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on the Subject of

Pediatric Trauma in the United States
Challenges of Ensuring Adequate Trauma Care for the Pediatric Patient

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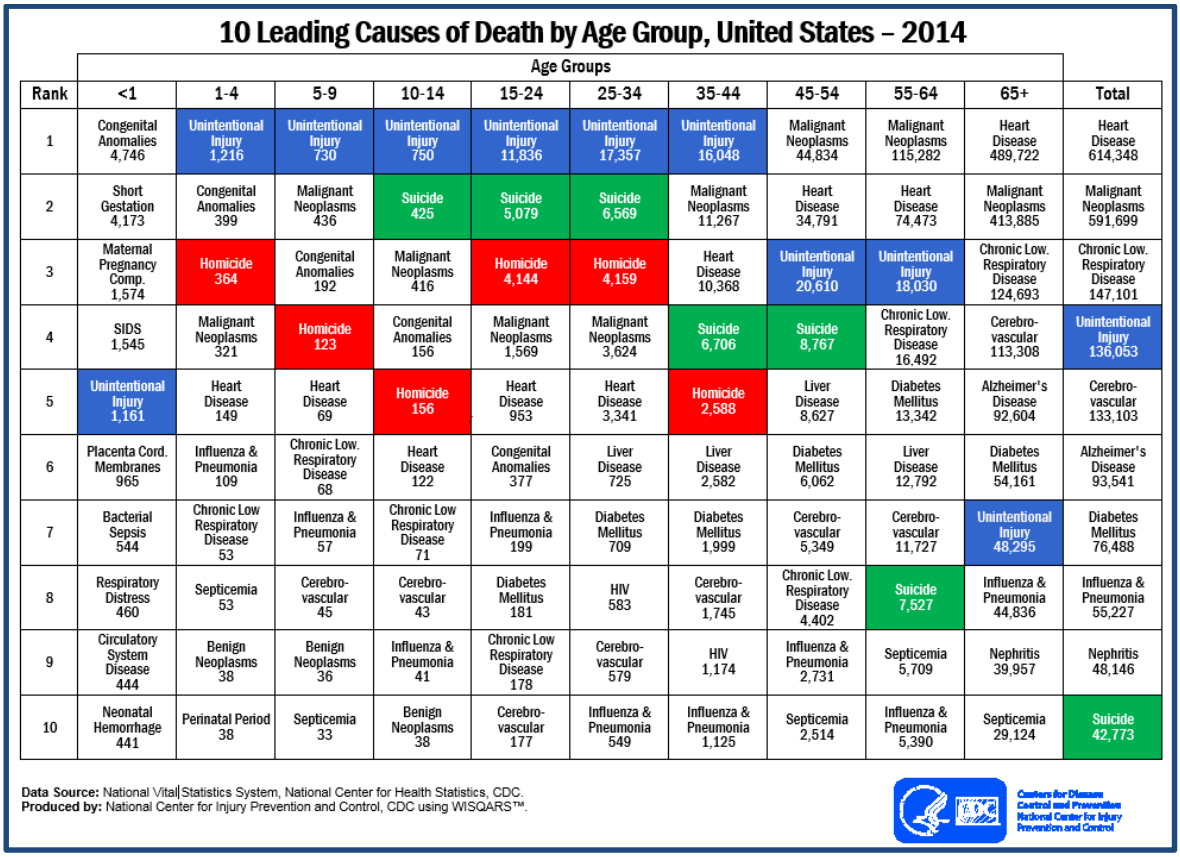
Pediatric Trauma in the United States: Challenges of Ensuring Adequate Trauma Care for the Pediatric Patient

I. OVERVIEW

Trauma care injuries, whether accidental or intentional, account for more deaths — approximately 10,000 annually — among infants, children and adolescents than all other causes combined — including infectious diseases, cancer and congenital defects.[1] The leading contributor causing death and disability is traumatic brain injury (TBI), and as *Figure 1* indicates, unintentional injury is the leading cause of death in children and young adults from age one through 44. Additionally, children account for 10 percent of all spinal cord injuries that occur each year.



10 Leading Causes of Death by Age Group, United States – 2014

	Age Groups										
Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	Total
1	Congenital Anomalies 4,746	Unintentional Injury 1,216	Unintentional Injury 730	Unintentional Injury 750	Unintentional Injury 11,836	Unintentional Injury 17,357	Unintentional Injury 16,048	Malignant Neoplasms 44,834	Malignant Neoplasms 115,282	Heart Disease 489,722	Heart Disease 614,348
2	Short Gestation 4,173	Congenital Anomalies 399	Malignant Neoplasms 436	Suicide 425	Suicide 5,079	Suicide 6,569	Malignant Neoplasms 11,267	Heart Disease 34,791	Heart Disease 74,473	Malignant Neoplasms 413,885	Malignant Neoplasms 591,699
3	Maternal Pregnancy Comp. 1,574	Homicide 364	Congenital Anomalies 192	Malignant Neoplasms 416	Homicide 4,144	Homicide 4,159	Heart Disease 10,368	Unintentional Injury 20,610	Unintentional Injury 18,030	Chronic Low. Respiratory Disease 124,693	Chronic Low. Respiratory Disease 147,101
4	SIDS 1,545	Malignant Neoplasms 321	Homicide 123	Congenital Anomalies 156	Malignant Neoplasms 1,569	Malignant Neoplasms 3,624	Suicide 6,706	Suicide 8,767	Chronic Low. Respiratory Disease 16,492	Cerebro-vascular 113,308	Unintentional Injury 136,053
5	Unintentional Injury 1,161	Heart Disease 149	Heart Disease 69	Homicide 156	Heart Disease 953	Heart Disease 3,341	Homicide 2,588	Liver Disease 8,627	Diabetes Mellitus 13,342	Alzheimer's Disease 92,604	Cerebro-vascular 133,103
6	Placenta Cord. Membranes 965	Influenza & Pneumonia 109	Chronic Low. Respiratory Disease 68	Heart Disease 122	Congenital Anomalies 377	Liver Disease 725	Liver Disease 2,582	Diabetes Mellitus 6,062	Liver Disease 12,792	Diabetes Mellitus 54,161	Alzheimer's Disease 93,541
7	Bacterial Sepsis 544	Chronic Low Respiratory Disease 53	Influenza & Pneumonia 57	Chronic Low Respiratory Disease 71	Influenza & Pneumonia 199	Diabetes Mellitus 709	Diabetes Mellitus 1,999	Cerebro-vascular 5,349	Cerebro-vascular 11,727	Unintentional Injury 48,295	Diabetes Mellitus 76,488
8	Respiratory Distress 460	Septicemia 53	Cerebro-vascular 45	Cerebro-vascular 43	Diabetes Mellitus 181	HIV 583	Cerebro-vascular 1,745	Chronic Low. Respiratory Disease 4,402	Suicide 7,527	Influenza & Pneumonia 44,836	Influenza & Pneumonia 55,227
9	Circulatory System Disease 444	Benign Neoplasms 38	Benign Neoplasms 36	Influenza & Pneumonia 41	Chronic Low Respiratory Disease 178	Cerebro-vascular 579	HIV 1,174	Influenza & Pneumonia 2,731	Septicemia 5,709	Nephritis 39,957	Nephritis 48,146
10	Neonatal Hemorrhage 441	Perinatal Period 38	Septicemia 33	Benign Neoplasms 38	Cerebro-vascular 177	Influenza & Pneumonia 549	Influenza & Pneumonia 1,125	Septicemia 2,514	Influenza & Pneumonia 5,390	Septicemia 29,124	Suicide 42,773

Data Source: National Vital Statistics System, National Center for Health Statistics, CDC.
Produced by: National Center for Injury Prevention and Control, CDC using WISQARS™.

Centers for Disease Control and Prevention
National Center for Injury Prevention and Control

Figure 1: Leading causes of death by age group in the United States, 2014. Source: Centers for Disease Control and Prevention (available at http://1.usa.gov/1U6AWTu, last accessed on May 21, 2016).

Annually, more than 10 million children require emergency department care for the evaluation and treatment of traumatic injuries.[2] The economic costs of pediatric trauma — including hospital and other ongoing costs related to lifelong disability and requisite skilled care in this sizeable cohort — are significant: $14 billion in lifetime medical spending and $66 billion in present and future work

[1] Arias E, MacDorman MF, Strobino DM, Guyer B. Annual summary of vital statistics. Pediatrics. 2003;112:1215–30.

[2] American College of Surgeons Committee on Trauma. Advanced Trauma Life Support for Doctors (ATLS) Student Course Manual. 8th ed. Chicago: American College of Surgeons; 2008. Pediatric trauma; pp. 225–45.

losses.[3] Despite improved preventative measures and care, pediatric traumatic injury and neurotrauma are major public health problems in the United States.

Children are not just "little adults." Due to a number of differences that exist between the developing immature brain and the mature adult brain, the impact of the types of injury and the considerations related to acute care and recovery vary accordingly. Examples of these differences include:

- Neurobiology — water content, receptor number and distribution, etc;
- Primary mechanisms of how they suffer injury at different ages — assault, recreational, motor vehicle, etc.;
- Response to injury, the cascade of secondary mechanisms — excitotoxicity, lipid peroxidation, etc. that lead to worsened brain injury;
- Response to treatment — medications and other therapeutics have a differing response in children; and
- Response to rehabilitation and recovery.

Because of these differences, special attention at all levels of care is essential — particularly in neurotrauma — and systems must be developed to address the uniqueness of children and their injuries. Furthermore, since injuries are occurring in a developing brain, there exist research opportunities to establish mechanisms for treatment and restoration of function for common adult brain injuries such as stroke, TBI, Alzheimer's Disease, Parkinson's Disease, and others.

II. PEDIATRIC NEUROSURGERY WORKFORCE

According to the American Trauma Society, overall, there are more than 5,000 trauma centers in the United States[4] and there are 217 Level I trauma centers in the country.[5] Some hospitals are designated as pediatric trauma centers as well. Pediatric neurosurgery is highly specialized field of neurosurgery requiring an extra year of clinical training and also frequently requires pediatric subspecialists to provide support in the areas of neurology, radiology, critical care, rehabilitation, etc. There are only approximately 350 board certified/board eligible pediatric neurosurgeons in the U.S. As a result, there is only one pediatric neurosurgeon for a catchment area of every 1,000,000 people. Consequently, most pediatric neurosurgeons are located in urban centers with surrounding referrals to the pediatric hospital or to a hospital that can support the requisite pediatric neurological specialists. While this number may be considered sufficient for the present

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[3] Miller TR, Romano EO, Spicer RS. The cost of childhood unintentional injuries and the value of prevention. Future Child. 2000;10:137–63.

[4] According to the American Trauma Society (available at http://www.amtrauma.org/?page=TraumaLevels, last accessed on May 21, 2016), trauma center levels across the United States are identified in two fashions — a designation process and a verification process. The different levels (i.e. Level I, II, III, IV or V) refer to the kinds of resources available in a trauma center and the number of patients admitted yearly. These are categories that define national standards for trauma care in hospitals. Categorization is unique to both adult and pediatric facilities.

Trauma center designation is a process outlined and developed at a state or local level. The state or local municipality identifies unique criteria in which to categorize trauma centers. These categories may vary from state to state and are typically outlined through legislative or regulatory authority.

Trauma center verification is an evaluation process done by the American College of Surgeons (ACS) to evaluate and improve trauma care. The ACS does not designate trauma centers; instead, it verifies the presence of the resources listed in "Resources for Optimal Care of the Injured Patient." These include commitment, readiness, resources, policies, patient care, and performance improvement. This is a voluntary process and lasts for a three-year period.

[5] American Trauma Society December 2015 Survey.

and future growth of the U.S. population for most pediatric neurosurgical diseases, it means that a significant proportion of pediatric trauma patients will be treated by neurosurgeons without specific additional pediatric qualifications, or even treated initially in hospitals without any neurosurgical coverage at all. Treatment by non-pediatric subspecialty neurosurgeons may be sufficient for many neurotrauma surgical needs and even optimal when time is of the essence, as neurosurgical training does include significant experience and specific learning goals and objectives for treating pediatric neurosurgical problems. However, for the most severely injured children, arrangements for surgical and medical stabilization and transfer of injured children are sometimes necessary for ongoing surgical and other aspects of care. This is because not every trauma center in the U.S. that might encounter a pediatric traumatic injury is equipped to care for the continuum of care related to the most severe injuries in children, particularly in rural settings where the gamut of pediatric specialists (such as pediatric neurointensivists and rehabilitation specialists) is lacking.

III. PREHOSPITAL CARE

One unique challenge with emergency pediatric care is that many emergency medical service vehicles are not fully equipped for pediatric transport. There is limited space on both air and ground ambulances, which results in limited availability of all sizes of pediatric airways, cervical spine immobilization devices and other vital equipment. Since airway compromise is a leading cause of preventable death, this is particularly troublesome, as it is frequently difficult to intubate children, especially with limited pediatric airway equipment and experience. Again, because of limited space, confirmatory equipment of appropriate intubation — such as the end tidal carbon dioxide ($ETCO_2$) monitor, which is particularly important in pediatric intubation — is often lacking in the field.

The distance from adult trauma centers to those with either pediatric qualifications or pediatric trauma centers varies depending on the region — e.g., Northeast/Atlantic corridor vs. Southwest or North Midwest — of the United States. Over three-fourths (78%) of the U.S. population lives within 60 minutes of a Level I or II pediatric trauma center via ambulance or helicopter, although this covers only 21.91 percent of the country's landmass (*Figure 2*).

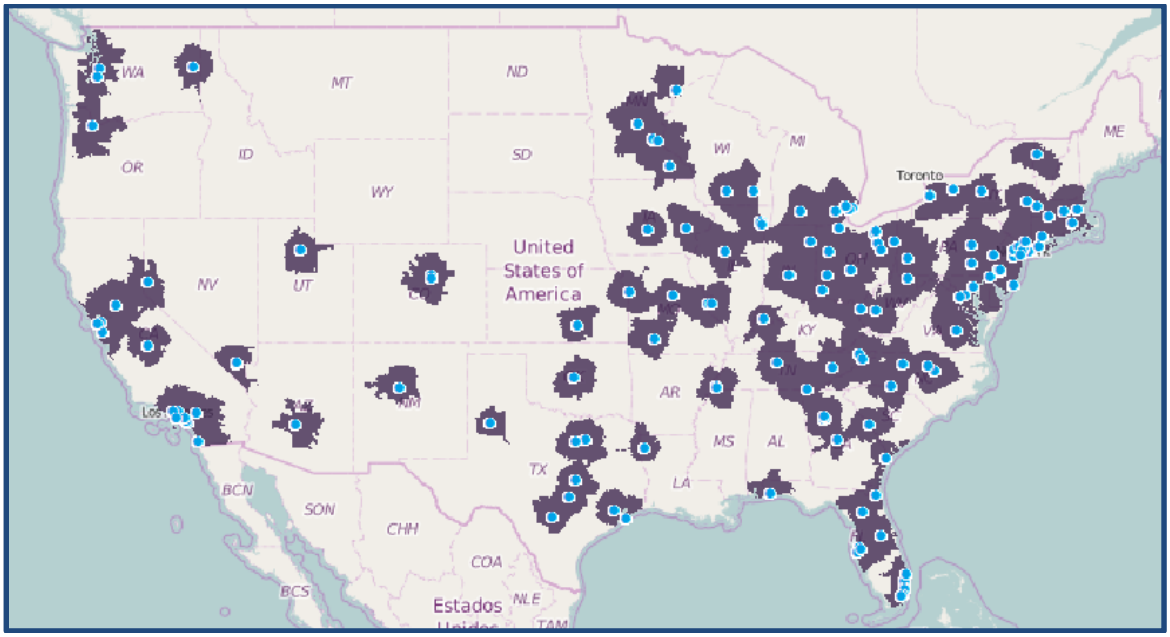

Figure 2: 60-minute access to Level I and II pediatric trauma centers by ambulance and helicopter. Source: American Trauma Society and the University of Pennsylvania (available at http://www.traumamaps.org/, last accessed on May 21, 2016).

If travel by ambulance is the only option, however, the situation is dire indeed. In this situation, less than one-half (48.15%) of the U.S. population can reach a pediatric trauma center in one hour, covering a mere 2.45 percent of the country's landmass (*Figure 3*).

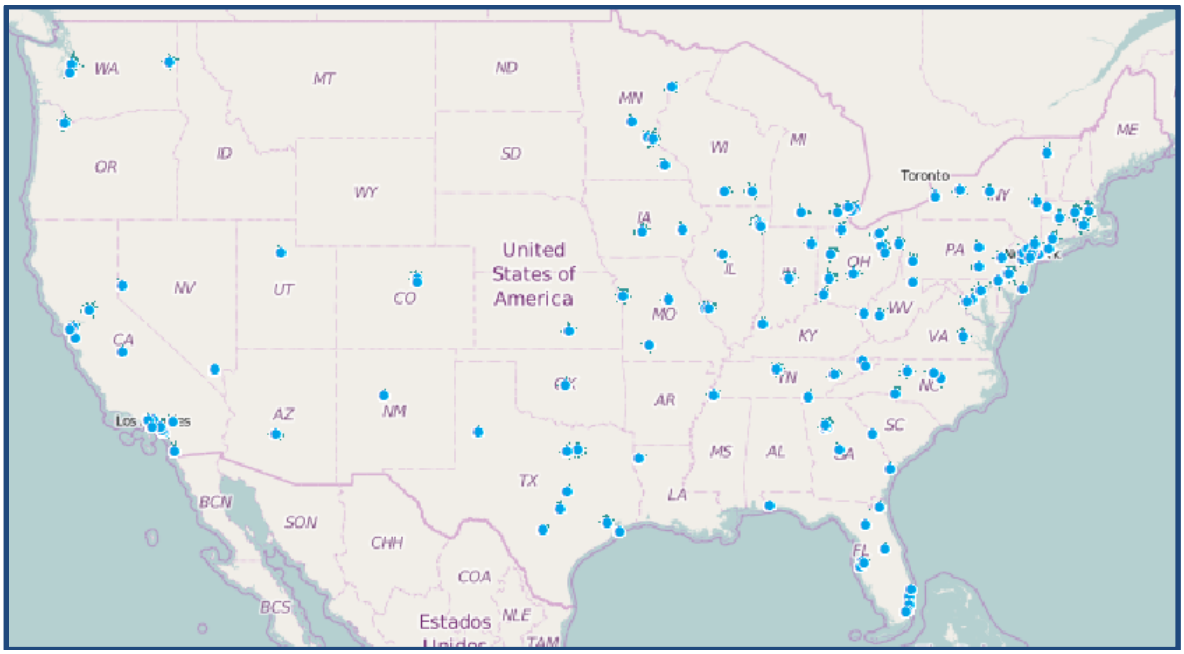

Figure 3: 60-minute access to Level I and II pediatric trauma centers by ambulance. Source: American Trauma Society and the University of Pennsylvania (available at http://www.traumamaps.org/, last accessed on May 21, 2016).

Local regulations and Emergency Medical Treatment and Labor Act (EMTALA) concerns might affect the decision to bypass local or adult centers, as clinical decision pathways for bypass are not always in place. Adult criteria for Level I trauma care and the possible need for an operating room soon after arrival do not translate directly to the care of children, and further study is required to determine the best measurements. Furthermore, variability in receiving hospital capabilities, as well as triage and transport systems that are not fully developed, contribute to pre-hospital challenges throughout those regions without direct access to pediatric centers.

Data show that children have better outcomes when they are transported to pediatric Level I and adult Level I trauma centers with pediatric qualifications, as compared to adult Level I, II or III trauma centers. The findings of these studies demonstrate that nonoperative management of blunt solid organ injuries is more common in experienced pediatric trauma programs[6] and children with orthopaedic and brain injuries have improved outcomes when treated at a pediatric trauma center or an adult center with pediatric qualifications.[7] Predictors of poor outcomes and need-to-transport directly to Level I or II trauma centers are not as well established as they are in the adult

[6] Sims CA, Wiebe DJ, Nance ML. Blunt solid organ injury: do adult and pediatric surgeons treat children differently? J Trauma. 2008 Sep;65(3):698-703.

[7] Potoka DA, Schall LC, Ford HR. Improved functional outcome for severely injured children treated at pediatric trauma centers. J Trauma. 2001 Nov;51(5):824-32; discussion 832-4.

population. Those guidelines that do exist are not widely disseminated to emergency medical services (EMS) providers.

Essential training programs for EMS providers have not been developed in a cohesive manner. Most specialized pediatric transport teams spend the majority of time on inter-facility transport. Many injured children are transported by "adult" EMS providers or parents and coaches. It is estimated that 10 to 15 percent of EMS transports are children, though 20 to 25 percent of emergency department (ED) visits are for patients younger than 19 years old. Intubation in children has been found to have worse outcomes if EMS providers were inexperienced or had little specialized pediatric training. Emergency tracheal intubation (ETI) in pediatric patients is rare, and as such, this skill is difficult to maintain. Studies show 40 to 60 percent field success rates in pediatric ETI, and possibly no clear outcome benefit over bag mask valve (BMV). Measures of severity of injury for children such as the Pediatric Glasgow Coma Score (GCS) are also less frequently used due a lower comfort level for assessing children among EMS personnel, resulting in wide inter-observer variability and potential for error in reporting, triaging, and effecting appropriate levels of care for kids.

Additionally, resuscitation efforts in infants and children differ from adults particularly with regards to fluid management. Children in shock present very differently than adults, with effects on key vital signs such as blood pressure much later in the course, and recovery becoming less likely after vital sign derangement.

Delineation of pediatric-specific care has been developed using evidence-based medicine, but variability in its distribution and implementation across transport networks persists. There are varying experiences with the Pre-Hospital Index (PHI) in children — a scoring system for field triage of trauma victims — and whether using it affects outcomes, thus requiring further study. Pediatric pain scales are not validated in the pre-hospital environment and require further study. Non-standardized reporting of the age in which patients become adults limits the applicability and comparability of various studies, and there is a need for standard definitions.

Further study is made difficult in that funds are limited for clinical training and research. Federal programs such as EMS for Children — administered by the Heath Resources and Services Administration (HRSA) in the U.S. Department of Health and Human Services (HHS) — funds grants and collaboration efforts. (*See* Appendix) However, these grants are possibly not widely known or utilized, and further education is, therefore, needed.

IV. SYSTEMS OF CARE AND THE CURRENT STATE OF TRAUMA CENTERS

It is important to note the difference between a trauma system and trauma centers. A trauma system is an integration system involving multiple components of care, which may be organized on a state, regional or county level, depending on demography, geography, epidemiology and governmental/regulatory demands. The American College of Surgeons (ACS) has provided a good deal of leadership in the field of trauma systems development, as injury is so often a surgical problem. Moreover, the ACS is the only organization currently providing a structured consultation process regarding trauma systems. The ACS process is based on a public health model incorporating multidisciplinary expertise and addresses issues of regionalization of care, disaster and mass casualty event preparedness, optimal number and placement of trauma centers, injury prevention based upon epidemiology of injury, and performance improvement among others. This program was developed with colleagues from the American College of Emergency Physicians (ACEP), the National Highway Traffic Safety Association (NHTSA), HRSA, state EMS directors, trauma nurses and others.

Issues of prehospital transportation of injured infants and children through the acute phases of care through the rehabilitative phases and community reintegration are an integral part of the evaluation of any system of trauma care delivery.

An inclusive trauma system recognizes that injured persons are cared for in a variety of settings, including designated trauma centers, but also including a wide range of other facilities with various levels of resource allocation.

It is also important to understand the difference between trauma center verification processes and designation processes for definitive care facilities. Verification may be performed by a variety of organizations, government entities, foundations, and the like, while according to the American College of Surgeons Verification, Review, and Consultation Program, "the designation of trauma facilities is a geopolitical process by which empowered entities, government or otherwise, are authorized to designate. The ACS does not designate trauma centers; instead, it verifies the presence of the resources listed in *Resources for Optimal Care of the Injured Patient*."

In the ACS process, adult trauma centers are categorized as Level I through IV, each with different criteria for verification level. Some states recognize Level V centers in special circumstances. (*See* Appendix) In the ACS model, adult trauma centers can be verified with pediatric qualifications or pediatric hospitals may have verification at different levels (now mirroring the adult levels) when they meet unique requirements and criteria for providing pediatric care.

Each state performs trauma center *designation* differently in their regulations. Not all states utilize the ACS verification program; while some states adopt the ACS verification process as one measure of a hospital's ability or qualification to definitively or optimally care for trauma patients, other states utilize their own systems.

One focus of systems outcomes research has been to assess the impact of special resources, expertise and experience on injured infants and children. Outcomes in pediatric trauma centers and adult centers with pediatric qualifications have been shown to be superior to adult trauma centers alone.[8] As there is variability across the U.S. as to the availability of qualified trauma centers and those with pediatric expertise and qualifications, there have been several proposed reasons for worse outcomes for children at lower-level trauma centers including lack of expertise, experience, pediatric subspecialists and pediatric equipment.

Several limitations exist in the present trauma delivery system for children. First, the role of Level III and IV centers in pediatric trauma care has not been well delineated. Level I trauma centers, primarily located in metropolitan areas, have the capability of taking care of all injured patients, including pediatric trauma victims, and in some states, adult Level I trauma centers can obtain added pediatric qualifications.[9] As previously noted, Level I and Level II pediatric centers also tend to be located in densely populated urban centers. In contrast, Level III and Level IV centers, mostly located in rural areas, are adept at assessment, stabilization and transfer of adult patients, but the expertise in caring for pediatric trauma victims may be uneven.

Secondly, the management of the pediatric trauma patient is complicated by a lack of uniform protocols for the triage and transport of pediatric trauma victims to appropriate facilities across the U.S. This fact is particularly the case in rural trauma hospitals. Existing protocols are typically

[8] Potoka DA, Schall LC, Ford HR. Improved functional outcome for severely injured children treated at pediatric trauma centers. J Trauma. 2001 Nov;51(5):824-32; discussion 832-4.

[9] Resources for Optimal Care of the Injured Patient, Committee on Trauma American College of Surgeons. 2006; American Trauma Society Position Statement, 2013-3, Trauma Systems.

created amid a framework of local or regional guidelines and managed by the centers involved. Although this type of approach might meet local or regional needs, the lack of standardized, nation-wide pediatric triage and transport protocols creates inconsistencies in the management of pediatric neurotrauma victims and may compromise care.

Thirdly, regulatory issues impact the present trauma systems for pediatric patients. The EMTALA statute — enacted in 1986 — prohibits the discriminatory practice of treating patients based on their ability to pay.[10] All hospitals that participate in Medicare or Medicaid services are expected to comply. Since then, EMTALA has protected thousands of pediatric trauma victims from the discriminatory practices of inappropriate transfer or denial of critical services. However, there is little research regarding how EMTALA affects the movement of pediatric trauma victims through systems of care. Level I pediatric trauma hospitals with well-defined, ACS-approved trauma programs accept all patients and have published emergency call schedules for critical specialties such as neurosurgery. However, due to call coverage inconsistencies and other factors, smaller or more rural trauma hospitals may have difficulty filling that obligation. Little is published on this issue.

Finally, workforce issues impact the ways in which systems become organized and care is delivered. For example, neurosurgeons with primarily adult practices may or may not be comfortable caring for pediatric trauma victims in any setting, trauma center or otherwise. Reasons for this include, but are not limited to:

- Comfort level and experience taking care of infants and children;
- Duration of time since completion of residency training;
- Hospital privilege restrictions to the practice of only adult patients; and
- Concerns about medical liability coverage for primarily “adult” surgeons caring for pediatric patients.

The available workforce of other types of physicians subspecializing in pediatric trauma care is limited. This includes pediatric general and other subspecialty surgeons, pediatric emergency physicians, pediatric intensivists, and pediatric rehabilitation medicine specialists. Furthermore, although generally trained to be capable of caring for pediatric neurotrauma victims, relatively few pediatric intensivists have specialized practices in neurotrauma.

V. TRAINING AND EDUCATION

Part of the challenge is to develop educational programs on the unique aspects of pediatric care for numerous providers across the spectrum, most of whom interact primarily with adult patients. This first requires raising the level of knowledge to a standardized baseline and then moving to a continuum of learning as new knowledge is defined. This includes training for EMS in the pre-hospital setting, education for lower level trauma center and non-trauma center hospital personnel, and even enhanced education in upper-level trauma centers across the spectrum of providers who may be asked to care for the pediatric patient. Substantial improvements in validated, outcomes-based education and assessment for neurosurgeons and emergency medicine physicians have been implemented for pediatric trauma in the context of the Accreditation Council for Graduate Medical Education’s Next Accreditation System (including the Milestones project). Significant challenges remain, however, in creating adequate learning exposure and validated assessment in the pediatric trauma clinical environment, particularly for team based aspects of care. Once an

[10] EMTALA and the Pediatric Emergency Department, Joseph Zibulewsky, MD, MHS, FACEP, FAAP, Assistant Medical Director, Department of Emergency Medicine, Baylor University Medical Center, Dallas, TX; Clinical Assistant Professor, Department of Surgery, Division of Emergency Medicine, University of Texas, Southwestern Medical Center, Dallas. AHC Media, August 1, 2001.

adequate interdisciplinary and inter-professional curriculum is developed, criteria for maintaining continuing medical education (CME) in pediatric trauma care and the development maintenance of appropriate educational materials — that are revised to reflect scientific and clinical practice guidelines developments — must also be established.

VI. TRENDS IN RESEARCH IN PEDIATRIC HEAD INJURY

While pediatric head trauma is common, challenges to clinical studies are numerous, and approaches have evolved over time.[11] Because the most severe injuries occur in smaller numbers, studies typically must involve multiple centers to reach statistical significance, introducing greater potential for center variability in treatment and outcomes and possibly confounding results. This type of research is also expensive, and standardization is challenging.[12] Because of the complexity of the brain and its functions, the wide variety of pathomechanisms of injury seen, and wide variation in genetic, epigenetic and demographic backgrounds of patients, TBI patients are very heterogeneous. Therefore, categorization of head injury types and determination of how to best group patients into randomization categories is another challenge. Efforts to characterize injury and specific patient factors influencing outcome are still being refined.[13] To address variability in treatments, attention has turned to so-called comparative effectiveness methods in large trials. These are methods that allow researchers to collect large amounts of data and then look backward to see what treatments worked best for which patients. It is hoped that this will allow for treatments to be more tailored to patients most likely to benefit from them, and reduce side effects and expense in those for whom the treatments won't make a difference.[14]

Numerically, most injuries are relatively mild in severity, while past research has naturally focused on children with more severe injuries because of the devastation they cause. In response to widespread increases in reporting of milder TBI, though, recent studies have aimed to include a wider breadth of injury severities.[15]

Children's brains and physiologies vary significantly during maturation from infancy through adolescence. More study needs to occur to understand the effects of these differences and whether treatments designed and tested in adults are helpful — or might be counterproductive —

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[11] Bell MJ, Adelson PD, Forbes ML, Kochanek PM. Traumatic Brain Injury in Children: Critical Care Management. in Albright AL, Pollack IF, Adelson PD. (Eds) Principles and Practice of Pediatric Neurosurgery (3rd Edition). Thieme Medical Publishers: New York, 729-742, 2014.

[12] Bell, M.J. and Kochanek, P.M., *Pediatric Traumatic Brain Injury in 2012 – The Year with New Guidelines and Common Data Elements.* Critical Care Clinics, 2012.

[13] Saatman, K.E., Duhaime, A.C., Bullock, M.R., Maas, A.I., Valadka, A.B., Manley, G.T., and Et.al, *Classification of traumatic brain injury for targeted therapies.* J Neurotrauma, 2008. Jul;25(7):719-38.

[14] Chin, K.H., Bell, M.J., Wisniewski, S.R., Balasubramani, G.K., Kochanek, P.M., Beers, S.R., Brown, S.D., and Adelson, P.D., *Effect of Administration of Neuromuscular Blocking Agents in Children With Severe Traumatic Brain Injury on Acute Complication Rates and Outcomes: A Secondary Analysis From a Randomized, Controlled Trial of Therapeutic Hypothermia.* Pediatric Critical Care Medicine, 2015. 16(4): p. 352-358.; Shein, S.L., Ferguson, N.M., Kochanek, P.M., Bayir, H., Clark, R.S.B., Fink, E.L., Tyler-Kabara, E.C., Wisniewski, S.R., Tian, Y., Balasubramani, G.K., and Bell, M.J., *Effectiveness of Pharmacological Therapies for Intracranial Hypertension in Children With Severe Traumatic Brain Injury—Results From an Automated Data Collection System Time-Synched to Drug Administration.* Pediatric Critical Care Medicine, 2016. 17(3): p. 236-245.

[15] Schneider, K.J., Iverson, G.L., Emery, C.A., McCrory, P., Herring, S.A., and Meeuwisse, W.H., *The effects of rest and treatment following sport-related concussion: a systematic review of the literature.* Br J Sports Med, 2013. 47(5): p. 304; Yeates, K.O., *Mild traumatic brain injury and postconcussive symptoms in children and adolescents.* Journal of the International Neuropsychological Society, 2010. 16(6): p. 953-960.

in children of different ages.[16] Research using animal models appropriate for answering questions about the immature brain may sometimes be required.

Concerns about radiation exposure in young children have dictated the development of specific imaging guidelines for children sustaining TBI so as to avoid missing potentially devastating intracranial injury, while not exposing those with milder or non-structural injury who will ultimately do well to the dangers of ionizing radiation. The use of magnetic resonance imaging (MRI) as a research tool for imaging brain injuries in children has garnered more recent attention.[17] However, MRI in children has its own challenges because sedation is often required for the more lengthy study times and need for the child to be still to get adequate images.

Based on these challenges, further work must be carefully considered. Recently, with emerging awareness of the significance of the problem in of TBI in our soldiers, athletes and children, there has been some much appreciated and necessary funding for traumatic brain injury research. Historically, this funding has not been proportional to the incidence of this public health problem, particularly given the large number of children affected by TBI, with effects that may last a lifetime. Continued research is needed to understand the differences in pediatric pathophysiology and responses to treatment so that clinicians can better tailor treatments to children of different ages. Injuries at both the milder and more severe ends of the spectrum continue to be important targets for pediatric traumatic brain injury research.

VII. ADVOCACY/POLICY

Neurosurgeons are committed to improving public education — including for legislators and community leaders — as to the unique issues in pediatric neurotrauma at local, state and national levels. Considering the magnitude of this public health problem for the children in our nation, many opportunities to improve care exist, including:

- Improved funding for injury prevention and injury prevention initiatives;
- Improved funding for pediatric neurotrauma and neurocritical care patient management;
- Improved funding for research for acute diagnosis and management, rehabilitation and chronic care; and
- Ongoing evaluation and refinement of trauma care systems which may require legislation for developing and facilitating pediatric neurotrauma networks of care, triage, and transport.

Neurosurgery has been a leader in attempting to address the gaps in the above initiatives including injury prevention through the development of programs such as the ThinkFirst National Injury Prevention Foundation.[18] ThinkFirst, which was developed by neurosurgeons,[19] has brought

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[16] Ferguson, N.M., Shein, S.L., Kochanek, P.M., Luther, J., Wisniewski, S.R., Clark, R.S.B., Tyler-Kabara, E.C., Adelson, P.D., and Bell, M.J., *Intracranial Hypertension and Cerebral Hypoperfusion in Children With Severe Traumatic Brain Injury: Thresholds and Burden in Accidental and Abusive Insults.* Pediatric Critical Care Medicine, 2016. 17(5): p. 444-450.

[17] Yuh, E.L., Mukherjee, P., Lingsma, H.F., Yue, J.K., Ferguson, A.R., Gordon, W.A., Valadka, A.B., Schnyer, D.M., Okonkwo, D.O., Maas, A.I.R., and Manley, G.T., *Magnetic resonance imaging improves 3-month outcome prediction in mild traumatic brain injury.* Annals of Neurology, 2013. 73(2): p. 224-235.; Cohen, A.R., Caruso, P., Duhaime, A.-C., and Klig, J.E., *Feasibility of "rapid" magnetic resonance imaging in pediatric acute head injury.* American Journal of Emergency Medicine, 2015. 33(7): p. 887-890.

[18] For more information about ThinkFirst, go to http://thinkfirst.org/.

community-based injury prevention education and age-appropriate curricula to a broad spectrum of children from elementary school through high school.[20] This successful program has continued to grow and operates in all 50 states and other countries around the world. Many neurosurgical training programs in the U.S. support local chapters of ThinkFirst to bring injury prevention education. Additionally, neurosurgery was a leader in the development of the pediatric traumatic brain injury guidelines for the treatment of infants, children and adolescents leading to improved neurotrauma and pediatric neurocritical care for injured children.[21]

VIII. CONCLUSION

Trauma is the most common cause of death in the U.S. pediatric population, with brain injuries being the most common specific cause of death and disability. Caring for these injured children is incredibly complex and requires specialized knowledge and access to specialty physicians. There are many challenges to be faced and opportunities for improvement — including ensuring adequate and appropriate pre-hospital care for all infants and children, access to specialty physicians and pediatric trauma centers, continued medical education and training for providers at all levels, funding for research for traumatic injuries, implementation of epidemiologically targeted prevention programs, and evolutions in systems of care. Our nation's children deserve more, and America's neurosurgeons stand ready to help make these vital improvements.

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[19] The ThinkFirst National Injury Prevention Foundation was first implemented nationally in 1986 as the National Head and Spinal Cord Injury Prevention Program under the direction of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS).

[20] The ThinkFirst National Injury Prevention Foundation's educational programs are aimed at helping people — especially those at high risk: children, teens and young adults — learn to reduce their risk for injury. Compelling presentations explain how an injury can change a person's life forever and how important it is to make safe choices. The message is simple: Use your mind to protect your body! Drive safely, buckle up, wear protective sports gear, avoid violence, don't dive into shallow water and avoid falls. Think first!

[21] Adelson, et al., *Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents.* Pediatr Crit Care Medicine, 2003. 3(4): p. S1-S75.

Appendix

EMERGENCY MEDICAL SERVICES FOR CHILDREN (EMSC)

The mission of the Emergency Medical Services for Children (EMSC) program is to reduce child and youth mortality and morbidity caused by severe illness or trauma. EMS for Children aims to ensure that:

- State of the art emergency medical care is available for the ill and injured child or adolescent;
- Pediatric service is well integrated into an emergency medical service system backed by optimal resources; and
- The entire spectrum of emergency services, including primary prevention of illness and injury, acute care and rehabilitation, is provided to children and adolescents as well as adults, no matter where they live, attend school or travel.

This program funds and supports pediatric emergency care improvement initiatives and projects in every U.S. State, Territory and the Freely Associated States (republics of Palau and Marshall Islands and the Federated States of Micronesia).

EMSC also supports:

- National Resource Center at Children's National Medical Center, which maintains the program's professional partnerships, disseminates information and supports a special collaboration with the Family Advisory Network (FAN).
- National EMS for Children Data Analysis Resource Center (NEDARC), which assists grantees in data collection, analysis and dissemination.

GRANT PROGRAMS

State Partnership Grants

State Partnership (SP) Grants: In response to the Institute of Medicine's (IOM) Report "Growing Pains," and in partnership with EMS professionals from across the country, the federal EMSC Program implemented baseline performance measures to address the gaps in health care identified in the IOM Report. Based on ongoing assessments conducted by the EMSC State Partnership grantees, the EMSC Program has been able to complete the only national assessment of pediatric pre-hospital emergency care in the nation. EMSC performance measure data has been collected from thousands of EMS agencies and hospital's to assess:

- Access to medical direction for EMS providers treating and transporting pediatric patients
- Appropriate pediatric equipment and supplies on ambulances to treat children; and
- Availability of inter-facility transfer agreements and guidelines (processes) designed to expedite the transfer of pediatric patients to the most appropriate facility.

Additionally, Program Partners in the states and territories focus efforts to ensure that:

- Prehospital providers receive education and training that is necessary to maintain competencies in pediatric patients;
- EMS Providers are trained to transport and transfer children to the most appropriate medical facility that has been officially recognized to be equipped and prepared to treat and stabilize pediatric patients during medical emergencies and traumatic incidents;

- Mandates are in place to ensure:
  - Pediatric medical direction is available 24/7;
  - EMS providers receive pediatric education continuously;
  - Ambulances are equipped with pediatric equipment and supplies; and
  - Hospitals with emergency departments are ready to treat and stabilize pediatric patients and they have agreements and guidelines to expedite the safe and efficient transport and transfer of children to the right care.

Targeted Issue Grants

Targeted Issue (TI) Grants are awarded to eligible applicants to help address issues of national significance that extend beyond State boundaries. Typically, these grants result in new products or resources, or show the feasibility of new methods, policies, or practices. Examples of products and resources developed:

- A national educational curriculum teaching EMT's and paramedics how to treat pediatric emergencies. The Program, called Pediatric Education for Prehospital Providers (PEPP), was originally developed with a TI grant and is now regularly updated and promoted through the American Academy of Pediatrics.
- Performance measures defining quality metrics for treating children in the emergency department.
- A pain management curriculum in the prehospital setting.
- Training curriculum teaching emergency care providers how to care for children with special health care needs.
- Training curriculum for school nurses to prepare for emergencies.
- Facial recognition software that can be used by hospitals to reunify parents and children during a disaster.

Studies conducted by TI grantees have resulted in new knowledge regarding:

- How to manage respiratory arrest in children in the prehospital setting.
- How to manage cervical spine injuries in children in the prehospital setting.
- Genetic markers for fever in children.
- Injury prevention strategies in children.

Current studies include:

- Increasing the comfort, knowledge, skills and competency of prehospital providers;
- Evaluating whether the prehospital administration of oral steroids by paramedics to pediatric patients with moderate to severe asthma reduces the time spent in the ED and the need for hospitalization;
- Developing a systems approach to dealing with the loss of life for both prehospital providers and families;
- Using a novel pediatric community paramedicine program to address gaps in managing pediatric asthma care;
- Developing pediatric evidence-based guidelines; and
- Developing an EMS Research Node to work in cooperation with the Pediatric Emergency Care Applied Research Network,

TRAUMA CENTER LEVELS[22]

Trauma categories vary from state to state. Outlined below are common criteria for Trauma Centers verified by the American College of Surgeons (ACS) and also designated by states and municipalities. Facilities are designated/verified as adult and/or pediatric trauma centers. It is not uncommon for facilities to have different designations for each group (i.e. a trauma center may be a Level I adult facility and also a Level II pediatric Facility).

Level I

A Level I trauma center is a comprehensive regional resource that is a tertiary care facility central to the trauma system. A Level I trauma center is capable of providing total care for every aspect of injury — from prevention through rehabilitation. Elements of Level I trauma centers Include:

- 24-hour in-house coverage by general surgeons, and prompt availability of care in specialties such as orthopedic surgery, neurosurgery, anesthesiology, emergency medicine, radiology, internal medicine, plastic surgery, oral and maxillofacial, pediatric and critical care.
- Referral resource for communities in nearby regions.
- Provides leadership in prevention, public education to surrounding communities.
- Provides continuing education of the trauma team members.
- Incorporates a comprehensive quality assessment program.
- Operates an organized teaching and research effort to help direct new innovations in trauma care.
- Program for substance abuse screening and patient intervention.
- Meets minimum requirement for annual volume of severely injured patients.

Level II

A Level II trauma center is able to initiate definitive care for all injured patients. Elements of Level II trauma centers Include:

- 24-hour immediate coverage by general surgeons, as well as coverage by the specialties of orthopedic surgery, neurosurgery, anesthesiology, emergency medicine, radiology and critical care.
- Tertiary care needs such as cardiac surgery, hemodialysis and microvascular surgery may be referred to a Level I trauma center.
- Provides trauma prevention and continuing education programs for staff.
- Incorporates a comprehensive quality assessment program.

Level III

A Level III trauma center has demonstrated an ability to provide prompt assessment, resuscitation, surgery, intensive care and stabilization of injured patients and emergency operations. Elements of Level III trauma centers Include:

- 24-hour immediate coverage by emergency medicine physicians and the prompt availability of general surgeons and anesthesiologists.
- Incorporates a comprehensive quality assessment program.
- Has developed transfer agreements for patients requiring more comprehensive care at a Level I or Level II trauma center.

[22] Source: American Trauma Society (available at http://bit.ly/1VeFB8c, last accessed on May 21, 2016).

- Provides back-up care for rural and community hospitals.
- Offers continued education of the nursing and allied health personnel or the trauma team.
- Involved with prevention efforts and must have an active outreach program for its referring communities.

Level IV

A Level IV trauma center has demonstrated an ability to provide advanced trauma life support (ATLS) prior to transfer of patients to a higher level trauma center. It provides evaluation, stabilization, and diagnostic capabilities for injured patients. Elements of Level IV trauma centers Include:

- Basic emergency department facilities to implement ATLS protocols and 24-hour laboratory coverage. Available trauma nurse(s) and physicians available upon patient arrival.
- May provide surgery and critical-care services if available.
- Has developed transfer agreements for patients requiring more comprehensive care at a Level I or Level II trauma center.
- Incorporates a comprehensive quality assessment program.
- Involved with prevention efforts and must have an active outreach program for its referring communities.

Level V

A Level V trauma center provides initial evaluation, stabilization and diagnostic capabilities and prepares patients for transfer to higher levels of care. Elements of Level V trauma centers Include:

- Basic emergency department facilities to implement ATLS protocols.
- Available trauma nurse(s) and physicians available upon patient arrival.
- After-hours activation protocols if facility is not open 24-hours a day.
- May provide surgery and critical-care services if available.
- Has developed transfer agreements for patients requiring more comprehensive care at a Level I though III trauma centers.