilateral in the vast majority of young patients. The use of a large suture also allows the option of removing the suture at the second look. Another last resort with life threatening pelvic hemorrhage is packing the pelvis tight and then actually closing the lower 1/3 of the abdominal fascia for a tamponade effect

Lessons Learned:

- Use hemostatic plugs for small bleeding pelvic wall holes
- If unilateral pelvic wall bleeding refractory to packing consider ipsilateral hypogastric ligation with a large suture
- If life threatening pelvic hemorrhage continues as a last resort consider packing and closing the lower 1/3 of the abd fascia for tamponade

- Consider use of a Foley catheter for hemostasis on defined holes

"Stomach multiple frag wounds – blow it up"

"29 y.o. female involved in explosion arrives hypotensive and multiple abdominal fragmentation wounds. Emergent Ex Lap – multiple small bowel wounds resect – I look at the stomach and it has a dozens of small hematomas – I open up the big ones – no full thickness injuries – oversew any serosal defects – open up the lesser sac – posteriorly the stomach is fine but how can I hedge my bet that no other of these hematomas are full thickness?"

Multiple fragmentation wounds of the stomach is a unique injury to combat wounded. All large hematomas need to be unroofed looking for serosal or full thickness wounds. Full thickness wounds need to be close in 2 layers and any serosal tears oversewn with Lembert stitches. One option successfully applied by combat surgeons in this situation is to place an NGT tube and fill the stomach bed with warm saline then have your anesthesia colleagues inflate the stomach with air as you manually occlude the duodenum. Then assess for any air bubbles or succus extrusion from any holes in the stomach.

Lessons Learned:

- Always open the lesser sac to visualize the posterior stomach
- Unroof any stomach hematomas as feasible to rule out underlying hole
- Close full thickness stomach holes with 2 layers
- Lembert any stomach serosal tears

- Consider stomach inflation under saline to assess for missed injury to the stomach

"Isolated frag wounds to the RUQ and liver"

"28 y.o. male with multiple frag wounds to RUQ – normal vitals – took him to the CT scanner. Had several fragments that looked like they went through the liver and lodged in the lung – we brought him back to the ED – placed a chest tube and based on the LA data observed his abdomen- he developed a broncho-biliary fistula – we took him to the O.R. a week later and closed the diaphragm defect but the fistula persisted his CBD was 3 mm so we did not think a T-tube would be an uneventful enterprise sent him to a third country for an ERCP and stent placement – he did fine after that…"

Combat wounds are not civilian injuries. You should think twice before applying new directions in civilian trauma to combat wounds. The safest approach for all combat penetrating wounds to the peritoneal cavity should be ex lap. Penetrating wounds to the RUQ in the patient with normal hemodynamics may have a nontherapeutic ex lap missing a diaphragm injury or transverse colon and missing such an injury may be disastrous – especially if the patient goes without surgical observation as they progress through the multiple legs of global transport.

Lessons Learned:

- The safest approach to all combat penetrating injury to the peritoneal cavity is ex lap

"The spleen had a small piece hanging off"

"37 y.o. male with multiple frag wounds to the LUQ from an explosion. Normal vital signs – took him for CT – he had a left pneumo and lots of fragments in his LUQ- placed a Chest tube and took him to the O.R. for ex lap- found diaphragm holes and the lower pole of the spleen was hanging by a few strands of tissue – removed the devitalized tissue and performed a splenorrhaphy with interrupted pledgetted prolenes – he did fine at first but 2 days later while he was about to board the helicopter for transfer he got hypotensive and had to bring him back for re-bleeding and then just performed a splenectomy…"

1As all surgeons know the spleen can bleed and can bleed any time post op after a splenorrhaphy. We have all heard or experienced life threatening rebleeding or delayed rupture from the spleen in our CONUS practices. Combat surgeons should not even consider splenorrhaphy in combat wounded servicemembers – it is not worth the risk of re-bleeding while in an aircraft 40,000 feet above the ground. Local nationals are a different consideration – a judgment

Fig 16

call - but you will need prolonged observation and must have immunizations given prior to discharge and probably a pre discharge CT scan to rule out any large hematomas or pseudoaneurysms. Immunizations should be given at level IV or level V – civilian studies have demonstrated maximal response to postsplenectomy immunizations at 2 weeks post splenectomy but combat wounded can be considered for immunizations after fluid shifts and major inflammation – optimally, consider any time between 7-14 days. Immunizations should include pneumovax, H. Flu, and meningococcus. In the patient with a significant spleen injury from blunt trauma – when you would observe in CONUS civilian practice- you should have a low threshold for splenectomy to avoid subsequent life threatening splenic bleeding.

Lessons Learned:

- Do not perform splenorrhaphy in servicemembers in a combat zone
- Have a low threshold for splenectomy in blunt trauma
- Give post splenectomy immunizations at level III or level IV
- DOCUMENT immunizations
- Give post splenectomy immunizations to all local nationals PRIOR to discharge

"A large retroperitoeal hematoma" (exposures)

"24 y.o. female with multiple fragmentation wounds to her back from a suicide vest explosion, normal vitals – scanned her had a lot of frags in the retroperitoneum with

lots of blood – took her to the O.R. for ex lap – found a large right retroperitoneal hematoma – not pulsatile nor enlarging – we had time so set up the Bookwalter retractor –called for another surgeon- we found holes in the IVC and the ascending colon…"

Fig 17. Large retroperitoneal hematoma

A large retroperitoneal hematoma will get your attention. These hematomas are often stable with the tamponade effect from the overlying tissues and peritoneum. If the patient is stable and you have a little time optimal exposure can be obtained with the Bookwalter retractor and calling in another surgeon (or 2!). proximal aortic control can be obtained at the diaphragm. And distal control can be obtained at the pelvis or by groin cut downs (by another surgeon). Almost the entire intra-abdominal IVC can be exposed by performing a Cattel-Braasch procedure (right medial visceral rotation) by taking down the ascending colon white line of Toldt and swinging the ascending colon

to the midline – performing a Kocher duodenal mobilization will then complete the dissection. On the left the aorta can be exposed by performing the left medial visceral rotation (aka Mattox maneuver) take down the left white line of Toldt and swing the descending colon, spleen, pancreas to the midline – swing up the kidney as needed. Temporary hemostasis for exsanguinating bleeding can be obtained with placement of an Allis clamp on the bleeders opposing the 2 sides of a bleeding structure. IVC bleeding can be slowed or stopped by placement of 2 sponge sticks prox and distal to the bleeding point.

Lessons Learned:

- Retroperitoneal hematomas can be challenging
- Place Bookwalter if the pt is stable
- Call for another surgeon or 2
- Always attempt proximal and distal control if feasible
- The intra-abdominal IVC can be exposed with right medial visceral rotation (Cattel) and a Kocher maneuver
- The intra-abdominal aorta can be exposed with a Left medial visceral rotation (Mattox)

"Colon injury and a red wound"

"44 y.o. male with multiple frag wounds to the abd – nl vitals – FAST negative – positive peritoneal penetration on CT went for ex lap found multiple wounds to the ascending colon with mild stool soilage – I performed a right hemicolectomy and end to side ileocolostomy. Due to the minimal soilage I closed his skin – 5 days later he had

a red wound with drainage – opened up the wound and packed…"

Penetrating colon injuries have a huge bacterial load by definition. Civilian penetrating colon injuries have a 50% wound infection rate if the skin is primarily closed. Leave the skin incisions open in all penetrating colon injuries. With significant succus soilage leave all the skin open even after small bowel injuries. Change dressings at least twice a day and consider placement of wound vac when clean. A delayed primary closure is an option – but do not attempt unless you are going to be able to observe the wound yourself.

Lessons Learned:

- Leave the skin incision OPEN after all colon injuries
- Leave the skin incision open with all small bowel injuries with significant succus soilage
- Do not attempt a delayed primary skin closure unless you are able to observe the wound

"Hypothermia, frag wounds to abdomen and head"

"34 y.o. male involved in an explosion with frag wounds to head and abd – unconscious and hypotensive – took him to the O.R. ex lap – packed pelvis and liver – stopped bleeding and was resuscitating him in the ICU – went for CT of head and had several intracranial fragments – the neurosurgeon wanted to take him to the O.R. and wanted to keep the room cool for a "hypothermic" craniotomy – I refused – had to call the DCSS…"

The benefits of hypothermia in brain injury is a hot area of neurosurgical research and currently is controversial. In

combat wounded it can be, and has been, utilized in the isolated head injury patient. There is no role for hypothermia in a fresh post-op damage control patient. The patient with multiple injuries is the general surgeon's patient – period. Everyone else is a consultant. If you think a craniotomy under hypothermic condition will hurt your patient this usually can be resolved with a simple discussion with the neurosurgeon – if this does not work that is why there is a chain of command – talk to the DCCS.

Lessons Learned:

- The general surgeons direct all aspects of care for the damage control patient
- The DCCS can be the final arbitrator for treatment disputes
- There is no role for a hypothermic craniotomy in multisystem injured damage control patients

"Massive colon injury – stoma or no stoma?"

"25 y.o. female with GSW to abdomen arrives at the CSH– took her straight for ex lap – stool everywhere and transverse colon in multiple pieces and mesenteric bleeding and a transected small bowel – stapled off all bowel – removed the injured segments of large and small bowel- stopped all mesenteric bleeding returned to the ICU for resuscitation – the next day she was normalized and brought her back to the O.R. – colostomy or primary anastomosis?..."

Colon injury in the civilian world has made a shift to primary repair and primary anastomosis in almost all penetrating colon injuries. Small holes in the damage

control patient should be closed in 2 layers. The question of what to do with colon destruction is not clear in combat. At a level II all destructive colon injuries should be stapled off or ligated with an umbilical tape after all bleeding is stopped or packed and ship when normalized as much as possible to a level III. At a level III the abbreviated operation should be the same – staple off return to the ICU for resuscitation and re-warming and then bring back to the O.R. for a washout and definitive operation. Consideration must be made in locals regarding colostomy – colostomy bags are often extremely hard for the patient to get and will set up for severe stoma complications – these patients also give the individual the luxury of observing post-op after an anastomosis and you should have a lower threshold for performing a primary anastomosis in these local nationals. In service members who will undergo global evacuation with intermittent surgeon observation and different surgeons at each level must be kept in mind as well and this situation will lower your threshold for a colostomy. In a review of combat colon injuries, transverse colon and left sided injuries were risk factors for anastomotic leak. In civilian trauma, a concomitant pancreatic or renal injury has been shown to increase the risk of anastomotic breakdown. Massive transfusion is a risk factor for anastomosis breakdown. Civilian damage control patients have shown no difference between stapled or hand sewn colon anastomosis in a multi- institution study (small bowel has a greater leak risk with stapled anastomosis).

Lessons Learned:

- Small fragmentation wounds to the colon should be primarily closed
- All destructive colon injuries should just be stapled off at level II (remove the injured segment)

- Colostomy should be performed with concomitant pancreatic or renal injury, persistent hypotension and massive transfusion at level III
- Isolated colon injury in the hemodynamically normal patient should be treated with primary anastomosis
- Have a lower threshold for colostomy in transverse and left sided colon injuries

"The pelvis was packed with 2 lap pads floating in a pool of blood"

"26 y.o. male with multiple frag wounds to abdomen/pelvis, chest and lower extremities – arrives to the CSH after an ex lap during a MASCAL at a FST – the abdomen had the following written in an indelible marker "pelvis packed"- he was very unstable so we took him to the O.R. gave him warm blood/FFP and took a second look – his pelvis was full of blood and we found 2 lap pads basically floating in the blood – we heard they were running out of supplies during the MASCAL – we repacked him and he did well post-operatively.."

The triage of medical supplies during a MASCAL at a level II facility is a reality at times. Just giving "enough" blood and other supplies to allow transfer to the next level is a reality a deployed surgeon may have to face. If running out of lap pads any sterile material that can help with filling up a space can be used, consider placing a few lap pads on the bleeding surface followed by sterile gowns, towels, gloves, and/or sterile drapes – these can be retrieved at the second look up the chain of evacuation – bleeding must be stopped at any cost.

Lessons Learned:

- During a MASCAL at a level II medical material may need to be triaged – this is a reality
- Lap pads can be extended with any sterile material that allows for volume – consider sterile gowns and drapes as packing material
- Stop bleeding with whatever is available

"Hole in stomach and left diaphragm"

"28 y.o. male with GSW to the left upper quadrant – brought him straight to the O.R for ex lap – GSW to stomach and colon with large hole in the diaphragm – closed hole in the stomach, stapled off colon, and fixed the diaphragm hole with 0 prolene – she developed a bad thoracic empyema – we had to do a thoracotomy…"

Penetrating injury to an intra-abdominal hollow viscus with a concomitant diaphragm injury is a set up for cross contamination of the pleural cavity. With these injuries it is important to irrigate the pleural cavity out and to place a chest tube for drainage. It is easy and takes just a few minutes to get a new Yankauer suction tip and to irrigate the pleural cavity out through the diaphragm defect – irrigate until clear. Enlarge the diaphragm defect if you need to confirm a clean pleural cavity. Then close the diaphragm defect and place a chest tube – *then* it is safe to irrigate the intra-abdominal cavity so that no contaminated irrigation fluid goes into the chest.

Lessons Learned:

- Place a chest tube for all diaphragm injuries

- If you have a diaphragm injury and a intra-abdominal hollow viscus injury – irrigate the pleural cavity out before repairing the diaphragm
- Do not irrigate the abdominal cavity until after you have repaired the diaphragm to minimize cross contamination

"Entrance left lower chest – large gaping wound on right"

"29 y.o. male with GSW to left lateral lower rib cage and large soft tissue defect over the 4-5th right ribs in the midaxillary line. I was thinking transmediastinal GSW. Placed bilateral chest tubes with minimal output and then he crashed and lost pulses in the ED. Performed an ED thoracotomy and found minimal blood and the pericardial sac was dry without evidence of any mediastinal bullet trajectory – did an ex lap – he had his diaphragm, colon and spleen injured. Resuscitated with splenectomy and stapled off colon – he survived – we found out later from the troops on scene that he had fallen and cut his right chest on a pipe…"

Anything can happen in combat. This case illustrates that what appears obvious may be quite wrong – getting a report from the on scene medic can be crucial. Bullets and fragments can go in any direction and with an unstable patient you will be in the O.R. and without the benefit from any preop imaging. You must rule out life threatening bleeding in the chest, pericardium, abdomen and "bleeding under the drapes" from extremities or large soft tissue defects- and you must know ASAP! Always keep in mind that the diaphragms can go up to the 4th intercostals space and you can easily have a diaphragm or intra-abdominal

injury with lower chest wounds. You must remain flexible and aggressive in your approach to finding what is bleeding. If the patient is stable an on table x-ray may help locate bullets/fragments and help ascertain the path of destruction.
In the patient with unexplained shock physiology – you must look in every cavity.

Lessons Learned:

- Projectile paths may be deceiving
- Aggressively rule out life threatening bleeding in the chest, pericardial sac, and abdomen
- Always evaluate for "bleeding under the drapes"
- Lower chest injuries may injure the intra-abdominal contents and/or diaphragm
- In hemodynamically normal pts consider an on table x-ray to help for projectile path determination
- Medic report on what happened to the patient can be critical
- You must rule out intracavitory bleeding at the first operation

"RPG blast with massive diaphragm loss"

"28 y.o. male near an RPG explosion arrives to the FRSS with a large gaping hole in his left flank, hypotensive – we take him to the O.R.- stool everywhere – staple off the colon – packed the flank – look up and he has a large diaphragm hole with diaphragm tissue loss , now what?"

Diaphragm injuries with diaphragm tissue loss are seen in combat injuries. The key to all damage control surgery is stopping bleeding and then stopping GI succus soilage. After this is completed direct attention to the diaphragm –

first place a chest tube in the ipsilateral chest. Next take a large Prolene and in a running fashion close any diaphragm that can be closed. IF a tissue defect remains place a temporary barrier – placing a blue towel between 2 IOBAN drapes and then placing under the diaphragm should keep bowel form entering the pleural cavity or sewing a radiology cassette drape directly to the diaphragm are options. Leave the abdomen open and with a loose temporary closure (e.g. loose IOBAN) so as not to have any intra-abdominal pressure to force bowel up into the chest. Resuscitated and ship ASAP. When the abdomen is cleaned out well at level III or level IV a Gortex synthetic can be placed or the diaphragm can be released and reattached at a higher costal level to gain definitive closure.

Lessons Learned:

- With large diaphragm defects stop bleeding and soilage first
- Place ipsilateral chest tube
- Leave abdomen open
- Quickly attempt primary closure with large nonabsorbable running suture
- Consider a temporary blue towel IOBAN barrier under the diaphragm or sewing radiology plastic cassette drape to the diaphragm

"GSW to the duodenum – getting cold"

"38 y.o. female with GSW to abdomen arrives to the FRSS in extremis – brought her straight to the O.R. – bleeding from mesenteric vessels – ligate them resect some small and large bowel – do my quick run of the

bowel and find a major hole in the duodenum with tissue loss – she is now cold and coagulopathic…"

Small holes in the duodenum can be easily closed in 1 or 2 layers. The large defects in the cold, coagulopathic damage control patient is another thing. You need to get out ASAP and do the roux-en -Y reconstruction (duodenal augmentation) during the definitive surgery stage of damage control at a level III or level IV. The best option in these challenging patients is to place a drain directly into the duodenal defect and close the injury around the drain with a whip stitch then pack off the area with laparotomy pads to soak up any succus drainage and ship to level III when resuscitated and warmed.

Lessons Learned:

- Do not attempt a Roux – en – Y duodenal augmentation during damage control with a large duodenal injury
- Place a drain in the duodenal hole and whip stitch the hole around the drain as best you can
- Place laparotomy pads around the injury
- At level II if in extremis with massive duodenal injury – staple off the duodenum, pack and place NGT
- Ship after resuscitation and warming to level III
- At level III when physiologically normal do the definitive duodenal augmentation with a Roux-en-Y anastomosis
- For devastating duodenal wounds consider pyloric exclusion and gastrojejunostomy

Urologic Injuries

"The bladder is blown wide open"

"34 y.o. male with transpelvic GSW –close range – arrives hypotensive – take him straight to the O.R. for ex lap. Pelvis is a stool, urine, bloody mess. Pack it off. Staple off the sigmoid colon – iliac vessels amazingly are intact but the bladder is blown wide open – he is coagulopathic and bleeding from the entire surface of the bladder mucosa – I packed the bladder open and went to the ICU for resuscitation…"

Massive bladder injury is a common occurrence with transpelvic high velocity GSWs. With coagulopathy the injured and raw surface of the bladder will bleed. The best damage control principle in this case is to simply pack the bladder with lap pads to stem the bleeding – and perform closure after the ICU resuscitation and correction of the coagulopathy at the definitive or second look operation. Generally, the bladder mucosa is very forgiving and can be closed primarily over a Foley catheter. However, in cases where a significant portion of the bladder is destroyed by the projectile, augmenting the bladder volume with a portion of small bowel or totally diverting the urine via an ileal conduit may be required at a level III or level IV MTF.

Lessons Learned:

- Pack the bleeding major bladder injury during the first operation
- Attempt closure at the definitive or second look operation
- Formal urinary diversion may be ultimately required if the bladder is unsalvageable

First To Cut

"The ureter was cut in half"

"26 y.o. male arrives to the FRSS with GSW to flank – hypotensive – bring him straight away to the O.R for ex lap. Has a big hole in the ascending colon, bleeding from the psoas muscle, and his right ureter is transected – stapled off the colon – packed the psoas hole, now what about the ureter?..."

Ureteral injury during damage control is of a low priority – stop the bleeding stop GI succus/stool soilage and then consider the ureter. Don't dissect the ureter out – just leave in place – if you are at a level II and have quick transport your options are to simply pack the ureter off with lap pads or perform a simple ligation – leave the sutures long for easy identification. Stenting or placing a small pediatric feeding tube for external drainage are of little added benefit and can be reserved for bailout at a level III. The definitive repair is dependent on the length of the injured segment and the location of the injury. Repair of small lacerations can be performed with interrupted absorbable sutures (e.g. PDS) over a stent at level III. Additional maneuvers that aid ureteral salvage are reimplantation with a Psoas hitch (good for distal ureteral injuries) or transureteroureterostomy (TUU- bypassing the injured ureter by anastomosing the proximal aspect of the damaged ureter to the normal contralateral side. If at a level III and there is concern for a ureteral injury consider the administration of indigo carmine or methylene blue either intravenously or by direct injection into the ureter to better identify ureteral injury.

Lessons Learned:

- Do not dissect out the ureter due to fragile blood supply
- At level II pack off the injured ureter or perform simple ligation (leave suture ends long)
- Placement of a pediatric feeding tube into the proximal ureter for external drainage can buy time at level III
- Use absorbable sutures over a stent for definitive repair
- Repair strategy dictated by length and location of ureteral injury
- Consider urine dye to look for small perforations Direct inspection of the ureter is the most sensitive way to diagnose a suspected ureteral injury as radiologic studies often have false negatives

"The kidney had 50 small frag holes"

"27 y.o. with multiple fragments to flank after an explosion attack. Arrives hypotensive with a positive FAST exam. To O.R. emergently for ex lap. Large left retroperitoneal hematoma with multiple bleeding holes in the peritoneum – did a Cattel maneuver, went straight into Gerota's fascia and delivered out the right kidney. Had multiple small frag wounds-no other injuries – still warm - not coagulopathic so I just packed the kidney and shipped him…"

Penetrating injury to the kidney that is actively bleeding is an easy fix if in damage control mode – just take it out. The uninjured normal sized contralateral kidney will be sufficient for life. The first question is the need for

isolation of the renal artery before opening Gerota's fascia – Civilian data supports just opening Gerota's fascia without renal artery isolation – saves time and decreases blood loss. Opening Gerota's fascia and bringing the kidney to the midline will give you access to a bleeding renal artery. The next question is 'should I take the kidney?' – if not in damage control mode – minor fragmentation wounds to the kidney will often be stopped with simple packing. At the second look laparotomy at a level III if bleeding has ceased – omentum can be packed around the kidney and J-P drains placed. Fibrin based sealants and hemostatic agents can be used as helpful adjuncts to control renal parenchymal bleeding and prevent urine leakage. One caveat – each kidney receives 12% of cardiac output and can re-bleed and re-bleed impressively – which would be suboptimal 40,000 feet above ground – renal preservation is a judgment call.

Lessons Learned:

- The right kidney can be exposed with the Cattel maneuver (Right medial visceral rotation)
- The left kidney can be exposed with a Mattox maneuver (left medial visceral rotation)
- Nephrectomy is the solution to an actively bleeding kidney injury in damage control
- Small fragmentation wounds can be treated with packing in stable warm patients
- Renal artery isolation prior to opening Gerota's fascia in the hypotensive patient with penetrating renal injury results in loss of time and blood
- Drain (closed suction drainage) all renal injuries
- Omentum and fibrin based hemostatic agents can be used to help seal renal injuries

"Both testicles"

"28 y.o. male arrives at the FST with multiple bleeding frag wounds to the groin from a mortar blast – on exam the scrotum had multiple frag wounds actively bleeding with massive scrotal skin loss– testicles felt disrupted. On scrotal incision the left testicle was in a hundred pieces and I removed it – the right testicle had frag wounds but had a chance with a urologist – due to the skin loss we placed the right testicle in the subQ tissue of the right thigh and shipped him to the CSH."

Testicle injury is a challenging injury for the general surgeon. The obviously destroyed testicle should be removed. For a testicle to survive and function, the Tunica Albuginea must be reapproximated around the exposed seminiferous tubules. This may require additional coverage with graft material (Tunica Vaginalis) This is best done by a urologist at a level III. Stop all significant bleeding and cover the injured testicle with scrotal skin if possible. Injured testes can be wrapped with moist gauze within a packed wound during evacuation to level III. If no scrotal skin is available after the testicle is repaired or inspected and deemed salvageable, place the testicle in a subcutaneous pocket in the upper thigh and ship ASAP.

Lessons Learned:

- Shattered testicles should be removed by controlling and ligating the spermatic cord proximal to the testis
- The testicular parenchyma must be completely covered by Tunica Albuginea or another suitable graft tissue for salvage

- The testicle may be placed in a subcutaneous thigh pocket if significant loss of scrotal skin
- Send the patient to a Urologist if a challenging injury

"GSW to the kidney and we tried to fix but he became coagulopathic"

"34 y.o. female arrives hypotensive with a GSW to the flank – we took her straight to the O.R. Bleeding left zone II hematoma – opened it up brought the kidney to midline and she had her lower pole hanging in the breeze. We called the urologist in and we attempted to repair it but she got cold , coagulopathic and had significant bleeding from the kidney parenchyma – her other kidney was normal in size and uninjured – we put the shattered left kidney in the bucket."

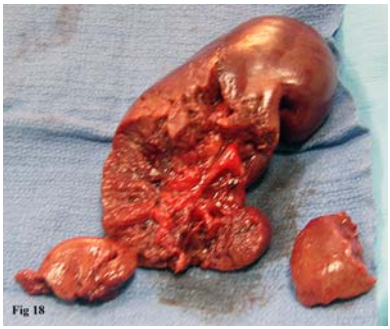
Fig 18

The bleeding kidney in a cold damage control patient should be removed ("life over kidney") – especially if the other kidney is intact and of normal size. . Only one-third of one kidney is required to keep a patient off of hemodialysis. If both kidneys are injured surgical measures should be employed to attempt to salvage some renal tissue – packing the kidneys off and warm resuscitation are temporary measures to buy some time. Attempts to repair an isolated injured kidney in a stable patient can be made in select patients with smaller lacerations and viable appearing renal

parenchyma. Exposed urinary collecting system injuries should be closed separately and in addition to the overlying parenchyma to prevent urinoma formation. Urology should be involved if possible.

Lessons Learned:

- The bleeding unilateral kidney can be removed as a damage control measure.
- One uninjured normal sized kidney can support life without need for dialysis
- Drain all kidney repairs. Use fibrin sealant if collecting system is repaired.

Chest Injuries

"Chest frags, amputation and 1000 CCs from the chest tube"

"27 y.o. male with left above the knee traumatic amputation, and multiple frag wounds to the left chest. Arrives to the CSH from the FRSS - cold, coagulopathic, and hypotensive. It has been 4 hours now and the left chest tube output was 1000 cc and the amputation was not bleeding – they had already tied off the artery. We placed Baer huggers – gave him warm FFP and PRBCs. I was thinking if I took him to the O.R. and opened his chest the heat loss would kill him – I just warmed him up and gave him blood and blood products and the chest tube output stopped – the tube was functioning and CXR revealed no retained hemothorax – he did well after that…"

85% of civilian penetrating chest wounds are treated with a simple chest tube. While the textbooks state that the indication for a thoracotomy in civilian chest trauma is 1000-1500 CCs from initial chest tube placement or 200 CCs per hour for 4 hours, the combat surgeon does not have the luxury of such formulae. The decision to perform a combat thoracotomy is based on where you are (level II vs. level III), blood and blood product support, the condition of the patient (hypothermia, coagulopathy) and wounding pattern (GSW vs. Fragments). The surgeon at a level II facility should have a lower threshold to perform a thoracotomy to stop bleeding earlier rather than later while a surgeon at a level III may have a higher threshold due to the logistics needed to warm and correct a coagulopathy (improve Base deficit, INR, Ph, and temperature). Since we do not currently have data support thoracotomy based

on chest tube output in combat wounds – we should use the civilian teaching as clear indicators for a thoracotomy (1500 CCs initial chest tube output and 200 CCS per hour for 4 hours) – situations with less chest tube output should be a judgment call based on you and your patient's situation/condition- but always beware of compensated shock in young healthy military personnel turning bad real quick.

Lessons Learned:

- Surgeons at a level II should have a lower threshold for performing a thoracotomy
- Correct hypothermia and coagulopathy aggressively with minimal to moderate chest tube output
- Have a low threshold for thoracotomy after a high velocity GSW to the chest with significant chest tube output
- Always perform a thoracotomy if initial chest tube output is >1500 CCs
- Follow INR, temperature, and Base deficit or lactic acid

"Frag wounds to 'the box"

"28 y.o. female with multiple frag wounds to the parasternal region, stable with SOB – placed bilateral chest tubes performed a FAST exam – which was negative – and then she crumped – brought her immediately to the O.R. – performed median sternotomy – released tamponade & fixed atrial hole – she walked out of the CSH a week later…"

Injuries to the “box” are worrisome for cardiac injury. The “box” is defined as an area from the clavicles to the costal margin and from nipple to nipple – this includes back wounds over this same area.. While FAST exam with views of the heart looking for pericardial blood approach 100% sensitivity in civilian centers specialized in ultrasound – they have the luxury of constant observation and the best in the world expertise in ultrasound. Furthermore, if there is a concomitant hemothorax the pericardium may have a hole with cardiac wound blood decompressing into the pleural cavity making the pericardial blood hard to see on ultrasound. The combat surgeon – especially at a level II does not have the luxury of constant observation – where the missed cardiac injury could easily result in death of the patient. Lung injury can be evaluated with CXR or bilateral chest tubes. The heart can be assessed (and reassessed) with ultrasound but the definitive way to assess the heart is to perform a pericardial window – a small incision is a small price to pay for not missing a cardiac injury. If the patient is hypotensive with frags or GSW to the “box” place bilateral chest tubes and O.R. for pericardial window – and do not forget the abdomen. If in extremis, O.R. for median sternotomy or thoracotomy based on chest tube output. If you have significant bleeding from a chest tube most would perform ipsilateral thoracotomy – you can release a tamponade from any thoracotomy and then you can clamshell if you need more cardiac exposure. If minimal chest tube output in the patient in extremis most would go straight to median sternotomy for maximal comfort when dealing with a cardiac injury. When performing a median sternotomy at a level II you will not have a pneumatic sternal saw – you will be using a Lebske blade and mallet – ask the

anesthetist to hold the ventilation on exhalation and try to stay in the middle of the sternum.

Lessons Learned:

- Penetrating injuries to the box can result in cardiac injuries
- In the normotensive patient, the pericardium can be assessed with FAST (and repeated FAST) and/or pericardial window
- The hypotensive patient with a penetrating "box" injury should have bilateral chest tubes, intubate, groin cordis and O.R. for pericardial window – if window is positive then median sternotomy
- The patient in extremis with a penetrating "box" wound should have chest tubes, intubate, groin cordis and median sternotomy or clamshell thoracotomy in the O.R. or E.D.
- Be familiar with the Lebske blade and mallet for median sternotomy or for going across the sternum for a clam shell thoracotomy
- Do not forget lower chest wounds can result in significant intra-abdominal injury

"Hole in the heart and no pledgetts"

"45 y.o. pedestrian involved in an explosion attack arrives to the FST with frag wounds to anterior chest – hypotensive – had fluid around heart on FAST. Placed bilateral chest tubes with minimal output- took to the O.R. emergently – did a median sternotomy with the Lebske knife had a small frag hole in his ventricle – took a 4-0 prolene – asked for a pledgett – we had none – used pericardium as a pledgett – he did fine."

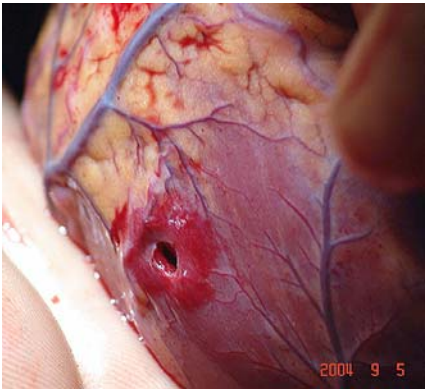

Fig 19. Small fragmentation hole in the heart ventricle

Cardiac injuries from fragmentation wounds can be small and allow for survival to the surgical facility. Isolated cardiac wounds are best approached by a median sternotomy or if in extremis a left ED thoracotomy with decompression of tamponade – always make incision anterior to the phrenic nerve. Bring the patient with vital signs to the O.R. and repair the injury. Holes next to a coronary artery are best repaired with a U stitch under the coronary artery. Pledgetts should be used and if you do not commercially available pledgetts a piece of pericardium can be used.

Lessons Learned:

- Isolated cardiac injuries are best approached by a median sternotomy
- At level II use a Lebske knife for sternal transaction
- Use prolene sutures on cardiac injuries
- Use pledgetts – the patients pericardium can be used as a pledgett

"Post-op day #5 and a retained hemothorax"

"27 y.o. local national with multiple frag wounds to his left chest arrives to the CSH with decreased breath sounds on the left – place a chest tube – 400 cc of blood and then <50 CCs and hour for 2 hours then stops bleeding – the next day the CXR was clear. On the 3rd day he had a moderate hemothorax on CXR – placed a second CT with CT direction – on the 5th day he still had the hemothorax – no thoracoscopic equipment…"

Retained hemothorax is a common complication after chest tube drainage for a hemothorax. The initial treatment is to place a second chest tube with CT mapping of the retained intrapleural blood – this maneuver is not always successful due to the solid clot that is often present. If the hemothorax is still present after placement of a chest tube a thoracoscopic debridement and decortication should be undertaken with the best results if done in the first 5 days. If thoracoscopic equipment is not available you can first try a small incision and Yankauer and irrigation and if no significant return then you should perform a thoracotomy for decortication of the blood rind – minimizing the incision as feasible. The danger is if the retained blood becomes a firm rind socking down a lobe – and thus you want remove the rind before it reaches this fibrotic stage in the first week.

Lessons Learned:

- Aggressively remove retained hemothorax
- Retained hemothorax is best diagnosed with a CT scan
- First move is to place a second chest tube with CT direction

- If thoracoscopic equipment is not available try Yankauer suction and irrigation through a small incision – if unsuccessful then perform minithoracotomy and decortication
- Perform a thoracoscopic decortication in the first 5 days
- If thorascopic decortication is unsuccessful perform thoracotomy
- Treatment of retained hemothorax "earlier the better"

"Damage control and esophageal injury"

"28 y.o. male involved in mortar blast – arrives at FST with head to toe frag wounds – hypotensive – FAST positive – bring him to the O.R. for ex lap – colon, small bowel , spleen bleeding – remove spleen, staple off and remove injured colon and small bowel – on pass I find a hole in the distal esophagus – about this time he becomes cold and coagulopathic- I whip stitched the goose defect closed and packed – we shipped him ASAP to the CSH."

Esophageal injury is a rare injury in both civilian and combat injured. From civilian data it is clear that primary repair of esophageal wounds have the best shot at healing if completed in the first 24 hours and earlier the better. If in damage control mode the thoracic esophagus should be widely drained – remember the proximal and mid thoracic esophagus is best exposed by a RIGHT thoracotomy and the distal thoracic esophagus by a LEFT thoracotomy- place a J-P in the hole and place a chest tube or 2. The intra-abdominal esophageal holes should be closed in 2 layers if possible and at buttressed with a fundoplication at

the definitive operation – place a hedge with a J-P drain close by as well. The esophageal holes should be closed in 2 layers and buttressed with intercostals muscle flap and always drain. Remember the esophagus does not have a serosa and poor blood supply – do not perform an extensive dissection of the esophagus. If you are at a level III and receive a delayed esophageal hole think wide drainage and consider a neck esophageal "spit fistula" – "better a live dog than a dead lion". Always place gastric drainage (G-tube) and enteral access with a j- tube or Moss type tube with esophageal injuries at the second look operation.

Lessons Learned:

- The proximal to mid thoracic esophagus is best exposed with a RIGHT thoracotomy
- The distal thoracic esophagus is best exposed with a LEFT thoracotomy
- In damage control mode – place a J-P drain in the esophageal defect and chest tubes
- Do not widely dissect he esophagus
- Always close the esophagus in 2 layers with a flap (intercostals or stomach)
- The ultimate last resort drainage includes a neck "spit fistula", tie off the distal esophagus with a umbilical tape or staple of, and place g-tube and j-tubes for gastric decompression and enteral feeding
- In the contaminated, infected medistinum consider combined drainage by sewing a Penrose to the end of a chest tube and place Penrose in the mediastinum and chest tube in pleural cavity

"Diffuse bleeding from the parietal pleural"

"34 y.o. male with high velocity GSW to the left chest – arrived to the CSH hypotensive and we placed a Chest tube – 1200 cc initial output and with continued output – took him the O.R. – started PRBCs and FFP – did a thoracotomy – he had bleeding from the lung but was able to wedge it out – there was diffuse ooze form the entire lateral parietal pleura …"

Diffuse bleeding from the pleura is not uncommon with a high velocity GSW with coagulopathic bleeding – first stop all surgical bleeding from the lungs and from any intercostals arteries – and rule out any cardiac bleeding. The chest can accommodate only limited packing due to loss of space. If the pleural is oozing from coagulopathic bleeding of course aggressively resuscitated and attempt to correct the coagulopathy with PRBCs : FFP in a 1:1 ratio, consider Factor VIIa if life threatening bleeding, platelets (or whole blood). You can coat the area with Surgicel and may have room for a single layer of a laparotomy pad – leave the chest open with an Ioban (or close skin only) temporary closure (always place chest tubes to remove air and observe for surgical bleeding). Bring back to the ICU and correct hypothermia, coagulopathy, acidosis and return later for second look, removal of lap pads and definitive closure with chest tubes.

Lessons Learned:

- The chest has limited space for "packing"
- Consider surgicel covered by a single layer of a lap pad
- Leave all "packed" chests open with an Ioban temporary closure

- Return to the ICU for correction of the lethal triad
- Return when resuscitated (coagulopathy, hypothermia and acidosis resolve) for definitive closure and pack removal

"It was just a little pneumothorax"

"29 y.o. male with blunt injury and explosion frags to legs (in a Moving vehicle hit by an explosion) intubated for GCS < 8. No frag wounds to chest or abd . E.R. CXR negative, slight widened mediastinum, scanned his chest and had a very, very small apical pneumothorax – the "occult PTX". Sent him to a neurosurgeon on a chopper. Arrived hypotensive and with low sats – he had a tension PTX treated luckily with a chest tube…"

The occult PTX (a small PTX seen only on CT scan) can be observed successfully in civilian trauma without positive pressure (intubation and ventilator). But a significant % of pts receiving positive pressure and pts undergoing global evacuation with changes in atmospheric pressure will develop a larger PTX some going on to tension. This can be prevented by the simple placement of a chest tube.

Lessons Learned:

All pts with an occult PTX in the combat setting should have a chest tube placed

"Frag wounds with lung hamburger"

"28 y.o. female involved in a explosion arrives to the FRSS hypotensive with multiple left chest frag wounds – place a left chest tube – get out 1700 cc of blood start PRBCs and FFP and bring her immediately to the O.R.

for a left thoracotomy – her lower lobe is just torn to &%$@! and part of the middle lobe – bleeding and gurgling at me…"

Lung injury is a common injury with fragmentation wounds to the chest. The majority are treated with a chest tube, FAST exam and then CT scan. By civilian teachings if more than 1500 cc at initial chest tube placement or more than 200 cc blood drains out every hour for 4 hours these patients clearly benefit from a thoracotomy, at thoracotomy you must open the pericardium to rule out cardiac injury – also rule out esophageal injury. Most thoracotomies in our experience reveal lung injury. Do not perform an anatomic lobe resection or pneumonectomy except as a last resort. If massive bleeding from the lung with impending exsanguination consider a "lung twist" in which the inferior lung attachments are transected and the lung is twisted around the hilum – this is associated with a high mortality (although most likely better than pneumonectomy) and should only be performed in dire situations. After a "twist" resuscitate then re-examine. Use a GIA stapler and perform piecemeal non-anatomic wedge resections for whatever is bleeding. For through and through GSWs use a tractotomy. Less is better.

Lessons Learned:

- Most chest frag wounds can be treated by a chest tube
- Do not perform a pneumonectomy or anatomic lobe resection except as a last resort
- Resect bleeding lung parenchyma with a GIA stapler in a non-anatomic minimal approach
- Consider a "lung twist" with massive life threatening lung hemorrhage

- At thoracotomy rule out cardiac injury and esophageal injury

"Massive chest wall destruction"

"28 y.o. male involved in RPG blast – arrives to the CSH intubated, hypotensive with low sats, massive left chest wall destruction -start blood, FFP and bring him straight to the O.R. He had several areas of blood and bubbling of air from his lung – I stapled them off – tied a few intercostals arteries. He was missing about 12 CMs of about 5 ribs – now what?..."

Massive chest wall injury is seen with military munitions. The first priority is to secure an airway and the O.R. In the O.R., stop all surgical bleeding, blood and blood product resuscitation, and warm. Non-anatomic stapler resections allow for minimizing lung parenchyma resection. The intercostals can bleed very vigorously and should be inspected. Small vessel chest wall bleeding can be addressed with a layer of a hemostatic agent – e.g. Surgicel followed by a single layer of a lap pad – the pleural cavity does not allow for massive packing. After stopping bleeding as best you can place a temporary chest wall closure with an Ioban drape or sew a Bogata bag over the defect to the skin. Go to the ICU for resuscitation and correction of the "lethal triad". Reconstruction will be undertaken at a level IV or level V.

Lessons Learned:

- Secure the airway and ventilation with massive chest wall injury first
- Stop all bleeding in the O.R. using non-anatomic resections and minimal packing

- Place a temporary plastic closure (e.g. Ioban)
- Post-op go to the ICU for resuscitation
- Transfer as soon as physiology is normalized

"E.R. thoracotomy in a MASCAL situation"

"24 y.o. male arrives during a MASCAL with GSW to abdomen and without a pulse – blood pressure reads 60/palp. We intubated him and performed an E.R. thoracotomy and clamped his thoracic aorta – we now had tachycardia of 180 and SBP of 65. All the O.R.s were full…"

The "E.R. thoracotomy" is controversial. The one clear indication where there are some positive results are with chest penetrating injury. The data on E.R. thoracotomy for blunt trauma without vital signs on the other hand, is dismal and has no role in a MASCAL. The role of an E.R. thoracotomy for exsanguinating abdominal trauma is undefined – there are no prospective randomized trials of E.R. thoracotomy versus rapid abd aortic control in the literature – although there are anecdotal case reports and series with survival with E.R. thoracotomy with major abdominal vascular injuries. The use of the E.R. thoracotomy is a judgment call based on logistics, MASCAL, O.R. availability. Clearly E.R. thoracotomy should not be used with blunt trauma in a MASCAL. The abd injury and E.R. thoracotomy should be only entertained if an O.R. is available. The one clear indication for E.R. thoracotomy during a MASCAL is the patient with penetrating chest injury in extremis as relief of a cardiac tamponade will buy you some time – extend the incision across the sternum into a "clamshell" – ligate the internal mammary arteries – the clamshell thoracotomy will give

you full access to the heart and all intrathoracic arteries. You can transect the sternum with a Lebske blade and mallet or with a pair of trauma shears or even a Gigli saw.

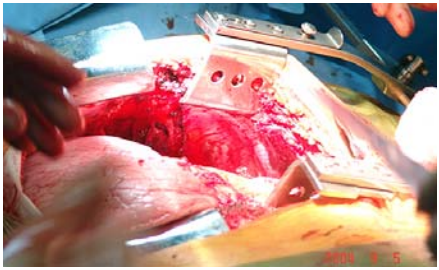

Fig 20. Clamshell thoractomy exposes the heart

Lessons Learned:

- E.R. thoracotomy for blunt trauma has dismal results and should rarely be performed – a never performed for blunt trauma in a MASCAL
- If an O.R. is available the E.R. thoracotomy for abd penetrating trauma is a judgment call
- The best results for E.R. thoracotomy are for the patient in extremis with penetrating chest trauma
- In a MASCAL – reserve the E.R. thoracotomy for penetrating chest trauma

"GSW to the lung"

"31 y.o. male with GSW to the left chest – ant to posterior thru and thru – arrives to the FRSS hypotensive and SOB – placed a chest tube – immediate return of 1600 cc of blood – started PRBCs – took him straight to the O.R. for thoracotomy – one hole bleeding profusely…"

High velocity GSW to the chest are actually rare in civilian trauma. The principals of damage control should be adhered to – stop bleeding as fast as possible with a

minimalist approach – "physiology over anatomy". The best way to get to the bleeding vessels is to expose them and then ligate them – this exposure can be obtained by performing a quick PULMONARY TRACTOTOMY. A tractotomy is performed by placing a GIA stapler into the bleeding tract and firing the GIA – this will staple off the edges and expose the bleeding vessels – then the exposed vessels and any bronchioles are then ligated with a prolene suture. Any peripheral GSW to the lung can be wedged out with the GIA stapler in a nonanatomic resection. At level II consider a temporary chest closure with an Ioban which will allow for quick re-exploration at level III.

Lessons Learned:

- Deep bleeding parenchymal GSWs to the lung should be opened with a GIA stapler tractotomy
- After exposure the vessels & bronchioles are oversewn with a prolene suture
- Peripheral GSWs should be removed with a nonanatomic wedge resection with a GIA stapler
- At level II consider Ioban temporary closure

Neck Injury

"Exsanguinating proximal neck wound"

"27 y.o. male with GSW to lower neck arrives to the FST with pulsatile arterial blood loss- I bypassed the ED and brought him straight to the O.R. and intubated him – held pressure and started standard CEA incision – when I got down to the hematoma and opened it – the blood actually hit the ceiling – I got a few deep prolene sutures down in a deep hole – not sure what I tied off - it held the bleeding off long enough for transport…"

Penetrating wounds low in the neck can be difficult to apply pressure to. The first priority is a secure airway so you can apply significant pressure without cutting off the airway. The next concern is proximal control – it will be a judgment call – if you think it is distal enough to get proximal control with a standard neck incision – an incision down the anterior border of the sternocleidomastoid - like for a Carotid endarterectomy (CEA) - dissect down proximally first and clamp the carotid low if you run into troublesome bleeding go to short MEDIAN STERNOTOTMY – enough to get a proximal clamp on the proximal carotid. If an O.R. is not immediately available you can try a Foley catheter for tamponade and this may buy you time but if the patient is exsanguinating in front of you "if in doubt – attack" and perform a median sternotomy in the ED with a Lebske knife. In the multi- injured damage control patient within the vortex of the lethal triad consider a shunt and reserve ligation as an extreme last ditch effort. If at a level II facility and the neck hematoma is stable – one option in many MASCAL situations is to intubate and transfer to a level III.

Lessons Learned:

- Definitive proximal control for proximal carotid artery injuries is a MEDIAN STERNOTOMY
- If an O.R. is not immediately available you can try Foley catheter tamponade
- If the patient is exsanguinating from a proximal carotid artery injury consider an ED median sternotomy with a Lebske knife in the ED
- Consider a shunt for near death damage control patients with major carotid injuries
- Use vein patch repair or vein interposition graft if primary repair will result in narrowing
- Consider carotid artery ligation in comatose patients

"The patient became coagulopathic and I had to ligate it"

"27 y.o. male with GSW to neck. Bleeding looked venous and well controlled with pressure – we took him to the O.R. and did a standard neck exploration. His Internal jugular was transected with bleeding from the surrounding muscles – at this point he had lost a significant amount of blood and was becoming coagulopathic so I ligated the IJ – he did fine."

With penetrating trauma to the neck the internal jugular is the most commonly injured vascular structure. It should be primarily repaired if easy but ligated if unilateral without hesitation – unless there is a concomitant brain injury. Ligating a venous structure is common when in damage control. Most large named veins should be repaired if feasible but most can be ligated without penalty. The exceptions to ligation are; both internal jugular veins, suprarenal vena cava (renal failure – high mortality), right

renal vein (remove right kidney at some point), splenic vein (perform splenectomy). The left renal vein has collaterals from the gonadal and adrenal veins and can be ligated close to the IVC. The popliteal vein should be salvaged if possible but ligation in damage control mode is no crime. The portal vein or SMV can be ligated if necessary but there will be massive fluid requirements.

Lessons Learned:

- Venous ligation is often the best option during damage control surgery
- Avoid IJ ligation if at all possible with a brain injury
- Do NOT ligate ***BOTH*** internal jugular veins
- Do NOT ligate the suprarenal vena cava
- Splenectomy with splenic vein ligation
- Nephrectomy with right renal vein ligation
- Left renal vein can be ligated close to the IVC
- Massive fluid resuscitation with portal vein ligation and second look – leave abdomen open
- Fasciotomy for IVC ligation
- Popliteal vein can be ligated or shunted if vein reconstruction is not feasible

"GSW to the neck –normal neuroexam and wide awake"

"29 y.o. male with GSW to his neck, arrived at the FST with packed nonbleeding wound, wide awake and neurologically intact. We intubated him – did a neck exploration- coagulopathic so packed neck wound – called the helicopter and then a RN asked me 'should we put on a c-collar?'"

There is danger in putting on a cervical collar on a patient with a penetrating neck injury – you cannot observe the wound for re-bleeding. With a penetrating wound to the neck if the patient is awake and is neurologically intact the spine is stable – in fact there are no reports in the world's literature of a patient with an unstable cervical spine fracture due to a penetrating neck wound who is awake with a normal neurologic exam. Reserve the cervical collar for the pt with penetrating neck wound who has an abnormal neuroexam, involved in blunt trauma, or who is comatose.

Lessons Learned:

- Consider the c-spine stable after penetrating neck trauma if the patient is awake with a normal neuroexam
- Place a c-collar for penetrating neck trauma if the patient is comatose or if the neuroexam is abnormal
- Place c-collar if blunt trauma until neck is cleared

"The O.R.s are full and pulsatile neck bleeding"

"So there I was, at a FRSS in a MASCAL – the first 4 pts were billed as the worst and 2 of them went straight to the O.R. for ex laps filling the only 2 tables we had – then the next wave came in – one fellow had a pulsatile arterial bleed from his neck – had to be the carotid – I mean impressive – we intubated him and tried manual compression with little success. I screamed I needed an O.R. table ASAP but it would be 20 minutes until we could get in…I took a Foley catheter and placed it into the bleeding neck hole, inflated the balloon and under tension clamped the catheter at the skin with a Kelly clamp – we then had no more significant bleeding and

brought him to the O.R and fixed a frag penetrating wound to the carotid."

Pulsatile arterial bleeding from the neck can give a surgeon quite the adrenal squeeze in the best of conditions. The first consideration should be the airway as hematomas in the neck can distort the trachea and compromise the airway – especially with a combative patient and while you are trying to manually compress the bleeding point. After the airway is secured sedation and placement of a Foley catheter should be considered if an O.R. is not readily available. The Foley catheter can provide a local tamponade effect. Direct finger compression against the vertebral column can also provide temporary control.

Lessons Learned:

- Secure the airway with penetrating exsanguinating neck wounds
- If O.R. is not available consider Foley tamponade for exsanguinating neck wounds
- Direct finger compression against the vertebral column can also provide temporary control

Brain and Spinal Injury

"Ventilation, ICP and the brain injured"

"27 y.o. male with explosion fragments to the brain arrives to the FST with a GCS of 5 – moving right side to pain – no movement on the left – intubate him and stabilize – calling for medevac – was considering hyperventilating him, had some mannitol – needed to send him to a neurosurgeon ASAP…"

Given that neurosurgical specialists are available at selected level III facilities, the question is how to treat patients optimally before transfer is common. First you must assure adequate blood pressure and oxygenation to the brain – stop all bleeding and maintain blood pressure and oxygenation by providing an airway, ventilation and addressing exsanguination. Cerebral perfusion pressure (CPP) is optimally >60. CPP is Mean arterial pressure minus intracranial pressure (ICP). Hence, hypertension should not be treated in acutely head injured patients. You will not have an ICP monitor. However, if lateralizing signs are present one can assume elevated ICP. A low PCO_2 or high PCO_2 in the brain injured in civilian trauma is associated with mortality and poor outcome – ensure the PCO_2 is between 30-35 unless directed by neurosurgical consultation or if signs of brain herniation are present. Signs of brain herniation include; flexor or extensor posturing or a blown pupil. Consider IV mannitol in the patient that is normotensive. Alternatively, hypertonic saline can be utilized in hypotensive patients with equal efficacy. Stabilization and early transfer are obviously paramount.

Lessons Learned:

- Maintain MAP and Sats in the brain injured
- CPP is MAP-ICP and should be >/=70
- Keep PCO_2 between 30-35 unless directed by neurosurgical consultation or signs of brain herniation
- Consider Mannitol IV/hypertonic saline in the brain injured patient with signs of elevated intracranial pressure
- Transfer ASAP

"Blunt spinal cord injury and damage control"

"24 y.o. male driver of a vehicle escaping an explosion at high speed runs into a pole – arrives at the CSH unstable but talking – unable to move or feel his legs – FAST positive- bring him to the O.R. – on table pelvis and chest x-ray both negative – ex lap pack his liver and remove his spleen, cold, coagulopathic bring him to the ICU – spine films show significant step off of lumbar spine – it is blunt and a spinal cord injury – do I give steroids?"

Giving high dose steroids to a damage control patient would represent a high infection risk. In light of the highly controversial benefit of steroids in blunt spinal injury in the first place – they have no role in a multiply injured combat wounded patient. The risk benefit analysis would be risking death for minimal gain. The role of high dose steroids is controversial due to inconclusive civilian data and can only be entertained combat wounded with ISOLATED BLUNT spinal cord injury – but we do not advise its use. There is NO role for steroids in PENETRATING spinal cord injury. The mortality of

civilian damage control laparotomy – without high dose steroids – is approximately 50% with a 40% morbidity – adding steroids to any multisystem trauma patient would most likely elevate both of these stats.

Lessons Learned:

- Due to questionable civilian data we do NOT recommend high dose steroids in combat wounded with isolated BLUNT spinal cord injury
- Combat wounded with PENETRATING spinal cord injury should NOT ever receive steroids
- Damage control or multisystem injured patients should not receive high dose steroids with blunt spinal cord injury due to risk of life threatening infections

"Head frag, pus and all alone"

"Up in the mountains – no helicopters for the foreseeable future due to weather – I get a 32 y.o. with a week old frag wound to his head, alter consciousness and frank pus coming from the head frag hole – I give him Rocephin and Vancomycin IV and get on the phone with a neurosurgeon – he says perform a craniotomy and drain the pus – so I take him to the O.R. and drill holes lift a bone flap with the Gigli saw and wash it out – place a drain – transfer awake and alive 2 days later…"

Neurosurgery for the general surgeon is challenging – but in remote locations it may be a life saving endeavor. In these situations it best to get some feedback from a neurosurgeon if at possible. A skull bone flap can be made with a Gigli saw after drilling multiple skull holes. A J-P drain can cut to size and placed for pus or blood drainage.

First To Cut

Before deploying, review the maneuvers for a simple craniotomy in case you are placed in this challenging situation.

Lessons Learned:

- The combat trauma surgeon needs to be able to perform a craniotomy with drill and Gigli saw
- Obtain neurosurgeon input prior to a craniotomy if possible
- Always place J-P drain after craniectomy

Burn Injury

"Burn resuscitation and the open abdomen"

"25 y.o. male involved in an explosion while in a vehicle came into the CSH. I used the rule of nines and came up with approximately 42% total body surface area burn (TBSA) burn. He received 2 liters bolus of LR before getting to us and then we rebolused him another 2 liters of LR. We took him to the O.R. for scrubbing and eshcarotomies and he received 7 more liters of LR. While awaiting transport he received another 10 liters of LR and developed abd compartment syndrome – I took him for decompressive laparotomy. I heard he died at the ISR 3 weeks later."

Secondary abdominal compartment syndrome is a well known complication of large resuscitation with crystalloid fluids and carries a high mortality in burn patients. Over-resuscitation has cause way more harm in current operations than under-resuscitation. Anecdotal reports have shown that placement of an intraperitoneal drain may allow for enough intraperitoneal fluid removal to avoid a decompressive laparotomy. Placement of a J-P drain before decompressive laparotomy should be considered. The best way to avoid over-resuscitation injury is of course prevention. MASCAL situation do not often allow time for calculating a burn IVF rate formula – in adults consider the **ISR RULE OF 10s** which will put you between the 2 most common burn resuscitation IVF formulas used in the United States, the Brooke formula (2 cc/kg) and the Parkland (4cc/kg).

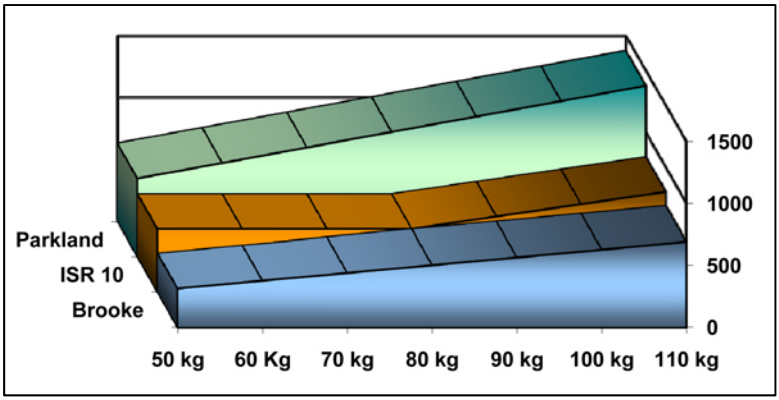

Fig 21. Brooke Formula

The ISR RULE OF 10s is very simple and is calculated by multiplying the % TBSA burn by 10 to arrive at the initial hourly rate of IVF for patient 40-80 Kg. For example 33% TBSA would be, 33% times 10 = 330 cc/hr. If over 80 Kgs then add 100cc for every additional 10 Kgs if the patient is over 80 kg – so a 100 Kg male with 33% burn would be 33 times 10 = 330 plus 200 so the total amount would be 530 cc per hour of LR. Always use the BURN FLOWSHEET as soon as possible.

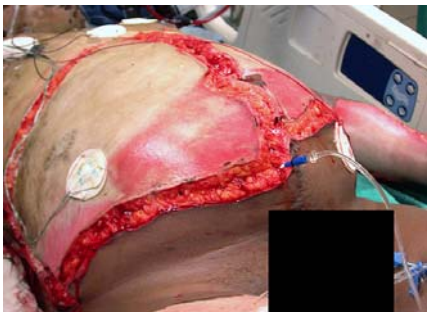

Fig 22. Continuous paracentesis to remove ascites from a massively resuscitated burn patient. The catheter output is flowing freely into a plastic bottle. This is a temporizing measure at best: the best treatment is prevention.

Fig 23. More is not better. Avoid this complication in burn patients by avoiding over-resuscitation.

Lessons Learned:

- Over-resuscitation of burned patients results in abdominal compartment syndrome and a high mortality rate
- Avoid boluses of IVF in burned patients – adjust IV fluid rate by 20% up or down based on urine output goal of 30-50cc per hour
- Consider starting the ISR RULE OF 10s and then follow urine output with the goal of 30 -50cc/hr
- Blood pressure measurement is unreliable in burn patients and is not the end-point of resuscitation. If you resuscitate to a ‘normal’ blood pressure, than you are giving too much fluid.
- Consider placement of a JP drain (intraperitoneal) before decompressive laparotomy
- Use the BURN FLOWSHEET as soon as possible

"Smoke inhalation – that tube better not come out"

"24 y.o. male in a vehicle hit by an explosion, secondary explosion – fire – trapped in the vehicle arrived with approximately 33% TBSA burn with black soot in his nose and mouth – obvious inhalation injury. We took him to the O.R., intubated him and performed escharotomies on circumferential burns on his arms and legs. CT scan was negative of abd/pelvis/chest/head/c-spine. His airway was going to swell big time with resuscitation."

Inhalation injury with burn injuries is caused by breathing in smoke and not from hot air. The patient with inhalation injury and/or any burns over 20% TBSA should be intubated PROPHYLACTICALLY for transport. Inhalation injury often results in increased fluid requirements. Soot in the mouth and/or nose is clinical evidence enough for intubation – i.e. have a very low threshold for intubation. The positive bronchoscopic examination for inhalation injury can be made at level III or level IV as you will not extubate a patient in theater based on the bronchoscopic exam, nor is there a therapeutic indication for bronchoscopy acutely unless there are ventilatory problems (e.g. mucus plug). Do not irrigate at the initial bronchoscopy as the irrigant can send soot down to the small airways/alveoli. One option used at level III is to have your OMFS colleagues wire the endotracheal (ET) tube to the teeth – sounds drastic but if the ET tube dislodges it may be impossible to put back in the best of situations let alone on a dark cramped helicopter or airplane!

Fig 24. Don't let this tube come out! Cotton umbilical tape ties were used to secure the tube circumferentially around the head. Adhesive tape WILL NOT stick to this face.

Fig 25. Bronchoscopic view of mucosal damage with inhalational injury

Lessons Learned:

- Intubate all burn pts with inhalational injury or >20% TBSA burns
- Have a low threshold for intubating
- Consider wiring the ET tube to the teeth for ET tube security during transport
- Do not irrigate at initial bronchoscopy – just suction

"Burned fingers and the "escharotendonotomy"

"Received a 29 y.o. patient with 56% TBSA burns – was not wearing gloves and had full thickness burns to his fingers. He had escharotomies at the CSH – they put incisions through his finger eschar in the sagittal plane in the middle of the top of the fingers down to the bone in places – his tendons were cut…"

Escharotomies are a very important part of acute burn care. The incisions should be down through the burned skin (eschar) and not involve the underlying fascia unless you are also dealing with a case of resuscitation-induced compartment syndrome. If the fingers have full thickness burns there is no data supporting finger escharotomies versus no finger escharotomies – most do perform finger escharotomies – if you do make 2 incisions on the lateral aspect of the finger down through the eschar only. The dorsum of the hand can be released with 2 (or more) parallel incisions through the eschar and not the underlying tendons. Arms and legs can be released with electrocautery with 2 bilateral incisions through the eschar. The chest and abdomen can be released with 2 longitudinal incisions connected with 2 transverse incisions.

Fig 26. HAND BURNS ARE COMMON. Elevate the burned upper extremity *above the heart* on pillows or blankets to reduce edema.

Fig 27. Correctly placed lower extremity escharotomies.

Lessons Learned:

- Burn escharotomies should be through eschar and not fascia
- Finger escharotomies should be 2 lateral incisions through eschar only
- Perform fasciotomy for burn resuscitation compartment syndrome if it arises. Do not perform "prophylactic" fasciotomies in burn patients.
- There is little past the MCP joint that is oxygen-sensitive as the anatomy here is mostly bone and tendon. The urgency to perform finger escharotomy is not the same as for muscle-containing structures. A finger that requires an escharotomy usually also requires a finger amputation when the patient arrives at definitive care
- The dorsal skin overlying the PIP joints is about the thinnest skin in the body and it is very easy to expose/damage the joint with either a burn injury or an escharotomy mis-adventure. Loss of the PIP joint puts you in the amputation category mentioned above
- If you MUST perform a finger escharotomy: fully flex the fingers, look at the lateral creases formed at the DIP and PIP joints and keep your incision

dorsal to these creases. Avoid escharotomy on functional surfaces- the radial surface of the index and the ulnar surface of the little finger

- Fasciotomy is not an innocuous procedure, and should not be prophylactically performed 'in case something goes wrong in flight'. Burn wound management of an extremity with an unnecessary fasciotomy is considerably more complicated than just dealing with the burned skin

Fig 28. Large blood loss requiring transfusion which occurred during a short helicopter transfer from a Level II to a Level III facility in Iraq following an unnecessary fasciotomy in a burn patient**.**

"I graft small burns – but they keep shearing"

"27 y.o. female – local national involved in suicide vest explosion and arrived with a 3% burn to the right arm – did a STSG. Post op she was moving around and the entire graft sheared off…"

Taking care of small burns until completion of care is not an uncommon occurrence with local nationals. STSG should be done with 10-12/1000 of inch thickness donors usually from the thighs. The burned skin needs to be excised down to good bleeding tissue. Epinephrine-soaked lap pads and electrocautery provide hemostasis after

adequate excision. The donor sites should be covered with xeroform and stapled into place and left to dry out and adhere. The grafted bed can be made almost immune to shearing by the placement of a negative-pressure (wound VAC) dressing. After the STSG is stapled into place bacitracin-coated veil or Zeroform ® (or the special wound VAC sponge –nonadherent) can placed over the STSG, and then the wound VAC sponge can placed over the veil or Zeroform®. Cover with a Ioban or wound VAC plastic dressing and hook up to suction. This method prevents non-opposition of the STSG and prevents shearing. Take the suction and sponge off after 72 hours – leave veil or Zeroform® on for 5 days then remove.

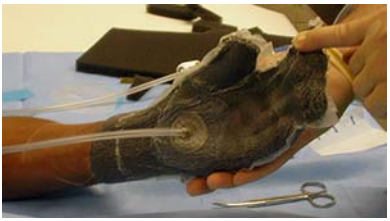

Fig 29. VAC is a great post-op skin graft dressing. The hand VAC shown here takes time to construct but speeds up graft take and decreases graft loss.
(Photo courtesy of James Williams PA-C.)

Lessons Learned:

- Small STSG grafts can be optimally treated with a wound VAC dressing
- STSG should be 10-12/1000 of an inch
- Place xeroform over donor sites and let dry to adhere
- If no VAC, immobilize grafts across joints with plaster
- On the back, consider two layers of veil (without bacitracin): if the patient moves, you have veil sliding over veil rather than veil shearing graft

- For small burns, use small meshes: a 3:1 mesh takes WEEKS to close, a 1.5: mesh is usually healed in 5-7 days.
- On marginal beds, the best graft take is obtained with 1.5:1 mesh that is left unexpanded
- In the absence of veil, fine mesh gauze or xeroform can be used over small grafts. Likewise for the absence of vacs: xeroform covered by kerlix and an ace bandage for 5 days works well.
- In the 'old days' we always immobilized one joint below and one joint above a graft. While this is overkill in contemporary CONUS practice, in the field, you sometimes have to revert back to the old ways of doing things

"Antenna to high power line - electrical injury"

"23 y.o. male arrives to the FST after a report of high voltage electrical injury – has 2 contact point injuries on his left forearm and right thigh with surrounding approximately 2% TBSA full thickness skin burn – doesn't look so bad…"

Electrical injuries are a "trap." They do not look so bad on the surface – the real potential for badness is in the underlying muscle bellies and nerves. Muscle necrosis can lead to myoglobinuria and compartment syndrome which will result in more muscle damage. The goals of treating a patient with an electrical injury are: 1. preventing myoglobinuria from causing kidney damage and, 2. to release any elevated compartment pressures to minimize subsequent muscle damage. When gross pigmenturia is present, urine output goal should be 80-100 ml/hr. If

pigment fails to gradually clear over 3 hours, (1) consider Mannitol IV if hydration is optimized; (2) alkalinize the urine with sodium bicarbonate drip; and (3) strongly consider fasciotomy and debridement of dead muscle. In the deployed setting at a level II consider prophylactic fascial release of any involved compartments and any compartments that are tight to physical exam, and transfer to a level III ASAP. At a level III in addition to physical exam compartment pressures can be monitored by rigging an A-line to a needle and inserting the needle into the muscle compartment. Any circumferential burn injuries should of course be released with a standard escharotomy. Work up patients for spinal injury (cervical to lumbar).

Fig 30. Myoglobinuria following high voltage electric injury *(Courtesy COL David Barillo)*

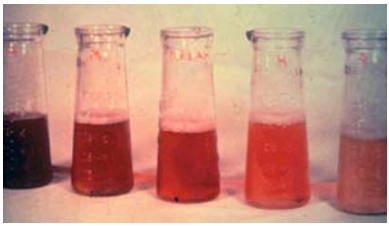

Fig 31. There is no better way to document clearing of pigment from the urine than collecting the urine hourly and looking at it.

Lessons Learned:

- Hydrate electrical injuries to avoid myoglobin-induced renal injury

- Consider IV Mannitol in addition to sodium bicarbonate IV
- Prophylactically release obviously involved muscle fascial compartments
- Observe all muscle compartments with physical exam and A-line pressure readings
- Electrical injuries are the only burn injury where fasciotomy is normally performed in contemporary burn practice. While your threshold for performing fasciotomy should be very high in most burn injuries, an increase index of suspicion for impending compartment syndrome is appropriate for electrical injuries. But you still need to have indications of impending compartment syndrome: do not perform prophylactic fasciotomy in electrical injuries
- The '100 cc of urine' rule is not automatic: if the patient has clear urine, titrate IV fluids to the usual goal of 30-50 cc/hr (or less!) If the urine is dark, aim for 75-100 cc/hr and add bicarb. Once the urine regains a normal color, drop back resuscitation with goal of 30-50 cc urine per hour.
- In austere conditions, it is not necessary to test for myoglobinuria or hemoglobinuria: if the urine is dark, you have it and need to treat it. If the urine is clear, you do not have clinical myoglobinuria or hemoglobinuria and do not need to treat it
- Mannitol is an osmotic diuretic and will make subsequent urine output measurement inaccurate as an index of adequacy of resuscitation
- Transfer all major electrical injuries to a burn unit ASAP

Blast

"What do I do with primary blast injury?"

"27 y.o. male involved in a dismounted explosion, his left ear drum was gone on exam, he had fragment wounds all over and he had shortness of breath – we intubated him scanned him and he had no pleural or peritoneal fragments but had a what looked like bilateral pulmonary contusion on x-ray 6 hours after injury – blast injury? What do I do?..."

Explosion injury is the one of the most common injury patterns the combat surgeon sees. Primary blast injury is injury caused simply by the "OVERPRSSURE" and is actually a rare injury. Secondary blast injury is most common and is from projectiles from the explosion – fragments. Tertiary blast injury is caused by blunt force as the body is propelled through the air and hits a structure. Quaternary blast injury is from burns from the explosion. Most primary blast injuries involve "air filled" structures – inner ear, lungs bowel (most commonly cecum). The most common primary blast injury is tympanic membrane rupture (5-20% involved in an attack), followed by lung injury (1-7% of attacks), and bowel injury (<1% of attacks). While tympanic membrane rupture is the most common primary blast injury pattern - it is not a screening test for primary blast injury – many with primary lung injury do NOT have a concomitant tympanic membrane rupture. Tympanic rupture is not treated in the combat zone; GI perforation from a primary blast injury is treated as any other GI perforation. Primary lung blast injury is treated with airway and ventilatory support.

Lessons Learned:

- The most common primary blast injury is tympanic membrane rupture (around 12% upon admission to a level III)
- Tympanic membrane rupture ***cannot*** be used as a screening test for primary blast injury to lungs or bowel
- Primary lung blast injury is treated with airway and ventilatory support

Reference:

Ritenour A, Blackbourne LH, Ritenour J, Renz E, Eastridge B, Chung K, Holcomb J Wolf S, Wade C. Incidence of primary blast injury among soldiers burned in combat explosions. J Burn Care Res 2008 28(2): S173.

Soft Tissue Injuries

"Large soft tissue injury and coagulopathy"

"33 y.o. male involved in an explosion arrives hypotensive. Looking him over, he had several frag wounds to the right leg with no bony involvement and equal pulses. But he had lost over ½ the mass of his right buttock. We put a pressure dressing on best we could - resuscitated him with blood and FFP – he stabilized and we scanned his pelvis –no fragments seen - we then brought him immediately to the O.R. He was cold, coagulopathic…"

Fig 32. Large soft tissue injury

Large soft tissue defects are rarely seen in civilian trauma but are common in combat explosions. These wounds should be addressed with the guiding principles of damage control. Stop bleeding, remove soilage, ICU resuscitation, return to O.R. Stop all surgical bleeding (large veins and any arteries) which will increase with resuscitation and debride/warm irrigate any dirt and foreign bodies. After suturing, the wound should be packed, Chitosan pads and Chitoflex (basically Chitosan coated kerlix) has been used as well as plain kerlix. If skin is available it can be sutured over the packing to allow for a temporary tamponade

effect. Although the classic teaching (dictum) is never to close a combat wound – the first goal of damage control (stop all bleeding) takes precedence -if a patient has life threatening coagulopathy and bleeding, frag wounds can be temporarily stapled (skin stapler) closed for tamponade and after resuscitation and correction of the coagulopathy the staples can be removed and wounds irrigated.

Lessons Learned:

- Large soft tissue injuries need damage control
- The skin sutured over packing can provide life saving tamponade
- Frag wounds can be temporarily stapled closed for hemostasis

Anesthesia

"Large fragment to the face"

"22 y.o. male with a wound caused by a projectile that destroyed most of his lower face. His mouth and lower jaw were a mess of bony fragments and strips of soft tissue. He was sitting up, coughing, and resisted any efforts to make him lie down."

This kind of presentation is very dramatic, but actually can be easy to manage if some principles are followed. It is appropriate to be concerned about his airway, but keep in mind that he has been doing a good job of maintaining his own airway from time of injury to time of presentation. Sedating medications have the potential to interfere with the patient's airway management. A prudent physician would not take away his ability to manage his own airway until the physician is ready to fully take over. If some analgesia is required, small doses of Ketamine may be ideal.

Immediate steps to take include obtaining intravenous access and applying non-invasive monitors. Provide supplemental oxygen as best possible. Assemble a team consisting of the most experienced laryngoscopist and a surgeon who has everything he needs to obtain surgical access, including adequate lighting, Bovie, and instruments. This may be in the O.R. rather than the ED. For the laryngoscopist, a gum bougie is a valuable adjunct. Two Yankauer suction systems are desirable in a case such as this, where there may be profuse bleeding into the airway. Induction and intubation should proceed only when everyone is ready, understands their role, and has all of their equipment. As long as bleeding is controlled,

intubation by direct laryngoscopy actually tends to be easy in the situation where facial structures have been traumatically amputated.

Lessons Learned:

- If a patient with airway trauma is maintaining his own airway, let him continue to do so until you are ready to fully take over that function.
- Gather the right personnel and the right equipment and agree on a plan for airway management before proceeding.
- Consider managing the case in the O.R. rather than the ED
- Have plenty of suction available.
- Ketamine, both as an analgesic and as an induction agent, can allow for some degree of preservation of airway reflexes and spontaneous ventilation.
- Difficult airways usually present when things are present that should not be (e.g. tumor, mass effect). When structures that are usually present have been blown away, it tend to make laryngoscopy that much easier.

"First to die was the anesthesia machine"

"In the middle of a mass casualty scenario, an unstable patient with a multiply-penetrated abdomen and chest was immediately taken to the O.R. from the ED. After connecting the patient to the anesthesia circuit, the power failed. The surgeon and I both knew that the patient would die in a matter of seconds if I didn't figure something out quick."

First To Cut

Mass casualty situations are often chaotic, and just when you think it can't get any worse, it does. One unpreventable situation occurs when equipment fails. The best way to prepare for this is to learn to do without. To practice, ask yourself during any given case "how would I do this case if I didn't have a ventilator? …a central line? …electricity?" Understand what is necessity and what is luxury. For example, electricity and reliance on backup battery power is not required to ventilate a patient if you use an Ambu® bag connected to the auxiliary oxygen supply of the Narcomed M. Most anesthetics can be started with muscle relaxant and Ketamine while you ventilate with an Ambu® bag, and maintained with total intravenous anesthesia (TIVA) delivered via micro or macro dripper. If properly prepared, you can focus on continuing the patient's surgical care, and not on trouble-shooting your equipment while your patient bleeds to death.

Lessons Learned:

- Expect equipment to fail at the worst times
- Learn to deliver anesthetics and provide optimum surgical conditions and patient safety with different techniques including low-tech, no power techniques, so you aren't dependent upon anything
- Although amnesia is still a goal, not everyone needs anesthesia, particularly those in hemorrhagic shock
- Ketamine should always be available for trauma anesthesia
- Continually drill yourself on what you would do if different components of your plan or your equipment failed

"Which patient are we talking about?"

"The young soldier on the O.R. table had a bloody dressing partially concealing a large, jagged piece of shrapnel that emerged from his lateral neck. He was pale and tachycardic, but did not appear to be actively bleeding. I placed noninvasive monitors and began pre-oxygenating while the nurse started taking the dressing down. I had my back turned and was looking in my anesthesia cart for supplies for a second IV when I heard the blood hit the floor. Lots of it."

In this case, either the dressing, the fragment, or both had prevented or obscured the blood loss. The patient clearly manifested signs and symptoms of shock and at this stage his physiologic reserves were likely minimal. Obtaining surgical control of bleeding and preventing further blood loss while simultaneously providing appropriate resuscitation is paramount to the casualty's survival. There are essentially two kinds of hemorrhagic trauma patients. The patient with ongoing hemorrhage needs to have the bleeding stopped right away. This is done with a tourniquet for extremity trauma, and with surgical interventions for thoraco-abdominal trauma, e.g. laparotomy and packing, Pringle maneuver, thoracotomy, etc. These maneuvers should not be delayed by anything other than establishing an airway and ventilation. In these situations it is imperative to control bleeding. Once bleeding is controlled, the anesthetist can focus on improving IV access or placing invasive monitors, etc. The second type of patient, like the patient in this scenario, is the one who needs to be handled very carefully until appropriate intravenous access and preparations are made to transfuse and manage potentially life threatening

bleeding. While you concern yourself with the airway, ventilation, and vital monitoring; use the skilled hands of the surgeon to help you with additional peripheral or central venous access, and arterial line placement. Whichever the case, everyone in the room must understand which kind of patient you are talking about. Ensure that other members of the surgical team understand the anesthetic and surgical plans.

Lessons Learned:

- In trauma, there must be 2-way communication between surgeon and anesthetist and other members of the surgical team.
- Sometimes the first priority is to get the belly open and stop the bleeding
- Sometimes the first priority is to fully line and monitor the patient and get blood in the room before cutting
- Everyone in the room, to include the nurses and techs, needs to understand what the priorities are

"Out here, the difficult airway algorithm is very simple"

"A half-dozen patients, on litters and on the ground, had been triaged 'immediate' and several needed to be intubated. I had a grade 4 view on the first patient and put the tube in the esophagus. On the second attempt, my luck wasn't any better. I felt like I could intubate him if I had a fiberoptic scope, but there were none immediately available, at least 4 other patients needed to be intubated STAT."

First To Cut

The American Society of Anesthesiologists' difficult airway algorithm is a great guide when you have one patient to think about and time is on your side. In a MASCAL, you must have a lower threshold to establish a surgical airway using a cricothyrotomy if you aren't immediately successful with laryngoscopy. It's a skill you need to have, but it may be feasible for a surgeon to perform it while you go on to the next patient needing airway management. A dose of ketamine can anesthetize the patient while preserving his respiratory drive, so it comes in handy in these situations. Out of necessity, the combat difficult airway algorithm is very compressed.

Lessons Learned:

- The anesthetist is a limited resource in a MASCAL
- Ketamine causes less respiratory depression that other anesthetics or opioids in equi-analgesic doses
- One good optimal attempt at direct laryngoscopy, with a gum bougie at the ready, is the first step
- The next step is to establish a surgical airway and prepare to manage the next patient
- Before the surgical airway is obtained, an LMA can be placed, allowing a medic to continue oxygenation/ventilation while you move on to the next patient

"The worthless femoral cordis"

"The patient with multiple penetrating abdominal wounds received 2 units PRBCs and 2 units thawed plasma through a femoral cordis before arriving in the O.R. Upon laparotomy, we found a disrupted vena cava and at least 5 units of blood in the belly."

First To Cut

For many practitioners in a combat hospital, the femoral vein is the easiest and most familiar site to establish large bore catheter intravenous access and place a central line. In all the commotion and confusion of the casualty receiving area, the contraindications can easily be overlooked. Blood given through a femoral vein never reaches the heart if the inferior vena cava is not intact. If there is any real chance that penetrating abdominal trauma has compromised the vena cava, it is essential to obtain venous access above the diaphragm. In the patient requiring fluid and blood resuscitation, 14 or 16 gauge IV's function as well as, if not better than central lines. Placement of central lines can take precious minutes resulting in increased time before patients are taken to the O.R. Additionally, central lines are associated with significant adverse events such as pneumothorax, carotid puncture. If the clinical situation dictates and a central line is necessary, there may be circumstances where a subclavian or internal jugular cordis is more advantageous than a femoral vein catheter.

Lessons Learned:

- Emphasis on central venous access may be overstated
- Central venous access should not delay operative intervention and can be performed simultaneously to surgery
- Two large bore 16-14 g IV's should be the standard for most trauma patients
- Penetrating abdominal trauma demands IV access above the diaphragm
- Placing a femoral cordis in such a case is a waste of time, energy, and blood

First To Cut

"I'll do that case tomorrow"

"At midnight, the whole O.R. staff—surgeons, anesthetists, nurses, and techs—are tired. The surgeon says that he'll do the last case, an extremity washout, in the morning, since the schedule for tomorrow is empty."

A superstitious person would say that the surgeon has now jinxed the O.R. A realist knows that luck is unpredictable. You can't count on the schedule being light at any time. Better to do the case now than risk not having it done by tomorrow. If a surgeon, nurse, or anesthetist is truly too tired to do a case, find someone who is not. If an unexpected bunch of surgical cases comes in the next morning, you'll be glad the washout case was done the night before and won't be put off another day. On the other hand, if the schedule stays empty, you have all day to rest and recover.

Lessons Learned:

- A free day can turn into a mess in the blink of an eye.
- If a case must be done, you can't wait until tomorrow.

Triage

"They just kept coming, one after another"

"A mortar went off in a parade field during a formation, the patients came in sets of 4 for a total of 30 patients. Many had total body fragmentation wounds including head injuries. Four patients came in hypotensive with abd / pelvic wounds and I took the 2 sickest to the O.R. the rest were parked in the ED."

During a mass casualty situation it struck me that the majority do not need to go to the O.R. immediately but that the O.R. was quickly filled. The main triage is done in the ED but not for the O.R. but for the CT scanner. The first priority as the triage surgeon is to list those that need to go to the O.R. for a life saving procedure followed by extremity salvage. The more difficult triage was for the CT scanner. We first made a list of all head injuries so we could figure out who needed a craniotomy. Extremity vascular injuries controlled with a tourniquet were first triaged for transfer to another facility for surgical repair. Neurosurgical triage was based on CT results and availability of a neurosurgeon. Remember that patients that will be delayed to the O.R. can be triaged to transport to another surgical facility if stable and feasible.

Lessons Learned:

- MASCALs result in filling the O.R. quickly
- Initial CT scan triage is important and often is reserved for head injuries
- Consider transporting stable, controlled extremity vascular injuries to other surgical facilities which

will maximize limb salvage if the wait for the O.R. is prolonged.

"Multiple patients with belly frag wounds – all at once"

"We had several patients who were hemodynamically normal and had multiple fragmentation wounds. We ex lapped 2 of them and found no intraperitoneal injuries. We scanned the other 2 and found that the fragments lit up real well on CT scan and found out that if the frag did not enter the peritoneal cavity these patients did not have a therapeutic laparotomy"

The arrival of the CT scanner to the combat zone has been revolutionary in the triage of fragmentation wounds to the back, flanks, abdomen and pelvis *in hemodynamically*

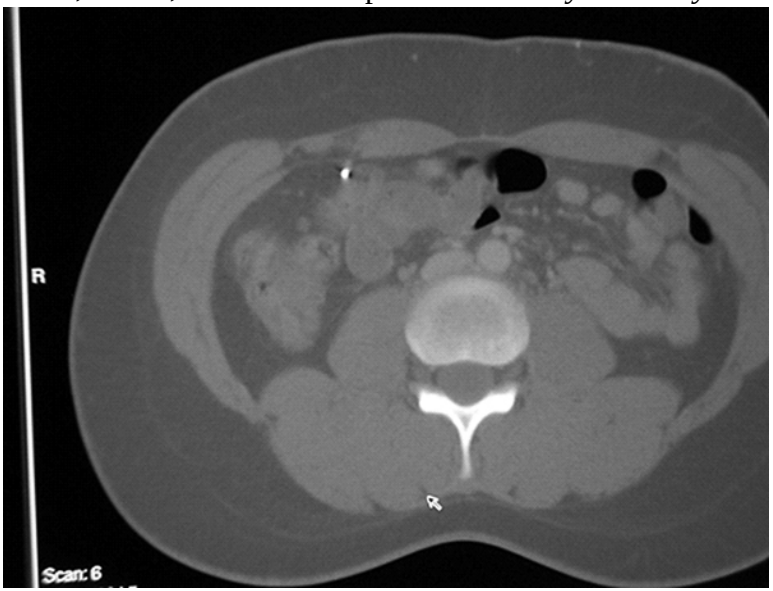

Fig 33. Fragment as seen on CT

normal patients. If the fragment does not enter the peritoneal cavity the patients can be observed safely during global evacuation. The use of the CT scanner can avoid negative ex-laps and avoid loss of precious O.R. time. If the patient has other injuries, such as a leg amputation, the decision to CT scan the abdomen is a judgment call based on the wounds and response to resuscitation. If the fragment enters the peritoneal cavity the safest approach is to perform an ex-lap.

Lessons Learned:

- CT scan is excellent for triaging abd/pelvic fragmentation injuries
- The safest approach to all patients with fragments seen in the peritoneal cavity on CT scan mandate ex lap
- Multiply injured patients with abd fragmentation wounds are triaged to the O.R. or CT scanner based on response to resuscitation and is a *clinical decision.*

Military Unique

"@#%&@&, There's a RPG round in his chest"

"22 y.o. arrives at my FST with a chest wound. We cut his clothes away and to our shock and dismay were the fins of a RPG round sticking out of his chest. We intubated him and prepared the O.R. with a sandbag barrier for at least my legs and groin. I put on my full body armor. The CRNA made it so he would not move and I cut the chest – old school – no electrocautery and did not touch the RPG with anything metallic. I removed the RPG and happily handed it to the Ordinance folks."

UXO - unexploded ordinance – although rare - is a truly unique experience for the combat surgeon. Courage is the first necessity as you must be in the O.R by yourself- but you can have some reassurance due to the fact that no UXO has ever exploded in the O.R. X-ray is safe but ***ultrasound may cause detonation and is forbidden.*** Maximizing protection is the next step – build a sandbag barrier as best you can and still get to the pt. Body armor should be worn with excellent eye protection. Due to the possibility of setting off the munition electrocautery CANNOT be used – do not worry about hemostasis as this can be obtained after the munition is removed. No reason to poke a sleeping lion – do not touch the munition with anything metallic. Anesthesia personnel must use long acting agents and gas is not an option as the pt monitoring will be delayed – use TIVA (total intravenous anesthesia). Make sure you contact EOD (explosive ordinance disposal) personnel ASAP to take the ordinance from you as soon as you get it out!

Lessons Learned:

- USE TIVA (TOTAL INTRAVENOUS ANESTHESIA) WITH COMPLETE PARALYSIS
- BUILD SANDBAG BARRIER
- WEAR FULL BODY ARMOR AND BALLISTIC EYE ARMOR
- NO ELECTROCAUTERY
- NEVER TOUCH ANY THING METALLIC TO THE ORDINANCE
- X-ray is safe
- Ultrasound is forbidden

"A local dog bit him and ran off"

"23 y.o. male arrived to the CSH with a jagged wound to his lower leg after being bitten by a stray dog on the battlefield. The dog ran off. We irrigated the wound and wrapped it open. We started the vaccinations…"

Interaction with local dogs on the battlefield is a very common occurrence. The rabies vaccination status of the local dogs is never truly known. All working dogs are vaccinated against Rabies. Some units with high exposure to local dogs vaccinate against rabies. Irrigate and remove all foreign bodies and debride necrotic tissue and leave the wound "open" -start antibiotics. Start the rabies vaccinations after a local dog bite.

Lessons Learned:

- Consider vaccinating all combat personnel for rabies with high exposure to local dogs
- Have rabies vaccination in stock

- If no prior vaccinations start the rabies vaccination ASAP after a local dog bite
- Irrigate, remove foreign bodies, debride and then leave all dog bites "open"
- Start antibiotics

"Working dog down - GSW to the belly"

"A working dog had a GSW to the abdomen. Barely responsive and breathing heavily – we took him straight to the O.R. – we could always take him off the table if we had human patients…tied his legs down – put bean bags on each side – the anesthesia folks looked up at me and said –uhhh what do we use for anesthesia?..."

Working dogs are a common site on the battlefield – and several surgeons and anesthetist have had to take care of injured dogs. Basic damage control principles are at play but there are some specific ways of getting there.
Anesthesia: Several anesthetics found normally in the CSH O.R. can be used. Typically anesthesia is induced through a peripheral IV using **K**etamine, Propofol, or thiopental and Succinylcholine for intubation. Maintenance can be continued with the above induction agents or with the volatile gas agent Isoflurane. Narcotics including morphine and Fentanyl should be titrated to effect. Glycopyrollate can be used for excessive salivation or to increase heart rate. Pavulon can be administered if prolonged muscle relaxation is desired. Dogs can be orally intubated with a long Miller blade and a 5.0-7.0 size endotracheal tube depending on the size of the dog. Human O_2 sat monitors work.
Resuscitation: IVs can be obtained in extremities (first choice front leg below elbow, second hind leg medially,

third choice jugular) dogs can take IV LR or NS but of course you cannot use human blood – use crystalloid, Hextend or Hespan. *Oxyglobin* is the first and only oxygen therapeutic to receive marketing clearance from the U.S. FDA for veterinary use. Oxyglobin; a chemically stabilized bovine hemoglobin, provides immediate relief from the clinical signs of anemia in dogs. Blood transfusions can be given from ANY dog at least for the first transfusion without regard to blood type with minor complications. Collect donor blood from any dog at 250 cc into human blood bags and transfuse as needed – after the first unit cross-matching is indicated. Factor VIIa (Novo VII) has also been successfully administered to treat hemophilia in dogs. The normal heart rate and respiratory rate is same as humans – Heart rate 60-100 and RR 10-20. For drug dosing estimate most dogs at 70 pounds.

Surgery: Chest tubes work the same but place into 7 or 8 intercostal space. Midline laparotomy. Bowel can be stapled and anastomosed with hand sewing. Ex-Fix can be placed.

Antibiotics: Antibiotics with low protein binding such as Cefazolin and Gentamycin have predictable serum levels in canines. Other canine antibiotics include: Clindamycin, Metronidazole, Amoxicillin, Ampicillin.

After performing an abbreviated or definitive laparotomy transfer the dog patient to a VET ASAP for further care.

Lessons Learned:

- General surgeons can and have operated on working dogs
- Dogs can be orally intubated – use
- Human O_2 sat monitors work
- Dogs can receive IV LR or NS

- Tie down all 4 legs in the O.R.
- Most anesthetics are ok: Ketamine, propofol, isoflurane
- Pain meds include fentanyl and morphine
- Use Oxyglobin for hemoglobin replacement
- Use ANY dog for blood donor for first transfusion only
- Donor blood should be 250 cc
- Transfer and call a VET ASAP

"Call a surgeon"

"27 y.o. male with frag wound to the neck – packed wound by the field medic with good hemostasis – the ED physician on call was an internal medicine doc – he pulled the packing out and we had massive arterial bleeding – I brought the patient up to the O.R. with my finger in the dike…"

"34 y.o. female with multiple frag wounds to the chest and SOB, the physician on call was a family practice doc – she put in a chest tube – when I go there the patient was in significant respiratory distress – I asked the CRNA to intubate and by this time the chest x-ray was on the box – the chest tube was subcutaneous…"

"28 y.o. hypotensive patient arrived to the CSH with full body fragmentation wounds – he had a central line placed, CXR, chest tubes, blood hanging for 20-30 minutes before they called me – the surgeon – I took him for an ex lap – he had 2 liters of blood in his belly…"

Trauma patients – especially unstable trauma patients require the involvement of a surgeon as soon as possible –

trauma is what we do. Many CSHs and other level III facilities have non-surgeons as first call in the ED – they do great work on non-trauma but a surgeon must be there to assess and direct care. the young healthy combat injured patient can go from compensated shock (looking good) to uncompensated shock in an instant. Also emergency physicians often do well with trauma initial stabilization but they cannot take a patient to the O.R. A surgeon must be called to assess the need to take a patient to the O.R. and in such a way as not to delay surgical hemostasis. It is a team effort.

Lessons Learned:

- A surgeon must be involved EARLY in the care of trauma patients
- Check all procedures performed by non-surgeons
- The surgeon must direct all aspects of care with major trauma and all penetrating trauma

"What does anyone use chlorine gas for anyway?"

"An explosion went off at the front gate – no initial wounded…then they started coming in droves complaining of shortness of breath – the EOD folks came in and said it was a chlorine gas attack – what do we do?..."

Chlorine gas has been used in explosions in combat. Treatment for inhalational injury is supportive. Remove any cutaneous contamination. There is a high risk of pulmonary edema and IV fluids should be used judiciously.

Lessons Learned:

- Chlorine gas inhalational injury treatment is supportive as needed to include intubation and ventilation
- Remove all cutaneous contamination ASAP
- Due to risk of pulmonary edema use IV fluid judiciously and avoid fluid overload

"Half way around the world and he wants a mole removed"

"40 y.o. Soldier comes to clinic at the deployed CSH and wants a mole removed – he stated it is getting bigger and darker – looks benign but I have been surprised by nevus pathology before – so I remove it and put it in formalin – send it to the level IV pathologist – only problem is they never received it and there is no record of it being sent…"

Getting pathology in the deployed scenario is a very risky business. No matter the pressure a combat surgeon must refuse to remove any tissue that will need a pathologic examination except to save life or limb. The safest answer is to have the patient with possible pathology evacuated to a facility with a surgeon and a pathologist. Performing biopsies and skin excisions in the combat zone is inviting disaster with a lost pathology specimen.

Lessons Learned:

- Performing a biopsy or skin lesion excision in the combat zone is inviting specimen loss
- Do not perform any biopsy or excisions if you do not have a pathologist with you at your surgical facility

Intensive Care Unit

"After we closed the fascia we could not ventilate, no urine, hypotensive - he was dying"

"40 y.o. male s/p damage control lap with small bowel, colon injuries, and packed liver. We took him back for his definitive operation after 2 washouts on post op day #4. the bowel edema was down his small bowel anastomoses looked good – we brought up his colostomy on post op day #3 and it looked good – we closed his fascia and had no increase in his peak inspiratory pressure in the O.R - we brought him back to the ICU and then next day his urine output fell to 5cc an hour refractory to fluid boluses, harder to ventilate – we measured his bladder pressure it was 35. About this time he dropped his pressure to 70 systolic – he was dying in front of me – I opened up the fascia and his bowel came protruding out and he dropped his pressure upon release to the 50s. We got him back with multiple fluid boluses and pressors…"

The decision to close the fascia after damage control laparotomy is a judgment call. Look at the bowel edema and measure the peak inspiratory pressure in the O.R. before you leave – any significant increase – definitely if >10 – open the fascia back up. Approximately 80% of closures are carried out within the first 10 days in civilian trauma so you do have some time. The abdominal wound vac allows separation of the bowel and the abdominal fascia with the plastic sheet. If the fascia is closed tight – you can hedge your decision with Q4 hour bladder pressure checks to monitor intra-abdominal pressure. When getting bladder pressures use less than 100 cc of saline (so you do

not get involuntary bladder contraction) – I use 50 cc. The triad of abdominal compartment syndrome to look for is: 1. decreased urine output 2. increase in peak airway pressure (decrease in tidal volume) 3. hypotension due to decreased venous return. Abdominal compartment syndrome is a clinical diagnosis but should be considered when bladder pressure is > 25. The treatment of abdominal compartment syndrome after a damage control operation is re-opening the abdominal fascia – if the patient is in extremis do it at bedside but expect hypotension from an abrupt loss of preload as the intravascular volume fills the increased venous capacitance in the abdomen. If you are dealing with secondary abd compartment syndrome from burn injury over-resuscitation consider placing an intraperitoneal J-P drain before laparotomy due the very high mortality in these patients.

Lessons Learned:

- Look for abdominal compartment syndrome with decreased urine output, increased peak airway pressure and hypotension
- Check bladder pressures after closing the damage control abdominal fascia
- Give fluid boluses before, during and after releasing abdominal fascia for compartment syndrome
- If the patient is in extremis, fascial release in the ICU can be life saving

"Post op in the ICU he was hypotensive and getting lots of blood"

"27 y.o. soldier with a GSW to abdomen – took him directly to the O.R., packed off the retroperitoneum, pelvis

and liver – resuscitated with Factor VIIa, FFP and PRBCs in the O.R. –started to get cold so packed and brought him to the ICU – he continued to be hypotensive, and required lots of blood – his laparotomy pads were blood soaked. Temperature was still 35 degrees – do I continue to resuscitate or bring him back to the O.R.?..."

The decision to bring a patient back to the O.R. before the planned second look is a judgment call – one that can be easy or very difficult. Civilian data for damage control laparotomy has identified some basic guidelines for return to the O.R.; 1. >10 units transfused in the first 24 hour post period, 2. abdominal compartment syndrome from packing too tight, 3. progressive acidosis. But the call is often a judgment call – is the patient bleeding from coagulopathic bleeding or from a surgically correctable source? If blood is pooling, the patient is hypotensive and you are having a hard time keeping up with the blood loss with transfusion the best call is often to warm the O.R. suite and return for an early second look for surgical bleeding. This applies for laparotomy, thoracotomy and large soft tissue injuries.

Lessons Learned:

- Observe post-op damage control patients in the ICU closely for surgical bleeding
- Evaluate, pH, signs of bleeding, blood pressure and blood transfusions closely
- Return to the O.R. early if you suspect continued bleeding from a source you can stop surgically or by repacking more efficiently
- Warm the O.R. prior to returning
- Evaluate for "packing" abdominal compartment syndrome post op after packing the abdomen even with an open abdomen

- Always consider surgical bleeding if the post-op resuscitation and indices are not moving in the right direction

"Post-op we got a CXR – classic TB"

"24 COALITION males with frag wounds to the abdomen – ex lap – resected bowel – nothing exciting – we got a post-op CXR and found classic findings for TB. We had a makeshift isolation room…"

Tuberculosis (TB) is not an uncommon finding in deployed medical settings. The key is having a plan for it before it arrives in your hospital. Level II facilities will face only by a history and these patients should be isolated as best as possible – one option would be to erect a separate tent area until evacuation. Evacuation should be in isolation as well. At level III contingency plans should be in place for such a patient or patients. Negative pressure rooms with filters should be made ready. Anti – TB medications and respiratory masks should be in stock and ready.

Lessons Learned:

- LEVEL II facilities should have a plan for the TB patient
- LEVEL II facilities should have a plan for advice on evacuating a potential TB patient
- LEVEL III facilities should have an ICU and ward contingency plan for TB patients
- LEVEL III should have isolation rooms with negative pressure and filters
- LEVEL III should have respiratory masks available
- LEVEL III should have anti- TB medications in stock

Post-Operative Complications

"S/P neck exploration with a fever"

"28 y.o. male with multiple frag wounds to the neck arrives at the FST– significant hematoma –Intubate and we take back to the O.R. for a neck exploration and find the IJ transected – we ligate the ends – find no other injury – irrigate place a small J-P and ship off to the CSH…"

"28 y.o. male arrives to the CSH after frag wound to the Neck s/p neck exploration and IJ ligation – he has a high fever and copious serosaguinous drainage from the J-P drain – we bring him to the O.R. and re-explore – we found a frag hole in the esophagus – closed in 2 layers and placed a muscle flap between the repair and the trachea – I heard he did fine."

Receiving a fresh post-op trauma patient that you did not operate on initially is a common scenario in combat surgery. After you receive the patient – that patient is your responsibility completely. Missing an injury and delaying repair can be life threatening. Have a low threshold for re-exploring a transferred patient – especially if anything is amiss. Almost all transferred patients after an ex lap from a level II should be transferred with the abd fascia open for a second look and washout at a level III – the re-exploration should be thorough.

Lessons Learned:

- Have a low threshold for re-exploring any transferred post-op pt

- Transfer post-op ex lap patients with open abd fascia from a level II unless no injury or minimal injury is found
- The accepting surgeon assumes absolute responsibility for the transferred patient

"Hey – that looks like a lap pad"

"44 y.o. male involved in a explosion with multiple frag wounds to the abdomen and hypotensive. I took him emergently to the O.R. for ex lap and found small liver holes that had stopped bleeding and a few small bowel holes we primarily closed. He had a few chest frag wounds so after placement of right chest tube we scanned him post-operatively. On the chest CT he had what looked like a lap pad above his liver. We took him back and removed a lap pad."

The most common operation in civilian practice with a retained foreign body (e.g. lap pads, malleable retractors, etc) is an emergent operation – all of our combat operations are in this category. Especially during a MASCAL with multiple O.R. teams switching out. Just because we are far forward the risk is still there and you pack off the abdomen and then if you elect to close the fascia it is essential that all counts are correct and an abd x-ray to rule out retained foreign body should be highly considered – if in a MASCAL situation getting an x-ray post-op is an option.

Lessons Learned:

- Retained foreign body is high risk after an emergent ex lap
- All counts must be correct

- Highly consider an abd x-ray if you elect to close the fascia to rule out retained foreign body

"Post-op day #10 and an intraperitoneal abscess"

"28 y.o. female s/p ex lap for small bowel and colon injury treated with small bowel resection and primary anastomosis and colostomy – fascia closed post op day #3 – at one week has fevers and intra-abdominal abscess on CT. Radiologist 'doesn't feel comfortable' perc draining…"

Intra-abdominal abscesses are a common complication after damage control laparotomy with bowel injuries. The patient should get 24 hours of prophylactic broad coverage (including anaerobes) IV antibiotics. Intra-abdominal abscesses are diagnosed with CT scan after the first week – small abscesses are often treated successfully with IV antibiotics if there is not an anastomotic leak. The rest should be percutaneously drained by CT guidance – if this is available – if large or not accessible or not possible where you are, re-ex lap at the earliest opportune time should be undertaken to drain any pus and assess the anastomoses.

Lesson Learned:

- Abscess is a common post ex lap complication
- Small abscesses are often treated successfully with IV antibiotics
- If perc drainage is not available consider transrectal, flank or lateral incisional drainage – if you must re – ex lap then it should be done earlier rather than later

"Post-op day # 8 and elevated WBC and free air on CXR"

"43 y.o. male POD # 8 s/p primary repair of a colon injury with fever, vomiting, and elevated white count – significant increase in free air on CXR and transverse preanastomotic colon dilated on AXR – took him to the O.R. for re ex-lap the colon anastomosis was intact and patent was about to close then ran the bowel – from stomach to terminal ileum – found a perforated duodenal ulcer even though has was on a PPI – patched it and closed – he did fine after that…"

Post-operative patients are at risk for PUD – especially when local nationals are involved as they often do not have any documentation for their preexisting health care. Anytime you do a re-look ex lap make sure you are very thorough – appendicitis, abscesses, cholecystitis, perforated viscus, and necrotic bowel segments have been found after a trauma laparotomy – be paranoid.

Lessons Learned:

- Have a low threshold for a CT scan and re-look ex lap after a trauma lap if the patient is not recovering on schedule
- The full range of complications are seen and need to be ruled out with a thorough exploratory laparotomy

"Anastomotic leak"

"36 y.o. male with multiple small bowel frag holes. Resected several segments with multiple holes with a GIA stapler. Packed the liver. Brought him the ICU for resuscitation. brought him back in 24 hours. Removed

liver packing – no bleeding – anastomosed the small bowel with GIA stapler and TA 50 stapler. Returned in 24 hours for fascial closure – during the washout had succus leaking from 2 of the sites – took all the anastomoses down and hand sewn them all with a 2 layer closure – he did fine after that…"

In damage control after a significant resuscitation the bowel walls swell with edema. In the civilian literature small bowel anastomoses leak less if they are hand sewn. With bowel wall edema the staplers are less effective and leak. Anecdotally, we have seen less small bowel anastomotic leaks with hand sewn anastomoses with the 2 layer closure (if the second layer Lembert sutures can be placed safely – otherwise 1 layer) in damage control small bowel injuries.

Lessons Learned:

- Small bowel has significant edema after a damage control resuscitation
- All small bowel injuries with damage control should be anastomosed with a hand sewn anastomosis

Reference:

Brundage SI, Jurkovich GJ, Hoyt DB et al. Stapled versus sutured gastrointestinal anastomoses in the trauma patient: a multicenter trial. J Trauma. 2001 Dec;51(6):1054-61.

"Fascial dehiscence"

"45 y.o. local with GSW to abdomen – small bowel injury, colon injury – all repaired primarily at 24 hrs post-op. Bowel not very edematous minimal resuscitation – closed fascia – no increase in peak airway pressure after

closure- next day started draining straw colored fluid from the abd wound – looked and found all fascia wide open and could see bowel – went immediately back to the O.R. for fascia re-closure…"

The decision to primarily close fascia is a clinical judgment. The amount of resuscitation, edema in the bowel the need for further resuscitation, subsequent surgeries with blood loss, transport will all weigh in on your decision. Almost all ex laps performed at a level IIb should have the fascia left open with a temporary coverage as the receiving surgeon will almost always like to take look themselves. If you close the fascia -in the O.R. check the peak airway pressure before and after fascial closure – a significant increase will signal that the fascia needs to stay open longer until bowel edema decreases. Local nationals anecdotally have poor protein nutrition in several AOs and have a higher fascial dehiscence rate. In these individuals, placement of retention sutures should be considered.

Lessons Learned:

- Ex lap with damage control at a level IIb should have the abdominal fascia left open
- Consider retention sutures in local nationals at fascial closure
- Check peak airway pressure in the O.R. before and after closing fascia
- With fascial dehiscence return to O.R. immediately for reclosure or temporary coverage

"Combined complications"

"27 y.o. male with open abdomen, right brachial vein interposition graft – his liver packs were removed 12 hours earlier. Found with distended abdomen, stooling, vomiting and hypotensive. His liver obviously was re-bleeding – took him to the O.R. had large hematoma around liver – repacked with cessation of bleeding – at end of case re-examined from head to toe – found his brachial repair had clotted off from the hypotension – fogarties and redid the brachial anastomosis with good result – he walked out of the hospital…"

The combat wounded have a high incidence of multiple injuries. With a complication it is paramount to re-examine the patient for new problems and to assess prior repairs.

Lessons Learned:

- Combat wounded have multiple injuries and can have complex complications
- With one complication rule out other complications by looking the patient over from head to toe

End of Life, Consent, Ethics

"Three patients - 1 local national and 2 U.S. soldiers"

"MASCAL - 20 patients arriving within 30 minutes: 3 patients that needed to go to the O.R…and 2 O.R. tables available – a hypotensive local national with a belly GSW, and 2 U.S. servicemen with extremity vascular injuries – if I took the local national to the O.R. at least one of the U.S. Servicemen might lose a leg – but if I took both US servicemen to the O.R. the local national would probably die in the ED. I took the local national to the O.R. immediately…"

Triage is rare in civilian practice but it's a real part of military medicine. Triage sounds deceptively simple—treat all patients the same. Triage of patients for available operating rooms and blood and blood products, Factor VIIa, etc is relatively easy, but emotionally it may be distressingly difficult. Remember that you yourself are a valuable resource that must be triaged where you can be most effective. Put your emotions aside and triage the patients the same no matter if they are suspected enemy injured combatants, local civilian or U.S. service personnel. This is a legal mandate of the Geneva Convention and you can be held accountable for any deviation of this policy. This is also the burden of being a doctor on either side of a conflict.

Lessons Learned:

- Treat all patients the same
- Triage based on need

"The local national refused surgery"

"28 y.o. local national arrives with to the CSH with a pulse-less arm after a GSW to the upper arm – clearly has a brachial artery injury. She adamantly refuses any surgery – she could lose the arm if we do not operate…"

Questions regarding consent often come up in the deployed setting. The rights of individuals in the combat zone depend on the patient's status. Detained individuals do not have right of refusal – we must do what we think is in their best interest to save life and limb. US service personnel do not have the legal right to refuse life or limb saving surgery. A local national not under detainment with a sound mind has the absolute right to refuse any and all surgeries. Unconscious or intubated patients are considered like US civilian emergencies and "give" implied consent. These rules outline a general approach, but remember that consent is nothing if it is not informed. Explain (often with an interpreter) the risks, benefits, and consequences of surgery and possibly refusing surgery. Pay attention to local cultural and religious considerations in your discussion and honor every patient's autonomy to make both good and bad decisions. If possible, document your discussion and document consent for any procedure—this will never be a bad decision.

Lessons Learned:

- US Servicemen and women cannot refuse life or limb saving surgery
- Detainees cannot refuse life or limb saving surgery but all planned surgeries should be explained in detail

- Local national civilians can refuse surgery but it is our moral obligation to make sure they truly understand the consequences to refusing
- It is in everyone's best interest to have US Service personnel, and anyone else, sign a consent for all surgeries

"Transferred to a local hospital"

"28 y.o. female local national with GSW to descending colon with large destructive injury – underwent resection and colostomy – on post op day #3 transferred her to a local hospital and we heard she died a week later from pneumonia…"

Whose standard of care are you following when you are in another country? With different capabilities? With limited resources?

Do your best in every situation but remember your surroundings. This can be an area of significant stress to combat surgeons – you have made a terrific "save" and literally brought someone back from certain death…but now it's time to let them go. Transferring civilians to the local level of care is a natural progression of their care but can be fraught with problems. Nursing care can be much less than we are used to or nonexistent with all nursing duties carried out by a family – if family is available. Are medicines available? Is it a safe environment where combatants reign or target? Is there any long term care for someone who has been seriously debilitated? It is imperative that a surgeon understand the capabilities of local hospitals and have communication whenever possible with an accepting surgeon prior to transferring a local national that you have operated on. This guarantees

nothing, but it is the best you can do. It is often possible to accomplish both your personal and professional duties in the same efforts.

Lessons Learned:

- Learn local accepting hospital, nursing, physician capabilities wherever you go as part of YOUR duty—you can't change them but you can sometimes alter what you do based on this knowledge.
- Transfer local nationals to the local level of care when it is safe and the timing is right.

"This is futile"

"25 y.o. female US service member hit with a mortar blast arrives to the CSH hypotensive and severely hypoxic – fragmentation wounds from head to feet – 20% TBSA burns, severe head injury – chest tubes – we did an ex lap and packed her liver and pelvis – removed colon and small bowel. Initially post-op she was hypotensive on 2 pressors. Her platelets dropped to 10,000. On day#3, she was on maximal ventilatory and pressor support, in renal failure and liver failure, and posturing – she was dying despite every effort…"

Remember you're purpose in a combat zone—you're there to save the casualties that can be saved. Some casualties will die before you ever get a chance…others will be more difficult and die despite your chance to save them. If in your opinion your patient has no chance of living and is determined to be undergoing "futile" medical care first seek the input of others—your colleagues, the patient's family, your command. This will be one of your most difficult

decisions, but it is your responsibility as a combat surgeons. Get help and a second opinion, but don't let someone else make your decision for you.
Futile care is difficult emotionally. Don't limit the chances of another patient by consuming the resources you know will not save the patient in front of you.
If possible, personally inform the patient's family ***but the chain of command must know what you are doing prior to any notifications***. Tell them you did everything possible. Involve the chaplain for help. Consider transferring the patient to the next level of care and try to get them home (or have the family meet them at level IV) even if they might die and even if this might use valuable resources. Say goodbye to your patient and let them go—either in attempt at going home or in another journey that they must take.

Lessons Learned:

- Do not attempt "withdrawal of care" in a combat zone – best to transfer the "futile" patient ASAP to the next level of care.
- Triage the futile patient to expectant if others will die if you continue their futile care.
- If possible personally inform the family of the condition of any patient undergoing "futile" medical care.

En Route Care

As a surgeon, you will from time to time be asked to accompany critically ill pts and you will be receiving these patients – keep in mind these worst case scenarios from transport.

Fig 34. Medical helo transport

En route scenarios I

"At forward surgery team (FST) electively intubated for flight to the CSH. Patient self extubated and reinserted at CSH, aspiration injury suspected."

"30 y.o. with head injury, combative and intubated. We sent by chopper to the neurosurgeon. When he arrived he had self extubated. It is hard to monitor sedation level in a cramped chopper…."

Adequate sedation and analgesia are very important for transfer of an intubated patient. The under-sedated patient can self extubate which can be a disaster in the air – yes, including death. Also, recall of the events can lead to severe emotional trauma and may lead to PTSD. Always keep in mind that paralytics do not afford ANY analgesia NOR sedation. If you paralyze a pt it is your moral obligation to provide adequate sedation and analgesia! If you accompany an intubated pt bring enough sedation and analgesic meds to get the job done. Always plan for the worst case scenario – self extubation -and plan out what you would do. Your OMFS colleagues can easily provide endotracheal tube tethering to the teeth for high risk airway pts (e.g. inhalation injury, neck hematoma, etc).

Lessons Learned:

- Ventilated pts undergoing transport must have adequate analgesia AND sedation
- Must have a plan if the pt becomes extubated (e.g. bag with O_2)
- Consider wiring ET tube to teeth in burns and cases where loss of airway will be life threatening
- If a paralyzed pt arrives severely tachycardic after considering hypovolemia consider inadequate sedation and analgesia

En route scenarios II

"The oxygen ran out and then his heart slowed and then went asystolic – we started CPR"

"55 y.o. male arrived after an ex lap at a level II to the CSH. He arrived without vital signs and with CPR. The

accompanying medic stated that the oxygen canister ran out on the chopper half way to the CSH."

When visualizing every possible in-flight problem one that can be prevented is running out of supplies. A preflight checklist should include adequate and back up supplies of oxygen, sedation, tourniquets, analgesia, decompressive needles, etc.

Lessons Learned:

- Preflight checklist must be run down to include adequate and extra supplies for in-flight care

En route scenarios III

"We could not ventilate him"

" We were transporting a patient who was post-op from an ex lap and then the ventilator started alarming and his sats went down into the 70s – we took him off the vent and starting hand bagging him we had a lot of resistance – we checked the ET tube and seemed to be in good position – the chopper was real loud and we could not auscultate anything – we darted both lung fields and had a rush of air from the left chest."

A tension pneumothorax can happen at any time – especially after positive pressure ventilation. If the patient has any problems with ventilation the first move is remove the ventilator from the equation and hand bag. If further problems continue you must consider airway – the endotracheal tube can be dislodged, kinked or occluded. The next common problem with difficult ventilation is a tension pneumothorax. One cannot ausculate – let alone move much – in a helicopter. Quickly looking and feeling

for tracheal deviation may point you to the correct side otherwise a long 14 gauge inserted in the 2 ICS bilaterally is the most expedient and first option for relieving a tension pneumothorax in-flight.

Lessons Learned:

- A tension pneumothorax can develop at anytime – especially with positive pressure ventilation
- If difficulty with ventilation remove the pt from the ventilator- bag and check the airway
- One cannot ausculate for breath sounds in a helicopter
- Looking and feeling for tracheal deviation may point to the correct side of a PTX
- The most expedient way to decompress a tension PTX in a helicopter is B/L needle decompression

En route scenarios IV

"His leg stump started to bleed"

"27 y.o. underwent an above knee amputation at the CSH – I accompanied him on the chopper ride to the next leg of his journey around the globe. In the middle of the flight his stump started to bleed – progressively worse – I removed the dressing and had arterial bleeding, I placed a windlass tourniquet and stopped the bleeding."

All initial amputations involve ligation of vessels and debridement. After resuscitation the SBP inevitably increases and can rebleed or a suture can become dislodged with movement, etc. Always plan for the worst case scenario. The same can happen with a vascular repair or vascular shunt. Always have a tourniquet available or

better yet place loosely around the leg proximal to the vascular intervention/amputation for in-flight ease of application of the tourniquet.

Lessons Learned:

- When transporting amputee pts or vascular pts plan for the worst case scenario
- Always have a tourniquet ready or loosely applied when transporting amputee or vascular patients

En route scenarios V

"He arrived with a head injury and his initial PCO_2 was 17"

"32 y.o. male with a penetrating had injury and impaired GCS seen initially at the FST – intubated there and then transported hand bagged to the CSH. On arrival he had normal vitals and sats but his ABG revealed a PCO_2 of 17."

Civilian trauma data has shown that the head injured patients that arrive from the field with a PCO_2 below 30 and above 35 have a worse outcome and worse mortality. Hand bagging has also been shown to result in lower PCO_2 levels from hyperventilation than mechanical ventilators. Brain injured patients should have their PCO_2 between 30 and 35 on a mechanical ventilator for transport to a neurosurgeon.

Lessons Learned:

- HYPERventilation and HYPOventilation can be deleterious in head injury

- The goal for PCO_2 is 30-35 in brain injured unless otherwise directed by a neurosurgeon
- Ventilators are more consistent than hand bagging during transport

En route scenarios VI

"He arrived cold at about 92 degrees"

"27 y.o. female s/p ex lap and packing at a FST arrives after 30 minute helicopter ride to the CSH with a single wool blanket cold – 92 degrees F and hypotensive. We had no idea if she was bleeding or not – but did not want to run her up the the O.R. and open her abd up – we put on Baer huggers – gave her warm fluids and warm blood…"

Hypothermia is highly associated with mortality in civilian and combat trauma. Due to the door gunners – helicopters cannot be closed up and can result in significant temperature loss. Combat surgeons have had significant anecdotal results from using the "HOT POCKET" - this is placing the live patient in a body bag, covered in 2 wool blankets and a space blanket – cutting out a hole for the endotracheal tube. Commercially available Hypothermia kits with blankets and an active heat source have also used with good anecdotal results as well.

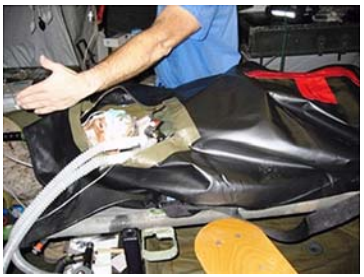

Fig 35. Hot pocket

Lessons Learned:

- HYPOTHERMIA KILLS
- A "Hot Pocket" with 2 wool blankets and a space blanket wrapped in an altered body bag will preserve body heat in most hypothermia risk situations.
- Commercially available hypothermia prevention kits are an option

En route scenarios VII

"On transport the cordis shifted position"

"24 y.o. male s/p an ex lap at the FST arrived at the CSH after a 25 minute helicopter transport severely hypotensive – we gave him 2 liters of NS – started blood, good b/l breath sounds. We brought him straight to the O.R., remained hypotensive, opened his abd – no blood just dry packs – put in b/l prophylactic chest tubes – gave him more blood – then we noticed the huge hematoma around his right groin cordis – it had shifted on transport out of the vein and we were filling the sub-Q tissues with fluid and blood…"

A cordis is used in trauma patients specifically for their large bore and short length to rapidly transfuse fluids – these properties also put the cordis at risk for being pulled from the vein on transfer. Of note, all large catheters placed for abdominal trauma should be placed in the subclavian or jugular as the fluid will be wasted into the abdomen if there is an IVC or iliac vein injury. All catheters need to be sutured secure in place and checked – especially if the patient is not responding to fluid resuscitation – if any doubt place a second catheter.

Catheters have also been known to come unconnected and again the short fat cordis is a set up for a major air embolism (if a patient is suspected of having an air embolus place in left lateral decubitus in the Trendelenberg position to capture the air bubbles in the right atrium/ventricle – prior to removing the cordis aspirate as much air as possible then consider attempting air retrieval by a Swan-Ganz catheter aspiration) . A cordis can be life saving but if malfunctioning can be a major hazard.

Lessons Learned:

- Do not use groin cordis for abdominal penetrating trauma
- Suture secure and check connections with a cordis
- Consider cordis malpositioning after transport – especially with unexplained response to resuscitation
- If feasible -place patient in left lateral decubitus in Trendelenberg position if you suspect air embolus

Field Expedient

"Field Expedient"

- **If chest tubes run out an endotracheal tube can be used as a thoracostomy tube**
- **Canteens can be marked and used as urinals in a mass casualty situation**
- **The finger of a sterile glove tied to a chest tube with a hole on the end can be used as a temporary Heimlich valve**
- **Sterile gloves can be used as sterile light handle covers**
- **A sterile gown can be used as a sterile drape for minor procedures**
- **Use Excedrin with caffeine far forward to avoid caffeine headaches**
- **Going days without showers – antifungal cream can come in handy**
- **A Petzl headlamp is great for reading and can be used as a backup O.R. light**
- **In a pinch – IV tubing can be used to secure an endotracheal tube or cricothyroidotomy tube**
- **An NGT tube or IV tubing can be used as a temporary vascular shunt**
- **SWAN-GANZ catheter has been used as a Fogarty catheter in larger arteries**
- **If you run out of lap pads anything sterile will work for packing – gowns, drapes, towels, gloves**
- **Cardiac pledgetts can be made from pericardium**
- **Placing irrigation fluid and IV fluid in a box and then running a Baer® hugger hose into the box can warm the fluids.**

Glossary of Terms

AXR	Abdominal X-Ray
CSH	Combat Support Hospital – Us Army Level III Surgical Hospital
CXR	Chest X-Ray
DPL	Diagnostic Peritoneal Lavage
ED	Emergency Department
EMEDS	Expeditionary Medical Systems (US Air Force level II and III)
FRSS	Forward Resuscitative Surgery System – US Navy Level IIb Surgical Facility
FST	Forward Surgical Team a Level IIb Surgical Facility – US Army
FRAG	Fragment, Fragmentation
FFP	Fresh Frozen Plasma
EX LAP	Exploratory Laparotomy
GSW	Gunshot Wound
LEVEL II	Level II (Level IIb) is a Small Surgical Unit – E.G. US Army FST or Navy FRSS – Usually 2 O.R. Tables
LEVEL III	Level III is a Larger Surgical Facility – Usually Large Blood Bank and Products, Subspecialtists – e.g. US Army CSH
MASCAL	Mass Casualty Situation
PRBC	Packed Red Blood Cells
RPG	Rocket Propelled Grenade
SBP	Systolic Blood Pressure
SOB	Shortness of Breath
STSG	Split Thickness Skin Graft
TBSA	Total Body Surface Area
y.o.	Years Old

Many Reasons
Why We Do What We Do....