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"Penetrating Pediatric trauma; How physiological parameters and management of children differs from an adult population"

Degree Project in Medicine
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Programme in Medicine

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Abstract

Degree project, Programme in Medicine,

"Penetrating Pediatric Trauma"

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Background: There is a growing need for knowledge to manage children with penetrating trauma as securely and correctly as adults. Firstly, pediatric vital parameters are age-specific and therefore differ from the adults. Secondly, children have higher physiological compensatory mechanisms, which means that the clinical picture of shock varies with age. The severity of trauma can be measured anatomically with Injury Severity Score (ISS).

Aim: The primary purpose of this study is to identify how pediatric physiological parameters differ from an adult population, and its potential correlation to death and ISS, when suffering from penetrating trauma. Evaluation of pediatric management was also of interest.

Methods: This is a retrospective cohort study, with information accessed from a Trauma-registry at Inkosi Albert Luthuli Hospital, in Durban, South Africa. The pediatric population consists of 33 patients within the ages ≥0- ≤15 years and an adult population of 40 patients within ages ≥24-≤45 years. All patients have suffered from penetrating trauma. Information regarding the type of penetrating trauma, physiological parameters at arrival, ISS, management, survival and gender and age of the patients was collected.

Results: Fifty-eight percent of the pediatric population was male, compared with the adult population (100%). The adults were solely injured through gunshot wounds and stabbings, whereas the children were injured in varied ways. The children had, in general, 8 units lower ISS than the adults. Hypotension correlated to an increasing ISS. Children were rarely, but successfully, managed conservative.

Conclusions: The children were not as severely injured as the adults, but tended to have worse vital signs. Larger study populations are required to determine what other parameters than hypotension that correlates to increasing injury severity. This study confirms the ambiguous nature of the pediatric trauma patient making its assessment a challenge.

Keywords: Penetrating pediatric trauma, vital parameters, Injury Severity Score, South Africa

Abbreviations

IALCH: Inkosi Albert Luthuli Central Hospital

ISS: Injury Severity Score

GSW: Gunshot Wounds

NISS: New Injury Severity Score

SATS: South African Triage Scale

TEWS: Triage Early Warning Score

SBP: Systolic Blood Pressure

BE: Base excess

NOM: Non Operative Management

Introduction

Trauma globally and in South Africa

The injury mortality rate of trauma will, within the nearest future, surpass that of HIV/AIDS, obstetric causes, malaria, and tuberculosis combined, according to studies (1). Globally, over 90% of all trauma deaths occur in low to middle-income countries, of which South Africa is a middle-income one, yet it is in these countries optimal medical facilities are lacking (2).

Trauma is a major health problem in South Africa, accounting for more than 50 000 deaths in 2009 (3). The majority of the trauma-related injuries in South Africa are violence or transport-related, most often occurring among young men influenced by alcohol or drugs. In the region of Kwazulu Natal, where this studie was performed, 102 000 pre-hospital trauma call-outs were recorded in the year of 2010. As much as 80% of these were considered serious or critical, and other studies have shown that 15% of the total trauma burden are patients requiring direct admission to a major trauma facility (2).

In South Africa public and private health systems coexist, the public one more frequently used by the poorer, percentually larger, part of the population. Medical resources and finances are skewed. 16% of the population are covered by the private sector, but accounts for 45% of total health care financing. Further on, according to a study from 2009, 79% of doctors work in the private sector (4).

This study was performed at Inkosi Albert Luthuli Central Hospital's (IALCH) trauma department. IALCH is a public tertiary/quaternary referral hospital, which provides sub-specialty services, with an annual acceptance rate of 12 000 admitted patients. IALCH is currently the only public Trauma Society of South Africa accredited Level 1 Trauma centre in South Africa. This indicates it’s high status regarding commitment and equipment compared to other public hospitals. All other Trauma facilities in South Africa are private. The Trauma Department of IALCH accepts 1900 patients, with 250 inpatient admissions, per year (Dr Hardcastle, Timothy 2019, oral communication, 15th October) (5).

Definition and measurement of trauma

Definition of trauma

The definition of penetrating trauma is an injury that occurs when an object pierces the skin and enters the body (6). Consequently, an open wound is created and underlying tissues, confined to the penetration path, get damaged through stretching and crushing (7). Stabbing and gunshots are the most common causes of penetrating trauma (8). Other objects such as pencils, fence posts, nails, dog bites, etc can of course also cause penetration. Perforating trauma, a form of penetrating trauma, is defined as when an object both enters and exits the body (6). Trauma is caused by the exchange of kinetic energy between an object and the human body. The level of trauma is defined by the mass and velocity of the penetrating object. The greater the mass and velocity, the greater the injury. The kinetic energy is increased fourfold by doubling the speed. The most distinct predictor of trauma severity is, therefore, the velocity. Consequently, a small, fast bullet probably creates more injuries than a big, slow one. This applies to stab wounds as well, which usually are not as severe as gunshot wounds (GSW), due to its lesser velocity (6).

The severity of GSW may be hard to determine. Depending on the path of the bullet through the body, changing direction when colliding with bone, penetration of an internal organ cannot be excluded without further examination. Further on, a penetrating object should only be removed where medical care is possible since it often tamponades the wound (8). Penetrating injuries to chest, neck, and head have significantly higher morbidity and mortality (7). Children's organs are closer in proximity, and therefore suffer a higher risk of more vital organs potentially damaged when exposed to penetrating trauma (9) (10).

Measurement of trauma

ISS

Injury Severity score (ISS) is the most widely used scoring system to quickly asses the level of severity of a multiple injured patient. ISS helps to quickly classify patients that demand full trauma activation or trauma center care (11). The ISS is based upon the abbreviated injury scale (AIS) which categorizes injuries by body area and severity. The body regions are as follows; head or neck, face, thorax, abdomen, extremity and external. The injury scoring system varies from 1 (minor), 2 (moderate), 3 (severe; not life-threatening), 4 (severe; life-threatening), 5 (critical; survival uncertain) to 6 (probably lethal). The ISS-score is the sum of the squares of the highest AIS grade in each of the three most severely injured areas (12). It only considers one major injury per area, although there might be several in each body region.(13) The scoring ranges from 3 to 75. A score of more than 15 is considered as a major trauma. A score of 6 in any body region, meaning " probably lethal, automatically generates a total score of 75, due to the severity thereof (12, 14).

In 1997 a new scoring system was presented called the New injury severity score (NISS). NISS presents a summary of the squares of the three highest Abbreviated Injury Scale scores, regardless of the body region. In reality, this means that for instance, two major injuries within the same body region will generate points in NISS, but not in ISS (13). Some studies have shown that the NISS predicts mortality in blunt trauma better than ISS (15), whereas ISS predicts length of hospital stay and intensive care unit admissions more accurately (16). Both NISS and ISS are used as of today. In this study the ISS has been assessed to determine patient injury severity. NISS may be a better predictor for outcome in penetrating trauma than ISS.

The South African Triage Scale

The South African Triage Scale (SATS) is a triaging system developed in resource-limited settings of South Africa (17). SATS subdivides patients into colour schemed groups, indicating preferred maximum time until management, depending on the level of emergency or deteriorating physiological parameters (18). SATS has been proven to be a highly sensitive tool to predict outcomes, as well as showing satisfactory levels of both undertriage and overtriage (17). One of the main consequences of implementing SATS is to minimize the delivery time of time-critical treatment of life-threatening conditions (8, 18). Studies have validated SATS as a useful tool to implement in major East African accident- and emergency centers (19) (17).

Patients with defined emergency problems, such as obstructed airways, current seizures, etc, are expedited to resuscitation instantly. Patients not suffering from “emergency problems” are subdivided into colour groups; red and orange; the most alerting ones, as well as yellow, green and blue; the less alerting ones, see table 1. The categorization of patients is based upon “Triage Early Warning Score" (TEWS), which values and scores the level of deterioration of physiological parameters. TEWS values mobility temperature, heart rate, respiratory rate, trauma (yes/no) and level of consciousness. Separate TEWSs are implemented in pediatric and adult patients (18).

Pediatric physiology

Normal pediatric vital parameters such as blood pressure, heart rate, and respiratory rate have age-specific values. They vary widely in comparison to adults. Standard principals are as follows: no child’s respiratory rate should be > 60 breaths/minute for a longer period, normal heart rate is roughly 2-3 times normal respiratory rate and lower systolic blood pressure (SBP) should be ≥ 60 mm Hg for neonates, ≥ 70 mm Hg for 1 month- 1 years old, ≥ 70 mm Hg + (2x age) for 1-10-year-olds and ≥ 90 for ≥ 10-year-olds. See table 2 and 3 for specific minimum ranges (20). Adults have vital parameters that are fairly stable throughout different ages, but with some minor age-dependent variations. Normal blood pressure is considered 120/80 mm Hg and the respiratory rates vary between 12-16. A pulse rate above 120 beats per minute is considered tachycardia in the trauma patient. A SBP lower than 90 mm Hg and a pathological clinical presentation should be taken seriously (20) .

There are several differences in the anatomy and ability to compensate physiological changes between the pediatric and adult body. For instance, pediatric patients are at higher risk than adults to suffer from airway obstruction. Smaller oral and nasal cavities, as well as proportionately larger tongues, contributes. Also, they have higher and more anterior glottic openings, greater amounts of adenoidal and tonsillar tissue and narrow high-riding larynx and a short trachea that also contribute to the risk of obstruction (21). Other physiological differences between children and adults are that children are more susceptible to hypothermia and hypoglycemia, as in comparison to adults who more commonly develop hyperglycemia due to insulin resistance, when exposed to trauma (22, 23).

Shock

The definition of shock is when oxygen and nutrient delivery to the tissues is inadequate to meet metabolic demands. Shock is divided into subgroups based upon the underlying pathophysiology; Hypovolemic, distributive, cardiogenic and obstructive and septic shock. In trauma medicine, hypovolemic shock due to hemorrhage is the most common one, whereas hypovolemic shock caused by fluid losses from severe diarrhea is the most common pediatric shock globally (20).

The clinical presentation of shock is tachycardia, weak pulse, delayed capillary refill, mottled, pale, cool skin and altered level of cognition. The most reliable and earliest sign of shock in children is tachycardia. Normotensive blood pressure early in shock is common among children, due to compensatory mechanisms such as an increase in heart rate and peripheral vascular resistance. When compared to adults decreases in blood pressure occur often somewhat earlier. In some pediatric cases, blood loss up to 50% occurs before blood pressure drops. One must note that, despite children's remarkable ability to compensate, a relatively small blood loss equals to a rather big percentage of a child's total blood volume. As an example, a blood volume of 25% in a 10 kg child equals only 200 ml. As in contrast, most adults will tolerate up to 1000-1500 ml blood loss with only tachycardia and decreased pulse pressure (systolic blood pressure – diastolic blood pressure) due to vasoconstriction, while a loss of more than that >30% leads to hypotension (23) .

Shock is therefore not synonymous with hypotension, as is often misconceived, even though it often is a part of the clinical presentation, especially in the adult population. Hypotension, especially in pediatric patients, is a late and life-threatening manifestation(24)**.** Once blood pressure drops, the shock often becomes refractory to treatment. A child suffering of acute trauma can therefore have lost gross volumes, relatively, of blood and be critically ill, but still maintain a normotensive blood pressure (20).

Laboratory findings are among others metabolic acidosis. Anaerobic metabolism, due to insufficient oxygen delivery, manifests clinically by an increase in lactic acid production and a following metabolic acidosis. Deteriorating base excess (BE) follows as well. Studies have shown there is a correlation between abnormal BE and low SBP. To identify shock among pediatric patients, measurements of BE and SBP should be combined (24). Other electrolyte disturbances are hyper/hypoglycemia, hypocalcemia and hypoalbuminemia. Hematologic abnormalities, such as thrombocytopenia, prolonged prothrombin and partial thrombin times, reduced serum fibrinogen levels, elevations of fibrin split products and anemia, is a common laboratory finding (25).

For children, an early recognition and treatment of shock is especially important and has led to decreasing mortality rates (25). Treating hypovolemic shock requires aggressive volume resuscitation, including blood transfusion if massive hemorrhage is anticipated (20).
One must note that even normalization of low blood pressure is not a reliable endpoint for assessing the success of resuscitation (26). Studies upon adults shows that **n**ormalized pH and lactate clearance are suggestively reliable endpoints indicating there is no more need for acute transfusions (27) .

Treatment: conservative or surgically interventional

Previous research has shown that non operative management (NOM) of penetrating injuries among children sometimes may be considered. Mentioned research proposes that children with solid organ injuries who are hemodynamically stable without signs of peritonitis are candidates. If the NOM is approached it acquires close monitoring for any signs of continuous hemorrhage. If hollow viscus injury is stated NOM is not adequate (28) (29).

Furthermore, hollow viscus injuries are may be difficult to detect during primary and secondary surveys. This injury becomes evident after repeated examinations (30). One study claims that the use of cat scans (CT) may avoid a delay to potential needed surgery, since it early can find indicatives of hollow viscus injury (29). Other studies do not recommend the use of CT due to low sensitivity (33%) and a higher dose of absorbed radiation among children. This study does also claim that observation and continuous examinations is enough for safe management (28) (31).

Studies demonstrate similar results concerning adults. A study from 2018 claims that minimally symptomatic stable adult patients, suffering from penetrating trauma, also are candidates for NOM. However, it also suggests there is a risk of missed injuries and delayed treatment (32). On the other hand, there is also a recent study proposing a delay in operation does not cause un unnecessary increase in mortality or morbidity (33).

The relevance of penetrating pediatric trauma

Penetrating trauma is a relatively rare, but increasing, type of injury in children. The rarity, as well as the increasing trend, is global. These epidemiological trends create an increasing need for knowledge on this aspect of trauma, whereas the ability to do so at the same time is limited (34) (35). The pediatric physiology and its responses to blunt trauma are relatively well known. On the other hand, there are few studies that examine whether the physiology of the pediatric body reacts similarly when exposed to penetrating trauma.

Some recent studies have shown that homicide accounted for 36.2% of all unnatural deaths in South Africa(36). The accuracy of crime statistics in South Africa is dubious, but despite this one can conclude that penetrating interpersonal violence among young adults is a wide-spread problem (36).

Penetrating trauma in children is not common globally outside warzones. In IALCH's database in Durban only 34 pediatric patients suffering from penetrating trauma had been admitted since 2007, within a database comprising a little more than 2600 patients. American statistics, that are about 10 years old, report that penetrating pediatric trauma only accounts for 1-10% of admissions to pediatric trauma centers (37, 38) . This further indicates the rarity thereof among children. On the other hand statistics also show that the most common cause of homicides in children and adolescents is firearm injuries (38). Since then, said trauma is increasing, as well as the need for research. The literature on managing penetrating pediatric trauma has primarily been developed based upon blunt trauma and on experience with the adult population (39). Therefore, the experience and knowledge in managing these injuries in children is partly lacking. Preventing deaths among children as well as implementing global partnerships, through sharing South Africa's developed knowledge of trauma care, is in alignment with United Nations Development programme's Global goals (goal 3.2, goal 17) and Agenda 2030 (40, 41).

Aim

The primary purpose of this study was to identify how physiological parameters differ from an adult population in regards to death and ISS, compared to a pediatric group with penetrating trauma. Observation and evaluation of pediatric management; conservative and operative, and its' potential impact on survival, was also of interest.

Hypothesis

The hypothesis of the study was that physiological parameters, except blood pressure, deteriorate more and earlier among the pediatric population. A larger percentage of the children are hypothesized to survive as well as to be managed conservatory.

Material and methods

This is a retrospective cohort study. Information has been accessed from the Biomedical Research Ethics Committee (BREC) Ethics Class Approved BCA207-09 Trauma-ICU-Registry at IALCH, in Durban, South Africa. The register contains data from 2007 to 2019. The database comprises in total a little over 2600 patients. Among these, 39% of adult patients suffered from penetrating trauma. Only 34 pediatric patients were found on review of the database to have suffered from penetrating trauma.

Population and data collection

A pediatric population within ages ≥0- ≤15 years and an adult population within ages ≥24-≤45 years have been audited. The age criteria for the pediatric population were chosen based upon IALCH's Pediatric reference chart for vital parameters. The age criteria were therefore not based upon when children legally become adults. An assumption was made that at the age of 24 the physiological response of the adult population differs from the pediatric population. The upper age restriction limit was chosen to 45 years, to exclude elderly patients with presumably different physiological responses to trauma.

All patients have suffered from, but not limited to, penetrating trauma. Patients who died during resuscitation were excluded. The included pediatric population reviewed children from the complete register, from 2007-2019. The adult population, on the other hand, are the 40 most recently admitted patients to the trauma intensive care unit, from 2018-2019.

All clinical notes in the register are written in English, some in the form of an electronic patient record (EPR) and others by hand (referral letters, anaesthesia notes, etc.), that are subsequently scanned into the EPR. Difficulties in interpreting information due to missing or discordant journal notes occurred. The South African supervisor assisted in interpreting ambiguous data or unclear terminology.

Variables

The following trauma variables were collected: gender, age, type of trauma, ISS, length of stay mortality, physiological parameters and management were reviewed. If complications were present, the numbers and specified complications were noted.

Physiological parameters at arrival such as blood pressure, pulse, respiratory rate, body temperature, glucose, POX, arterial blood gas including PH, BE and Lactate were collected. Information regarding resuscitation and intervention was collected. Fluid resuscitation (during the first 24 h, excluding baseline) (volume), thoracic drainage (if yes; number) and intubation (if yes; number and how long) were noted. Regarding intervention NOM (within the first 72 hours of emergency department arrival) (percentage) and surgical intervention (including laparotomy, thoracotomy, craniectomy etc (percentage) was reviewed. Notes of what type of surgeon (general/pediatric surgeons and/or resident/specialist/attending surgeon) was taken.

Statistical methods

To calculate the means of ISS and its potential correlation to abnormal parameters a univariate general linear model was used in SPSS. Each physiological variable was assessed. An analysis of the ISS, independent of physiological parameters, comparing the two groups was also performed. A post Hoc analysis was performed to deduce confidence intervals and p-values for the differences.

The percentage of the populations with abnormal physiological parameters at arrival was calculated. Additionally, the percentage with abnormal laboratory parameters of the part of populations “triaged red” was calculated. Descriptive data were depicted through simple cross tabs.

Ethical considerations

A pre-existing ethical approval of retrospective studies of the trauma registry from The Biomedical Research Ethics Committee of the University of KwaZulu-Natal covers this study. Due to sensitive information regarding pediatric patients, anonymity and discretion are crucial. Since the patient's names and personal numbers have been replaced with randomized numbers and the fact that the study is retrospective, patient anonymity is ensured. The study was regulated by the basic principles for medical research enunciated in the Declaration of Helsinki.

Results

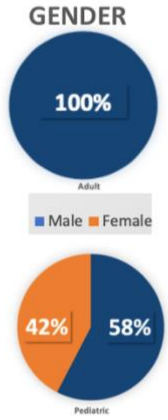
Epidemiology and injury patterns

The children were not as homogenous a group as the adults, in many ways. Gender wise, 42% of the children were female, whereas all the adults were male, see table 4. Most of the children were in the younger age-span with a mean age of 6 (inclusion criteria 0-≤15 years) years), and the mean age for the adults was 33 (inclusion criteria (≥25 - ≤45 years), see table 5.

The children showed a vivid variation when it comes to injury patterns when compared to the adults. Most of the children were injured by GSW (48.5%), but also by stabbings (9.0%), impalement (24.0%) and in other ways (24.0%), for instance penetrating injuries as a consequence of animal attacks. The adults' source of injury was solely GSW (51.0%) and stabbings (48.7%), see table 6.

Concludingly, the majority of the adult population consisted of men aged around 30 years, who had been shot or stabbed. The pediatric population consisted of smaller children, both girls and boys, injured in varied ways.

Only 2 (6.1%) of the 33 children demised, suffering from GSW and mauling by dogs. Similar numbers were shown among the adults, 4 (10.0%) out of 40. One of the children, 2-year-old girl passed away the following day after the injury. She suffered from lethal GSW to the abdomen and lower limb, with an ISS of 25. Her vital parameters were severely deranged with a pulse 176bpm, BP 80/55 mm Hg, POX 82, pH 7.1 and a BE of -17. The other child, a 5-year-old boy suffered from lethal mauling injuries. Upon arrival he had already developed sepsis, with a pulse of 148 bpm, blood pressure of 130/81 mm Hg, pH of 7.34 and BE of -6.1. His ISS was 21 and he passed away after 12 days after admission.



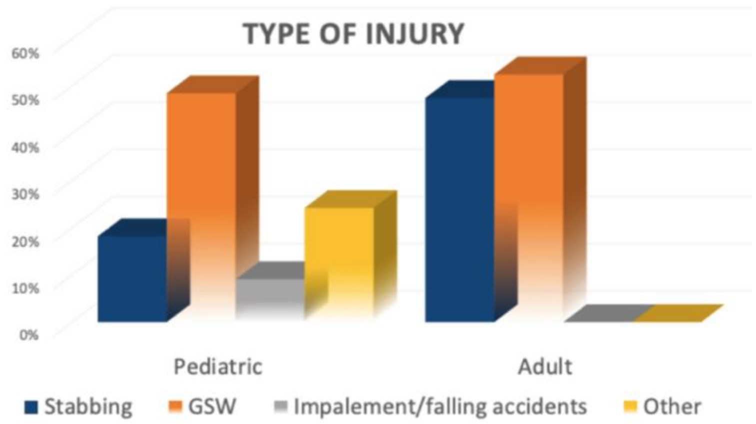


Figure 1. *Gender* Figure 2. *Type of injury*

No statistical analysis of injury pattern and ISS and their potential correlation to death at discharge was performed, since only 2 respectively 4 patients passed away.

Physiologic parameters and correlation to death at discharge and ISS

There are differences in physiological parameters at arrival between children and adults. In general, the children present a more clinically deranged picture than adults. A larger percent of the children upon arrival had hypotension, tachycardia, an abnormal BE (<3) and acidosis, see table 7.

Only 2.5% of the adults arrived with hypotension, when compared to 12.1% of the children.

Thirty-seven and a half percent of the adults arrived with tachycardia, compared to the children where the majority did so, a 72.7%, see table 7.2. A big part of both of the study groups had a BE less than -3, 42.5% among the adults and 58.6% among the children. A distinctly higher portion of the children had acidosis upon arrival, 58.6%, compared to 15.4% for the adults, see table 7. The largest percentual difference between the groups was in regard to acidosis, with a 43.2 percent difference (p: 0.05, KI: 0.22-0.644). The second-largest difference was in regard to tachycardia, with a 34.7 percent difference (p: 0.05, KI: −0.025-0.218).

Table 7.2. *Percentual differences between the populations*

	Percentual difference between the populations (decimal)	CI	p-value
Hypotension	9.6 (0.096)	0.127- 0.558	<0.05
Tachycardia	34.7 (0.347)	−0.025-0.218	<0.05
BE, <3	16.1 (0.161)	−0.075 -0.397	<0.05
Acidosis	43.2 (0.432)	0.22-0.644	<0.05

No statistical analysis of physiologic parameters and their potential correlation to death at discharge was performed, since only 2 respectively 4 patients passed away.

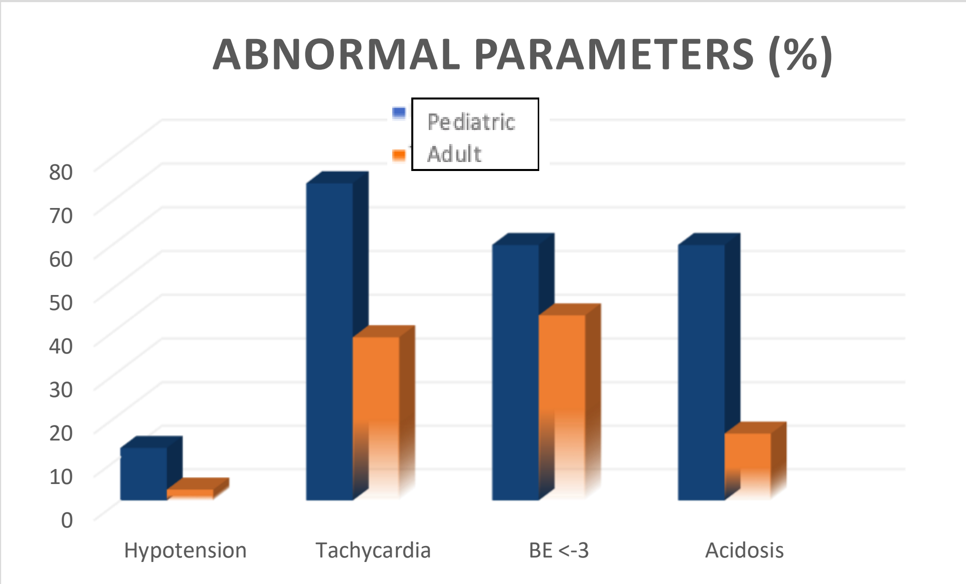


Figure 3. *Abnormal parameters of the pediatric and adult population.*

Both populations were triaged into either the green/yellow and red/orange groups (using the SATS Triage Coding (18)) and percentages were calculated in the same way, see table 8. Among the red/orange triaged pediatric patients 51.9 % had acidosis upon arrival, as in comparison to only 15.2% of the adult group. Thirty seven percent of the pediatric population had a lactate more than 2.5 upon arrival, whereas in the adult population it was present in 51.5%. The majority of the pediatric population had a large base deficit (>-3) on arrival, 55.6%. Similar numbers were shown among the adults at 45.5%.

Table 8. *Abnormal parameters within "red/orange triaged groups" regarding pH, lactate and BE*

Red/orange triaged	**Acidosis (%)**	**High lactate, > 2,5 (%)**	**Low BE, < 3 (%)**
Adult population	15.2	51.5	45.5
Pediatric population	51.9	37.0	55.6

Statistical analysis reviewing a potential correlation between ISS and deranged physiological parameters and abnormal pH and BE showed no statistical significance, except for its correlation to hypotension. When suffering from hypotension the adult population had a higher mean ISS of 38.5 (p:0.01, KI: 9.6-67.4) (see table 9.2) than the pediatric population.

The pediatric population mean ISS was 18.5 (KI: 5.6-31.4) and the adult population mean ISS was 57 (KI 31.1-82.9)(see table 9.3). When the adult population did not suffer from hypotension, their ISS decreased by 31.0 (p:0.04, KI: -60,7- -1.4). In comparison to the pediatric population, when normotensive, the adult population had a higher mean ISS by 7.45 (see table 9.2).

As mentioned no statistical significance was shown when a similar analysis was performed based upon tachycardia, acidosis and low BE and its correlations to ISS. Throughout all analyses, the adult group showed a higher ISS, which was statistically significant (p: <0.01, <0.03,<0.04 <0.05) (see table 9.1 10.1, 11.1, 12.1) but not correlated to the physiological parameters. The children had in general an 8,2 units lower ISS (KI: 1.937-14.423, p< 0.02) than the adult population, see table 13.2.

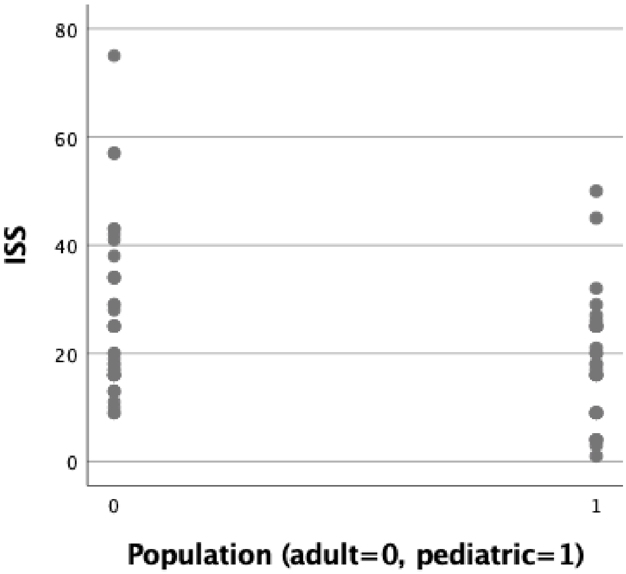


Figure 4.1. *Injury Severity score and its correlation to population*

To summarize, the adult population had a higher ISS than the pediatric population. Neither acidosis, low BE nor tachycardia could be proven to correlate to this. Hypotension showed a tendency of correlation to ISS correlation to ISS.

Management

Three of the children and five of the adults had NOM. None of the patients died during their time at the hospital. This is excluding one adult patient who passed away, whom upon arrival had no spontaneous respiration effort on ventilation and was chosen to neither have escalation therapy or active resuscitation. Besides from this patient, all the adults had stable vital signs. The children had deranged blood pressure and pulse, but had, on the other hand, suffered from injuries of the chest, face or extremities, hence no organ injuries.

Discussion

The pediatric population consisted of younger children, both girls and boys, injured in varied ways. The majority of the adult population consisted of men aged around 30 years, who had been shot or stabbed. Only 2 (6.1%) of the 33 children demised, suffering from gunshot wounds and mauling by dogs. Similar numbers were shown among the adults, 4 (10.0%) out of 40.

The children did, in general, have more deranged vital signs such as hypotension, tachycardia, low base excess, and acidosis, despite a lower ISS. A distinctly higher portion of the children had tachycardia, 72.7%, as in comparison to the adults, 37.5%. Twelve point one percent of the children arrived with hypotension, as in comparison to the adults, 2.5%. A distinctly higher portion of the children had acidosis upon arrival, 58.6%, compared to 15.4% of the adults. A big part of both of the study groups had a base excess of less than minus three, 42.5% among the adults and 58.6% among the children.
The children had, in general, 8.2 units lower Injury Severity Score than the adults. Hypotension correlated to an increasing ISS. Children were rarely, but successfully, managed conservative.

Quality of the data

Firstly, the data was collected from electronic patient records, written after the resuscitation of patients. Therefore the data, such as blood pressure, pulse, etc., may have not been collected systematically, or in the exact same way, however since a template is used and the nursing staff manually records the first vitals, the records are expected to be reliable. Secondly, physiological parameters have an individual variation within normal values. This complicates attempts to interpret the data and conclude how variations of physiological parameters correlate to a change in ISS.

To some extent, the patients in this study are representative of the South African trauma population in general, but several things complicate the matter. A study from 2013 assessing the referral patterns to the trauma center of IALCH, shows that only 540 of 1,212 external referrals were accepted for admission (42). For instance, the ones that make it to the emergency room have either received a life-threatening, but not instantly fatal injury, or are referred from other hospitals where the initial resuscitation has already been completed. Some patients have already undergone surgery and/or other stabilizing measures before they reach IALCH. It is sometimes hard to know if inotropes and fluid resuscitation have been given at the base hospital, and let alone the volumes. The physiological presentation of the patients that reach IALCH do therefore generally not represent a body's initial response to trauma, but rather a later presentation, sometimes after resuscitation. One must bear in mind that the time of the injury until arrival at the emergency room of IALCH can be several hours. Reasons for this can be rural trauma locations, prolonged time for the ambulance to arrive or patient delay (2). Of course, this does not apply to the patients that are directly referred from the scene of trauma.

One must note that the admitted patients in most cases have suffered from severe major trauma, often referred from other hospitals. Therefore, more general frequencies of penetrating trauma, from minor to major, probably would differ to some degree from the trauma type frequency admitted to IALCH's intensive care unit (43).

Gender and physiologic parameters

The majority of the children were boys. In general, globally, penetrating trauma seems to have a higher incidence among boys than girls (44-46). Among adults, several studies tend to depict a male dominated population suffering from penetrating trauma as well (47-49).

A higher percentage of the children than the adults presented a clinical picture with abnormal parameters. A majority (73%) of the children had tachycardia upon arrival, which is of no surprise since the earliest sign of shock in children is tachycardia (20). As much as 12,1% of the children had hypotension. Despite the fact, according to previous research, that this is a late and life-threatening manifestation, only two of the children demised (6%) (24). The young girl, who passed away two days after arrival, had severely deranged parameters at arrival, whereas the boy presented with a fairly stable clinical picture. The boy had already developed sepsis upon arrival and had to go through multiple surgeries. These two combining factors might explain his demise. He passed away 12 days after initial admission.

A large percentage of both the pediatric, 58,6% and adult group, 42,5%, had a BE lower than 3 upon arrival. This further indicates that deranged BE is a part of a worsening clinical picture, as previous studies has stated (50). Also, acidosis seems to be indicative of this. One ought to keep in mind that a distinctly higher portion of the children had acidosis upon arrival, 58,6%, as when compared to the adults, 15,4%.

To summarize, a relatively low percent of the pediatric population had hypotension upon arrival, but a distinctly higher percent had deranged BE levels. Assuming a high percentage of the children were shocked, based upon a high risk of bleeding out, this study confirms previous research indicating that measurement of SBP in conjugation with BE is advantageous when identifying shock (24).

Among the adult patients triaged orange/red, high lactate was the most common deranged variable (51.5% versus 37.0% in the pediatric population). Among the children, acidosis was much more common (51.9% versus 15.2 % in the adult population). Deranged physiological parameters, therefore, show a tendency of correlation to elevated lactate levels among adults, but acidosis among children. Since the orange/red triaged groups only contain 33 adults and 27 children, bigger study populations are needed for reliable conclusions.

Since so few patients demised (2 respectively 4 patients), there was no statistical analysis performed of potential correlation between injury pattern/deranged physiological parameters/ISS and their potential correlation to death at discharge.

Overall, one might conclude that children have a far more deranged clinical picture than that of the adults. Despite this, children seem to survive the most challenging physiological conditions. This implies that the pediatric clinical presentation is difficult to interpret.

Injury severity score

The penetrating pediatric trauma population is globally small. The need for further knowledge on this topic is increasing, but the shear lack of volume for this group challenges the findings of statistical significant variations.

Hypotension showed a tendency of correlation to ISS, but besides from that this study can solely analyze the difference of ISS between the two populations and not the potential correlations to the other physiological parameters. The pediatric population did, in general, have a lower ISS. There are multiple potential interpretations and reasons for this. On the other hand, one might ask oneself why ISS is higher among adults. There are a number of aspects for this difference in ISS that one has to bear in mind.

Firstly, the injury patterns among children and adults vary. For instance, a high percentage of penetrating trauma among adults are as a result of attempted homicide, whereas the underlying mechanism of injuries among children vary more. Therefore multiple stabbings or gunshots intentionally in different regions are probably more common among adults than children and consequently generate a higher ISS. This is the most probable reason for variations of ISS.

As a consequence of the intentionality of the trauma among adults, one might assume that a similar trauma will result in more deranged physiological parameters in the adult than the pediatric population. A stab with intent to kill among adults, for instance aiming at an organ, will generate the same ISS as an unintentional organ-sparing-impalement in the same region among children. Consequently, a child and an adult might have the same ISS, but the adult could hypothetically present a more severely injured clinical picture.

To complicate the matter, recent studies have implied that ISS is a misleading score when applied to both a pediatric and an adult population (11). Said research proposes that the same value of ISS depicts different levels of trauma severity between a child and an adult. The same study concludes that a suitable ISS- threshold for major trauma should be 25 for a child and 15 for an adult. Applying said thesis on this study's results implies that the children at IALCH's weren't as badly injured as one would think. This study can neither confirm nor deny this thesis since the results are solely correlated to the ISS and not the clinical picture.

Management

Most of the patients at IALCH had surgical intervention. Since IALCH is a referral hospital all the patients suffered from major injuries, and therefore more often require surgery. At a primary hospital, there is probably a greater proportion of patients that do not require surgical intervention, since more patients arrive with minor injuries and stable parameters. Three of the children had NOM, even though their vital parameters were not stable. On the other hand, they suffered from injuries in the chest, face and extremities, without any solid organ or arterial injuries. If NOM of children suffering from penetrating abdominal injuries is beneficial one cannot tell, as earlier studies have proposed (29).

Regarding the adult population, there were five patients, out of whom all survived, who had NOM. They all had stable vital signs upon arrival, and no hollow viscus injury. With this in mind, as well as previous studies have indicated, there are good reasons to believe that NOM, during the right circumstances, is beneficial (28).

Conclusions/Further studies

Penetrating pediatric trauma occurs to both girls and boys and is more common among younger children. The injury patterns vary, as in comparison to adults who solely suffered from GSW or stabbings. ISS is in general lower among the pediatric patients accepted to the trauma department in IALCH, Durban. The children did, in general, have more deranged vital signs such as hypotension, tachycardia, low BE, and acidosis, despite a lower ISS. This implies that children's clinical presentation is difficult to interpret.

Increasing ISS correlated to hypotension, but other correlations between vital signs and ISS could not be proven, due to too small group samples. ISS did predominantly correlate to age group though. The children's lower ISS is not something that can be generalized, since a lot of the patients presenting to IALCH are referred from other hospitals, and therefore a degree of preselection and self-triage occurs.

Regarding management, three of the children had NOM, out of whom all survived. These children suffered from injuries to chest, face, and extremities, but none with arterial or organ injuries. One, therefore, cannot in this study conclude whether NOM is or is not beneficial in the case of an organ injury. Among the adults, five had NOM, out of whom all survived. During the right circumstances, such as stable vital signs and no hollow viscus injury, NOM therefore, seems to be a beneficial way to manage penetrating organ injuries among adults. This is in alignment with previous studies. Since IALCH only accepts the most severe cases, one can speculate that children with solid organ injuries, that might be candidates for NOM, not have been referred to IALCH. If successful NOM of solid organ injuries generally is more or less common among children, this study therefore can not conclude. To determine if survival rates are higher among children with NOM, larger study populations are needed. Since IALCH only accepts the most severe cases of the region, one can speculate that children with solid organ injuries, that might be candidates for NOM, not have been referred to IALCH. If successful NOM generally is more or less common among children, this study can not conclude.

To investigate what parameters become more deranged as injury severity rises, will require studies with a larger population. If this happens one would be able to evaluate the severity of children's deranged physiologic parameters with greater certainty. If one would like to compare pulse, blood pressure, pH, BE and its impact on the severity of the trauma, one could investigate if there is a correlation between the mentioned parameters and its impact on mortality. In this study, the population sample of children was too small, as well as the outcome of death (two children). Penetrating trauma is globally a rarity, making this topic a challenge. Furthermore, an evaluation of other pediatric scoring systems, such as the Pediatric trauma score, in comparison to ISS is also of interest. If they depict the severity of trauma similarly, this would increase the knowledge of the reliability of ISS for a pediatric population. As a consequence of this, ISS credibility when it comes to evaluating the level of trauma in both the pediatric and adult populations would increase.

This study can confirm the ambiguous nature of the pediatric trauma patient making its assessment a challenge. It calls on a high level of suspicion by the treating physicians as vital signs can deteriorate more rapidly than adult patients. Hypotension, in particular, can be considered as an early warning sign.

Populärvetenskaplig sammanfattning

Barnkroppars reaktion på penetrerande yttre skador

Penetrerande våld innebär yttre skador som går igenom huden, till exempel skottskador och knivhugg. Denna typ av våld är en ovanlig, men globalt ökande, typ av skadeform på barn. På grund av att det är ovanligt, finns det i dagsläget endast få studier av hur just barns kroppar reagerar på penetrerande skador.

Anledningen till att den här typen av studie är relevant är för att barns och vuxnas kroppar reagerar på olika sätt när de utsätts för våld, och kunskapen om detta är betydelsefull för vilken typen av behandling de skadade skulle behöva. Till exempel är barn ofta mer benägna att bibehålla ett normalt blodtryck initialt, medan vuxna snabbare tappar i blodtryck. Orsaken till detta är att barn har större fysiskt kompensatorisk förmåga, vilket gör att de kan bibehålla sitt blodtryck trots att de till exempel har blivit skottskadade. När barn däremot får lågt blodtryck är de ofta bortom räddning, till skillnad från vuxna vars blodtryck ofta kan normaliseras med hjälp av läkemedel och vätska. Den fysiska allvarlighetsgraden av en skada kan mätas av Injury Severity Score (ISS). Med hjälp av ISS kan man gradera en patients allvarlighetsgrad, beroende på antalet skador och lokalisering av skadorna.

Syftet med studien är att granska om ändringar i barns fysiologiska parametrar såsom blodtryck, puls och avvikelser i blodprover vid en stigande ISS skiljer sig från vuxna. Om det går att utläsa en fysiologisk skillnad hos skadade barn och vuxna kan slutsatser dras om vad som är särskilt viktigt att granska hos barn när de undersöks då de blivit utsatta för penetrerande våld, för att kunna ge den bästa behandlingen.

Den här studien genomfördes på en traumaenhet på ett sjukhus i Durban, Sydafrika och informationen hämtades från datajournaler. Trettiotre barn och 40 vuxna, som har blivit utsatta för penetrerande våld, granskades.

Studien visade också att 58% av barnen var pojkar, till skillnad från de vuxna där alla var män. Bland barnen förekom flera olika skademekanismer, till exempel knivhugg, pistolskott, samt olyckor såsom djurattacker och liknande. Bland de vuxna var alla antingen skjutna eller knivhuggna. För att kunna dra vetenskapliga slutsatser behöver man se tydliga skillnader mellan barn- och- vuxen gruppen, eller alternativt undersöka ett stort antal barn. Eftersom data från endast 33 barn undersöktes gick det endast att utläsa ett fåtal resultat. Ett resultat visade att blodtrycket var en parameter som skiljde sig åt mellan barn och vuxna när det kom till ISS. Det framgick också att de vuxna generellt hade ett högre ISS än barnen, vilket innebär att de alltså var mer skadade. Trots att barnen inte var lika skadade som de vuxna, tenderade de i en större grad ha mer avvikande fysiologiska parametrar. Detta motsäger tidigare studier.

Penetrerande våld på barn är ett ökande problem på global nivå och det är viktigt att ny kunskap genereras. I framtiden bör liknande studier genomföras på fler barn för att öka kunskapen om vad som är speciellt viktigt att undersöka hos barn som drabbats av penetrerande våld.

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Appendix

Tables

Table 1. *SATS priority levels and target times to be seen with-in*

Priority Colour	Target time	Management
Red	IMMEDIATE	Take to the resuscitation room for emergency management
Orange	< 10 mins	Refer to majors for very urgent management
Yellow	< 1 hour	Refer to majors for urgent management
Green	< 4 hours	Refer to designated area for non-urgent cases
Blue	< 2 hours	Refer to doctor for certification

Table 2. *Adult reference chart for tachycardia and minimal systolic blood pressure according to ATLS*

Age	Tachycardia	SBP, minimal
Adult (> 14 y)	> 120	90 mm Hg

Table 3. *Pediatric reference chart for upper acceptable level of normal pulse rate and minimal systolic blood pressure according to Inkosi Albert Luthulis Hospital's guidelines*

Age	Tachycardia	SBP, minimal
0	>140	60
3 m	>140	70
6 m	>140	70
1 year	>130	72
2 years	>120	75
3 years	>120	75
4 years	>110	80
5 years	>110	80
6 years	>110	80
7 years	>100	85
8 years	>100	85
9 years	>100	90
10 years	>90	90
11 years	>90	90
12 years	>90	90
13 years	>80	90
14 years	>80	90

Table 4. *Gender*

	Female (%)	Male (%)
Pediatric population	42.4	0
Adult population	57.6	100

Table 5. *Age*

	Mean age	Median age
Pediatric population	6.3	5.0
Adult population	33.8	33.0

Table 6. *Injury patterns*

	Stabbing (%)	GSW (%)	Impalement (%)	Other (%)
Pediatric population	18.2	48.5	9.1	24.2
Adult population	48.7	51.3	0	0

Table 7. *Abnormal parameters regarding hypotension, tachycardia, BE and pH*

	Hypotension (%)	Tachycardia (%)	BE, < 3 (%)	Acidosis (%)
Adult population	2.5	37.5	42.5	15.4
Pediatric population	12.1	72.7	58.6	58.6

Table 7.2. *Percentual differences between the populations*

	Percentual difference between the populations (decimal)	CI	p-value
Hypotension	9.6 (0.096)	0.127- 0.558	<0.05
Tachycardia	34.7 (0.347)	−0.025-0.218	<0.05
BE, <3	16.1 (0.161)	−0.075 -0.397	<0.05
Acidosis	43.2 (0.432)	0.22-0.644	<0.05

Table 8. *Abnormal parameters within "red/orange triaged groups" regarding pH, lactate and base excess*

Red/orange triaged	**Acidosis (%)**	**High lactate, > 2,5 (%)**	**Low BE, < 3 (%)**
Adult population	15.2	51.5	45.5
Pediatric population	51.9	37.0	55.6

Table 9.1. *Hypotension, population and covariation and its correlation to ISS.*

Tests of Between-Subjects Effects

Dependent Variable: ISS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2187.418[a]	3	729.139	4.334	.007
Intercept	10764.536	1	10764.536	63.983	.000
Population	1612.477	1	1612.477	9.584	.003
Hypotension	793.594	1	793.594	4.717	.033
Population* Hypotension	735.298	1	735.298	4.370	.040
Error	11608.664	69	168.242		
Total	50595.000	73			
Corrected Total	13796.082	72			

a. R Squared = .159 (Adjusted R Squared = .122)

Table 9.2. *Parameters estimates of ISS depending on hypotension, population and covariation*

Parameter Estimates

Dependent Variable: ISS

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	18.500	6.485	2.853	.006	5.562	31.438
Adult population	38.500	14.502	2.655	.010	9.570	67.430
Pediatric population	0[a]	.	.	.	.	.
No hypotension	-.603	6.918	-.087	.931	-14.405	13.198
Hypotension	0[a]	.	.	.	.	.
[Population1pediatric0adult=0] * [Hypotension=0]	-31.038	14.846	-2.091	.040	-60.655	-1.420
[Population1pediatric0adult=0] * [Hypotension=1]	0[a]	.	.	.	.	.
[Population1pediatric0adult=1] * [Hypotension=0]	0[a]	.	.	.	.	.
[Population1pediatric0adult=1] * [Hypotension=1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Table 9.3. *Estimated marginal means of ISS depending on population, hypotension and covariation*

Estimated Marginal Means

1. Population

Dependent Variable: ISS

Population	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Adult	41.179	6.568	28.077	54.282
Pediatric	18.198	3.459	11.298	25.099

2. Hypotension

Dependent Variable: ISS

Hypotension (0=no, 1=yes)	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
0	21.628	1.590	18.455	24.800
1	37.750	7.251	23.285	52.215

3. Population* Hypotension

Dependent Variable: ISS

Population	Hypotension (0=no, 1=yes)	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Adult	0	25.359	2.077	21.215	29.502
	1	57.000	12.971	31.124	82.876
Pediatric	0	17.897	2.409	13.091	22.702
	1	18.500	6.485	5.562	31.438

Table 10.1. *Tachycardia, population and covariation and its correlation to ISS.*

Tests of Between-Subjects Effects

Dependent Variable: ISS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1161.812[a]	3	387.271	2.084	.111
Intercept	32694.831	1	32694.831	175.900	.000
Population	956.990	1	956.990	5.149	.026
Tachycardia	12.254	1	12.254	.066	.798
Population * Tachycardia	50.865	1	50.865	.274	.603
Error	12453.427	67	185.872		
Total	48598.000	71			
Corrected Total	13615.239	70			

Table 11.1. *Acidosis, population and covariation and its correlation to ISS.*

Tests of Between-Subjects Effects

Dependent Variable: ISS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1013.331[a]	3	337.777	1.790	.158
Intercept	24190.512	1	24190.512	128.213	.000
Population	864.565	1	864.565	4.582	.036
Acidosis	14.406	1	14.406	.076	.783
Population * Acidosis	34.611	1	34.611	.183	.670
Error	12075.184	64	188.675		
Total	48101.000	68			
Corrected Total	13088.515	67			

a. R Squared = .077 (Adjusted R Squared = .034)

Table 12.1. *Low base excess, population and covariation and its correlation to ISS.*

Tests of Between-Subjects Effects

Dependent Variable: ISS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1799.332[a]	3	599.777	3.415	.022
Intercept	32177.112	1	32177.112	183.221	.000
Population	759.027	1	759.027	4.322	.042
LowBE	683.435	1	683.435	3.892	.053
Population* LowBE	22.162	1	22.162	.126	.724
Error	11415.218	65	175.619		
Total	49257.000	69			
Corrected Total	13214.551	68			

a. R Squared = .136 (Adjusted R Squared = .096)

Table 13.1 *Population and its correlation to ISS.*

Tests of Between-Subjects Effects

Dependent Variable: ISS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1210.012[a]	1	1210.012	6.826	.011
Intercept	35197.848	1	35197.848	198.557	.000
Population	1210.012	1	1210.012	6.826	.011
Error	12586.070	71	177.269		
Total	50595.000	73			
Corrected Total	13796.082	72			

a. R Squared = .088 (Adjusted R Squared = .075)

Table 13.2. *Parameters estimates of ISS depending on population*

Parameter Estimates

Dependent Variable: ISS

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	17.970	2.318	7.753	.000	13.348	22.591
Adult population	8.180	3.131	2.613	.011	1.937	14.423
Pediatric population	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Table 13.2. *Estimated marginal means of ISS depending on population.*

Estimated Marginal Means

Population

Dependent Variable: ISS

Population	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Adult	26.150	2.105	21.952	30.348
Pediatric	17.970	2.318	13.348	22.591

Figures

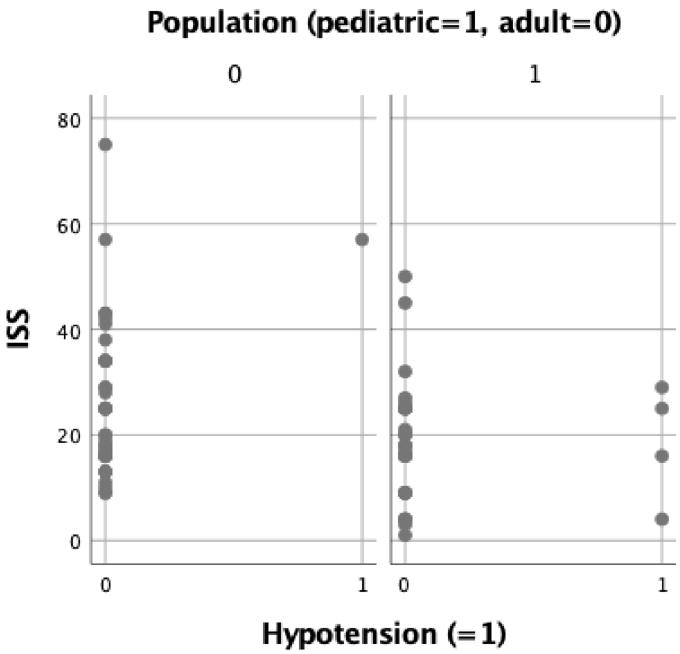

Figure 4.1. *Injury Severity score and its correlation to hypotension*

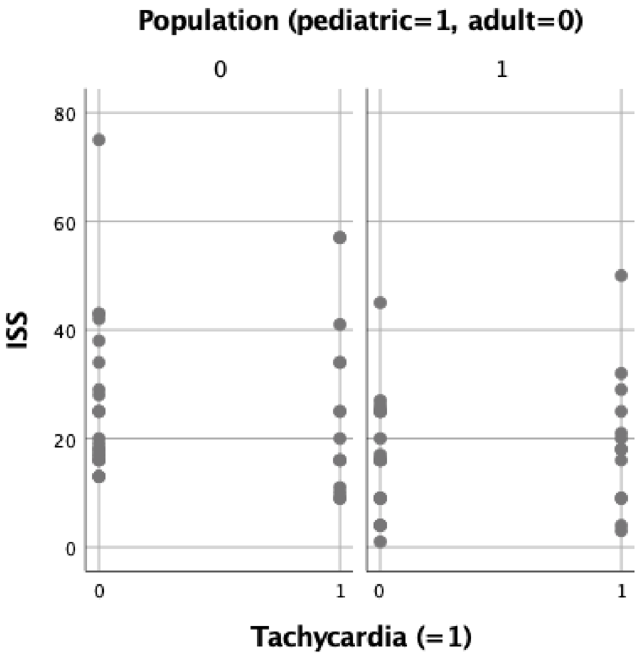

Figure 4.2. *Injury Severity score and its correlation to sinus tachycardia*

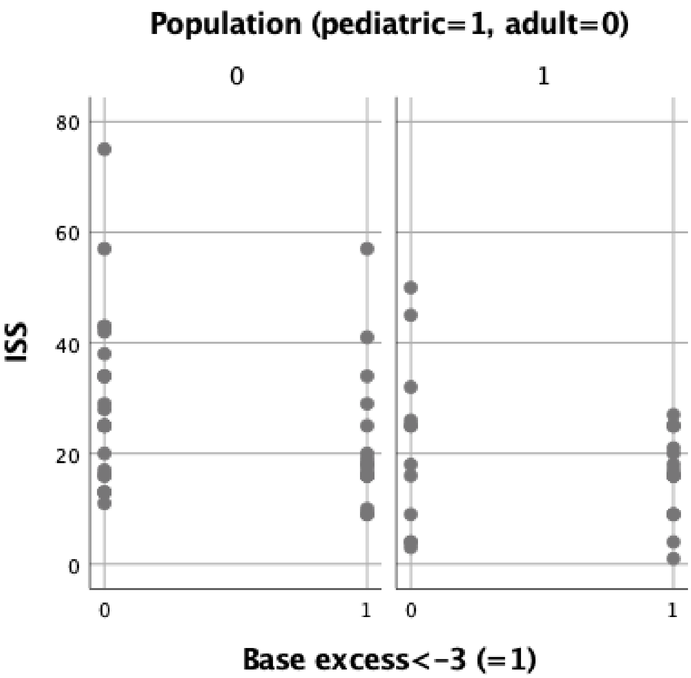

Figure 4.3. *Injury Severity score and its correlation to base excess beneath normal range*

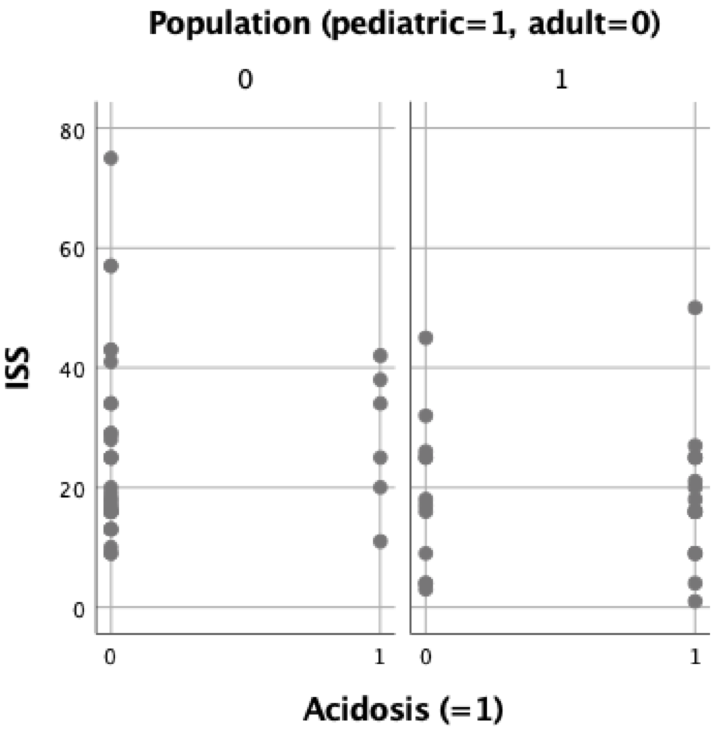

Figure 4.4. *Injury Severity score and its correlation to acidosis*

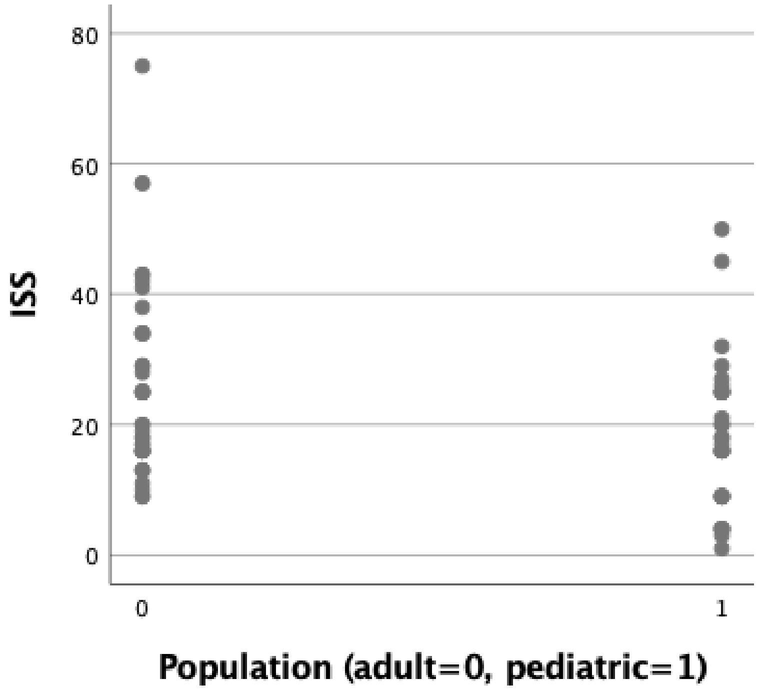

Figure 4.1. *Injury Severity score and its correlation to population*