Initial assessment and transportation of an injured child
Claudio Schvartsman,1 Renato Carrera,2 Sulim Abramovici3

Abstract

Objectives: Since trauma has a great impact on mortality and preventable morbidity among children and adolescents, in addition to its social consequences, the aim of this study is to evaluate peculiarities regarding prehospital, in-hospital, and interhospital assessment of injured pediatric patients.

Sources of data: The Cochrane database was searched for systematic reviews and controlled trials, the MEDLINE and LILACS databases were used for the last 5 years, and review of older reference sections in significant publications using trauma, pediatric trauma, primary survey, secondary survey, in-hospital assessment, prehospital and transportation as keywords.

Summary of the findings: There are different strategies that constitute the systematic assessment of the injured pediatric patient. Nevertheless, almost all strategies involve knowing the peculiarities about the pediatric population, with regard to age, to the growth and development process, and finally, to the minimally acceptable and available resources.

Conclusions: The most important principle is to do no further harm. If the peculiarities about airway maintenance, ventilation, circulation with hemorrhage control, disability, exposure up to secondary survey and preparation of prehospital and interhospital transportation are properly taken care of, better results will certainly be obtained.


Introduction

Traumatic injuries have been described since the advent of medical literature. Their importance as a public health problem has been restated quite recently.1 Although it had been considered the neglected disease of modern society,2 trauma has become an important issue in several countries due to its morbidity and mortality, affecting all individuals regardless of age, gender, ethnics, creed, or social background.

In North America, trauma is considered the major cause of death among children and adolescents.3-5 This cause of mortality is also observed in other countries of the American continent5 and in developing countries.7

In addition to the high rates of mortality, it causes remarkable morbidity, producing increasing economic damage on a worldwide basis.6,8

Every year, one in every five U.S. children is treated for traumatic events. Traumatic injuries constitute the major group of diseases that requires medical care, being accountable for over 20% of hospital admissions and days spent in a hospital.9
In our setting, "External Causes" play a crucial role in mortality of children aged between 1 and 14 years, and determine representative morbidity, with a significant number of admissions/year and considerable hospital costs.\textsuperscript{10}

Treatment of traumatized children starts at the scene of injury with the arrival of the prehospital care team, their evaluation and approach, followed by the transport to an appropriate hospital unit, preferably the one closest to the scene.\textsuperscript{11}

At hospital, primary care is provided in the emergency department, which includes establishing rapid physiological balance, consisting of the identification and treatment of injuries that jeopardize the child’s life (primary survey), and of the identification of other injuries (secondary survey), guidance for definitive treatment (definitive care). During re-establishment, rehabilitation concludes the treatment of traumatized children.

Improved resources of hospital emergency services and pediatric intensive care units have had an extremely positive impact on the rates of morbidity and mortality of a wide variety of severe clinical conditions, including trauma. Resources are not available in all hospital units, due to the complexity and high costs of their development and maintenance, thus requiring a regional and hierarchical system for severely ill children. A system with these characteristics implies the transfer of patients from poorly equipped health units or from an extrahospital environment to better-resourced hospitals. An adequate system for pediatric transport is of paramount importance to medical care and may decisively influence the prognosis.\textsuperscript{12}

Due to the importance of trauma and its social consequences for children, adolescents, and their families, our objectives are centered around the peculiarities of the assessment and transport of traumatized patients.

\textbf{Trauma care system}

Transport is certainly an integral part of an organized trauma care system. Transport takes place in at least one moment of the chain of events: from the scene to the hospital, a responsibility of prehospital care. When it is necessary to transfer a patient from the original hospital unit to another one with better resources (human, material), interhospital transport is considered.

In the last 20 years, papers on trauma care systems, including (initially) exclusive systems and, more recently, also inclusive systems, published by different authors, support the hypothesis that trauma-related mortality is reduced with the implementation of a trauma care system. The same applies to morbidity-generating phenomena.\textsuperscript{13-16}

\textbf{Initial assessment and management}

The American College of Surgeons’ Committee on Trauma\textsuperscript{17} considers the assessment of traumatized patients on hospital admission, categorizing care as follows: Primary survey, resuscitation, adjuncts to the primary survey, reassessment, secondary survey and adjuncts to the secondary survey, new reassessment and, finally, definitive treatment. Initial primary survey and simultaneous resuscitation in traumatized children are not different from those carried out in adult traumatized patients. However, physiological and anatomical particularities of the children must be considered by all health professionals in emergency trauma services.

Children have less body mass, smaller amount of elastic connective tissue and less fat, resulting in a greater energy transfer, which combined with a more compact organ structure (organs closer to one another), predisposes to multisystem injuries of greater severity.

The younger the children, the less calcified their skeletal structure and the higher the compliance of their bone structure. This means a higher frequency of injuries to intracavitary organs without associated bone injury.

The younger the children, the greater the body surface/volume ratio. This ratio decreases with growth. Therefore, children are more prone to develop hypothermia even under favorable climatic conditions.

In the presence of stressful situations, or in case of an aggressive event, children respond with a pattern of general behavioral regression. Hostile environment, unknown people, and attitudes regarded as aggressive increase the difficulty in interacting with those people around them.\textsuperscript{17}

The effects from traumatic events on children may produce physical and psychological consequences. Residual personality disorders, cognitive sequelae, and posttraumatic stress syndrome are often manifested by the victim and family members.\textsuperscript{18}

It is worth recalling that children have to recover from the traumatic event and to maintain their growth and development as well. Physical and psychological effects should not be overlooked in this context.

\textbf{Primary survey}

Primary survey begins with the examination of the airways of the traumatized child to detect partial or total obstruction, determined by secretions, debris, or even by the loss of support to the base of the tongue. Airway patency is crucial for maintaining airflow and is therefore a priority in emergency care of traumatized patients. The approach prioritizes airway patency.

Airway maintenance maneuvers or even the establishment of a definitive airway are used. Maintenance maneuvers (chin lift, jaw thrust, use of an oropharyngeal or nasopharyngeal tube) are methods that can be perfectly used in traumatized children. Special attention must be given to the use of the oropharyngeal tube which should be placed using a tongue depressor, since a 180° rotation may injure the soft tissues in the oral cavity, aggravating the risk by causing additional injuries.

The definitive airway for children treated in the emergency room consists of orotracheal intubation.
Nasotracheal intubation is not an easy procedure to be carried out in the emergency room; cricothyroidotomy should only be performed when necessary, preferably by a qualified surgeon who is used to the anatomy of the pediatric trachea. One should underscore that the cricothyroid membrane is the support for the upper segment of the trachea in children, and if this fact is overlooked, it may result in deleterious future consequences.

Jet ventilation, along with percutaneous cricothyroidotomy, is a temporary form of oxygen supply when it is difficult to secure a definitive airway in the pediatric patient. However, it is a procedure that does not allow the clearance of the CO₂ produced, causing hypercapnia.

In cases in which the definitive airway cannot be easily established, rapid sequence intubation has been increasingly used as a routine procedure in pediatric emergency. The use of drugs that produce extremely quick muscle paralysis and sedation of traumatized children allow securing a definitive airway.17,19,20

One should also consider that all airway maneuvers must be performed with the cervical spine in a neutral and aligned position.

Afterwards, as soon as airway patency is obtained, assessment of ventilation is begun, with inspection, auscultation and percussion of chest sounds. Life-threatening injuries are detected at this moment, receiving either palliative or definitive treatment. Hypertensive pneumothorax, open pneumothorax and massive hemothorax are treated as soon as they are identified. Insertion of a chest tube should be performed in the fourth or fifth intercostal space of the affected side, anteriorly to the midaxillary line using an appropriate-sized drain (according to the child’s age and size) by placing it through the space immediately above the incision.

Ventilation is monitored through clinical signs, oxygen saturation and blood gas measurements.

The next step in primary survey concerns the evaluation of circulation and treatment of apparent bleeding. Augustemal injuries and misaligned long bone fractures are the major sources of apparent bleeding, which can be controlled with sterile compressible dressings or alignment of an occasional source of fracture. The next step is to secure vascular access, preferably two peripheral accesses with short and thick catheters, which might not be an easy task. If this type of access is not possible, intraosseal access is a possibility, allowing for adequate infusion. The clinical use of intraosseal access in children is well established, and can even be used for volume expansion in cases of trauma and hemorrhagic shock.1,21-24

The third step is the identification of a possible source of occult bleeding in the abdominal, pelvic and chest cavities. The presence of hemothorax confirms the diagnosis of a source of occult bleeding, which is usually detected on clinical and radiological examination. Usually, if the pelvis is stable, not allowing lateral expansion for the clinical maneuver, the source of local bleeding is probably negligible, but it is significant otherwise. Under this circumstance, a large hematoma may be formed due to the large amount of bleeding.25 The absence of pelvic stability can be confirmed by a plain hip x-ray in the emergency room, one of the complementary exams to the primary survey. Therefore, the abdominal cavity should now be examined for occult bleeding. Obviously, during the primary survey, together with resuscitation, volume expansion through rapid infusion of Ringer lactate solution heated at 39 °C in the dose of 20 ml/kg of estimated body weight, which may be repeated three times, determines a pattern of hemodynamic response that falls within either of the following categories: positive, transient, or negative. Examination of the abdominal cavity for occult bleeding can be done using the Focused Assessment for the Sonographic evaluation of Trauma patients (FAST) or diagnostic peritoneal lavage. The latter method, however, often yields false-positive results. FAST is a simple and harmless method that can be easily performed at bedside, and has been increasingly used in hospitals nowadays.26 An ultrasound scan is performed for detection of free fluids in the abdominal cavity by examining the hepatorenal and splenorenal spaces, cul-de-sac, and pericardium.

In many situations, failure to control hemodynamic stability in the emergency room results in the necessity for a surgical approach for hemostatic control. Damage control surgery involves hemostatic control, leaving the correction of other visceral injuries for a later occasion, after correction of hypothermia, metabolic acidosis and bleeding due to consumption coagulopathy – lethal triad.27

Subsequently, a minineurologic examination for assessment of pupils regarding their symmetry and photoreaction, and an assessment of the level of alertness using the Glasgow coma scale are performed. Finally, the whole body is exposed to thermal control to prevent hypothermia.

Primary survey concludes with the functional balance of the traumatized child, with clinical evaluation and some elements of physical examination using chest and hip x-rays and, in some cases, radiographic images of the cervical spine (profile), in addition to blood typing and arterial blood gas analysis, measurement of urinary output via a catheter, gastric intubation, saturation and electrocardiogram.

Secondary survey
The secondary survey should only be initiated after the end of the primary survey, treatment of life-threatening injuries, reassessment, confirming the conditions for a detailed analysis, performing a head-to-toe examination, and indicating relevant complementary exams for the detection of injuries one might suspect of.

Resuscitation and efforts to identify life-threatening or potentially life threatening injuries should not be compromised despite further examination. It must be accomplished as soon as the therapeutic approach allows so.

In 2004, Soundappan et al.28 stated that a reasonable number of injuries were left undiagnosed after the
secondary survey, after a management plan had been established during definitive care, pointing out the necessity of tertiary care, when the detailed reassessment of the traumatized child should occur up to 24 hours after admission.

**Transport**

**Prehospital**

Prehospital care reduces mortality and the deleterious consequences of trauma. Assessment and management of airways and ventilation at this stage contribute towards the qualification of medical centers which have made every endeavor to improve prehospital care, therefore producing better survival rates.

Prehospital care consists of initial care with airway management, ventilation, circulatory management, proper immobilization and referral for the hospital unit.

The prehospital response time interval, defined as the time elapsed from receipt of an emergency call to the arrival of emergency aid at the scene, has been assessed at different medical centers with the aim of reducing the total prehospital care time. Nevertheless, studies show that the reduction in the response time did not have a significant impact on the overall survival of traumatized individuals, or did not categorically establish whether the feasible response time accounts for the decrease in mortality when evaluating an efficient and qualified prehospital care system.

Airway management using basic procedures and maintenance of ventilation have been acclaimed in prehospital care. Control of apparent bleeding has also been well established. Volume expansion remains controversial. Attempts of hemodynamic stabilization of traumatized patients by the prehospital care team increases the time spent at the scene of injury and consequently the total time of prehospital care.

Several authors advocate resuscitation at the scene of injury. Several others criticize it. The major concern of the latter authors lies in the expectation to initiate volume expansion before controlling a possible source of bleeding, through vascular access and infusion of volume expanders.

Different response intervals have been shown in varied publications. However, there is an average of 10 minutes for the arrival of the prehospital care team at the scene of injury. This is more remarkable when dealing with accidents in urban areas. According to the New York City Fire Department, the mean response time interval for emergency care ranged from seven minutes and 49 seconds to nine minutes and 31 seconds in 1999, 2000 and 2001.

The mean total prehospital care time interval between the call of an emergency service and arrival at the hospital ranges from 30 to 50 minutes in different publications on the subject, in urban centers with distinct care systems.

A recent retrospective study, carried out in California, USA, compared the use of land versus rotary-wing aircraft transport in prehospital care and showed that land transport is better for distances shorter than 10 miles. For longer distances, aircraft transport was more appropriate.

The pieces of equipment used for prehospital care consist of ground ambulances and rotary-wing aircraft.

**Interhospital transport**

When it is not possible to have an appropriate and thorough assessment of traumatized patients, when resources are not readily available, or when assessment by a specialty physician is required, interhospital transport plays a fundamental role, and should be regarded as a strategic tool as far as the concept of trauma care systems is concerned.

Obviously, roles should be clearly defined as to operational contact between physicians, the information given should allow the transfer of patients for better management, care and treatment, and transport should never pose any additional risk to traumatized patients.

A transport system for children, although it may work in conjunction with a general transport system, with several shared components, such as vehicles and administrative framework, should include pediatricians in its organization, coordination and integration. Participation of specialized professionals remarkably reduces risks and improves the rates of morbidity and mortality associated with transport.

The system should also include specific training for pediatric intensive care transport, customized protocols, equipment and inputs that are suitable to the care of children and newborn infants.

Its basic framework should consist of: a call center, a multidisciplinary team able to deal with specific transport needs, appropriate vehicles equipped for different kinds of accidents.

Vehicles may range from ambulances with basic equipment to sophisticated aircraft. They must be roomy, allow for temperature control, be safe, and have their own sources of power. They vary a lot depending on the type of service, geographical region and basic purposes. Vehicles for interhospital transport are classified as rotary-wing aircraft (helicopters) and fixed-wing aircraft (airplanes).

The advantage of ground ambulances is that they are universally available and can be immediately summoned. Their physical space is often sufficient for the installation of all the necessary equipment, allowing the health team to move comfortably in them, and maintenance costs are not high. They are probably the cheapest mode of transportation for distances shorter than 93 miles and also an essential component for the complementation with fixed-wing aircraft transport.

Technological breakthroughs have given rise to increasingly smaller medical equipment with improved power management (using batteries), thus allowing for the installation of all the necessary equipment in helicopters for basic and advanced life support.
The basic advantage of helicopters is that they can reach difficult access areas and get to the scene of injury in a very short time. This makes helicopters an interesting alternative for interhospital transport and even in prehospital care, by facilitating the transport to the referral hospital. Hospitals with a heliport can receive or send patients with minimal time delay. The disadvantages of a helicopter includes tight space, level of noise and vibration, which often hinders or does not allow an adequate clinical assessment during the flight and neither allows an emergency procedure. Helicopters can only be used under good weather conditions and if visibility is adequate.

Finally, the use of fixed-wing aircraft allows quicker access to long distances. They may have a pressurized cabin, their size is adequate for comfortable patient care, they may be equipped with different types of respirators, incubators and cylinders for respiratory gases, and allow small onboard medical procedures.

Their major drawbacks are the consequences of altitude and the high cost. Despite its high costs, the use of this type of transport may be more economical in case of long distances.

**Effects of altitude and air transport**

Altitude can produce reasonable adverse effects. As altitude increases, air pressure drops and, consequently, partial oxygen pressure also falls. This occurs even in aircraft with a pressurized cabin.

The respiratory system reacts by increasing the minute volume by means of a rise in the tidal volume. Hyperventilation may cause a decrease in $\text{PaCO}_2$ and respiratory alkalosis with leftward shift of the oxyhemoglobin dissociation curve. Hypoxia can result in pulmonary vasoconstriction, with an increase in pulmonary artery pressure and in right ventricular stroke work.

Therefore, reduction of partial oxygen pressure is important to patients with limited cardiopulmonary function, and may result in decompensation as the airplane rises up into the sky. Since artificial cabin pressurization decreases, but does not eliminate the effects of altitude and its establishment is not immediate but gradual, many patients will need supplemental oxygen supply, and the pilot must make the plane gain altitude gradually before leveling off at cruise altitude.

Gases expand at higher altitudes. Thus, patients with chest trauma who needed to be drained due to pneumothorax or hemothorax, and who have subcutaneous emphysema, should have drainage supervised during the flight. Patients with (postoperative) paralytic ileus should have their digestive tract decompressed by way of a gastric tube.

Other effects, such as stress caused by noise, vibration and temperature reduction, should be considered as well.

**Special care for traumatized children during interhospital transport**

Different situations involving traumatized children during air transport have to be considered:

- **airways**: patent, with supplemental $\text{O}_2$ supply (additional if receiving such support before transportation); in case of doubt, a definitive airway should be secured;
- **ventilation**: special attention should be paid to the necessity of ventilators; the therapeutic pattern should be at least similar to that used before transportation; if properly ventilated, the probability of the patient having hypoxemia during transport is reduced, especially on rotary-wing aircraft. Pneumothorax must be drained before transportation;
- **Vascular access** should be available; if necessary, the health team may establish it during the flight, thus not causing any transport delays;
- **Appropriate immobilization**, with specific restriction to each case, paying special attention to the use of pneumatic splints on pressurized airplanes, because they may expand during the flight;
- **Postoperative abdominal surgery patients** may present with paralytic ileus and should therefore have their digestive tract decompressed via a gastric tube.

The major objective of transport is to provide appropriate medical care in the shortest possible time, but in compliance with safety rules. Airway patency, adequate venous access (preferably two accesses), monitoring of vital and clinical parameters, and prevention of clinical deterioration of patients are the main goals during transport.

**Conclusions**

An extremely important issue regarding the care of traumatized patients, especially children and adolescents, is not inflicting additional injuries.

If the peculiarities about airway management, ventilation, circulation with bleeding control, minineurologic examination, exposure, and secondary survey are taken into consideration, and once vital functions are stabilized and prehospital and interhospital transport is properly prepared, results will certainly improve, and mortality and morbidity will be reduced.

**References**

2. National Academy of Sciences (USA) - Committee on Trauma and Committee on Shock. Accidental death and disability: the disease of modern society. Division of Medical Sciences, Washington, DC; 1966.

Correspondence:
Claudio Schvartsman
Av. Dr. Enéas de Carvalho Aguiar, 647
CEP 05403-090 – São Paulo, SP, Brazil
Telefax: + 55 (11) 3069.8500
E-mail: schvartsman@globo.com