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THE SYSTEM OF CARE FOR INJURED CHILDREN IN THE STATE OF COLORADO AND THE ROCKY MOUNTAIN REGION OF THE WESTERN UNITED STATES

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Abstract

This article describes the different levels of trauma center designation in the United States and focuses on the pediatric trauma centers in the state of Colorado. These urban centers serve a large geographic area that is characterized by rugged mountains, wide open plains and rapidly changing weather patterns. Critical care ground and aeromedical

transport are utilized for severely injured children and the quality of care, from initial management in the field until discharge from the hospital, is critically evaluated by a robust trauma performance improvement (PI) program. The PI program uses audit filters, data analytics and bench-marking to continuously evaluate the network of care to optimize outcomes.

Keywords: *injuries, organization of medical care, trauma centers, children*

Overview

Pediatric trauma is the leading cause of childhood morbidity and mortality in the United States. Each year about 9 million children are treated for an injury, 600,000 are hospitalized, and approximately 12,000 die [1]. Approximately 100,000 of those who survive their injuries are permanently disabled. These disabilities may limit their ability to perform age-appropriate everyday activities and reduce their lifetime potential. Most children in the United States who sustain a traumatic injury are initially evaluated in a hospital emergency department, however, many emergency departments across the country do not qualify as trauma centers because they do not have the resources to treat severely injured patients. Those patients who are

deemed to have severe physical injuries may bypass a local emergency department and be transported directly to a trauma center, or they may be transferred by the treating emergency department to a trauma center.

Levels of Care

Trauma centers in the United States are designated at one of five levels, each level corresponding to the types and breadth of resources available and the number of patients admitted per year (Table 1). Trauma center designation is generally a state responsibility that is overseen by the state's department of public health or emergency medical services. Although the criteria used to designate a trauma center's level can vary from state to state, most states have adopted guidelines that closely parallel

Table. General Criteria for Trauma Centers in the United States

Level I	Capable of providing total care for every aspect of injury – from prevention to rehabilitation. Has 24-hour in-house coverage by general surgeons with prompt availability of specialty care (e.g. neurosurgery, plastic surgery). Provides local and regional leadership and has organized teaching and research efforts. The trauma center meets the minimum annual volume criteria of severely injured patients (Injury Severity Score > 15).
Level II	Meets the same clinical care requirements as a level I center, including immediate coverage (< 15-minute response time) by general surgeons with prompt availability of neurosurgery, orthopedic surgery, etc. A level II trauma center is able to initiate care for all injured patients, but patients with tertiary care needs (e.g. cardiac surgery, hemodialysis or microvascular surgery) may need to be referred to a level I trauma center. Does not have the leadership, teaching or research requirements of a level I.
Level III	Provides prompt assessment, resuscitation and stabilization of injured patients, including surgery and intensive care. Has transfer agreements in place for patients who need more complex care at a level I or II trauma center. Provides 24-hour immediate coverage by emergency medicine physicians with prompt availability of general surgeons.
Level IV	Provides advanced trauma life support prior to transferring patients to a higher level trauma center, including evaluation and stabilization. Has a 24-hour emergency department, laboratory coverage and diagnostic capabilities.
Level V	Provides initial stabilization and diagnostic capabilities and transfers patients to higher level trauma centers. Has basic emergency department with trauma nurse and/or physician available upon patient arrival. After hours protocols are in place if the facility is not open 24-hours/day.

those developed by the American College of Surgeons Committee on Trauma (ACS-COT; <https://www.facs.org/quality-programs/trauma>) [2]. In addition to publishing and periodically updating these guidelines, the ACS-COT has a well-established program to verify the presence of the necessary resources that are required at adult and pediatric trauma centers. These include commitment, readiness, resources, policies and a performance improvement program. The ACS-COT verification program verifies level I and II pediatric trauma centers and level I, II and III adult trauma centers. Thus, a trauma center can be both a “verified” (by the ACS) and “designated” (by the state) trauma center. A facility that cares for both adult and pediatric trauma patients can have separate verification and designation levels. So, for example, a trauma center that cares for adults and children may be designated as an adult level I and pediatric level II trauma center. At this time, in 2018, there are 533 ACS verified trauma centers in the United States, of which 57 are level I pediatric trauma centers (PTCs), seven are level II PTCs, and 46 are level I or II adult trauma centers with a level II PTC.

Pediatric trauma centers are facilities with the specialized resources, including pediatric sub-specialists and appropriate equipment, needed to care for children with severe physical injuries. According to ACS-COT guidelines, ACS verified pediatric trauma centers must meet the same requirements as ACS verified adult trauma centers, but in addition:

- A level I pediatric trauma center must have at least two surgeons who are board certified in pediatric surgery and must annually admit 200 or more injured children < 15 years old;
- A level II pediatric trauma center must have at least one board certified pediatric surgeon and must admit 100 or more injured children < 15 years old.

Pediatric trauma centers are expected to provide trauma care for the most severely injured children and play a leadership role in education, research, and planning with other trauma centers and non-trauma center hospitals in their state and/or geographic region.

Trauma centers limit injury related morbidity and mortality relative to non-trauma centers that treat severely injured patients [3,4]. Among pediatric trauma patients, age-appropriate treatment, equipment and pediatric intensive care unit (PICU) availability are associated with improved outcomes [5]. Densmore et al [6] showed that children cared for at pediatric trauma centers (PTCs) have a lower mortality rate (4.9%) than those cared for at adult trauma centers (7.4%) or children’s units within adult trauma centers (9.1%). These findings hold true when controlling for Injury Severity Score. Notrica et al [7] examined the relationship between ACS-verified pediatric trauma centers and pediatric mortality using a population-based analysis of state mortality rates. They found that states with ACS verified PTCs had lower population-based statewide pediatric injury mortality rates than those of states with

no ACS-verified trauma centers. Other studies looking at actual survival rates or functional outcomes have similarly demonstrated the advantages of PTCs [8, 9, 10, 11].

The ACS-COT recommends – and most states have developed – transfer criteria to promote the transfer of severely injured children to pediatric trauma centers. Unfortunately, due to the limited number and geographic distribution of pediatric trauma centers, severely injured children may initially be managed at a non-trauma center or an adult trauma center, where specialized pediatric resources are not available. A recent analysis of data from the American Trauma Society and the U.S. Census Bureau's American Community Survey found that 57 percent, or 41.9 million, of the estimated 73.7 million children in the United States lived within 30 miles of a high-level pediatric trauma center during the period 2011–2015 [12]. In areas without high-level pediatric trauma centers, injured children may be initially evaluated or definitively managed at a high- or mid-level adult trauma center. In this case, 88 percent, or 65.1 million children in the US live within 30 miles of a pediatric or adult trauma center.

Most state-wide and regional trauma systems in the United States have self-evolved over time and not been designed from the beginning. Moreover, few designating authorities have processes in place to guide system-wide planning and development [13, 14]. Instead, economic incentives are driving the proliferation of trauma centers and the duplication of services in many urban areas across the United States. Between 2009 and 2012, more than 200 new adult and pediatric trauma centers opened in the United States¹. This trend has led to concerns about dilution of case volume and experience, reductions in research and training opportunities, and greater system-wide costs² [13,15]. Growing recognition of these issues has stimulated interest in the creation of trauma networks in accordance with need [13, 16]. Given the benefits of caring for severe-

ly injured children in verified pediatric trauma centers, and the growing pediatric population in our state and region, we are developing a pediatric trauma network to serve the needs of severely injured children in our region of the Western United States.

Pediatric Trauma and Burn Care in Colorado and the Rocky Mountain Region of the Western US

Colorado is located in the Rocky Mountain region of the Western United States. It is notable for its diverse geography, four distinct seasons, dry climate and more than 300 days of sunshine per year. The beautiful outdoor surroundings and the generally mild climate promote year-round outdoor activities, ranging from skiing and snowboarding, to hiking and biking, camping and rock climbing. These activities expose outdoor enthusiasts to rugged and sometimes austere mountain environments, where communication is spotty and the nearest trauma center is hours away. As a result, the initial care of injured adults and children in our region of the US is provided by local pre-hospital providers, who are experienced in the initial stabilization and management of individuals with major injuries. They are supported by an efficient and established network of ground and aeromedical transport teams that work with local trauma centers, to determine which injured patients can be cared for locally and which should be transferred to a higher level of care.

The pediatric trauma network that we are developing is composed of one level I pediatric trauma center, two level II pediatric trauma centers, and a host of level I, II and III adult trauma centers that are comfortable in the initial and oftentimes definitive management of injured children. The principal resource for the region is Children's Hospital Colorado (<https://www.childrenscolorado.org/>), which is the only ACS verified, level I pediatric trauma center in Colorado and the seven state Rocky Mountain region. As such, Children's has rightly assumed a leadership role in organizing and providing all aspects of pediatric trauma care, from prevention, through injury management, rehabilitation, pediatric trauma research and outreach education. Denver Health Medical Center, which is an ACS verified adult level I trauma center in downtown Denver, is also a level II pediatric trauma center (<https://www.denverhealth.org/services/trauma>). Denver Health primarily cares for injured children and adolescents from the inner-city of Denver. Children's Hospital Colorado is building a new children's hospital and plans to open

¹ 1 Boom In Trauma Centers Can Help Save Lives, But At What Price? Kaiser Health News in Collaboration with USA Today. 2016. Available at: <http://khn.org/news/trauma-centers/>. Accessed October 14, 2018

² Moore EE. Change at Level I trauma centers in Colorado would impact patients. The Denver Post. 2013. <http://blogs.denverpost.com/opinion/2013/08/16/trauma-patients-in-colorado-could-lose-high-quality-medical-care/41265/> Accessed October 23, 2018

a level II pediatric trauma center in Colorado Springs, Colorado in mid-2019. This new location, which is about 150 kilometers south of the main Children's Hospital, will serve the southern part of Colorado, western Kansas and Northern New Mexico. The individuals who oversee the trauma programs at these three pediatric trauma centers are actively engaged in all aspects of the trauma system in Colorado, including planning, implementation and evaluation. These same individuals contribute administrative leadership, medical leadership and academic leadership at the state, regional and national levels, to ensure that the network of care is responsive to the needs of injured children across the region.

Children's Hospital Colorado is a 400-bed free standing, academic, not-for-profit children's hospital located on the Anschutz Medical Campus in the city of Aurora, Colorado. It is adjacent to and affiliated with the University of Colorado School of Medicine. The Children's Hospital emergency department and its affiliated sites logged more than 73,000 ED visits in 2017, of which more than 17,500 were for an injury. In 2017, there were 1,641 trauma and burn patients who met trauma registry inclusion criteria. The Trauma and Burn Center is supported by a 24/7 transfer center, which facilitates on-line communication between pre-hospital providers, emergency medicine physicians and our trauma surgeons, as well as our sub-specialty surgeons and intensive care unit physicians. Children's Hospital manages its own critical care transport program, which is composed of three 24/7 dedicated flight teams, consisting of flight nurses (RNs), respiratory therapists (RTs) and emergency medical technicians (EMTs). These highly trained clinicians travel to the scene of an injury or an outside hospital via ground ambulance, an Airbus H-130 helicopter with a 250 kilometer range, or for long distance transports across state lines a turbo prop airplane or Lear jet, provided by an affiliated flight program (<https://reachair.com/>). In 2017 our transport program transported more than 5,000 children of all ages to Children's Hospital Colorado. Of those who were injured and transported, 55% were transported by ground ambulance, 35% by private vehicle and 10% by helicopter or fixed wing aircraft. The mechanisms of injury for these patients were blunt (85%), penetrating (7.5%) and thermal (7.5%).

The level I pediatric trauma center at Children's Hospital Colorado is staffed by a core group of pediatric trauma and acute care surgery (TACS) surgeons,

who take in-house call 24/7, to immediately respond to our patients' needs. The TACS service is separate from the pediatric surgery service and primarily managed by a core group of five pediatric surgeons and six mid-level providers (nurse practitioners and physician assistants), who work collaboratively with the on-call TACS surgeon. We are supported by 15 pediatric orthopedic surgeons and a host of sub-specialty surgeons, including five pediatric neurosurgeons and three pediatric cardiac surgeons. The physicians at Children's Hospital Colorado are on the faculty of the University of Colorado School of Medicine. We teach medical students, residents and fellows and all of us have some degree of research interest. As a level I pediatric trauma center, we strive to provide timely and informative outreach education to pre-hospital providers, nurses, mid-level providers and physicians from our local and regional referral areas, and at national and international forums.

The pediatric burn center at Children's Hospital Colorado is staffed by one pediatric burn surgeon, five burn nurses and all the necessary ancillary pediatric services, including nutritionists, child life specialists, social workers, occupational therapists and physical therapists. The Juvenile Fire Setting Evaluation and Treatment Program is staffed by a pediatric psychologist, who assesses fire setting behaviors and helps youth make safer decisions. The Burn Camps Program is a therapeutic medical specialty camp for pediatric burn survivors and their families. The program supports four camper programs per year, the biggest of which is summer camp, which draws approximately 80 burn-injured children from across the country, the United Kingdom and Russia. The Camps Program employs confidence building tools and assists burn survivors in social and emotional skill development, while challenging negative and limiting beliefs (<https://www.noordinarycamps.org>). The Burn Camps Program is supported by several philanthropic groups, including the Colorado Firefighter Calendar (<http://cofirefightercalendar.org/>).

Trauma Performance Improvement

It is impractical and financially unrealistic to expect all injured children to be cared for at level I and II pediatric trauma centers. Rather, the processes and practices that lead to improved outcomes at these centers should be identified and disseminated to trauma centers that provide initial and oftentimes definitive care for injured children in their local area. This work is being spearheaded in the United States at the national level by the

ACS Trauma Quality Improvement Program (TQIP; <https://www.facs.org/quality-programs/trauma/tqip>), which utilizes the infrastructure of the ACS National Trauma Data Bank (NTDB) to collect valid and reliable data from trauma registries. This data is risk adjusted and shared with participating trauma centers to identify institutional characteristics that are associated with improved outcomes. The ACS Pediatric TQIP program provides similar, risk-adjusted data for benchmarking at pediatric trauma centers and adult centers that treat children, to track outcomes and improve patient care. We use this information to improve the care we provide at our institution and bring these findings and resulting protocols to our referring providers and organizations at the regional and local levels. For example, the proliferation of CT scanners at large and small hospitals across our region has led to an increasing number of indiscriminate “pan-scans” of injured children, whereby an injured child may be CT scanned from literally “head to toe”. To reduce the number of “pan-scans” we created a poster composed of evidence-based imaging algorithms for children [17].

The Children’s Hospital Colorado Trauma and Burn Programs strive to provide the best care possible, to achieve optimal outcomes. To that end, we use a formal, stepwise, internal performance improvement process for problem identification, followed by data-driven analysis to resolve issues within the quality framework of the institution. Too often the problems that arise in organizations are addressed in superficial ways – someone works around a problem to accomplish an immediate objective, and does not address the root cause of the problem to prevent its recurrence. By not addressing the root cause, the same problem or same type of problem recurs again and again, and operational performance does not improve. The Trauma Performance Improvement and Patient Safety (PIPS) Program at Children’s Hospital Colorado is different. It utilizes primary, secondary, tertiary and quaternary levels of review to: 1) determine if there is an opportunity for trauma performance improvement; 2) analyze the opportunity; 3) develop a corrective plan, and 4) monitor the outcome(s) of the corrective plan to determine if improvement was realized. This process is a cycle, since the first solution may only partially solve the problem. The initial solution may need to be modified or totally changed. This cycle, or loop, continues until a reasonable result has been achieved. The loop is closed once the best possible resolution of the initial problem

is achieved and documented. This process is overseen by the PI Committee and reported at the monthly Multi-disciplinary Trauma Committee meeting (MTC).

Levels of Review

The trauma PI process begins with the collection of qualitative and quantitative information at both the patient level and the systems level. Trauma registrars abstract data from each trauma and burn patient’s electronic medical record and input this data into the trauma registry (TraumaBase, Clinical Data Management). The initial review process examines the appropriateness of care, effectiveness of care, and queries the quality of care and responsiveness of the system to identify opportunities for improvement. Audit filters are used to screen charts for quality issues, such as surgical attending ED response time > 15 minutes, ED time > 1 hour, time from ED to OR > 2 hours, massive transfusion protocol activation (all MTPs are audited), or antibiotics > 1 hour for open fractures. Patient events that trigger an audit filter are initially reviewed by the Trauma Nurse Coordinator (TNC) and the Trauma Program Manager (TPM), either of whom may be able to resolve the issue(s) and close the case with little to no intervention. When the problem is more complex it is brought to the second level of review, which involves review by the Trauma Medical Director (TMD) and/or the Performance Improvement Medical Director (PIMD). If the case cannot be closed at the second level of review it is brought to the Multi-disciplinary Trauma Committee (MTC), which meets monthly to systematically review mortalities, significant complications and process variances associated with unanticipated outcomes to determine opportunities for improvement. The MTC is composed of all 11 pediatric surgeons who serve on the trauma call panel, a liaison from each of the sub-specialty surgical services, and liaisons from the following services: anesthesia, ED, PICU, rehabilitation, blood bank, ED nursing, PICU nursing, child protection team, etc. Based on the review process at MTC the appropriateness and timeliness of care are judged and opportunities for improvement are outlined. The escalated levels of review are detailed below.

I. First Level (primary) Review: The TNC or TPM reviews all identified cases or issues collected from the previous 1–2 weeks. Some cases or referrals may be closed at this level of review. If a valid concern related to trauma care is identified, the case will move to the next level of review.

- II. Second Level (secondary) Review: This level of review is completed by the TMD and/or PIMD. After discussion, a second level review case may be closed, result in the development of an action plan, or be referred to Multi-disciplinary Trauma Committee (MTC), Trauma Performance Improvement (PI) committee meeting, or Pediatric Surgery M&M for further evaluation and discussion.
- III. Third Level (tertiary) Review: This level of review is completed by the Multi-disciplinary Trauma Committee (MTC). Cases are prepared in advance, identifying all pertinent background information, protocols followed or not followed, along with a summary of specific issues of concern. Slides are prepared by the TPM and reviewed by the TMD ahead of the meeting. The case is formally presented and reviewed by the MTC members. Opportunities for improvement are identified and appropriate action plans are developed. Cases with identified emergency medical services (EMS) issues are referred to the EMS Medical Director. Referring hospital care concerns are referred to that hospital's ED Medical Director, ED Manager, Trauma Program Manager or TMD.
- IV. Fourth Level Review: The fourth level of review is reserved for those cases that need to be channeled through the Clinical Quality & Medical Staff Services Department of the hospital, and/or Multi-specialty Peer Review Committee, or may need to be sent outside of the facility for external review.

Determination of Cause

The cause of an issue is assigned to one of four categories: provider-related, disease-related, system-related, external-related or any combination of all four. All contributing factors are investigated and tracked when a case is reviewed and all adverse outcomes are further categorized as:

- Provider related issue: issue related to omission or commission by a provider
 - Skill based: failure to execute stored task instructions (e.g. technique or surgical priorities)
 - Rule Based: protocol compliance, regulatory compliance, credentialing compliance
 - Knowledge based: failure due to insufficient knowledge
 - Chain of command or failure to notify supervisor
 - Behavior

- Disease related issue: expected sequela of disease or injury. These are treatment failures due to patient characteristics that are beyond the control of a provider. This category includes patient non-compliance and refusal of treatment.
- System related issue: not specifically related to provider or disease. Rather, the issue is related to equipment malfunction or a facilities issue (e.g. design, construction, malfunction, obsolescence, availability). This category can be further broken down into management issues (staffing, training, budget), organizational culture (chain of command, delegation of authority, communication channels), faulty protocols and/or processes (time pressures, schedules, standards, documentation, oversight), or lack of knowledge transfer (supervision, training).
- External issue: these are failures beyond the control of the organization (e.g. care prior to arrival)

Injury Prevention

ACS verified adult and pediatric trauma centers must work collaboratively with local community leaders to promote and prioritize injury prevention efforts. These efforts have been largely dictated by available resources and unevenly distributed, because of difficulty identifying populations and locations of greatest need. We recently leveraged trauma registry and epidemiologic data to map pediatric injuries by geographic location, to identify areas that might benefit from more injury prevention efforts and resources [18]. This was done by systematically examining all children treated for traumatic injuries at Children's Hospital Colorado (level I PTC) and Denver Health Medical Center (level II PTC) and mapping these injuries by zip (postal) code of residence. Univariate and multivariate linear models were then used to identify demographic predictors of various pediatric injuries in specific zip codes, so called "hot spots". Higher rates of pediatric traumatic injuries were associated with zip codes that had larger Hispanic populations, fewer owner occupied homes (more rented homes and apartments), and more married couples with children. We have used these data to identify communities in need of more injury prevention education and resources.

A determination of proximate cause should play a role in injury prevention efforts. Adolescent alcohol and/or drug abuse may be important contributing factors to an injury. Screening for alcohol and/or drug abuse is

therefore mandatory at all ACS verified trauma centers, and when a patient screens positive a social worker is assigned to provide counseling and resources [19, 20].

Summary

The social, emotional and financial costs associated with managing a severely injured child are not trivial.

It is therefore incumbent upon us, as pediatric surgeons who care for injured children, to continually assess and strive to improve the quality of care we provide. To do so we must critically evaluate our processes of care and leverage bench-marking data, to determine best practices and disseminate these findings regionally, nationally and internationally.

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