

Progress in Trauma Surgery During 2007 Perspectives on Practice, Outcome and Education

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ABSTRACT:

Clinical strategies in the American trauma community were reviewed at the 66th Meeting of the *American Association for the Surgery of Trauma* in Las Vegas. The group discussed development of a workforce model for Acute Care Surgery and the training, which will be required to provide an adequate group of trained practitioners going forward. Initial clinical discussion centered on the use of fresh frozen plasma and Factor VIIa. Increasing use of both of these materials appears to reduce overall transfusion requirements and improve outcomes if applied in a controlled, but aggressive fashion in high-risk patients soon after presentation. The value of vascular stenting, a technology first reported in 1919, was reinforced as well as the utility of contemporary stent grafting using interventional radiology for patients with major vessel injury amenable to this technology. Continued controversy was noted regarding nonoperative management of solid organ injury. The use of angiography and the timing of follow-up computerized tomographic scanning in abdominal solid organ trauma received extensive discussion. Similarly, the role of CT and MRI imaging in cervical trauma continues to be debated. Finally, quality assurance initiatives to confirm the effectiveness of practice in trauma centers and in resident education were discussed. A growing emphasis on skill-based multidisciplinary training rather than traditional single discipline didactic education is seen.

KEY WORDS: Shock, Massive Transfusion, Hemorrhage, Trauma education

Introduction

The 66th meeting of the *American Association for the Surgery of Trauma* took place at the J.W. Marriott Las Vegas Resort. Dr. David Feliciano of Grady Memorial Hospital and Emory University presided. A combination of reports discussed the practice of acute surgery, outcomes improvement and new techniques. In this review, I discuss selected papers from the meeting while citing relevant work from the trauma literature.

Trauma Systems and Outcomes

Presentations opened with a review of the evolution of training and practice in Acute Care Surgery in the United States. The trauma community seeks to evolve to an Acute Care Surgery discipline with expanded practice in thoracic, vascular, neurologic and orthopedic problems.^{1,2} In part, this desire is fueled by the shrinking operative realm of the general surgeon and diminished availability of surgical subspecialists to support the American trauma system. In a survey sent to trauma directors in over 1200 trauma programs in the United States, an excellent response was received from Level I (92%), Level II (72%) and Level III (59%) centers.³ When trauma centers were polled regarding the ability of trauma panel surgeons to provide vascular, thoracic and complex abdominal surgical coverage, a small minority of centers at each level were able to provide support in these areas with a pure trauma surgeon

panel. Clearly, the American training system must evolve if Acute Care Surgery with broader clinical responsibilities is to evolve in the way it has in some European centers. At present, the typical American trauma surgeon has limited exposure to thoracic, major vascular, urologic and orthopedic cases. Remarkably, surgeons in rural areas have wider exposure in these topic areas than major urban trauma centers where subspecialists are more likely to be available.

Shafi and coworkers from the University of Texas Southwestern and the University of Toronto examined data in the National Trauma Data Bank from Level I trauma centers to assess consistency of outcomes with verification status as a trauma center.⁴ In a review of over 250,000 patients, a clear mortality difference was seen among centers verified as capable of providing Level I care to adults in the United States. These writers suggest that more than verification of availability of resources may be necessary to assure optimal Level I trauma center performance.^{5,6} It is important to note that these workers did not examine outcomes other than mortality. In addition, internal validation of data was not performed. Barie and coworkers examined critical care outcomes in a major New York trauma center and noted that mortality remained flat despite a 30% increase in APACHE III scores during a 17 year practice review.⁷ These authors cited a variety of interventions

over the course of this study, which they suggested were related to consistent ICU outcome despite increasing acuity. Among interventions noted, were use of isolation techniques in all beds, low tidal volume ventilation, glycemic control, introduction of Activated Protein C for the severely ill sepsis patients and limitation of transfusion.^{8,9} This New York experience parallels American data for ARDS where progressive improvement in outcome is seen even before introduction of low tidal volume and improved PEEP strategies.

Intubation drugs in acute resuscitation were also discussed. Hildreth and coworkers from the University of Tennessee, in a prospective, randomized controlled study examined a small group of patients for biochemical evidence of adrenal insufficiency with single dose etomidate administration during rapid sequence intubation.¹⁰ Patients receiving etomidate required a longer duration of mechanical ventilation, had longer ICU stays and received more blood products. Unfortunately, a physiologic explanation for these findings was not evident and a mortality difference with the use of etomidate was not demonstrated. Additional review of the role for etomidate in intubation for trauma resuscitation is warranted.¹¹

Two papers discussed strategies to improve outcome in rural trauma or during prolonged transport. Hansen and coworkers from several regional hospitals in Norway demonstrated improved compliance with damage control strategies using an instructional technique focused on creation of multidisciplinary teams with shared responsibility and improved communication between disciplines.¹² This Norwegian trial suggested improved compliance with resuscitation technique even in rural hospitals where severe injury is infrequently seen.¹³ The University of Vermont assessed the use of telemedicine in ambulances bringing critical patients to trauma centers over prolonged distances.¹⁴ This study utilized human patient simulator technology and evaluated paramedic response with traditional radio as opposed to telemedicine support from the trauma center. When assisted by telemedicine, the EMT group studied was better able to respond to simulation tasks involving complex trauma including catastrophic hemorrhage, tension pneumothorax and pericardial tamponade. Use of traditional radio control interventions led to delayed or missed opportunity to improve patient outcome in these simulation exercises.¹⁵

Progress and Perspectives in Vascular Surgery

Old and new vascular prostheses were featured in discussion of vascular interventions. Demetriades, representing the AAST Multiinstitutional Trial Committee, presented prospective, multicenter data on efficacy and safety of endovascular stent grafts in traumatic thoracic aortic injuries.¹⁶ Practice in trauma centers contributing to this database has shifted dramatically with 65% of patients receiving aortic stent grafts as opposed to 35% of patients receiving open repairs. The risk of death with aortic repair is eight times greater in an open procedure as opposed to the stent graft technique. Complications, however,

did not differ between approaches. The stent graft population had a 20% incidence of endo leaks and other mechanical complications, which frequently required complicated repairs. Concern was also expressed that the availability of stent grafts led to excessive implementation of this technology for minimal injury.^{17,18} In most cases, stent graft or open aortic repair was delayed greater than 50 hours suggesting that immediate intervention for thoracic aortic injury can be delayed with careful management of blood pressure and heart rate. Other concerns raised were the absence of long-term data and off label use of stent technology. Subramanian and the Grady Memorial Trauma Center of Emory University reminded the Association of the value of temporary vascular shunt technology noting that initial reports of temporary intravascular shunts appeared in the British literature in 1919.¹⁹ Reviewing charts of patients treated with temporary intravascular shunts from 1997 to 2007, patency of shunts in both arterial and venous circulation lasted up to 24 hours. A low thrombosis rate of 5% was reported with an amputation rate of 18% in threatened extremities. In 786 patients managed for vascular injuries over the 10 year period reviewed, 9% of patients had approximately 100 arterial or venous shunts placed.

Recent data from the National Trauma Data Bank were reviewed to evaluate the impact of deep vein thrombosis surveillance patterns on the rate of deep venous thrombosis reported.²⁰ Using simple regression, these investigators demonstrated a 1% incidence of deep vein thrombosis detection for each 1% increase in ultrasound surveillance rate. Further analysis of the data suggests that the quartile of hospitals performing most aggressive surveillance had a 7-fold higher DVT rate than the average combined DVT rate in the first three quartiles (1.52% vs 0.22%). While inconsistencies in patient populations and deep vein thrombosis prophylaxis may exist among trauma programs, there appears to be correlation between our attempts to find this complication and the reported incidence.

Adams and coworkers from Memorial Health University Medical Center in Savannah reviewed the state-of-the-art results with aggressive prophylaxis and screening for venous thrombotic events in a large, single center patient population.²¹ Admitted patients in this study (without traumatic brain injury) were started on low molecular weight heparin prophylaxis within 48 hours and had sequential compression devices and compressive stockings as tolerated. Data was collected as part of a retrospective quality review. A 2.5% incidence of DVT and a 0.7% incidence of pulmonary embolism were noted in this large patient population. Overall, duplex screening was performed within the first week after trauma. Seven percent of duplex studies were positive but 80% of positive duplex studies took place in asymptomatic patients. These investigators admitted the lack of a consistent approach to venous thromboembolism prophylaxis in the group with traumatic brain injury where the neurosurgical community has been reluctant to embrace early administration of prophylactic low molecular weight heparin. All patients with deep venous thrombosis in this study

met high-risk criteria including traumatic brain injury, spinal cord injury, significant lower extremity fractures or pelvic fractures.^{22,23}

The role of resuscitative emergency department thoracotomy for patients with exsanguinating abdominal injuries was reviewed by the Temple University Trauma Center.²⁴ Remarkably, in a small group of patients receiving resuscitative thoracotomy, 16% of patients survived to discharge. All of these individuals were neurologically intact. Predictors of successful emergency department resuscitative thoracotomy were sinus rhythm, signs of life in the emergency department and vital signs on emergency department presentation. These patients were critically ill as reflected in an average use of 29 units of packed red blood cells per survivor.²⁵

Perspectives in Transfusion and Bleeding

Recombinant Activated Factor VIIa, as an acute pro-hemostatic agent has revolutionized the approach to resuscitation in major hemorrhage after various types of injury.²⁶⁻²⁸ Two papers document a potential role for even earlier administration of Factor VIIa than traditionally practiced. Spinella and the U.S. Army Institute of Surgical Research in San Antonio reviewed battlefield data from the Iraq conflict originating in a combat support hospital in Baghdad between December 2003 and October 2005.²⁹ Five percent of patients in this facility received massive transfusion defined as 10 units of packed red blood cells administered in the initial 24 hours. In this retrospective study, attending concern for major bleeding and coagulopathy led to administration of Recombinant Activated Factor VIIa an average of two hours after admission in a patient group with a high percentage of penetrating trauma. A 21% reduction in death from hemorrhage was noted with divergence in survival curves visible by 6 to 12 hours in patients receiving Recombinant Activated Factor VIIa as opposed to those who were not offered this therapy in addition to blood product administration. Titration of Factor VIIa therapy, typically dosed at 90-120 $\mu\text{g}/\text{kg}$, was with thromboelastography done at the bedside. Early use of Factor VIIa was related in part to the limited availability of plasma in the combat theater. This data argues, however, that early recognition of the need for Factor VIIa may lead to improved outcomes. Support for this approach came from the R Adams Cowley Shock Trauma Center at the University of Maryland. Stein and coworkers compared a group of patients with early administration of Recombinant Activated Factor VIIa and those without this therapy in the setting of traumatic brain injury.³⁰ Use of plasma and time to operation were significantly reduced with early use of Recombinant Activated Factor VIIa in this small study, which was not powered to evaluate outcome. Mortality and complications were not different between patients receiving early Factor VIIa and those receiving plasma to control coagulation changes in traumatic brain injury. A wide range of Recombinant Activated Factor VIIa doses were administered. At present, this is off-label drug administration and the optimal timing and dose of Recombinant Activated Factor VIIa in the

setting of injury, particularly traumatic brain injury remains unclear. There was no statistical increase in thromboembolic events through a small number of strokes were seen in patients receiving Recombinant Activated Factor VIIa.

The importance of reversing the anticoagulated trauma patient was reinforced by a paper presented from the University of California San Francisco East Bay Program based in Oakland.³¹ In patient groups where age and Injury Severity Score were comparable, mortality was almost three-fold higher in patients with a presenting INR greater than 1.5 (26.5%) as opposed to those with an INR less than or equal to 1.5 (9%). When they studied INR as a continuous variable, and controlled for age ISS and INR, multivariate analysis gave a mortality risk estimate of 37% increase for a one unit increase in INR. Liberal testing of INR was recommended. Discussants noted that a convenience sample was employed in this study and patients evaluated were greater than the age of 50 years. Correlation of INR to cause of death was not clear and the cause for elevation in INR was not consistent in patients studied.³²⁻³⁴ Finally, the effect of normalization of INR on mortality must be evaluated.

Optimal practices for massive transfusion and outcomes associated with this policy were discussed in three papers.^{35,36} The Denver General trauma group questioned the extent of administration of fresh frozen plasma in patients receiving blood transfusion.³⁷ Noting that most administration of fresh frozen plasma and packed red blood cells occurs within the first six hours in trauma associated with significant blood loss, the Denver group reviewed mortality associated with varied ratios of fresh frozen plasma to packed red blood cell administration. While the U.S. military has proposed a 1: 1 ratio of packed red blood cells to fresh frozen plasma administered in the initial hours after trauma, the Denver data suggests that a ratio of 1: 2 to 1: 3 units of fresh frozen plasma to packed red blood cells is most appropriate. It is important to note that this data is retrospective and the data set utilized by the Denver program is far smaller than that which guides present military practice. The appropriate use of blood products to address the need for adequate red cell mass and relief for coagulation factor deficiency continues to receive investigation. The Vanderbilt Medical Center reviewed a one year experience with a Trauma Exsanguination Protocol with rapid release of fixed quantities of packed red blood cells, platelets and fresh frozen plasma in patients deemed to be at risk for rapid blood loss.³⁸ With initiation of this protocol, the trauma team receives 10 units of packed red blood cells, 4 units of fresh frozen plasma and 2 units of platelets. A second request leads to a subsequent pack of 6 units of packed red blood cells, 4 units of fresh frozen plasma and 2 units of platelets. In all, 69 patients treated with the Trauma Exsanguination Protocol were compared with 70 patients from the trauma registry having similar injury characteristics. Mortality was lower with the Trauma Exsanguination Protocol at 30 days and an increased number of unexpected survivors were seen based on TRISS methodology. Remarkably, this improvement in outcome

was seen without inclusion of Recombinant Activated Factor VIIa in the resuscitation protocol. The New Orleans Trauma Center representing Tulane University and Louisiana State University compared outcomes with resuscitation for massive hemorrhage utilizing a 1: 1 as opposed to a 1: 4 ratio of fresh frozen plasma units to packed red blood cell units in patients receiving 10 or more units of packed red blood cells in the first 24 hours in hospital.³⁹ Approximately 5% of patients in the New Orleans experience required more than 10 units of packed red blood cells in the first 24 hours. Thus, a relatively small dataset of 135 patients was produced for comparison. Similar to recent reports from the military, these investigators saw a statistical improvement in outcome when the ratio of packed red blood cells to units of fresh frozen plasma administered approximated 1: 1 as opposed to 1: 4. Unfortunately, other product use was not recorded or controlled in this series.

Conflicting reports regarding the role of leukoreduction came from trauma centers in the southern United States.⁴⁰⁻⁴² First, the University of Alabama at Birmingham examined the combined effects of leukoreduction and administration of packed red blood cells of varying duration of storage on outcome.⁴³ Even with institution of universal leukoreduction, mortality was incrementally increased when packed red blood cells stored for greater than 14 days were administered. The adverse effect of administration of packed red blood cells with prolonged storage increased with the number of units of packed red blood cells administered. This limited data set suggests that leukoreduction is not the answer to increased complications associated with administration of packed red cells having prolonged storage times. Unfortunately, administration of fresh frozen plasma and other blood products was not recorded or controlled in this study. Benefit from leukoreduction was seen in a report from the University of Texas Southwestern Medical Center in Dallas.⁴⁴ Contrary to the Alabama report, the University of Texas group reported incremental improvement in outcome for patients receiving blood stored 14 or 21 days in the setting of leukoreduction. No increase in multiple organ dysfunction was noted with administration of packed red blood cells stored for 14 or more days. Like the Alabama report, this presentation was compromised by lack of complete data regarding characteristics and quantities of other blood products administered. Benefits proposed for leukoreduction in this report clearly require further study and confirmation.

Erythropoietin has received significant attention in the critical care community as a means to decrease red blood cell transfusion with its attendant complications.^{45,46} Napolitano from the University of Michigan presented trauma-specific outcomes from two recent trials utilizing this protein.⁴⁷ This subset analysis demonstrated modest reduction in transfusions but significant reduction in overall trauma patient mortality. An explanation for this finding may rest in other characteristics of erythropoietin, which is known as a stimulus to angiogenesis, for antiapoptosis and antiinflammatory properties. A smaller, single center study from the Carolinas Medical Center

proposed safe cost reduction with elimination of routine erythropoietin use in the critical care population of the trauma service.⁴⁸ These authors, however, made little attempt to reduce erythropoietin use in mildly injured patients. Notably, even this small dataset included a modest mortality benefit in patients receiving erythropoietin. Mechanisms for improved outcome with erythropoietin in injured patients require further evaluation. Only subset data in post hoc analyses are available today.

Abdominal Trauma

Management of splenic injury dominated papers in the sessions on abdominal trauma.⁴⁹⁻⁵³ Gray and coworkers from Ontario, Canada examined the natural history of splenic pseudoaneurysm formation after blunt injury.⁵⁴ Noting a high incidence of splenic pseudoaneurysms between 4 and 5 days after injury, this group obtained a follow-up CT at approximately 48 hours after injury and used angiography based on the 48 hour CT scan to embolize additional splenic artery pseudoaneurysms identified on 48 hour CT imaging. Listeners were surprised when follow-up CT scanning was recommended even for AAST Grade I or Grade II splenic injuries. Routine hospital stay in this patient group also was longer than that seen in other centers. Most concerning was the high overall mortality rate in patients with nonoperative splenic management which eliminated late splenic hemorrhage in this small series. Detail regarding mortality with nonoperative management of the spleen was not provided. A disproportionate incidence of severe head injury was noted in patients receiving the 48 hour CT scan and more aggressive angiographic management of late splenic pseudoaneurysm.

Cohn and the trauma program at the University of Texas Health Science Center in San Antonio reviewed CT grading systems for both liver and splenic injury and noted poor inter-rater consistency and a high rate of failure to diagnose critical injuries.⁵⁵ Clinical data must be used with the CT image to identify patients requiring angiography and possible embolization. Savage representing the trauma programs at the University of Tennessee in Memphis and the University of Alabama Birmingham discussed the role of outpatient CT scanning in patients with all grades of splenic injury.⁵⁶ She noted 80% of AAST Grade I and II injuries were healed on CT at 25 days while 70 days were required for 80% of patients to heal Grade III injuries and above. In this series of over 400 splenic injuries, approximately 10% of injuries appeared to worsen on follow-up scanning and nearly 20% of severe injuries were not healed at 3 months. Routine follow-up of splenic injuries for 8 to 12 weeks was recommended particularly in patients with AAST Grade III lesions and above. Walusimbi from the Wright State School of Medicine examined immunologic function of the spleen after embolization for trauma.⁵⁷ Using an immunologic panel including T and B cell counts, complement levels and properdin quantification, the only difference noted was a rise in B-lymphocyte counts after embolization. Reviewers commented that none of the assays described truly quantified

splenic function and that immunoglobulin production could have been measured. A small participating patient cohort also limited this study.

Two additional papers discussed the management of intestinal anastomoses in abdominal sepsis and abdominal wall closure techniques.^{58,59} First, a multiauthor series from Cali, Columbia and the University of Pittsburgh compared delayed primary anastomosis with traditional diverting enterostomy for intraabdominal sepsis.⁶⁰ Patients receiving delayed intestinal anastomosis came from a trauma surgery group while traditional general surgeons used intestinal diversion techniques. Delayed primary anastomosis was possible in 85% of patients requiring anastomosis in the setting of abdominal sepsis without increase in mortality. Early anastomoses required multiple laparotomies and a final laparotomy to close the abdomen was typically performed 48 hours after the intestinal anastomosis was performed. Forty percent of anastomoses were colonic while the remainder involved small bowel. Readmission for enterostomy takedown was avoided in the patients receiving serial laparotomies at the initial hospitalization and pulmonary morbidity was also reduced. A methodologic concern raised in this report was the use of two different surgical teams to perform the two approaches to intestinal management in abdominal sepsis. Bee and coworkers at the University of Tennessee at Memphis compared Vacuum-Assisted Closure (VAC) to synthetic (polyglactin) mesh closure in patients requiring temporary abdominal coverage after damage control laparotomy or abdominal compartment syndrome.⁶¹ These authors noted a low overall fistula rate (1-5%) with either technique in a patient population with severe injury (Injury Severity Score 30-33). There was suggestion of increased fistula rates from anastomotic suture lines and feeding tubes when abdominal suction dressings were employed. Use of less expensive mesh products also had economic advantage over VAC technology. Overall, both VAC and mesh approaches are useful for abdominal coverage and equally likely to produce delayed primary closure. Apart from a slightly higher fistula rate with VAC utilization, other parameters studied were comparable.

Cervical Trauma: Imaging Perspectives

Identification and management of cervical spine and vascular injury was discussed in two important manuscripts.⁶²⁻⁶⁴ Eastman and coworkers from the University of Texas Southwestern Medical Center and Parkland Memorial Hospital in Dallas reported on a CT angiography-based protocol for early identification of blunt cervical vascular injury.⁶⁵ The CT-based strategy was compared to previous catheter-based arteriography. In a review of over 3000 trauma admissions from April 2005 through July 2006, approximately 1% of patients were found to have some form of blunt cerebrovascular injury diagnosed by CT alone. These injuries were managed nonoperatively, typically using a combination of heparin and antiplatelet agents. Utilizing CT angiography, the duration from admission to scanning and injury identification was

reduced to three hours as opposed to over 30 hours with traditional catheter-based cervical angiography. During historical catheter-based angiography for screening, the overall stroke rate for blunt cerebrovascular injury was 15.2% while with initiation of CT angiography, the stroke rate was reduced to 3.8%. If a 64-slice CT scanner is employed, one contrast dose will allow scanning of both the neck and torso. No acute operations for cervical vascular injury were required in this series and approximately 7-10% of trauma admissions were felt appropriate for cervical vascular screening. The criteria of Biffi and coworkers were utilized to create the cervical vascular management protocol employed at this center. Optimal imaging to evaluate the cervical spine was reviewed in a report from the R Adams Cowley Shock Trauma Center presented by Menaker and coworkers.⁶⁶ While the quality of CT imaging has clearly continued to improve, magnetic resonance imaging is required for cervical spine clearance in patients where physical examination remains unreliable. In this series of 205 patients with normal cervical CT scans, 18 individuals (8.9%) had abnormal MRI. Two of these individuals required surgical stabilization for ligamentous dysfunction. Notably, MRI in these patients was frequently done as late as 10 days or more after injury. Seventy-two hours is the standard time for MRI imaging after injury due to the decline of ligament edema, which facilitates detection of ligamentous injury. Despite logistic difficulties in obtaining timely MRI in this patient group, the Shock Trauma investigators support dual imaging with CT and MRI for patients with abnormal neurologic exam (Glasgow Coma Score of 14 or less) and normal cervical spine CT imaging.

Perspectives in Education and Training

Opportunities for quality improvement and education were discussed in two final papers.^{67,68} Ivatury and the Virginia Commonwealth University Medical Center trauma program investigated patterns of management errors associated with death in a five year review of over 18,000 admissions to a Level I trauma center.⁶⁹ Of 827 deaths, 739 records were available for review. A number of general observations were made. First, system errors were relatively uncommon. Errors in the resuscitation area reflected inappropriate management of airway compromise, failure to meet resuscitation needs of patients or missed injuries. Another site for education and quality improvement was the intensive care unit where inconsistent use of optimal care bundles was noted along with delayed recognition of complications. A common theme in errors identified was failure to communicate vital information and lack of teamwork by participants in resuscitation and ICU. In part, to address this concern, Knudson and coworkers from the University of California San Francisco and the Stanford University Medical Center evaluated the impact of simulation-enhanced education and crisis management skills during trauma resuscitation as opposed to the same orientation curriculum in didactic sessions.⁷⁰ When a post-training written examination was administered, residents had nearly identical average scores. When crisis management skills were

evaluated in a multidisciplinary setting, however, residents receiving prior simulation-enhanced teaching scored higher in team management and decision making. Simulation-based education warrants additional evaluation as a means to enhance aspects of care not readily evaluated on routine written exams or taught in standard didactic sessions.

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