Final Report

The Development of Pediatric Trauma and Injury Severity Score and National Registry of Pediatric Injury, Thailand

By

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The Development of Pediatric Trauma and Injury Severity Score and National Registry of Pediatric Injury, Thailand

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ABSTRACT

Globally, injury deaths among children are increasing year-by-year, even though these are preventable. The injury prediction score has been used as a tool to aid in the decision making for managing injured patients. However, previous prediction scores have shown many limitations and only a few were specific to children. This study aimed to develop and validate a pediatric injury severity risk prediction model in Thai children and compare it with pre-existing scores.

A cross-sectional study consisting of the derivative and validated phases was conducted from April 2010 to October 2012. The data, which was collected from 34 collaborating hospitals, was used to derive and validate the risk prediction model for pediatric injury. A total 43,516 injured children (aged 0-18 years) who used emergency services were enrolled. Fifteen predictive variables were considered to include in the risk prediction model of death. Logistic regression was applied to derive the model. The calibrated and discriminative performances were assessed using the observed per expected ratio (O/E) and concordance statistic (C-statistic).

For the derived phases, injury death was 1.7% (95% CI: 1.57-1.82). The ten predictors: age, airway intervention, physical mechanism of injury, injured body regions (head-neck, thoracic, and abdominal regions), GCS, systolic blood pressure, pulse rate, and respiratory rate were significantly associated with death and were kept in the final model. The O/E ratio and the C-statistic were 0.86 (95% CI: 0.70-1.02) and 0.938 (95% CI: 0.929-0.947), respectively. The coefficients derived from logic regression of the significant variables were used to create a scoring scheme and were classified into four risk classifications with respective likelihood ratios of 1.26 (95% CI: 1.25-1.27), 2.45 (95% CI: 2.42-2.52), and 4.72 (95% CI: 4.57-4.88) for low, intermediate, and high risk of death.

The internal validation was done by 200-repetition bootstrap technique and showed a good performance with a very small bias for calibration of 0.002 (95 % CI: 0.0005-0.003) and C-statistic of 0.938 (95% CI: 0.926-0.952). A comparison of our model's performances with previous pediatric injury models demonstrated a higher discriminative performance than those which were predicted by Tepas, Tepas & Ramenofsky, Rosso, and pediatric poly-trauma scores which were 0.876 (95% CI: 0.862-0.891), 0.876 (95% CI: 0.861-0.891), 0.893 (95% CI: 0.879-0.908) and 0.874 (95% CI: 0.860-0.888), respectively.

We developed a successful simplified risk prediction score of Thai pediatric injury with satisfactory calibrated and discriminative performances which was better than previous pediatric prediction scores. It is a promising tool for evaluation of injured children in ER settings and needs further external validation.

KEY WORDS: CALIBRATION / C-STATISTIC /LOGISTIC REGRESSION / PEDIATRC TRAUMA AND INJURY SCORE / VALIDATION

การพัฒนาระบบคะแนนประเมินความรุนแรงและโอกาสเสียชีวิตในผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุและการพัฒนาฐานข้อมูลการบาดเจ็บระดับชาติสำหรับเด็กไทยในระบบภาคีเครือข่าย

ศักดา อาจองค์ วัลลิภากร, พบ., Ph.D., อัมรินทร์ ทักขิญเสถียร, Ph.D., อดิศักดิ์ ผลิตผลการพิมพ์, พ.บ., M.P.H., ไพบูลย์ สุริยวงศ์ไพศาล, พ.บ., M.Sc.

บทคัดย่อ

อัตราการเสียชีวิตจากการบาดเจ็บหรืออุบัติเหตุในเด็กมีแนวโน้มสูงขึ้นทุกปีทั่วโลก แม้สามารถป้องกันได้ก็ตาม ในอดีตได้มีการนำระบบคะแนนการคาดการณ์ความเสี่ยงต่อการเสียชีวิตในผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุ มาใช้เป็นเครื่องมือในการตัดสินใจในการดูแลรักษาและบริหารจัดการผู้ป่วยที่ได้รับการบาดเจ็บ อย่างไรก็ตามพบว่าระบบดังกล่าวมีข้อจำกัด และมีเพียงน้อยระบบที่มีความสอดคล้องและสามารถใช้ได้กับป่วยเด็ก การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อพัฒนาระบบคะแนนการคาดการณ์ความเสี่ยงต่อการเสียชีวิตในผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุในเด็กไทยและตรวจสอบประสิทธิภาพและเปรียบเทียบกับระบบเดิมที่เคยมีมาก่อน

การศึกษาแนวตัดขวาง เพื่อนำมาใช้ในการสร้างระบบคะแนนการทำนายความเสี่ยงต่อการเสียชีวิตในผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุ และตรวจสอบประสิทธิภาพของระบบที่สร้างขึ้น โดยเริ่มทำการศึกษาวิจัย ตั้งแต่เดือนเมษายน 2553 ถึง เดือนตุลาคม 2555 จากการรวบรวมข้อมูลจาก 34 โรงพยาบาล ในระบบเครือข่ายทั่วประเทศ พบจำนวนผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุที่ได้รับการดูแลรักษาที่ห้องฉุกเฉิน ทั้งสิ้น 43,516 ราย (อายุ 0-18 ปี) ตัวแปรที่มีนัยสำคัญทั้งสิ้น 15 ตัวในขั้นต้น ได้ถูกพิจารณาและนำเข้าสู่โมเดลการทำนายความเสี่ยงของการเสียชีวิตโดยการวิเคราะห์ถดถอยพหุคูณโลจิสติก และนำโมเดลสุดท้ายที่ได้มาวิเคราะห์และเปรียบเทียบความสามารถของระบบคะแนนในการทำนายความเสี่ยงต่อการเสียชีวิตทั้งด้านการปรับเทียบและในด้านการจำแนกความถูกต้อง นำมาวิเคราะห์โดยใช้ผลจากการสังเกตต่ออัตราส่วนที่คาดหวัง (O / E) และสถิติความสอดคล้อง (C-statistic)

พบอัตราการเสียชีวิตที่เกิดจากการบาดเจ็บร้อยละ 1.7 (95% CI: 1.57-1.82) 10 ตัวแปรที่มีนัยสำคัญต่ออัตราการเสียชีวิตท้ายสุดหลังจากวิเคราะห์ถดถอยพหุคูณโลจิสติก ได้แก่ อายุ การช่วยเหลือด้านทางเดินหายใจ กลไกทางกายภาพของการบาดเจ็บที่ได้รับ ระบบของอวัยวะที่ได้รับการบาดเจ็บ (ศีรษะและคอ, ทรวงอก และ ช่องท้อง), ระบบประเมิน GCS, ความดันโลหิตตัวบน อัตราการเต้นของชีพจร และอัตราการหายใจ โดยมีความสัมพันธ์อย่างมีนัยสำคัญกับการเสียชีวิตและถูกนำไปสร้าง แบบแผนการสร้างระบบคะแนน ค่าอัตราส่วน O / E และ C-statistic ที่ได้ คือ 0.86 (95% CI: 0.70-1.02) และ 0.938 (95% CI: 0.929-0.947) ตามลำดับ ค่าสัมประสิทธิ์ที่ได้มาจาก likelihood ratio ของตัวแปรถูกนำมาจัดแบ่งกลุ่มการสร้างรูปแบบของการให้คะแนน โดยจำแนกเป็น 4 กลุ่ม โดยมีความเสี่ยงเพิ่มขึ้นตามลำดับตามอัตราส่วนของความน่าจะเป็นสำหรับความเสี่ยงต่ำ กลาง และ

สูงของการเสียชีวิต เท่ากับ 1.26 (95% CI: 1.25-1.27), 2.45 (95% CI: 2.42-2.52) และ 4.72 (95% CI: 4.57-4.88) เมื่อเทียบกับกับกลุ่มที่ไม่มีความเสี่ยงตามลำดับ การตรวจสอบ internal validation ได้ถูกวิเคราะห์ต่อด้วยเทคนิค Bootstrap (โดยการนำข้อมูลออกและใส่กลับคืนซ้ำ ๆ กันทั้งสิ้น 200 ครั้ง) สุดท้ายพบว่าแบบแผนระบบคะแนนคาดการณ์ความเสี่ยงต่อการเสียชีวิตนี้ มีประสิทธิภาพที่ดีและมีอคติที่เกิดขึ้นน้อยมาก เท่ากับ 0.002 (95% CI: 0.0004-0.003) และ ค่า C-statistic เท่ากับ 0.873 (95% CI: 0.872-0.875) ส่วนการเปรียบเทียบกับระบบคะแนนการคาดการณ์ความเสี่ยงต่อการเสียชีวิตในผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุกับระบบคะแนนที่เคยมีมาก่อน แสดงให้เห็นถึงประสิทธิภาพของแบบแผนระบบคะแนนการคาดการณ์ความเสี่ยงต่อการเสียชีวิตที่สร้างขึ้น มีประสิทธิภาพในการจำแนกที่สูงกว่า เมื่อเทียบกับ ระบบคะแนนการคาดการณ์ความเสี่ยงต่อการเสียชีวิตในผู้ป่วยเด็กของ Tepas, Tepas & Ramenofsky , Rosso และ Poly trauma score ซึ่งเท่ากับ 0.876 (95% CI: 0.862- 0.891), 0.876 (95% CI: 0.861-0.891), 0.893 (95% CI: 0.879-0.908) และ 0.874 (95% CI: 0.860-0.888) ตามลำดับ

ระบบคะแนนการคาดการณ์ความเสี่ยงต่อการเสียชีวิตในผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุที่ได้ถูกพัฒนาขึ้นนี้ พบว่ามีความสามารถที่ดีสำหรับการคาดการณ์ความเสี่ยงต่อการเสียชีวิตของการบาดเจ็บในเด็กไทย ทั้งในด้านการปรับเทียบและประสิทธิภาพในการจำแนกเป็นที่น่าพอใจและดีกว่าระบบเดิมที่เคยมีมา และเป็นเครื่องมือที่มีประโยชน์สำหรับการประเมินผลในเด็กที่ได้รับบาดเจ็บที่มารับการรักษาที่ห้องฉุกเฉิน และน่าติดตามในขั้นตอนการตรวจสอบโดยวิธี external validation ต่อไปกับประเทศแถบเอเชียและฝั่งตะวันตกต่อไปในอนาคต

EXECUTIVE SUMMRY

This research aimed to develop of pediatric trauma and injury severity score and national registry of pediatric injury, Thailand. The working group called Thai task force of Pediatrics Injury was created and collaborated to design an optimized database which aim to develop prediction score of death. The cross-sectional study was conducted based on amount of injured children 43,516 cases across countries via 34 collaborating hospital distribute coverage all of region and stratified by trauma level care. The period of study was from April 2010 to October 2012. The univariate and multivariate analyses and multiple logistic regression analysis were used to select the significant factors related with death outcome among injured children. A risk prediction model was derived using a logistic regression analysis that included 15 predictors. Model performance was assessed using the concordance statistic (C-statistic) and the observed per expected (O/E) ratio. Internal validation of the model was performed using a 200-repetition bootstrap analysis.

The variable and outcome measures death related to injury or trauma within 30 days. The six domains of predictive variables were collected which were Demographic and general data including age, sex, weight, height, occupation, and geographic region, Pre-hospital data were transport types and duration, prior communication, and trauma care level. Mechanism of injury including surgical perspective mechanism (i.e., blunt, penetrating, or both) and physiological mechanism (i.e., gravity related injury, velocity related injury, or both), Trauma related injury regions including brain and head/neck, face, thorax, abdomen, upper or lower extremities and external soft tissue injury, the airway management which were intervention, airway adjuncts (e.g., oxygen supplementation and positive ambulatory bag, etc.), GCS and vital signs including GCS, Pulse rate (PR), Systolic blood pressure (SBP) and respiratory rate (RR)

The primary data analyses were Mean and standard deviation (SD) were used to describe continuous variables if data were normal distribution, otherwise median and ranges were used. Frequency and percentage were used to describe categorical data. An overall death rate along with its 95% confidence interval (95% CI) was estimated. Data analysis consisted of 2 phases as follows; Derivation phase, the 21 independent variables were included in a data set that was used to develop risk prediction of death. A simple logistic regression analysis was used to evaluate the association between mortality and each of the variables. Variables with a p-value < 0.10 were included in a multivariate logistic model. The likelihood ratio (LR) test with backward elimination of variables was used to determine the most parsimonious model. Calibration and discrimination performance of the final model was then assessed. For calibration performance, a goodness of fit of the final model was assessed using the Hosmer-Lemeshow test. A ratio of observed to expected values (O/E) was also estimated. A receiver operating characteristic curve (ROC) analysis was used to estimate discriminative performance, and the C-statistic was estimated. The coefficients of the variables included in the final model were used to create scoring schemes. Total scores were calculated by summing the coefficients of all significant variables. The ROC analysis was applied to calibrate score cut-offs by estimating a likelihood ratio positive (LR+) for each distinct score cut-off. The prediction scores were then classified into risk stratification for ease of application in clinical practice. Validation phase, because the death rate was quite low, all data were included in the 200-repetition bootstrap model used for internal validation. For each sample, the final logistic model resulting from the derivation phase was constructed, and parameters (i.e. predicted probability and the C-statistic) were estimated. Correlations between the observed and predicted values were assessed using the Somer'D correlation statistic (D boot). Model calibration was then assessed using D orig-D boot, where D orig was the Somer'D correlation obtained from the derived data. A value close to 0 implied an optimistic calibration. Discrimination was also assessed by comparing the C-statistics results of the original model with the bootstrap modelling results. Score performance was compared with the pre-existing PTSs using ROC curve analysis. Net reclassification improvement (NRI) and integrated discrimination improvement (IDI) statistics were also applied. These measures allowed us to analyze benefit gains and losses when using our prediction scores compared with the PTSs scores. All analyses were performed using STATA 12.0 software (College Station, TX, USA). A P-value <0.05 was considered to be statistically significant.

The results, death occurred in 1.7% of the injured children (95% confidence interval [95% CI]: 1.57–1.82). Ten predictors (i.e., age, airway intervention, physical injury mechanism, three injured body regions, the Glasgow Coma Scale, and three vital signs) were significantly associated with death. The C-statistic and the O/E ratio were 0.938 (95% CI: 0.929–0.947) and 0.86 (95% CI: 0.70–1.02), respectively. The scoring scheme classified three risk stratifications with respective likelihood ratios of 1.26 (95% CI: 1.25–1.27), 2.45 (95% CI: 2.42–2.52), and 4.72 (95% CI: 4.57–4.88) for low, intermediate, and high risks of death. Internal validation showed good model performance (C-statistic = 0.938, 95% CI: 0.926–0.952) and a small calibration bias of 0.002 (95% CI: 0.0005–0.003).

Conclusions, finally we developed and validated (internal and external validation) a simplified Thai pediatric injury death prediction score with satisfactory calibrated and discriminative performance in emergency room settings, and also create a Pediatric Injury Surveillance Database as a networking among the 34 collaborated sites integrated with their work and reports. This database could be useful for the future such as aspect of prehospital care, special injury e.g. child abuse, sexually abuse, objects related injury issue as western countries were interest, or invent a easy tool through an electronic equipment(smart phone, tablet, transfer computer) can aid of quick usage guide the physicians, paramedics or healthcare provider in emergency services system to optimize care of injured child in future

PART I

INTRODUCTION

The global injury problem among children is increasing year-by-year although it is preventable. Injuries are still a major problem since they were the first rank cause of death in children reported by the Centre of Disease Control and prevention (CDC) in 2003 (1). In addition, they were the second common causes which brought children to visit an emergency department (2). Although the mortality rate trends to decrease in developed countries (e.g., Sweden, Japan, and the United States) due to improvement of trauma care quality and injury prevention policies (3-5), there is no decreasing trend in developing countries particularly in South East Asia. In Thailand, they accounted for nearly a half of all cause of deaths since the last decade (6) and the trends were decreased, but still accounted for nearly 25% of total death as for the annual reports for causes of deaths in Thai children aged < 15 years by the Ministry of Public Health (7). The mortality rates caused by accident and poisoning, suicide-homicide, and other injury categories during 20022006 were 25.7, 24.7, 27.3, 25.3, and 25.6 per 100,000 populations. These rates were similar to the most recent report by the UNICEF 2008 (8) in which the mortality rate was 23.7/100,000 population.

The trauma care system in Thailand has been developed and revised in order to improve the quality of care, reduce morbidity, disability, and mortality, and also reduce the cost of treatments from acute and chronic morbidities after injuries (9-11). With very much concern by the government, human resources (e.g., emergency care team), advanced modality of treatments, and some prevention strategies have been adopted to reduce injuries (12-14). For the human resource, specialty training of emergency of medicine in Thailand has been developed since 2004 in order to increase the number of emergency physicians across the country. In addition, the emergency care system has also been standardized to improve the quality of care.

Once children are injured, their lives are threatened and several factors are associated with their survivals. These factors can be children's characteristics (e.g., age gender, weight, underlying disease), pre-hospital factors (e.g., mechanism of injuries, anatomic injured region, cause of injuries, type and duration of transportation, first aids, etc.), and hospital factors (e.g., type of trauma center, trauma care team, quality of emergency care, patient's physiologic reserve at arrival). These factors have been studied and used to develop clinical prediction scores to predict injury severity and survival probability. The scores should be helpful for emergency physicians and team in prioritizing needs of treatment management of injured children particularly in limited resource setting. Proper managements include type of trauma center, physician and team, and treatment interventions should be allocated according to the probability of survival. In addition, the scores should also guide whether children require to be hospitalized. As a result, poor outcomes from injured children (e.g., morbidity, disability, and mortality) should be decreased.

The most well know clinical prediction score in trauma is the trauma injury severity score (TRISS) (15). The score has been built by fitting the revised trauma score (RTS) and injury severity score (ISS) into the logit equation, in which the outcome variable was death (16-18). Since the score was developed using majorly adult subjects (~90%), the score's performances in children in term of calibration (reproducibility) and discrimination are still in doubt (19-20) since the physiologic reference ranges used for creating the RTS scores were adults' references. In addition, age was categorized as 55 years or older and thus applying this to children will result in no age effect. Therefore, the TRISS score was later modified and revised for children, called the Pediatric age-adjusted TRISS score (PAAT), by replacing the RTS with an age-specific pediatric trauma score (ASPTS) in the equation (21).

Although the PAAT score's performance in the original population was good, the score has some limitations as follows: the score has not been externally validated and thus validity for applying the score to different populations and countries is of concern. Survival probability in children age < 15 years is assumedly the same and thus age has been ignored in the equation. Four variables, which were Glasgow coma score (GCS), systolic blood pressure (SBP), pulse rate (PR), and respiratory rate (RR) were used in the ASPTS calculation. The SBP, PR, and RR were then categorized using their distribution mean and standard deviations (SD) and then coded 0, 1, 2, and 3, in which the lower code reflected abnormal values. In assigning coding for these variables much depended on each individual variable's distribution and thus could not be easily to applied to an individual patient in different population. The GCS was assessed based on three components (i.e., eye, verbal, and motor responses) and ranged from 0 to 15. This was also categorized into four groups and coded as 0, 1, 2, and 3. The codes for all variables were included in the PAAT equation as ordinal data and used the same weight for each variable, which might not be realistic. For instance, severe hypotension might be far worse than normal SBP and so the survival probability of this group might not be 3 x weight times lower than the normal group. The full components of GCS might also be the problem in assessment particularly in the verbal component, which was difficult to assess in children and or intubation. Recently, simplified to only one component (e.g. motor) may be used instead of the full GCS if the prediction performances are still good (22-25).

Another component considered in the PAAT equation was the ISS score. This score reflects anatomical severity, which was calculated by summing scores of the three most severely injured regions considering only one injured region out of six body regions (26). As a result, multiple injuries in the same body region are not considered, and so might not represent overall injured severities. The new injury severity score (NISS), calculated by summing the severity scores of the three most severe injuries regardless of body regions, has been developed and yielded better performance than the ISS and should be used instead off the ISS (27-28). However, the NISS did not consider the body-region effects, which were different severity by body regions.

An alternative for development of a clinical prediction equation is dealing with relevant variables by including original variables individually into the model rather than including them as scores (29). For instance, SBP, RR, PR, and GCS should be included in the equation rather than including the ASPTS score. This method is better since some individual variables may not be significantly associated with survival and thus should not be considered in the final score equation. Also the proper weight for each individual variable and its category can be estimated using coefficients of the logit model rather than simply assigning codes as 0, 1, 2, or 3.

The Pediatric trauma score (PTS) was importantly one of the injury prediction scores that seemed to have been properly implemented and had more specificity for children injuries than TRISS. It was also specifically designed for triage of the child with traumatic injury, which included management aspects such as suggestion to transfer. It correlated well with injury severity, mortality, resource utilization, and the need for transport to a pediatric center. It was calculated as the sum of six measures parameters such as weight, airway, systolic blood pressure (SBP), consciousness, fracture and wound. However, the score was poor performed in liver and spleen injuries in children with isolated blunt abdominal trauma because the model did not consider body regions (30-31). Because PTS was mostly specific to children, PTS was studied and various appropriate cut-offs were applied based on the previous variables, and assigned codes.

Tepas 1987 (32) had modified the original PTS by assign grading from -1, 1 and 2 (-1: major or immediate life threatening, 1: minor or potentially major injury, and 2: minimal or no injury) for each of six determinants. This was complied with standard advanced trauma life support protocol and thereby provided the quick assessment objectives which mandated not only accurate initial assessment, but also appropriated those differences of physiology which affected the potential of mortality. This suggested that the PTS of 6 or lower would increase risk of death as well as morbidity, and PTS less than 2 was definitely death. The PTS has been later calibrated the cutoffs of the score by Tepas & Ramenofsky 1988 (33) , Rosso 2012 (34, 34).

As for those mentioned reasons, addition with some other important variables (e.g., duration of transportation, type of injuries, pre-hospital airway management, trauma body regions, etcetera) have not been considered in previous scores but these might be important in our setting. This study was therefore conducted with the following research questions and objectives.

1.1 Research Question

- What variables were significantly associated with mortality in Pediatric trauma and injury?
- What variables should be contained in the simplified risk prediction score of death?
- Did our risk prediction score have better performances than previous pediatric injury scores, such as the original and modified PTSs?

PART II
OBJECTIVES

Primary Objectives

- To develop a simplified Thai-Pediatric trauma and injury score of death
- To assess the Thai-Pediatric trauma and injury score's performances
- To internally validate the Thai-Pediatric trauma and injury score
- To create scoring scheme of the Thai-Pediatric trauma and injury score
- To calibrate the Thai-Pediatric trauma and injury score cutoffs and stratify risk classification accordingly

Secondary Objective

- To compare our developed score's performance with original and modified PTSs

PART III
LITERATURE REVIEW

3.1 Burden of injury and trauma in children

In the past decade, pediatric injury and trauma has become a leading cause of morbidity and mortality in Thailand, as well as in other developed and developing countries. It is one of the most important causes of premature death, and represents 50% of all causes of deaths in children when correlated with infectious disease and other non-communicable diseases. The death rate from injury has fluctuated between 30% and 53% of total deaths in Thai children aged < 15 years as reported by the Bureau of Policy and Strategy, Ministry of Public Health, 2003-2007 (35). The injury death is one of the problems in Burden of Diseases that we need to prevent and improve quality of care, such as improved facilities of trauma care, and establish an injury surveillance system not only adults but also in children. From the Ministry of Public Health statistics, we found the mortality rate of children 0-19 years was 18.4 percent of total deaths in all age groups (7). As a result, many strategies had been developed to decrease mortality and morbidity from injury and trauma in children.

3.2 Concepts of injury severity score

Injury prediction score is an established medical score to assess trauma severity in aspects of mortality, morbidity and/or hospitalization time after trauma. The score is intended to give an accurate prediction which represents the patient's degree of severity of illness by integrating several important denominators (e.g., age, sex, injury types, injury mechanisms, co-morbidity, and etcetera) with a trustworthy statistical model. In fact, achieving this degree of accuracy might be unrealistic, and needed information is always lost in the process of score development. As a result, despite a myriad of scoring systems having been proposed, all of the previously useful injury prediction scores have both advantages and disadvantages. Part of the reason for such inaccuracy is the inherent anatomic and physiologic differences that exist between patients, age, sex, type, pre-existing or comorbidity of illness, mechanisms of injury and others. In order to improve accuracy to estimate patient outcome, we need to accurately quantify the patient's anatomic injury, physiologic injury, and any pre-existing medical problems, which might be impact on the patient's physiologic reserve and ability to respond to the stress of the injuries sustained.

Since 1987, Boyd (15) and Champion (16-18) have demonstrated and subsequently revised the predictive capacity of any model that increased accuracy by the inclusion of additional relevant information in the development of the TRISS.

Today, despite unreliability issues of this score which have been reported, this methodology is still commonly used as a standard of injury prediction score. It derived from combining between anatomical and physiological grading of injury severity (Injury Severity Score-ISS and Revised Trauma Score-RTS) with patient age in order to predict outcome of survival from trauma.

3.3 Pre-existing injury severity scores in children

3.3.1 Trauma Injury Severity Score (TRISS)

TRISS determines the probability of survival (Ps) of a patient from the ISS and RTS by using the following survival probability (Ps) equation (15):

- $Ps = 1/(1+e^{-b})$
- $e = 2.718282$

Where 'b' = b0 + b1 (RTS) + b2 (ISS) + b3 (age index)

The b0-b3 coefficients were derived from multiple logistic regression analysis of the Major Trauma Outcome Study (MTOS) database.

Age Index was "0" if the patient was below 54 years of age or "1" if 55 years and over, and b0 to b3 were coefficients, which were added on from different mechanisms of injury (blunt and penetrating trauma). If the patient was less than 15 years old, the blunt coefficients were used regardless of mechanism.

- Blunt injury:

  b0 = -1.2470, b1 = 0.9544, b2 = -0.0768, b3 = -1.9052

- Penetrating injury:

  b0 = -0.6029, b1 = 1.1430, b2 = -0.1516, b3 = -2.6676

From the above formula, TRISS determines the probability of survival (Ps) of a patient from the ISS and RTS. The score has served as the standard for outcome prediction in trauma for at least more than 20 years. The TRISS methodology aimed for two important objectives, i.e., injury severity prediction and performance improvement, and comparative among different injury care levels. TRISS seems to work well as predictive score to guide physician management especially in adult trauma.

However, it has several limitations to use as an outcome prediction in pediatric trauma populations for many reasons. First, the RTS used as physiologic assessment components of injury severity in TRISS methodology was based on adult physiologic based-parameters. These cannot apply to younger children because the pre-existing injuries data, which was used to develop this methodology was derived from population data which only contained 10.8% pediatric patients (age less than 15 years old). Demonstration of this problem can show the categorized age-group in TRISS also had problems to verify the developed cut-off age at 55 years old, by assigned age score equal “0” if patient’s age was less than 55 years old and score equal “1” if older than 55 years old. This means no age effect, if a patient’s age is less than 55 years old. There was lack of age effect in pediatric patients by using the lower value of area under curve from ROC from 0.92 to 0.87 when they applied the age effect into the model (36-37), but this issue is still unclear (21).

Second, the information of victims in the stage of TRISS methodology development excluded many severe conditions (e.g., the children who were intubated, burnt, sedated, had medical paralysis and other inter-hospital transfer factors), despite all of these injured patients were reported as a large proportion in the Trauma Audit & Research Network TARN database. If TRISS methodology did not include these conditions, it means that it excluded more seriously injured patients out of the model (selection bias), which had a chance to worsen outcomes more than the general trauma population (18, 38).

Third, the inconvenient usage of TRISS was the separated-coefficients for some type of injuries such as penetrating, blunt abdominal trauma and head injury. They have demonstrated strongly evidences to support non-universal TRISS methodology across types of injured mechanism. This methodology can only use one universal coefficient among each group of blunt abdominal trauma, penetrating injury and head injury. Third reason, TRISS is a tool which combines the ISS and RTS tools. The ISS may also contribute to inaccuracy when used with the pediatric age group. The ISS may under estimate the severity of coexisting injuries within a same body region, and it includes a variety of injury combinations within each numerical ISS value (18, 35, 36).

Fourth reason, the death outcome in TRISS may include deaths from non-trauma causes occurring more than 30 days after the injury. Some authors recommend using death within 30 days for a cut-off point of injury death.

Finally, there are no existing tools that consider consumer products (object related injury) and true mechanisms of injury in the previous prediction model despite they are important relevant associated injury parameters.

We can summarize that the main major usefulness of TRISS categorizes in two purposes. The first purpose is injury severity assessment into a score based system to guide the physicians to management of the injury. The second purpose is the evaluation of trauma system benefit among trauma networks as a standard quality assessment comparable index in the Trauma Audit & Research Network. The TRISS methodology has been widely criticized over the years, but it still remains valid and in common use. Although many authors have suggested new indicators, improving TRISS methodology represents a sound solution.

The other pre-existing of anatomic and/or physiologic injury prediction scores, which were developed earlier and have been used for injury prediction in the pediatric age group include such as Trauma Score (TS), Revised Trauma Score (RTS), Pediatric Trauma Score (PTS), Abbreviated Injury Scale (AIS), Injury Severity Score (ISS) and (PAAT). These parameters were also chosen and considered by physicians based on either anatomic or physiologic function or combination of both systems together. Along with these pre-existing injury scores, there were a wide range of parameters of good quality for use to categorize the severity of injury, management and to predict of the death/survival outcome.

3.3.2 Trauma Score (TS)

The TS includes five physiologic or physical examination components, including the Glasgow Coma Scale (GCS), which are scored and added together to determine the TS value and probability of survival (Table 3.1 and 3.2) (30). TS, mainly assesses key physiologic parameters after injury to help in the triaging of patients. The parameters used are respiratory rate, respiratory expansion, systolic blood pressure, capillary refill (return) and Glasgow Coma Score (GCS) The limitation was the usage of two subjective measurements (respiratory effort and capillary refill) and it underestimates severity in the patient with an isolated head injury who is cardiovascular stable (16, 17, 18, 30).

Trauma score = (points for respiratory rate) + (points for respiratory expansion) + (points for systolic blood pressure) + (points for capillary return) + (points for Glasgow Coma Score). The range of the score is a maximum score of 16 and a minimum score of one (30).

The design of TS included triage concerned aspects which is the advantage of TS , but it still has several disadvantages and so is not suitable for use in the pediatric age group especially two subjective variable measurements (capillary refill and respiratory effort) which were included in the TS model. It might be a cause of inaccurate prediction. Another disadvantage point is the underestimation of severity in the patient with an isolated head injury who is cardiovascular stable.

3.3.3 Revised Trauma Score (RTS)

The RTS was a third generation physiology based measure in mortality prediction models (17). It was developed to address some of the limitations of the TS. The subjective components were no longer are incorporated (Table 3.3). RTS has been used as a pre-hospital triage score, and it is one combined-part of TRISS methodology.

The sum of results in each category is assigned only if the count of RTS <12, which suggests the physicians should send the patient early to a trauma centre or high facilities center.

- Equation of RTS = 0.9368 GCS + 0.7326 systolic blood pressure + 0.2908 respiratory rate
- The results of this score range between 0 – 7.8408 , and correlate with survival, e.g. a score of 4 indicates 40% mortality

RTS is useful in pre-hospital scores and management aspects such as suggestion to transport patient, and addresses some of the limitations of the TS, and disused the subjective-components from the old TS. There are limitations to its use which come from component scores inside RTS, especially the GCS. The GCS also has limited utility in children, particularly those less than 36 months. In a patient who has an endotracheal tube in place, they cannot verbalize. A patient who receives paralytic and sedative medication has a chance to receive an invalid score which may effect to their prediction outcome. Other factors, shock, hypoxemia, drug use, alcohol intoxication and / or metabolic disturbances alter the patient's level of consciousness interfere with the scale's ability to precisely reflect the severity of a traumatic brain injury may alter the accuracy of prediction probability.

3.3.4 Pediatric Trauma Score (PTS)

The PTS (30-31) is patterned after the evaluation process of the Advanced Trauma Life Support Course and is specifically designed for triaging of the child with traumatic injury (37), and includes management aspects such as suggestion to transfer. PTS correlates well with injury severity, mortality, resource utilization, and the need for transport to a pediatric center. It is calculated as the sum of six measures (Table 3.4). However, it is a poor predictor of liver and spleen injuries for children with isolated blunt abdominal trauma (29).

Because PTS is mostly specific to children, PTS was studied by applying appropriate various cut-offs based on the previous variables, and assigning codes. Tepas 1987 (31) developed the original PTS with the six determinants of assigned grade from -1, 1 and 2 (-1: major or immediate life threatening, 1: minor or potentially major injury, and 2: minimal or no injury) which complied with standard advanced trauma life support protocol. This aims to provide a quick assessment objective which mandated not only accurate initial assessment, but also applied appropriate application of those differences of physiology which affected the potential for mortality. They summarized that a PTS of 6 and below has an increased potential for mortality as well as morbidity, and a PTS below 2 was 100 percent potential for death. One year later, Tepas & Ramenofsky 1988 (32) improved the quality of score by assigning PTS above 8 demonstrated zero percent mortality, with PTS 0 or below had 100 percent mortality, and PTS from 8 to 0 showed an increased linear relationship for mortality and clarified as immediate danger of increasing mortality without appropriate and timely intervention. Some advantages of the PTS score were easy to memorize, fast to apply and had a physiologic profile that enabled immediate decision making when coping with a pediatric trauma patient. Recently Rosso 2012 (33) modified the cut-offs of score (PTS between 9-12 was considered as moderate trauma, 4-8 assigned as severe trauma, 1-3 as a high risk of death, and -6 to 0 as improbable survival). Finally, Rosso in the same year modified PTS with a cut-off point of $\geq$ 3 or less to use as pediatric polytrauma score (34) which had both high specificity and high predictive value to accurately discriminate low risk cases (sensitivity 66%, specificity 94%, PV^+ 66% and PV^- 94%, mortality respectively for score less than 3).

3.3.5 Abbreviated Injury Scale (AIS)

AIS is an anatomical scoring system developed in 1969. The AIS has been revised and updated many times. The AIS scale is similar to the Organ Injury Scales introduced by the Organ Injury Scaling Committee of the American Association for the Surgery of Trauma, although AIS is designed to reflect the impact of a particular organ injury on patient outcome (Table 3.5).

Each injury is initially assigned an AIS score for six body regions (head, face, chest, abdomen, extremities and external). The AIS has been developed and frequently updated by the Association for the Advancement of Automotive Medicine which monitors the scale (38-39).

The disadvantages of the AIS scale are it does not provide a comprehensive measure of injury severity, and the scale does not represent a linear scale, i.e. the difference between AIS1 and AIS2 is not the same as the difference between AIS4 and AIS5. When we use AIS alone, the current AIS version is not useful for predicting patient outcomes or mortality. Instead, it forms the basis of the ISS and TRISS.

3.3.6 Injury Severity Score (ISS) and New Injury Severity Score (NISS)

The ISS was introduced to follow AIS in 1974 as a method for describing patients with multiple injuries and evaluating emergency care (40). It had been classed as the 'gold standard' of severity scoring before the TRISS era. Each injury is initially assigned an AIS score and only one from each of the six body regions (head, face, chest, abdomen, extremities and external). The highest three of the AIS scores (only one from each body region may be included) are squared and the ISS is the sum of these scores. Today, ISS is another added part of TRISS (41).

Disadvantages of ISS and NISS:

- Inaccurate AIS scores are carried forward.

- Many different injury patterns can yield similar ISS scores.

- It is not useful as a triaging tool.

- It only considers one injury per body region and therefore may underestimate the severity in trauma victims with multiple injuries affecting one body part.

- The NISS is a modified version of the ISS developed in 1997. The NISS sums the severity score for the top three AIS injuries regardless of the body region; hence, NISS scores greater than ISS values indicate multiple injuries in at least one body region.

Although the AIS do not reflect the combined effects of multiple injuries, it forms the foundation for the ISS. Baker et al introduced the ISS in 1974 as a means of summarizing multiple injuries in a single patient. The ISS is defined as the sum of squares of the highest AIS grade in the three most severely injured body regions. The six body regions are defined, as follows: the thorax, abdomen and visceral pelvis, head and neck, face, bony pelvis and extremities, and external structures. Only one injury per body region is allowed. The ISS ranges from 1-75, and an ISS of 75 is assigned to anyone with AIS of 6. That mean, if an injury is assigned an AIS of 6 (un-survivable injury), the ISS score is automatically assigned to 75. An example of an ISS calculation is showed in Table 3.6. The usefulness of the ISS is limited because it was not useful as a triaging tool, it may under estimate the severity on a multiple injured patient effected on one body region, and it is unable to adjust for the cumulative effect of coexisting injuries in one region (e.g., subdural hematoma and intraparenchymal hemorrhage), it lacks a direct linear relationship between increasing score and severity, and it lacks consideration of pre-existing conditions which may affect trauma outcomes (36, 42-43). Nonetheless, the ISS is a valid predictor of mortality, length of stay in the hospital or intensive care unit, and cost of trauma care. The American Academy of Pediatric uses the AIS descriptors of severity, but uses only four body regions: head/brain/spinal cord, thorax/neck, all other serious injuries, and all non-serious injuries (30).

Recently, Osler et al (26) reported a modified ISS (new ISS or NISS) based on the 3 most severe injuries regardless of body region. This simple but significant modification of the ISS avoids many of its previously acknowledged limitations. By preserving the AIS as the framework for injury severity scoring, the NISS remains familiar and user-friendly. Preliminary studies suggest that the NISS is a more accurate predictor of trauma mortality than the ISS, particularly in penetrating trauma. Other researchers have demonstrated that the NISS is superior to the ISS as a measure of tissue injury in predictive models of post-injury multiple oragan failure (MOF). Osler et al recommend that the NISS replace the ISS as the standard anatomic measure of injury severity.

3.3.7 Pediatric Age Adjusted TRISS (PAAT)

Development of PAAT

Schall LC et al (21) has recently developed the Age-Specific Pediatric Trauma Score (ASPTS) by adjusting age specific variables (SBP, Pulse, and RR) in conjunction with Injury Severity Score (ISS) for prediction of severity outcome (survival) which is called PAAT. The ASPTS is derived from SBP, pulse and RR for patient categorization using the mean and standard deviations (SD) which were then used to divided each physiologic variables (SBP, Pulse, and RR) into four intervals. The GCS intervals were modified from intervals which were the same as used for the RTS scheme. The intervals defined for each variable and coded scores (0-3) assigned to each interval have been shown in Table 3.7.

$$ASPTS = W_1GCS + W_2SBP + W_3PULSE + W_4RR$$

Where W_1 = 1.8945, W_2= 1.4366, W_3=0.5908, and W_4 = 0.1843. The W's represent weights derived from logistic regression.

- Ps = 1/(1+e-b)
- e = 2.718282

Where Ps is the probability of survival, and $A = b_0+b_1(ASPTS) + b_2(ISS)$,

b0 =-2.2949, b1=0.8416, b2=-0.5813

ASPTS is a continuous score 0-12.32, ISS is the sum of squares of the three highest AIS-90 grades in the three most severely injured areas among six anatomic regions and ranges from 0-75.

The studied results showed no significant difference between observed and expected survival, and might be more accurate than TRISS, and ASCOT which had significantly underestimated overall survival across age groups, blunt injuries and head injuries.

Previously seven Injury prediction scores have been used in the pediatric age group. Despite its imperfections, trauma severity scoring remains important for many reasons. A new Injury prediction score may reflect a significant improvement in methodology, but this requires several appropriate parameters and further validation (internal and external validation). Scoring systems applied in intensive care units are not useful for predicting survival for the individual injured patient. Many models are used for audit purposes, and some are used as performance measures and quality indicators of a unit or level of care. However, both utilities are controversial because of poor adjustment of these systems to case mixtures. Moreover, the pre-existing severity scores are being used for purposes, for which they were not intended (e.g., decisions to withdraw support or on the allocation of resources). Continued research hopefully will improve methodology and make accurate trauma prediction, particularly on an individual patient basis, and in reality.

3.4 Conceptual framework

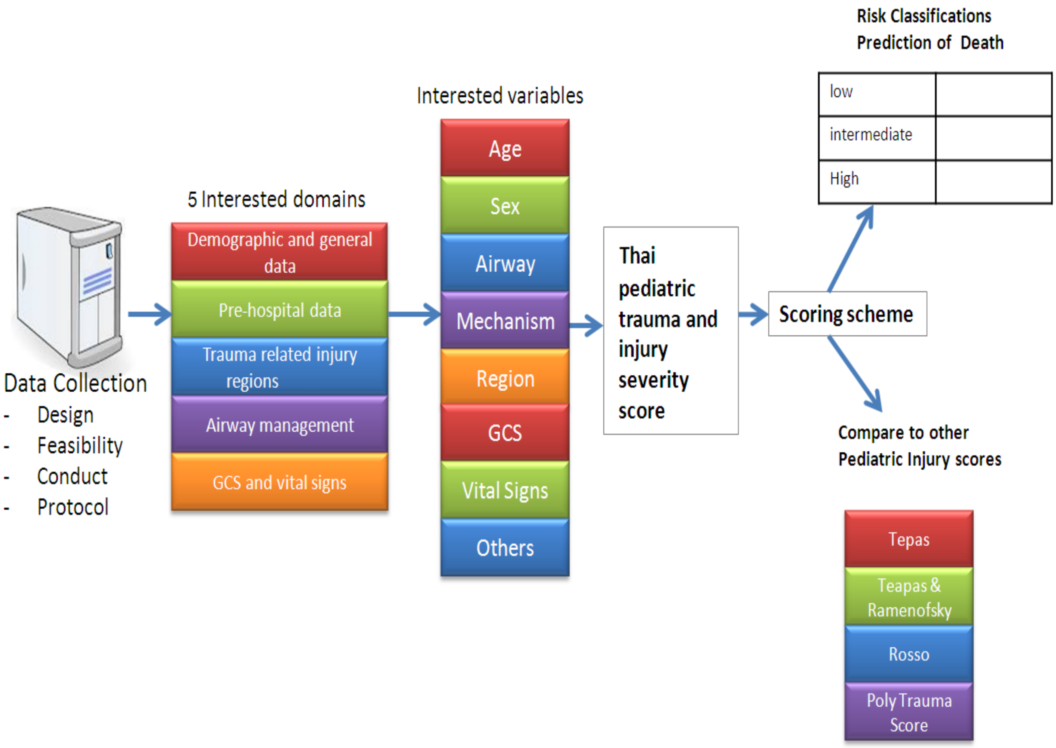

Figure 3.1 Conceptual framework

Table 3.1 Calculation of Trauma score

Parameter	Finding	Points
Respiratory rate	>= 36 per minute	2
	25-35 per minute	3
	10-24 per minute	4
	0-9 per minute	1
	Absent	0
Respiratory expansion	Normal	1
	Shallow	0
	Retractive	0
Systolic blood pressure	>= 90 mm Hg	4
	70-89 mm Hg	3
	50-69 mm Hg	2
	0-49 mm Hg	1
	absent pulse	0
Capillary return	Normal	2
	Delayed	1
	None	0
Glasgow Coma Score	14-15	5
	11-13	4
	8-10	3
	5-7	2
	3-4	1

Table 3.2 Trauma score and correlated probability of survival

Trauma Score	Probability of Survival
16	0.99
15	0.98
14	0.95
13	0.91
12	0.83
11	0.71
10	0.55
9	0.37
8	0.22
7	0.12
6	0.07
5	0.04
4	0.02
3	0.01
2	0
1	0

Table 3.3 Revised Trauma Score

GCS	Systolic BP(mmHg)	Respiratory rate	Score
13-15	>89	10-29	4
9-12	76-89	>29	3
6-8	50-75	6-9	2
4-5	1-49	1-5	1
3	0	0	0

Table 3.4 Pediatric Trauma Score

Systems	-1	+1	+2
Weight (Kg)	< 10	10-20	>20
Airway	Un-maintainable	Maintainable	Normal
Systolic BP(mmHg)	< 50	50-90	>90
Conscious Level	Coma	Deterioration	Normal
Wound	Large open wound	Small and closed wound	No
Musculoskeletal injury	Multiple, open fracture	Closed fracture	No fracture

The sum of score are classified as follows:

Tepas (1987) (31)

9 - 12 : they assign as minor trauma condition

6 - 8 : they assign as potentially life threatening condition

0 - 5 : they assign as life threatening condition

< 0 : they assigned as usually fatal condition

Tepas & Ramenofsky (1988) (33)

> 8 : Low risk

0 - 8 : Moderate risk, all injured children with PTS < 8 should be triaged to an appropriate pediatric trauma center.

< 0 : High mortality (100 % mortality)

Russo (2012) (34)

12 : No to low risk

9 - 11 : Moderate risk

4 - 8 : Severe trauma

1 - 3 : High risk

-6 - 0 : Fatal risk (improbable survival)

Pediatric Polytrauma Score (35)

< 3 : Low risk

≥ 3 : High risk

Table 3.5 Abbreviated Injury Scale (AIS)

Injury Threat	AIS Score
Minor	1
Moderate	2
Serious	3
Severe	4
Critical	5
Un-survivable	6

Table 3.6 Example of ISS Calculation

Region	Injury	AIS	ISS =(AIS^2)
Head/Neck	Single cerebral contusion	3	9
Face	No injury	0	
Chest	Flail chest	4	16
Abdomen	1. Liver laceration	4	25
	2. Completely shattered spleen	5	
Extremity	Fractured femur	3	
External	No injury	0	
		Injury Severity Score (ISS) = 50	

Note: ISS = Sum ((three most weighted region injury) ^{2}).

ISS equals 75 for any patient with an AIS 6 injury.

Table 3.7 Revised Age Specific Pediatric Trauma Score (ASPTS)

GCS Score	SBP	Pulse	RR	Scores
13-15	Normal	Normal	Normal	3
7-12	Mild-Moderate Hypotension (SBP< mean-2SD)	Tachycardia (Pulse > mean +SD)	Tachypnea (RR> mean + SD)	2
5-6	Severe Hypotension (SBP< mean -3 SD)	Bradycardia (Pulse < mean-SD)	Hypoventilation (RR < mean-SD)	1
3-4	0	0	0 or intubated	0

PART IV

METHODOLOGY

4.1 Study design and setting

This study was a multicenter cross-sectional study, which conducted between April 2010 and October 2012. The study was collaborative by the Thai Taskforce of Pediatric Injury (TTPI), i.e., Ramathibodi Hospital and other trauma care centers across the country, which aimed to set up the National Pediatric Injury & trauma Registry of Thailand (NPIRT). The numbers of hospitals have been described according to trauma care level and region, see Table 4.1. The level of trauma care was classified based on the national master plan for development and improvement of outcomes of accident and trauma care, 1998-2009, the Ministry of Public Health (MOPH). Among 837 hospitals across the country, 44 (19 School of Medicine hospitals and 25 regional hospitals), 70 (i.e., provincial hospitals), and 723 (i.e., district hospitals) were trauma level I, II, and III-IV, respectively.

We had initially invited 15 trauma care centers across 5 regions of Thailand to participate with this NPIRT in late 2010. Then, we were faced with flooding crisis in 2011 which made data registry far behind schedule and some trauma centers had their lost data. We therefore seek for the collaboration from the Bureau of Epidemiology, the MOPH, to be authorized accessing to the injury surveillance (IS) data registry. As a result, additional 19 hospitals from the SI were included and resulted in 34 hospitals which participated with this study. This consisted of 12 (47%), 11 (28%), and 11 (25%) hospitals for trauma care level I, II, and III-IV, respectively.

4.2 Studied population

Data for all of injured children who attended at emergency services at 34 collaborating hospitals during our study period were retrieved in our study. Patients were eligible if they met these criterion: aged 0-19 years, and had any of following trauma or injury: falling, struck by or against, cut and pierce, gunshot wound, animal bite, transport injury, injured from child abuses, burn and scald, fire-gun, foreign body aspiration, drowning or near drowning.

The study was approved by the Institutional Review Boards (IRBs) of the Faculty of Medicine Ramathibodi Hospital and MOPH.

4.3 Sample size estimation

We calculate sample size using results of review study at the level I-trauma care center at Chaingrai hospital, Chiangrai province, Thailand. Medical records between January and December 2009 were reviewed and there were 2,546 pediatric traumatic patients. Among them, 35 patients died (1.37%, 95% CI: 0.95%-1.91%). Sample size is estimated based on estimation of mortality rate (MR), as describe below.

$$\boldsymbol{N} = (\boldsymbol{Z}_{\left(\frac{\alpha}{2}\right)}{}^{2}\boldsymbol{pq}\,)/\,(\boldsymbol{CI\ width})^{2}$$

p = MR of injury in children

q = 1-p

CI = Confidence interval

As for the pilot study, 95% CI of the estimated MR varied from 0.95% to 1.91%. For the worse scenario, the estimated MR is set at 0.0095. The CI width of this estimation and design effect for multicenter collaboration are set of ± 0.005 and 0.2, respectively.

The estimated sample:

$$\begin{aligned} n &= \frac{1.96^2 \text{x}(0.009\text{x}0.9905)}{0.005^2} \\ &= 1445.93 \\ &= 1446 \end{aligned}$$

Taking into account design effect of 0.2, 7229.70 children were required to enroll.

Missing data of 25% was set and thus at least 9,037.13 children were required.

4.4 Data collection and management

The collaborative meeting between doctors and nurses who worked in the TTPI was organized. Research objectives were announced and roles of collaborative sites were demonstrated. Knowledge in pediatric injury and trauma and required variables were standardized. Data collections were performed based on the central web NPIRT database (http://pts.mahidol.ac.th), where all trauma cases had to be registered via our web site. The registration forms were designed, which consisted of 5 sequential domains as follow: patient demographic data, pre-hospital data, injury factors and associated risks (types and mechanism of injury, site of injury and injured body region), GCS and vital signs, diagnosis-disposition and outcome.

For the IS data, the databases were modified to comply with our NPIRT databases. Some variables were re-classified/coded and some variables were added. Totally there were 4 domains, which were demographic domain (age, sex, weight, height, occupation), pre-hospital care domain, injury factors and associated risks domain (injury epidemiology data, risk behaviors, transfer, injury body regions, vital signs), and domain of diagnosis to discharge data.

Web-databases were then constructed using PHP version 5.2.9 and MySQL client version 5.0.51a. The data from individual trauma care centers were entered real-time via the web-databases. The data quality control program was constructed as a web-based application based on coded variables, feasibility, and cross-checks in order to verify and validate data. All of these data were double checked by the database administration team.

Data were cleaned and checked by summarizing and cross-tabulating between the relevant variables to check for completeness and data validation. Inquiries were made to local collaborative sites if there was any incorrect or missing data. Medical records from each hospital were then retrieved to check and correct data.

4.5 Data Monitoring

Before conducting the study, the principal investigator from the central site visited all hospitals to check facilities, number of patients, and staff's knowledge about data collection and measurement. Data monitoring was performed at least once during data collection process. Internal audit was performed in every monitoring by randomly select 20% of subjects to check for completeness and validity. Common problems and solution for solving the problems were discussed to improve data collection system.

4.6 Outcome and independent variables

The outcome of interest was death related to injury or trauma within 30 days. The independent variables of 5 domains were as follows:

a) Demographic and general data consisted of age, sex, weight, height, occupational, and regions.

b) Pre-hospital data consisted of transport duration, prior communication, and trauma care level.

c) Mechanism of injury consisted of

- Surgical perspective mechanism
- Blunt (i.e. struck by against, abuse & neglect, etc)
- Penetrating (i.e. fire-gun, cut & pierce, animal bite, etc)
- Both blunt and penetrating
- Physiological mechanism
- Gravity related injury
- Velocity related injury
- Both gravity and velocity related injury

d) Trauma related injury region

- Brain & Head/Neck
- Face
- Thorax
- Abdomen
- Extremity of bone
- External (Soft tissue injury)

d) Airway management was categorized as no intervention, airway adjuncts which included oxygen supplementation, positive ambulatory bag, face mask ventilation and adjuncts airway with nasopharyngeal or oropharyngeal airway, and intubation.

e) GCS and vital signs domain,

- GCS was a quick, practical standardized system for assessing the degree of consciousness, involved eye opening, verbal response, and motor response, all of which are evaluated independently according to a rank order that indicates the level of consciousness and degree of dysfunction.

- The GCS was assessed numerically by the best response, improvement, stability, or deterioration of a trauma patient's level of consciousness, which was crucial to predicting the eventual outcome of conscious level. The sum of the numeric values for each parameter can also be used as an overall objective measurement which measures 3 parameters–maximum score of 15 for normal cerebral function, 0 for brain death. The higher score result reflected more severe of trauma and impaired of consciousness (44).
- Vital signs consisted of pulse rate (PR), systolic blood pressure (SBP), and respiratory rate (RR), which were measured at emergency room.
- The SBP were abnormally classified if SBP < 60 mmHg in neonates, SBP < 70 mmHg in Infants, SBP <70 mmHg + (2 x age in years) in children 1-10 years old, and < 90mmHg in children older than 10 years old; otherwise it was classified as normal (45).
- The PR was classified as tachycardia if PR>190/min if aged <=2 years old, PR >140/min in aged > 2-10 years old, and PR > 100/min in aged > 10 years old. Fatal tachycardia was defined as PR ≥ 220/min in infant (age < 1 years old) and PR ≥ 160/min in children aged ≥ 1 years old. Bradycardia was defined as PR < 60/min.
- The RR was classified as normal and tachypnea (normal RR classified as 30-60/min if age < 2 years old, 24-40/min in aged 1-3 years old, 22-34 /min in aged 4-5 years old, 18-30/min in aged 6-12 years old and 12-16 in aged > 12 years old, otherwise it was classified as tachypnea), and consciousness was consisted of awake, verbal response, pain stimulus, and unresponsiveness.

4.7 Previous risk prediction scores

There were 3 different versions of the PTS, in which the same of six variables were used for calculate scores but different cut-off points in classifying risk children. Six variables included weight, airway, SBP, consciousness, types of fracture, and wound; each of them was assigned grades of -1 for major or immediate life threatening, 1 for minor or potentially major injury, and 2 for minimal or no injury. The total score was then categorized using different cutoff points as follows:

The original PTS (Tepas 1987)

≤ 6 : increasing mortality as well as morbidity

≤ 2 : 100 percent risk of mortality

Tepas and Ramennofsky 1988

> 8 : 0 percent mortality

≤ 0 : 100 percent mortality

0 - 8 : i ncreased risk of mortality

Rosso DB 2012

9 - 12 : moderate trauma

4 - 8 : severe trauma

1 - 3 : high risk of death

-6 - 0 : improbable survival

Rosso DB (Pediatric poly trauma score)

In the same year Ross et al. also proposed this model to use as pediatric polytrauma score by modified PTS with a cut-off point of > 3 or ≤ 3 which had yield both high specificity and high predictive value for accurate discrimination of low risk cases (sensitivity 66%, specificity 94%, PV+ 66% and PV- 94%, mortality respectively for score less than 3)(34).

4.8 Statistical analysis

An overall death rate along with its 95% CI was estimated. Data analysis consisted of 2 phases, i.e., derive and validation phases as follows.

4.8.1 Derivation phase

The whole data of 43,516 were used, 21 variables (i.e., age, sex, weight, transportation time, airway management, velocity-gravity related mechanism of injury, mechanism of injury (blunt, penetrating, both), sites of injury, trauma body region(head-neck, face, thoracic, abdominal-pelvis, musculoskeletal, soft tissue injuries), wound types, fracture types, GCS, Vital signs (PR, SBP, RR and consciousness) were considered to include in the risk prediction model of death. A simple logistic regression was applied to assess the association between mortality and each of the 21 independent variables (46). The variables with p-value < 0.10 were simultaneously considered in multiple logistic model. To avoid multi-colinearity, variables which might be highly-correlated (e.g., sites of injury and injury body regions, wound types and soft tissue injury, and fracture-musculoskeletal injury) were GCS and vital signs domain not included into the same model; only one of each pair which was most significant was thus selected. The likelihood ratio (LR) test with backward elimination was used to determine the parsimonious model. Performance of the final model was then assessed by exploring calibration and discriminative performances. For the calibration, a goodness of fit of the final model was assessed by using Hosmer-Lemeshow test (46). In addition, a ratio of observe to expected values (O/E) were also estimated. A receive operating characteristic curve (ROC) analysis was applied to estimate the C-statistic.

The coefficients of variables in the final model were used to create scoring schemes. Total scores were calculated by summing up coefficients of all variables. The ROC curve analysis was applied to calibrate score's cutoff by estimating a likelihood ratio positive (LR^+) according to each cutoff. The prediction score was then classified into risk strategies to ease application in clinical practice.

4.8.2 Validation phase

Since the death rate was quite rare, the whole data were used for internal validation using the bootstrap with 200 repetitions. For each sample of the bootstrap, the final logistic model suggested from the derive phase was fitted, and parameters (i.e. predicted probability and the C-statistic) were estimated. The correlation between the observed and predicted values of death was assessed using the Somer'D correlation, called D_{boot}. The calibration of the model was then assessed by subtracting the original Somer'D correlation ($D_{orig)}$ from the D_{boot}(i.e., D_{orig}-D_{boot}), and the value closed to 0 was optimism calibration. Then discrimination of the model was also assessed by comparing the original C-statistic versusthe C-statistic from the bootstraps. (47-51)

Finally, the score performance was compared to the preexisting PTSs using ROC curve analysis. In addition, a net reclassification improvement (NRI) and integrated discrimination improvement (IDI) were also applied (52-53). These were used to analyze the strengths and advantages of this pediatric injury prediction score in the aspect of positive (net gain) and negative (net loss) to summarize in total net gain (sum of net gain and loss) from the results of the score predicting system with theirs cut-offs to obtain benefit in categories of survival and death outcomes, and compared among the preexisting pediatric injury scores. All analyses were performed using STATA 12.0 (54). P value < 0.05 was considered as statistically significant.

Table 4.1 Lists of collaborated hospitals by trauma care level (I-IV) and region.

Trauma care level *	No.Hospital	No.Studied hospitals	Region	Hospital	Subjects
Level I	44	12	Central	Ayuthaya Hospital	710
				Saraburi Hospital	1,122
				Sawanpracharak Hospital	1,603
			North	Chiangrai Regional Hospital	918
			North East	MaharatNakornratsima Hospital	2,832
				Khonkan Hospital	2,412
				Sappasitthiprasong Hospital	2,695
				Udonthani Hospital	2,899
			East	Chonburi Hospital	1,262
			South	Hatyai Hospital	1,236
				MaharatNakornsrithammaraj Hospital	1,778
				Ratchaburi Hospital	1,025
Level II	70	11	Bangkok,	Ramathibodi Hospital	2,354
			Central	NopparatHospital,andLerdsin Hospital	478
				PranangklaoNonthaburi Hospital	356
			Central	Buddhachinaraj Hospital	1,052
				Lampang Hospital	1,283
			North	Surin Hospital	2,414
			North East	Chophayaabhaibhubejhr Hospital	626
			East	PhrapokklaoChantaburi Hospital	828
				Suratthani Hospital	1,974
			South	Yala Hospital	1,076

Table 4.1 Lists of collaborated hospitals by trauma care level (I-IV) and region. (cont.)

Trauma care level *	**No.Hospital**	**No.Studied hospitals**	**Region**	**Hospital**	**Subjects**
Level III-IV	723	11	Central	ChaoprayayomrajSupanburi Hospital	758
				Nakornpathom Hospital	1,928
			North	Uttaradit Hospital	1,229
			North East	Burirum Hospital	130
			East	Chachoengsao Hospital	1,116
				Rayong Hospital	806
			South	Chumphon hospital	1,197
				Vachira Phuket Hospital	862
				Krabi Hospital	888
				Takuapa Hospital	316
				Trang Hospital	1,398
	837	34		Total	43,561

PART V

RESULTS

5.1 General characteristics of subjects

During the study period, data of 43,561 injured children who attended at emergency medical services of 34 studied hospitals were entered and retrieved from the databases. Of which, 13,382 (31%), 11,750 (30%), 7,529 (17%), 4,638 (11%), 3,430 (8%), and 2,832(7%) injured subjects were from the North-East, South, Central, East, North, and Bangkok, respectively (see Table 5.1). The baseline characteristics of subjects have been described in Table 5.1. Among them, mean age was 11.4 $\pm$ 5.5 years, and weight was 45 kg (range = 7-76), 71% were males. About 92% of patients injured mainly within their residential areas, 39% of cases were transferred by ambulance, and the rests were transferred by non-ambulance and their own transportations. About 47% had prior communication with the referral hospital before transportation of patients. About 51% of patients did not need the initial first aid at the scene of injury. Among 49% patients who required the first aids, 87% of them were provided initial first aid. The mechanisms of injury were mainly blunt (72%), followed by penetrating (14%) and non-classified (4%). Among the injury classification, the top five of common injuries were transportation (46%), falling (18%), cut and pierce (8%), struck by/ or against (8%), and abuse, assault & neglect (6%).

The estimated overall death rate was 1.7% (95% CI: 1.57-1.82), where the death rate was highest in the East region (2.41%, 95% CI: 1.97-2.85) but it was lowest in Bangkok (0.78%, 95% CI: 0.45-1.10). Among injury classification, cause of death was highest in drowning (8.0%) followed by weapon, fire-gun, bomb-explosion, or firework injury (2.6%), transportation (2.4%), burn and scald (2.3%), and poisoning (1.3%), respectively.

5.2 Derivation phase

The whole data of 43,561 subjects were used to derive the risk prediction score of death. A univariate analysis of 5 domains from 21 variables suggested that 20 variables were significantly associated with death, see Table 5.2. Five variables have not been considered in the multivariate analysis with following reasons. Since association between duration of transportation and death would depend on type of trauma, we rather did not consider this variable in the same model that had already considered type of trauma in the equation. The external soft tissue and musculoskeletal injury were highly associated with wound and fracture type, these variables were thus not considered in the multivariate model. A number of injury sites was also associated with injured body region; this variable was not included either. The consciousness which measured by AVPU system was highly associated with GCS system, and thus was not considered.

These 15 variables (i.e., age, sex, weight, airway intervention, velocity-gravity related mechanism, mechanism of injury, trauma body regions (head-neck injury, thorax injury, abdomen-pelvis injury), wound types, fracture types, GCS, SBP, PR, RR) were thus simultaneously included in the multivariate logit model, but only 10 variables were significant and thus kept in the final model, see Table 5.3. The logit equation was described in the Appendix A. The performances of risk score were evaluated by explore calibration and discrimination properties. The goodness of fit of the mode was assessed and found it fitted well with our data (Hosmer-Lemeshow Chi square = 13.64, d.f. = 5

p =0.092) with the O/E ratio of 0.86 (95%CI: 0.70-1.02). The model was also well in discriminate death from survive subjects with the C-statistic of 0.938 (95% CI: 0.929-0.947), see Figure 5.1.

For demographic domain, only age was significantly associated with death, by younger subjects were poorer prognoses than older subjects. This suggested that patients aged 1-5 and 6-12 years were 1.9 (95% CI: 1.4-2.6) and 3.0 times (95% CI: 2.0-4.3) respectively higher risk of death than patients aged 13-19 years.

Airway management was also affected on patient survival, subjects who were intubated were about 10.9 (95% CI: 8.6-13.7) higher odds of death than patients who were not intubated. An injured subjects with adjunct airway and support ventilation were about 3.3 (95% CI: 2.4-4.6) times higher odds of death than subjects who did not require the airway management.

The mechanism and region of injury domains were also significant risks factors of death, which included physical mechanism related injury (velocity and gravity forces) and injured region. For physical mechanism, gravity, velocity, and both related injuries were respectively 2.0 (95% CI: 1.4-3.0), 1.3 (95% CI: 1.0-1.7), 1.4 (95% CI: 1.1-1.9) times higher odds of death when compared to none velocity and gravity related injuries. Among injured regions, injured at head and abdomen were the most affected on death followed by thorax with the ORs of 5.0 (95% CI: 4.1-6.1), 5.0 (95% CI: 4.0-6.5) and 4.6 (95% CI: 3.5-6.0).

Subjects with GCS less than 9 were about 4.0 (95% CI: 3.2-5.1) times higher odds of death than subjects with GCS 9 or higher. All 3 variables in vital signs domain (i.e., abnormal vital signs for PR, RR, and SBP) were significantly associated with death. Injured subjects with bradycardia and tachycardia were respectively 11.3 (95% CI: 7.5-17.0) and 2.2 (95% CI: 1.8-2.8) significantly higher odds of death when compared to subjects with normal PR. The injured subjects with abnormal SBP and RR were 5.0 (95% CI: 3.9-6.4) and 2.2 (95% CI: 1.5-3.1) times higher odds of death than those subjects with normal range of RR and SBP.

Scoring scheme

The scoring scheme for each variable was created using its coefficient from the final model, see Table 5.4. Summation of each score yielded the total scores, which ranged from 0 to 15.16. Calibration of score cutoff was performed using ROC curve analysis and its result was described in detail in Appendix B. To ease of application in clinical practice and simplicity, the total score was classified into 4 risk strategies according to its performance and distribution, indicating the cutoff of 1.02, 1.96, and $\geq$ 3.06; which represented to low, intermediate, and high risk of death. The LR+ of these corresponding risk strategies were 1.26 (95% CI: 1.25-1.27), 2.47 (95% CI: 2.42-2.52), and 4.72 (95% CI: 4.57-4.88), respectively, see Table 5.5. The positive predictive values (PV^+) of these corresponding risk groups were 1.88% (95% CI: 1.74-2.04), 3.64% (95% CI: 3.36-3.94) and 6.73% (95% CI: 6.20-7.29), respectively.

The scoring scheme should be easy to apply in practice. For instance, a child aged 6 years was transferred by the ambulance to the ER of a 30 bed-hospital due to head injury from car accident. His PR was 140/min, RR was only 6/min, SBP was 100 mmHg, and thus he was on endotracheal intubation during transit and the GCS was 8 at ER arrival. He was scored 1.09 for aged 6 years, 2.39 for intubation, 0.36 for physical mechanism both velocity and gravity related injury, 1.61 for head injury and 0 for the remaining regions, 1.40 for in-hospital GCS < 9, 0.8 for PR 140 /min, 0 for SBP 100 mmHg, 0.89 for dyspnea, with spontaneous respiration 6/min. The total score was 8.54, which was classified as high risk of death with the LR^+ of 4.72 and PV^+ of 6.73%. This patient requires intensive care and aggressive management, and thus should be transferred to trauma care centre with better facilities as soon as possible if this 30-bed hospital cannot manage.

5.3 Validation phase

The bootstrap technique was applied to internally validate the risk score by re-sampling subjects with 200 replications from the whole original data. The Somer's D correlation coefficients were respectively 0.873 (95% CI: 0.872-0.875) and 0.872 (95% CI: 0.863- 0.881) for the bootstrap and original data, which yielded a percent error of only 0.20%. The estimated bias, (D_{origin}-.D_{boot}), was 0.0017 (95% CI: 0.0005-0.0030), which indicated low bias and thus the model was internally well calibrated. The estimated O/E ratio for the bootstrap data was 0.86 (95% CI: 0.70-1.02), and C-statistic of 0.938 (95% CI: 0.926-0.952).

5.4 Comparison of performances of prediction models

We compared our model to other previous models including Tepas score 1987, Tepasscore1988, Rosso score 2012, and pediatric polytrauma scores 2012 .The C-statistics were 0.876 (95% CI: 0.862-0.891), 0.876 (95% CI: 0.861-0.891), 0.893 (95% CI 0.879-0.908) and 0.874 (95% CI 0.860-0.888) for Tepas score 1987, Tepas score 1988, Rosso score 2012, and Pediatric Polytrauma scores 2012, respectively (see Table 5.7). The C-statistics of theses and our scores were statistically significant different ($p < 0.001$), see Figure 5.2. This indicated that our model was better in discrimination of death from survival subjects than the previous models.

The NRI was estimated by comparing our model with other 4 models. Probability of death estimated from each model was classified by mean of probabilities of death from each cut-offs of the previous scores, as described in Appendix C-F. The reclassification tables by death and survive groups were constructed for each comparison pair. As summaries in Table 5.6, reclassification results suggested that our model could improve in classification of subjects in both death and survival groups. The rate of improvements ranged from 4.4% to 13.6% in the death group, but loss 2.9% to gain 7.4% in the survival group. The overall NRIs were 19.7%, 18.0%, 16.2%, and 1.5 % when we compared ours to the Russo BD (2012), Tepas & Ramenofsky (1988), Tepas (1987), and Polytrauma score (2012), respectively. This indicated that our model was a bit better discriminative performance than all models, except the Polytrauma score (2012) in which the performance was not much different. In addition, our model also gained in discrimination when compared to preexisting models as previously mentioned with the IDI of 0.06 (95% CI: 0.03-0.09).

Table 5.1 Describe characteristics of subjects

Characteristics	N (%)
Number of subject	43,561
Demographic data	
Age, year, mean ±SD	11.37 + 5.52
Sex	
Male	30,883 (70.96)
Female	12,678 (29.10)
Weight, Kg, median (min-max)	45(7-76)
Occupation	
Parent care	7,513 (17.25)
Student	25,790 (59.25)
Other	10,258 (23.50)

Table 5.1 Describe characteristics of subjects (cont.)

Characteristics	**N (%)**
Regions	
Bangkok	2,832 (6.50)
Central	7,529 (17.28)
North	3,430 (7.87)
North-East,	13,382 (30.72)
East	4,638 (10.65)
South	11,750 (26.97)
Injury location	
Resident province	40,210 (92.33)
non-resident province	3,342 (7.67)
Pre-hospital information	
Transfer route	
Own transport	12,483 (28.66)
Non-Ambulance	14,137 (32.45)
Ambulance	16,941 (38.89)
Prior communication	
Yes	23,120 (53.07)
No	20,441 (46.93)
Trauma level	
I	20,492 (47.04)
II	12,441 (28.56)
II	7,220 (17.57)
IV	3,408 (7.82)
Pre-hospital support	
Not need	22,248 (51.07)
Not provide	2,812 (6.46)
Provide	18,498 (42.47)

Injury types and mechanism	
Injury Mechanisms	
Blunt	31,482 (72.27)
Penetrate	5,940 (13.64)
Both	1,943 (4.46)
Non-classify	4,196 (9.63)
Physical mechanisms	
Velocity related	1,528 (8.75)
Gravity related	8,191 (19.44)
Both	22,003 (52.21)
Non-classified	10,368 (24.60)
Types of injury:	
Transportation	19,928 (45.75)
Falling	7,902 (18.14)
Poisoning	461 (1.06)
Animal Bite &Sting	1,641 (3.77)
Struck by against	3,426 (7.86)
Cut &pierce	3,502 (8.04)
Burn & Scald	1,005 (2.31)
Fire gun & explosion	1,582 (3.63)
FB Aspiration & suffocation	1,359 (3.12)
Drowning & Submersion	355 (0.81)
Abuse, assault & neglect	2,400 (5.51)
Object related injury:	
Chemical &Food product	801 (1.84)
Home & Office, Work place	12,730 (29.22)
Sport equipment	639 (1.47)
Weapons	2,047 (4.70)
Transportation related	20,317 (46.64)
Natural objects - animal	3,3362 (7.72)
Miscellaneous	3,664 (8.41)
Length of stay, day, median (range)	2 (0-63)

Outcomes	
Major outcome	
Survive	42,821 (98.30)
Death	740 (1.70)
Short term disabilities	
Minor outcome	
Major	1,862 (4.40)
Minor	3,624 (8.40)
None	37,334 (87.20)

Table 5.2 Factors associated with death in pediatric trauma and injury: A univariate analysis

Factors	Group				
	Death	**Survive**	**OR**	**95%CI**	**P value**
	n = %	**n = %**			
Demographics domain					
Age, year					
0 - 5	113(1.2)	9,342(98.8)	1.8	1.4-2.4	< 0.001
6 - 12	131(1.2)	10,478(98.8)	3.0	2.1-4.3	
13 – 19	496(2.1)	23,001(97.9)	1		
Sex					
Female	175(1.4)	12,503(98.6)	1		0.001
Male	565(1.8)	30,318(98.2)	1.3	1.1-1.6	
Weight, kilogram					
≤ 25	147(1.2)	12,335(98.8)	1		< 0.001
26 - 45	134(1.3)	9,909(98.7)	1.1	0.9-1.4	
46 - 55	227(2.1)	10,504(97.8)	1.8	1.5-2.2	
> 55	232(2.3)	10,073(97.8)	1.9	1.6-2.4	

Pre-hospital domain					
Duration of transport, hour					
≤ 1	142(1.7)	8,312(98.3)	1.2	0.9-1.5	0.001
1 - 2	299(2.0)	14,443(98.0)	1.5	1.2-1.8	
2 - 3	138(1.6)	8,555(98.4)	1.2	0.9-1.5	
> 3	161(1.4)	11,511(98.6)	1		
Airway management domain					
No intervention	224(0.6)	38,704(99.4)	1		< 0.001
Adjuncts	81(3.9)	1,975(96.1)	7.1	5.5-9.2	
Intubation	435(16.9)	2,141(83.1)	35.1	29.7-41.5	
Mechanisms and injury regions domain					
Velocity-Gravity Related mechanism					
Velocity Related	41(2.6)	1,541(97.4)	3.0	2.0-4.3	< 0.001
Gravity Related	97(1.2)	8,160(98.8)	1.3	1.0-1.8	
Both	510(2.2)	22,844(97.8)	2.5	2.0-3.1	
None	92(0.9)	10,276(99.1)	1		
Mechanism of injury					
Penetrating	69(1.2)	5,871(98.8)	1		< 0.001
Blunt	536(1.7)	30,946(98.3)	1.5	1.1-1.9	
Both	56(2.9)	1,887(97.1)	2.5	1.8-3.6	
Non-Classified	79(1.9)	4,117(98.1)	1.6	1.2-2.3	

Table 5.2 Factors associated with death in pediatric trauma and injury: A univariate analysis (cont.)

Factors	Group				
	Death (n = %)	Survive(n = %)	OR	95%CI	P value
Sites of Injury, sites					
0	82(2.2)	3,636(97.8)	1		< 0.001
1	168(0.7)	25,519(99.4)	0.3	0.2-0.4	
2	159(1.8)	8,579(98.2)	0.8	0.6-1.1	
≥ 3	331(6.1)	5,087(93.9)	2.9	2.3-3.7	
Trauma body region					
Brain/Head-Neck					
Yes	527(4.8)	10,355(95.2)	7.8	6.6-9.1	< 0.001
No	213(0.6)	32,466(99.4)	1		
Face Region					
Yes	43(1.5)	2,903(98.5)	0.8	0.6-1.2	0.298*
No	697(1.7)	39,918(98.3)	1		
Thoracic Region					
Yes	124(13.1)	821(86.9)	10.3	8.4-12.6	< 0.001
No	616(1.4)	42,000(98.5)	1		
Abdomen-Pelvis Region					
Yes	143(7.6)	1,743(92.4)	5.6	4.7-6.8	< 0.001
No	597(1.4)	41,074(98.6)	1		

Table 5.2 Factors associated with death in pediatric trauma and injury: A univariate analysis (cont.)

Factors	Group				
	Death	**Survive**	**OR**	**95%CI**	**P value**
	n = %	**n = %**			
Musculoskeletal Region					
Yes	161(0.9)	18,045(99.1)	0.4	0.3-0.5	< 0.001
No	579(2.3)	24,776(97.7)	1		
External Soft tissues Region					
Yes	171(1.0)	16,196(99.0)	0.5	0.4-0.6	< 0.001
No	569(2.1)	39,918(97.9)	1		
Wound types					
Large-open (major)	449(2.7)	16,195(97.3)	2.0	1.5-2.7	< 0.001
Small closed (minor)	247(1.0)	23,466(99.0)	0.8	0.5-1.0	
None	44(1.4)	3,160(98.6)	1		
Fracture types					
Open/Multiple Fracture	115(4.0)	2,756(96.0)	2.5	2.0-3.0	< 0.001
Single Fracture	198(1.3)	14,962(98.7)	0.8	0.7-0.9	
No Fracture	427(1.7)	25,103(98.3)	1		

Severity domain					
Total GCS In-Hospital					
< 9	389(18.6)	1,700(81.4)	26.8	22.9-31.4	< 0.001
≥ 9	351(0.9)	41,121(99.1)	1		
Musculoskeletal Region	161(0.9)	18,045(99.1)	0.4	0.3-0.5	< 0.001
Yes	579(2.3)	24,776(97.7)	1		
No					
External Soft tissues Region					
Yes	171(1.0)	16,196(99.0)	0.5	0.4-0.6	< 0.001
No	569(2.1)	39,918(97.9)	1		
RR					
Tachypnea	611(2.1)	28,986(97.9)	2.3	1.9-2.7	< 0.001
Normal	129(0.9)	13,835(99.1)	1		
Consciousness(AVPU)					
Awake	313(0.8)	39,722(99.2)	1		< 0.001
Verbal	33(2.8)	1,161(97.2)	3.6	2.5-5.2	
Pain stimulus	30(7.4)	377(92.6)	10.1	6.8-14.9	
Unresponsiveness	364(19.0)	1,561(81.1)	29.6	25.0-35.0	

Table 5.3 Multivariate logistic regression of factors associated with death outcome

Factors	Coefficient	SE	P value	OR (95 % CI)
Age, years				
≤ 5	0.65	0.16	<0.001	1.9 (1.4-2.6)
6 - 12	1.09	0.19	<0.001	3.0 (2.0-4.3)
13 - 19				1
Airway management				
ET Intubation	2.39	0.12	<0.001	10.9(8.6-13.7)
Adjuncts	1.21	0.16	<0.001	3.3 (2.4-4.6)
None				1
Physical mechanism				
Velocity related	0.24	0.14	0.08	1.3 (1.0-1.7)
Gravity related	0.71	0.20	<0.001	2.0 (1.4-3.0)
Both	0.36	0.15	0.013	1.4 (1.1-1.9)
None				1
Head-Neck injury				
Yes	1.61	0.10	<0.001	5.0 (4.1-6.1)
No				1
Thorax injury				
Yes	1.52	0.14	<0.001	4.6 (3.5-6.0)
No				1
Abdomen-pelvis injury				
Yes	1.62	0.13	<0.001	5.0 (4.0-6.5)
No				1

GCS				
< 9	1.40	0.12	<0.001	4.0 (3.2-5.1)
≥ 9				1
PR				
Bradycardia	2.42	0.21	<0.001	11.3 (7.5-17.0)
Tachycardia	0.80	0.11	<0.001	2.2 (1.8-2.8)
Normal				1
SBP				
Abnormal	1.61	0.12	<0.001	5.0 (3.9-6.4)
Normal				1
RR				
Abnormal	0.79	0.21	<0.001	2.2 (1.5-3.1)
Normal				1

Table 5.4 Creating Thai Pediatric trauma and injury scoring scheme

Factors	Score
1) **Age, years**	
≤ 5	0.65
6 - 12	1.09
≥ 13	0
2) **Airway**	
Intubation	2.39
Adjuncts	1.21
No intervention	0
3) **Physical Mechanisms**	
Pure Velocity	0.24
Pure Gravity	0.71
Both	0.36
None	0
4) **Head-Neck injury**	
Yes	1.61
No	0
5) **Thoracic injury**	
Yes	1.52
No	0
6) **Abdomen-Pelvis injury**	
Yes	1.62
No	0
7) GCS	
< 9	1.40
≥ 9	0

Table 5.4 Creating Thai Pediatric trauma and injury scoring scheme (cont.)

Factors	Score
8) **Pulse rate**	
Bradycardia	2.42
Tachycardia	0.80
Normal	0
9) **Respiratory rate**	
Abnormal	0.79
Normal	0
10) **Systolic blood pressure**	
Abnormal	1.61
Normal	0
Total	**0-15.16**

Table 5.5 Risk classification of death by Thai Pediatric trauma and injury score.

Score cut-off	Risk groups	Score Development discrimination capacities					
		Outcome		Sensitivity (%)	Specificity (%)	LR^+(95% CI)	PV^+ (%)
		Death	Survive				
<1.02	Very low	1	8,559				
≥1.02	Low	25	16,862	99.84	20.61	1.26 (1.25-1.27)	1.88 (1.74-2.04)
≥1.96	Intermediate	42	8,244	95.90	61.24	2.47 (2.42-2.52)	3.64 (3.36-3.94)
≥3.06	High	566	7,845	89.3	81.00	4.72 (4.57-4.88)	6.73 (6.20-7.29)

LR^+, likelihood ratio positive; PV^+, positive predictive value

Table 5.6. Comparison of model's performances between our and other models

Models	**ROC Area**	**95 %CI**	**Survive** RI	**Death** RI	**NRI** (95% CI)
Thai-PedTRISS	0.938	0.929-0.947	-	-	-
Tepas (1987)	0.876	0.862-0.891	+0.0564	+0.1057	+0.1621 (0.1122-0.2120)
Tepas&Ramenofsky(1988)	0.876	0.861-0.891	+0.0740	+0.1056	+0.1797 (0.1298-0.2296)
Russo BD (2012)	0.893	0.879-0.908	+0.0609	+0.1357	+0.1965 (0.1326-0.2604)
Pediatric Polytrauma (2012)	0.874	0.860-0.888	- 0.0294	+0.0442	+0.0148 (-0.0367-0.0663)

NRI, net reclassification improvement; RI, reclassification improvement

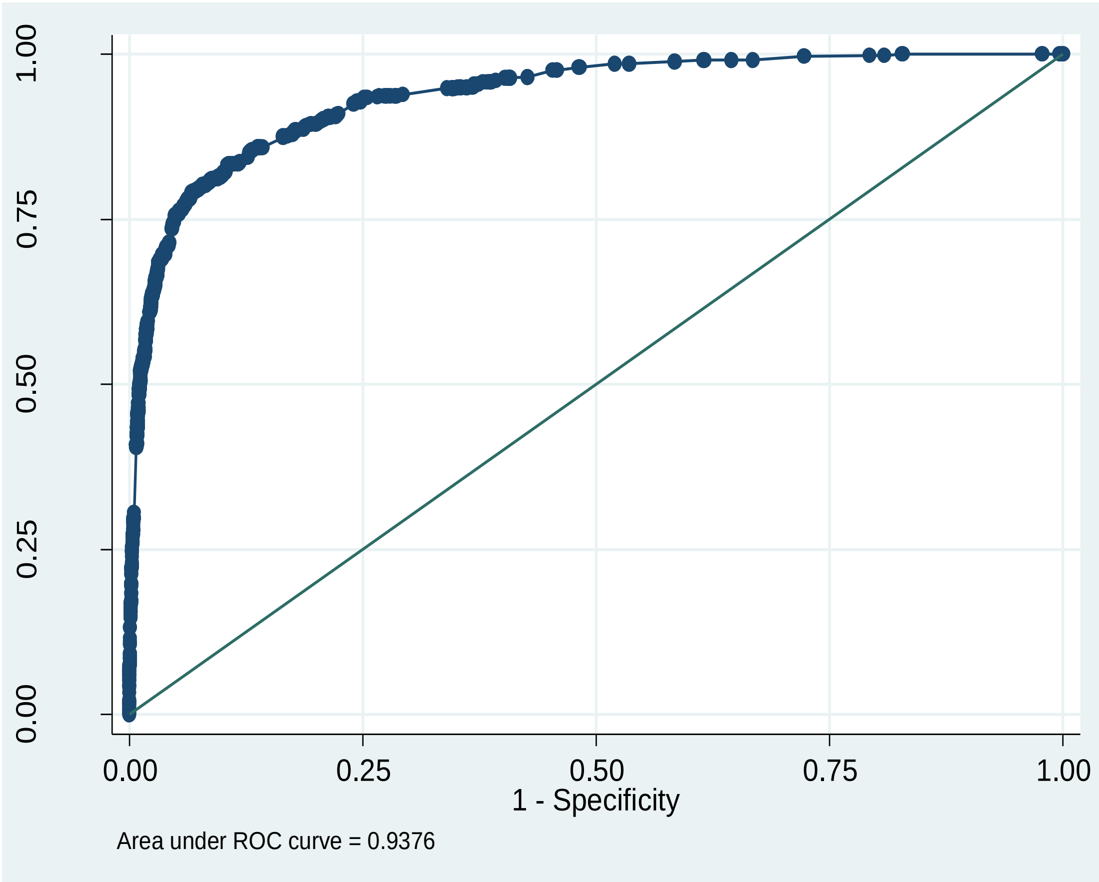

Figure 5.1 Receiver-operator characteristic (ROC) curve of death according to point of Thai Pediatric trauma and injury score in derivation data set.

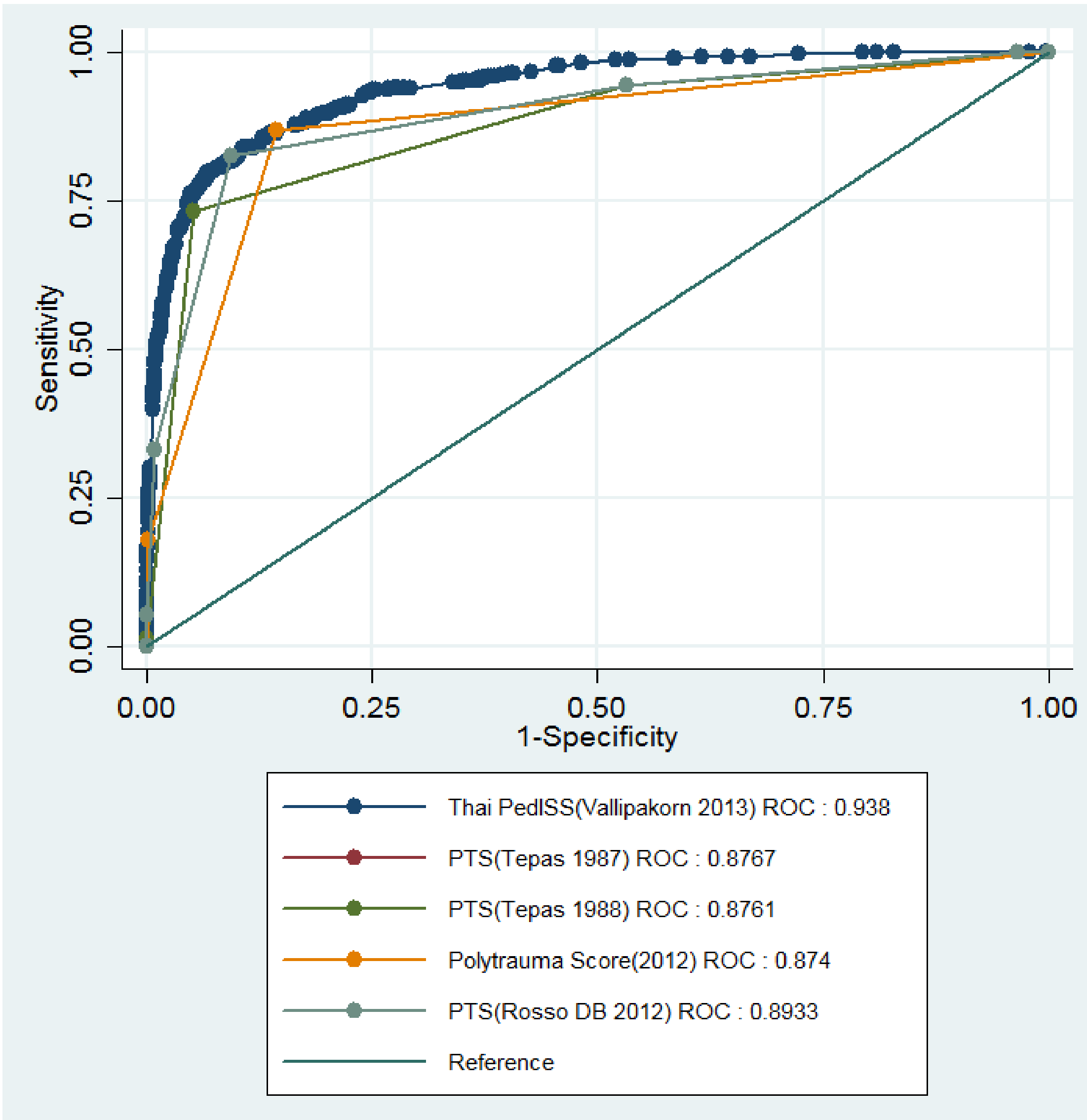

Figure 5.2 Comparisons of C-statistics between Thai Pediatric trauma and injury score and other previous scores.

PART VI

CONCLUSION & DISCUSSION

6.1 General findings

We performed a cross-sectional study by including 43,561 children with injury and trauma from 34 hospitals across the country. The most common injuries were transportation, falling, and cut and pierce, whereas the most common mechanism was blunt. The estimated overall death rate was 1.7%, and the highest was in the Eastern region (2.4%), but it was lowest in Bangkok (0.78 %). The cause of death was highest in drowning (8.0 %) followed by weapon, fire-gun, bomb-explosion, or firework injury (2.6%), and transportation (2.4%). The risk prediction score of death was derived and indicated that 10 variables were significantly associated with death, which were age, intubation, physical mechanism, injured at head, abdomen, and thorax, GCS, PR, RR, and SBP. The derived model fitted well with the data and also gave good discrimination of death from survival subjects with the C statistic of 0.938 (95% CI: 0.929-0.947), and 0.938 (95% CI: 0.926-0.952), in the derived and internally validated data, respectively. The simplified Thai-Pediatric trauma and injury scoring scheme was created, indicating that children whose score exceeded about 3 would have high risk of death.

In Thailand, emergency medicine has developed since 2005, but the services systems have not yet covered all specialties, particularly in Pediatric Emergency Medicine, e.g., injury and trauma care service. These constraints are mostly due to lack of human resources, man power, medical equipment and supply, budget, and knowledge. Most trauma and injured children are treated by general or emergency physicians, not pediatricians who specialize in trauma care. Moreover, a well organized and maintained trauma/injury data registry in children still needs to be setup, which will be useful in aiding clinical decisions on allocation of treatment managements. Our study should lead to set up the data registry which covers important variables to create risk prediction models and severity grading systems. However, friendly software of the risk prediction model needs to be developed to encourage health personnel in emergency settings to use it in routine practice. For user friendly and increased of robustness, Maungkaew et al (2013) studied and established an artificial neural network system with web based application to support the decisions of treatment and decrease mortality rate in injured children (55).

6.2 Our versus previous risk scores

For more than 2 decades, many risk prediction scores of death in trauma patients have been developed mainly focusing on adult traumas, but some scores have been specifically studied in children, e.g. PTS (30-32), PAAT (21), NISS (28,41). The PTS, originally developed in children, considered 6 variables (i.e., weight, airway, SBP, level of conscious, fracture and extremities' lesion), in which 3 variables were similar (i.e., airway, GCS, and SBP) to our model, but the rest of the variables were not found as significant predictors. Our model has also added more 7 significant variables (i.e., age, physical mechanism, 3 injured body regions (head-neck, thorax, and abdomen-pelvis), PR, and RR) which were not considered in the PTS. Our model has considered individual body regions and thus multiple injuries rather than single injury. Each region was weighted differently following the suggestion of logistic regression. In addition, we also considered a mechanism of injury in the model, PR, and RR. For the PR, we considered bradycardia, tachycardia, and normal which gave more detail than just considered as abnormal vs. normal PR. As a result, our risk score was superior than the PTS (31-32), and other which modified score cut offs of PTS (33-34).

The PAAT (21) later modified the TRISS in pediatric patients, but it has not been externally validated. It was also not ease to apply in general, because it used a standardized (z-score) systolic blood pressure in the model which was not easy to calculate at an accident scene, and also the z-score was based on the US database. As a result, applying the PAAT to Thai or other children universally is still questionable in its performances.

The NISS was specifically developed in children by modifying the ISS (27-28, 56-58). The original ISS dealt with body regions using the AIS approach, which classified the severity score of body regions (i.e., head, face, chest, abdomen, extremities and external soft tissue) into 1 to 6 (minor to un-survival). Each region was considered only once and only the 3 highest AIS scores were summed and considered in the ISS. Therefore, multiple trauma or injuries in the same region were ignored and would result in under estimate of severity. The NISS later tried to solve the ISS limitation by considering the 3 highest AIS summed scores regardless of the body regions and its performance was better than the ISS; particularly in penetrating trauma and measurement of tissue injury in multiple organ failure. The disadvantage of ISS and NISS in inaccurate AIS scores is still carried forward, different injury patterns and organ systems can yield similar ISS scores in spite of different severity. Difficulties of coding and comprehensive detailed requirements are not easy and thus useful as a triage tool. The NISS ranges from 1-75, in which the AIS of 6 automatically resulted in the NISS of 75, despite that organ looks very severe, but not necessarily always fatal. Although the NISS is promising, it has not yet been commonly included in the TRISS (37-38).

The TRISS is one of the popular scores that has been used in adult trauma and injury. The score determines the probability of survival using RTS and ISS. Despite TRISS seems to work well to guide physician managements especially in adult trauma, we found some limitations of applying the scores in children. First, the RTS (i.e., physiologic assessment) used in the equation was adult-reference physiologic based-parameters that could not directly apply to children. The age group in the TRISS was originally designed for adults (i.e., > 55 and < 55 years) which meant no effect of age if applying in children. In addition, some important variables (i.e., airway management and other inter-hospital transfer factors) were not considered in the TRISS model (18, 36).

6.3 Risk factors of death

The effect of airway management on death in our model was similar to the PTS, i.e., intubation was worse prognosis by about 10 times higher risk of death than non-intubation. This could be explained by the fact that patients with intubation were more severe than patients without intubation and thus they had higher risk of death. Because the mild to severe case of injured children usually recommends to support with oxygen and ventilation due to poor physiologic reserve, and easily prone to y hypoxemia and hypoventilation, although they only have simple upper airway obstruction. The airway manipulation such as adjuncts of airway (promote airway patency through ventilation support by facemask and an ambu-bag with or without oxygen supplementation) are simple supportive techniques which can restore oxygenation and ventilation to children. If children are categorized in severe injury condition, the chance to rapidly worsen ventilation and oxygenation can occur anytime. These are need endotracheal intubation and ventilation support.

The level of conscious measured by the GCS was also an important variable to predict death. The GCS higher than 9 was as high as 2.8 times higher risk of death than the GCS lower than 9. This corresponded with findings by Cicero, et al (59), which found that only the GCS and Glasgow motor component could predict pre-hospital and on arrival death.

We considered vital signs by categorizing them as low, normal, and high; not abnormal and normal groups such the PTS did, because the physiological mechanism responses of low and high levels of vital signs were different and thus should result in different effects. We found as we expected for PR, but not for RR and SBP, i.e., bradycardia was far worst effect than tachycardia, i.e., about 11 and 2 times higher risk of death than normal PR. For RR and SBP, the effects of low and high were similar and we thus combined them as abnormal RR and SBP.

The SBP in our model showed high association with death outcome, because most traumatic injuries usually cause blood loss, and because children have poor physiologic reserve. Also when the child has a problem with potential respiratory distress, or respiratory failure, they can become worse leading to hypotension and cardiopulmonary arrest more easily than adults (45).

Our model also found that age was one important predictor of death with the odds of about 2 to 3 times higher odds in age ≤ 5 and 6-12 than 13-19 years. This indicated that younger children were more risky when they had trauma or injury than older children. Only the PAAT accounted for age effects via ASPTS, whereas the PTS did not. A trend of age effect was opposite to the finding by Nance ML et al (2010) (60) , which showed younger age had a protective effect when compared with older age of 13-15 years. These different results might be explained by different age groups may be exposed to different types of trauma and injury and thus resulted in different severity and risks of death. In addition, different countries had differences in legal policy for vehicles and road traffic safety which may indirectly affect children.

Previous predictions scores had considered conventional mechanism of injury (which was based on surgical perspective and indirect consequences of injury), as blunt and penetrating, but this was not found significantly associated with death in our score. Contrastingly, we found that considering physical mechanism (which more directly caused injury), as velocity and gravity force related injury was significantly associated with death; and thus this was added in the score, instead of blunt and penetrating injury. Our results showed higher odds of death in gravity than velocity related injury. For this reason, the gravity and velocity related injuries were characterized as original combined direct forces which could predict the outcome of injury better than other type of injuries. The momentum is an original physical force, which is the object's mass multiplied by velocity (mass x velocity), so the larger mass and high velocity had a chance to produce more dangerous injury or a higher chance of death. This is why gravity is directly related to injury. In a vertical fall, the velocity increases with the height due to gravity. This theoretical reason might explain why velocity in vertical line (i.e., gravity) correlated with the outcome of death.

The injured body region at head-neck, thorax, and abdominal-pelvis, were also important risk factors of death. It was found that these injured regions moderately affected death with the ORs about 4.6 to 5.0. Our model considered the injured regions individually and let data from logistic regression suggest which region was significantly important risk, and how it should be weighted in the final score. Among 6 injured regions, only 3 regions were significant risks and thus they were kept in the final score whereas the other 3 regions (face, soft tissue, and musculoskeletal regions) were eliminated. Calculation of the score was straight forward by weighting about 1.61, 1.62, and 1.52 for head-neck, abdominal-pelvis, and thorax regions, respectively. This did not require extra calculations such as other scores (e.g., AIS, ISS and TRISS) did, which were prone to error calculation. Although we did not consider the number of injured sites because of multicolinearity with injured regions, considering individual regions would reflect and capture the number of injured sites indirectly. As expected, injury of vital human organs was more severe and risk to death than minor organs.

Vital signs were the most important risk factors of death particularly PR and SBP. For the PR, bradycardia was about 11 times higher odds whereas it was about 2 times higher odds for tachycardia when compared to normal PR. Bradycardia was an ominous sign of higher severity effect from injury. In normal situations, the PR would increase once the child was injured. This would be a warning sign to early administer treatment and intervention as soon as possible. If management was delayed and the body could not compensate any more, it would change to bradycardia and blood pressure would drop or turn to shock stage if proper treatment and management had not yet been administered.

6.4 Calibration of scoring cutoff

The ROC curve analysis was used to calibrate score cutoffs. A discrimination capability of each score was identified using LR^+, which was a ratio of sensitivity versus 1-specificity. This parameter has been suggested to use in diagnostic study which aims to select the new test because it has incorporated and accounted for 2 parameters (sensitivity and specificity) at once (61). In addition, the LR^+ does not depend on the prevalence/incidence of interested events like the PV^+ does. The LR^+ indicated how much given the score cutoff would increase the pretest probability (or prevalence) of death. Following a recommendation of User's Guides for Evidence-based Medicine, the LR+ of ≥ 10, 5-

10, 2-5, and 1-2 are respectively classified as conclusive, moderate, small but sometimes important, and very small changes of pretest probability of death. Our results suggested 3 cutoffs, i.e., ≥ 1.02, ≥ 1.96, and ≥ 3.06 with the LR+ of 1.26, 2.47, and 4.72, respectively (62). We named these corresponding cutoffs as low, intermediate, and high risk of death, respectively. Children in the high risk group were about 5 times more likely to die than survive. Although our LR+ did not reach to 10, it could moderately shift the pretest of death from about 1.5% to 6.7%.

6.5 Use of Thai Pediatric trauma and injury score

We encourage physicians and health care providers in emergency settings to use our Thai-Pediatric trauma and injury score in a routine practice. To calculate the score, 10 variables are needed to measure and the score can be easily calculated as shown in the scoring scheme table 5.4. Risk classification of our score should be able to aid in making decisions whether patients should be transferred or treated in that trauma care center, given prompt facilities, equipment, and healthcare personnel support. For instance, a child has been brought to a hospital with trauma care level I with high risk classification, so s/he should be transferred straight away to a hospital with trauma care level III and proper management should be administered during transfer. Only low risk classification should be observed in the trauma care level I hospital. The intermediate risk classification may be able to be treated with close observation in the trauma care level II hospital or transfer to the level I.

6.6 Strengthen of our study

Our study has many strengthens. First, we conducted a large scale cross-sectional study that included data from 34 trauma care levels (12, 11, and 11 for level I, II, and III-IV) across all regions of Thailand. This data provided a good picture of trauma and injury and thus was a good representation of Thailand. Data from each trauma care level were entered to our web database which had good quality control for data entering. All data of 43,516 patients were used to construct the risk prediction score of death.

Second, we considered 21 factors that had been reported as risk factors of death in trauma and injury in previous studies. Multiple logistic regression was applied to select important variables which could predict probability of death. We considered individual variables rather than combining them as scores, before putting them in the logit equation, as commented previously. This would let data indicate the proper weight for each variable and yield better performance than the previous scores. In addition, vital sign variables were more detailed categorized as low, normal, and high rather than categorized as abnormal and normal values. This could separate the effects of early and late compensations of a physical body once trauma or injury occurred.

Third, we created a scoring scheme based on 10 variables which were easy to measure and should be available in routine practice. The total score was easy to calculate and was classified as low, intermediate, and high risk of death according to recommended score cutoffs. This should be useful for emergency physicians and health care providers to aid in making decisions to provide proper management. In addition, the score may be used for evaluation of the quality of a pediatric trauma care center.

Finally, we internally validated the score using bootstrap technique with 200 replications. With this technique, instead of splitting, the data of 43,516 children were used for construction and internal validation. Our results suggested very low bias in both calibration and discrimination and thus our score gave good performance.

6.7 Limitations of our study

Our study had some limitations. We did not standardized instruments used for vital sign assessments and thus there might be measurement error and bias across different trauma care levels. In Thailand, most emergency nurses or other health care providers in emergency services have attended triage courses for screening and categorizing patients' severity based on vital signs. For the current practice, the vital signs are mostly measured by an oscillometric non-invasive blood pressure device which is more convenient given an emergency setting and takes a shorter time for measurement than a manual device (63). Although we did not standardize the instruments, we had meetings about twice a year with research nurses to remind them about the technical skill of vital signs measurements. In addition, we performed internal audits in every site during monitoring by randomly selecting 20% of subjects to check for completeness and validity. This should have helped in minimizing error.

Second, we have not yet performed external validation of the Thai-Pediatric trauma and injury score. Its score performance in general children outside the studied trauma care centre may be not as good as the derived centre. To be able to do this required data from other centers those have not been included in the derived data. This is on our priority plan for further research. Friendly software for calculation of Thai-Pediatric trauma and injury score should be constructed. The software should be easily installable and be compatible with other personal digital assistant or portable electronic computers to encouraged physicians, nurses, and other health care providers in emergency setting to use it.

6.8 Further studies

A cross-sectional study need to be conducted which aim to externally validate our Thai-Pediatric trauma and injury score. At least data from 5 provinces with 1 province for each region should be collected using the same methods used in the derived phases. A software development is also required, which can be conducted parallel to the external validation phase or wait until results of external validation are complete. Implementation of the software and evaluation of using it in terms of bugs and satisfaction should be evaluated. In addition, while conducting the derived phase, we found that levels of trauma care should also be evaluated and standardised. Most hospitals had been classified to a level based on the size of the hospitals with less consideration of facilities available in the hospitals. Another point that should be brought to improve the quality of trauma care for our country is transportation time. A transportation policy for trauma and injury should be set up with standardized quality. Current resources for this including staff in emergency medicine, ambulance service for children, medical instruments, and knowledge of medical personnel should be explored and studied. Results of this should help the policy makers to plan for proper allocation of resources.

6.9 Conclusion

The Thai-Pediatric trauma and injury score of death has been developed and validated using 10 variables (i.e. age, intubation, physical mechanism, injured at head, abdomen, and thorax, GCS, PR, RR, and SBP). These variables are easy to assess and measure form routine practice. A scoring scheme that is easily to calculate and interpret has been constructed. Children with high risk classification require emergency treatment and management. Friendly software for this need to be constructed and installed in a portable computer to encourage use of the software. In addition, the risk model needs to be externally validated in the general Thai population or outside the country.

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APPENDICES

APPENDIX A

Logistic equation

$$
\begin{aligned}
In\left[\frac{P}{1-P}\right] = -7.82 \\
&+ 0.65\ x\ (Age\ \ \leq 5\ yrs) \\
&+ 1.09\ x\ (Age\ 6-12\ yrs) \\
&+ 1.21\ x\ (Adjuncts\ Airway) \\
&+ 2.39\ x\ (Intubation) \\
&+ 0.24\ x\ (Pure\ velocity\ related\ injury) \\
&+ 0.71\ x\ (Pure\ gravity\ related\ injury) \\
&+ 0.36\ x\ (Both\ velocity\ and\ \ Gravity\ related\ injury) \\
&+ 1.61\ x\ (Head-neck\ injury) \\
&+ 1.52\ x\ (Thoracic\ injury) \\
&+ 1.62\ x\ (Abdominal-Pelvis\ injury) \\
&+ 1.40\ x\ (GCS<9) \\
&+ 2.42\ x\ (Bradycardia) \\
&+ 0.80\ x\ (Tachycardia) \\
&+ 0.79\ x\ (Dyspnea) \\
&+ 1.61\ x\ (Abnormal\ SBP)
\end{aligned}
$$

Abnormal vital signs : Systolic blood pressure (SBP), Pulse rate (PR; tachy-bradycardia), Respiratory rate (RR; Dyspnea) reference abnormality cut off values from Pediatric Advanced Life Support(PALS), American Heart Association(AHA), 2010.

APPENDIX B

Calibration of Thai-Pediatric trauma and injury score cutoff using ROC curve analysis.

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-	
(>= 1.76e..)	100.00%	0.00%	1.50%	1.0000		
(>= .2418..)	100.00%	0.17%	1.67%	1.0017	0.0000	
(>= .3649..)	100.00%	0.26%	1.76%	1.0026	0.0000	
(>= .653949)	100.00%	0.30%	1.80%	1.0030	0.0000	
(>= .7115..)	100.00%	2.18%	3.65%	1.0223	0.0000	
(>= .7902..)	100.00%	2.19%	3.66%	1.0224	0.0000	
(>= .8017..)	100.00%	17.10%	18.35%	1.2063	0.0000	
(>= .8958..)	100.00%	17.18%	18.43%	1.2075	0.0000	
(>= 1.0189)	99.84%	19.03%	20.25%	1.2331	0.0083	
(>= 1.032..)	99.84%	20.62%	21.81%	1.2578	0.0076	(1st Cut point)
(>= 1.043..)	99.68%	27.64%	28.73%	1.3777	0.0114	
(>= 1.091..)	99.68%	27.70%	28.79%	1.3788	0.0114	
(>= 1.15516)	99.21%	33.12%	34.12%	1.4835	0.0238	
(>= 1.166..)	99.21%	35.44%	36.40%	1.5367	0.0223	
(>= 1.333..)	99.21%	35.45%	36.41%	1.5371	0.0222	
(>= 1.365..)	99.21%	38.41%	39.32%	1.6108	0.0205	
(>= 1.444..)	99.21%	38.47%	39.38%	1.6124	0.0205	
(>= 1.455..)	98.90%	41.49%	42.36%	1.6903	0.0266	
(>= 1.456..)	98.90%	41.52%	42.38%	1.6910	0.0266	
(>= 1.501..)	98.58%	46.41%	47.19%	1.8395	0.0306	
(>= 1.591..)	98.58%	47.92%	48.68%	1.8928	0.0296	

(Continue)

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 1.60788)	98.11%	51.73%	52.43%	2.0326	0.0366
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
(>= 1.612..)	98.11%	51.74%	52.44%	2.0331	0.0366
(>= 1.616..)	98.11%	51.79%	52.48%	2.0349	0.0365
(>= 1.63736)	98.11%	51.79%	52.49%	2.0350	0.0365
(>= 1.686..)	98.11%	51.79%	52.49%	2.0351	0.0365
(>= 1.697..)	97.63%	54.19%	54.84%	2.1313	0.0437
(>= 1.802..)	97.63%	54.21%	54.86%	2.1320	0.0436
(>= 1.809..)	97.63%	54.65%	55.29%	2.1528	0.0433
(>= 1.820..)	96.69%	57.28%	57.87%	2.2630	0.0578
(>= 1.833..)	96.69%	57.30%	57.89%	2.2642	0.0578
(>= 1.849..)	96.53%	59.20%	59.76%	2.3661	0.0586
(>= 1.854..)	96.53%	59.21%	59.77%	2.3664	0.0586
(>= 1.858..)	96.53%	59.21%	59.78%	2.3668	0.0586
(>= 1.860..)	96.53%	59.22%	59.78%	2.3671	0.0586
(>= 1.881..)	96.53%	59.43%	59.99%	2.3794	0.0584
(>= 1.892..)	96.53%	59.72%	60.27%	2.3962	0.0581
(>= 1.956..)	96.06%	60.69%	61.22%	2.4434	0.0650 (2nd Cut point)
(>= 1.977..)	95.90%	61.24%	61.76%	2.4742	0.0670
(>= 1.997..)	95.90%	61.25%	61.77%	2.4747	0.0670
(>= 2.049..)	95.90%	61.34%	61.86%	2.4807	0.0669
(>= 2.102..)	95.90%	61.37%	61.89%	2.4826	0.0668
(>= 2.123..)	95.90%	61.67%	62.18%	2.5019	0.0665
(>= 2.134..)	95.90%	62.05%	62.56%	2.5273	0.0661
(>= 2.155..)	95.58%	62.51%	63.01%	2.5494	0.0707
(>= 2.167..)	95.58%	62.58%	63.08%	2.5547	0.0706

(Continue)

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-	
(>= 2.185..)	95.58%	62.61%	63.11%	2.5563	0.0705	
(>= 2.225..)	95.58%	62.78%	63.27%	2.5677	0.0704	
(>= 2.23899)	95.58%	62.97%	63.46%	2.5811	0.0701	
(>= 2.388..)	94.95%	65.30%	65.75%	2.7368	0.0773	
(>= 2.39809)	94.95%	65.31%	65.76%	2.7373	0.0773	
.	.	.	.	.	.	
.	.	.	.	.	.	
.	.	.	.	.	.	
(>= 3.016..)	89.59%	80.00%	80.14%	4.4790	0.1301	
(>= 3.020..)	89.59%	80.34%	80.48%	4.5574	0.1296	
(>= 3.040..)	89.59%	80.39%	80.53%	4.5681	0.1295	
(>= 3.042..)	89.59%	80.39%	80.53%	4.5692	0.1295	
(>= 3.048..)	89.59%	80.44%	80.58%	4.5810	0.1294	
(>= 3.052..)	89.59%	80.49%	80.63%	4.5923	0.1293	
(>= 3.056..)	89.59%	80.55%	80.68%	4.6054	0.1292	
(>= 3.060..)	89.43%	80.99%	81.12%	4.7057	0.1305	
(>= 3.063..)	89.27%	81.10%	81.22%	4.7237	0.1322	(3rd Cut point)
(>= 3.068..)	88.96%	81.33%	81.45%	4.7654	0.1358	
(>= 3.068..)	88.96%	81.34%	81.46%	4.7684	0.1357	
(>= 3.072..)	88.80%	82.06%	82.16%	4.9505	0.1365	
(>= 3.077..)	88.80%	82.18%	82.28%	4.9840	0.1363	
(>= 3.081..)	88.80%	82.19%	82.29%	4.9867	0.1363	
(>= 3.088..)	88.80%	82.20%	82.30%	4.9900	0.1362	
(>= 3.099..)	88.80%	82.21%	82.31%	4.9927	0.1362	
(>= 3.109..)	88.64%	82.21%	82.31%	4.9839	0.1381	
(>= 3.110..)	88.64%	82.25%	82.34%	4.9933	0.1381	
(>= 3.114..)	88.49%	82.32%	82.41%	5.0048	0.1399	
(>= 3.11799)	88.17%	82.47%	82.55%	5.0288	0.1434	
(>= 3.131..)	88.17%	82.56%	82.65%	5.0566	0.1433	

(Continue)

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 3.163..)	88.17%	82.57%	82.65%	5.0580	0.1433
(>= 3.178..)	88.17%	82.58%	82.66%	5.0601	0.1433
(>= 3.190..)	87.85%	83.02%	83.10%	5.1750	0.1463
(>= 3.199..)	87.85%	83.03%	83.10%	5.1758	0.1463
(>= 3.204..)	87.85%	83.45%	83.51%	5.3076	0.1455
(>= 3.204..)	87.70%	83.45%	83.52%	5.2996	0.1474
(>= 3.204..)	87.70%	83.50%	83.56%	5.3135	0.1473
(>= 3.208..)	86.28%	85.59%	85.60%	5.9879	0.1603
(>= 3.213..)	86.28%	85.84%	85.84%	6.0918	0.1599
(>= 3.215..)	86.28%	86.01%	86.01%	6.1663	0.1595
(>= 3.220..)	86.28%	86.01%	86.01%	6.1674	0.1595
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
(>= 10.57..)	1.58%	100.00%	98.52%		0.9842
(>= 10.65..)	1.42%	100.00%	98.52%		0.9858
(>= 10.68..)	1.26%	100.00%	98.51%		0.9874
(>= 11.44..)	0.95%	100.00%	98.51%		0.9905
(>= 11.73..)	0.79%	100.00%	98.51%		0.9921
(>= 11.73..)	0.63%	100.00%	98.51%		0.9937
(>= 11.83..)	0.47%	100.00%	98.50%		0.9953
(>= 12.32..)	0.32%	100.00%	98.50%		0.9968
(>= 12.82..)	0.16%	100.00%	98.50%		0.9984
(> 12.82..)	0.00%	100.00%	98.50%		1.0000

APPENDIX C

Reclassification table by comparing our model with the Tepas 1987.

Risk in Tepas (Probability)	Risk in our model					
Survive	< 0.0005	0.0005-0.0023	0.0023-0.0372	0.0372-0.7766	> 0.7766	Total
< 0.0005	12	756	637	20	0	1,425
0.0005-0.0023	62	10,182	7,242	523	1	18,010
0.0023-0.0372	34	11,104	7,809	973	0	19,920
0.0372-0.7766	0	351	986	803	10	2,150
> 0.7766	0	0	2	2	1	5
Total	108	22,393	16,676	2,321	12	41,510
Death	< 0.0005	0.0005-0.0023	0.0023-0.0372	0.0372-0.7766	> 0.7766	Total
< 0.0005	0	0	0	1	0	1
0.0005-0.0023	0	1	14	20	0	35
0.0023-0.0372	0	5	41	86	2	134
0.0372-0.7766	0	9	75	335	38	457
> 0.7766	0	0	1	4	2	7
Total	0	15	131	446	42	634

*Yellow color represents the number of injured children correctly reclassified while blue color represents the number of injured children incorrectly reclassified from our model

APPENDIX D

Reclassification table by comparing our model with the Tepas & Ramenofsky 1988.

Risk in Tepas & Ramenofsky model (Probability)	Risk in our model				
Survive	< 0.002	0.002-0.004	0.004-0.777	> 0.777	Total
< 0.002	11,012	7,879	543	1	19,435
0.002-0.004	11,138	7,809	973	0	19,920
0.004-0.777	351	986	803	10	2,150
> 0.777	0	2	2	1	5
Total	22,501	16,676	2,321	12	41,510
Death	< 0.002	0.002-0.004	0.004-0.777	> 0.777	Total
< 0.002	1	14	21	0	36
0.002-0.004	5	41	86	2	134
0.004-0.777	9	75	335	38	457
> 0.777	0	1	4	2	7
Total	15	131	446	42	634

*Yellow color represents the number of injured children correctly reclassified while blue color represents the number of injured children incorrectly reclassified from our model.

APPENDIX E

Reclassification table comparing our model with the Russo 2012

Risk in Russo (Probability)	Risk in our model				
Survive	< 0.002	0.002-0.004	0.004-0.777	> 0.777	Total
< 0.002	11,012	7,879	543	1	19,435
0.002-0.004	11,138	7,809	973	0	19,920
0.004-0.777	351	986	803	10	2,150
> 0.777	0	2	2	1	5
Total	22,501	16,676	2,321	12	41,510
Death	< 0.002	0.002-0.004	0.004-0.777	> 0.777	Total
< 0.002	1	14	21	0	36
0.002-0.004	5	41	86	2	134
0.004-0.777	9	75	335	38	457
> 0.777	0	1	4	2	7
Total	15	131	446	42	634

*Yellow color represents the number of injured children correctly reclassified while blue color represents the number of injured children incorrectly reclassified from our model

APPENDIX F

Reclassification table by comparing our model with the Polytrauma score 2012.

Risk in Polytrauma score (Probability)	Risk in our model			
Survive	< 0.009	0.009-0.405	> 0.405	Total
< 0.009	30,713	4,774	18	35,505
0.009-0.405	3,546	2,270	73	5,889
> 0.405	15	85	16	116
Total	34,274	7,129	107	41,510
Death	< 0.009	0.009-0.405	> 0.405	Total
< 0.009	12	62	9	83
0.009-0.405	61	295	81	437
> 0.405	2	61	51	114
Total	75	418	141	634

*Yellow color represents the number of injured children correctly reclassified while blue color represents the number of injured children incorrectly reclassified from our model

OUTPUT

1.International Journal Publications

-1. We published in International publication in BMC Pediatrics 2014

Publication	Title	Journals
1) **Vallipakorn SA**, Plitapolkarnpim A, Suriyawongpaisal P, Techakamolsuk P, Smith GA, Thakkinstian A	**Risk prediction score for death of traumatized and injured children**	**BMC Pediatr. 2014 Feb 28;14:60. doi: 10.1186/1471-2431-14-60** **(IF=1.93)**
2) Vallipakorn SA, Thakkinstian A, Plitapolkarnpim A.	**The Nationwide Survey of Child Abuse by National Pediatric Injury and Trauma Registry of Thailand**	**+Inter-CAP (An International Conference on Child abuse Pediatrics, 1-2 June 2015, Uppsala, Sweden** (Abstract & Oral presentation)

2.Others e.g. national journal publication, proceeding, international conference, book chapter, patent

-2.Other than international publication and conference, Other of information of Pediatric injury in one local site (Ramathibodi Hospital database) can publish 1 paper of **"The Profile of Pediatric Patients Visit Emergency Department at Urban University Hospital in Thailand " [Corresponding author]**, and author try to exact only sexually abuse database in children and publication in other one of **"The study of familial history and associated risks of sexually abused children at Ramathibodi Hospital"[Corresponding author]** as following table;

Publication	Title	Journals
1) Pandee U, **<u>Vallipakorn SA</u>**, Plitponkarnpim A.	**The Profile of Pediatric Patients Visit Emergency Department at Urban University Hospital in Thailand.**	**J Med Assoc Thai. 2015 Aug;98(8):761 -7.**
2) Jengtee S, Augsusingha P, Aimarom C, Plitapolkamrpim A, **<u>Vallipakorn SA.</u>**	**The study of familial history and associated risks of sexually abused children at Ramathibodi Hospital.**	**J Med Assoc Thai. 2014 Sep;97(9):923 -31.**
3) Muangkaew N, Viriyapant K, **<u>Vallipakorn SA</u>**, Techakamolsuk P.	**The Severity and Mortality Forecasting System of Pediatric Injuries using Artificial Neural Networks.**	**The 9th National Conference on Computing and Information Technology (NCCIT2013), 9th -10th May 2013.** (Abstract & Poster presentation)

3.Others Applications:

Provide Knowledge and Application to Doctor & Nurse

(1) Invited Speaker on "**Pediatric Injury and transportation"**, Annual Conferences Ramathibodi Home Coming Day, 20-25 September 2011, Faculty of Medicine, Ramathibodi Hospital, Bangkok, Thailand

(2) Invited Speaker on "**Pediatric Injury Data System and Its Utilization"**, Safe Community on Child safety and Injury surveillance, 12 September 2011, Faculty of Medicine, Ramathibodi Hospital, Bangkok, Thailand

(3) Invited Speaker on "**Management in Pediatric Emergency and Trauma"**, Emergency and Trauma management, 13 June 2012, The Emerald Hotel Bangkok, Thailand

Provided Knowledge and Application to Local Community at NAN Province (

(1) 26 November 2015 12.00-12.30 PM **" Turning Injury Data into Community Action "**
Chair: <u>Dr.Sakda Arj-Ong Vallipakorn</u>, Ramathibodi Hospital,
Mahidol University,Thailand

"One Child's Death, Thousands Children' Lives Saved"

by Dr. Pornchai, Nan Hospital,Thailand

"From Untapping Injury Surveillance Data to Community-based Prevention"

by Dr. Pongthep Wongwacharapaiboon, Nan Hospital, Thailand

Open discussion Moderate by Chair : Dr.Sakda Arj-Ong Vallipakorn

(2) 26 November 2015 14:00-16.30 PM: **"Post-congress on Child Safety Promotion"**

"**Training 5"** (Conducted in English)

Speakers:

- Professor Gary A. Smith, President of Child Injury Prevention Alliance
- Dawne Gardner-Davis, Cincinnati Children's Hospital Medical Center
- Emma Jonsson, Sweden
- Dr. Pongthep Wongwacharapaiboon, Nan Hospital
- Dr. Pornchai Ngamsitilerk, Nan Hospital
- Dr. Waraporn Techasena, Former Deputy Director of Human Resource Development, Nan Hospital
- Dr. Sakda Arj-Ong Vallipakorn, Ramathibodi Hospital
- Dr. Chatchai Imarom, Department of Community Medicine, Ramathibodi Hospital
- Ms. Kronwika Buntanon, Child Safety Promotion and Injury Prevention Research Center(CSIP, Thailand)
- Ms. Yaowapa Dithayam, Talad Krieb Day Care Center

Course Attendees: 100 Medical staff

Hosted by: CIPA Child Injury Prevention Alliance, Nationwide Children's, Nan Hospital, Department of Community Medicine, Ramathibodi Hospital, and Child Safety Promotion and Injury Prevention Research Center.

https://issuu.com/nansafecom2015/docs/proceeding_en_final

4. Provided useful information of injury prevention.

(4.1) อันตรายจาก “น้ำลายเอเลี่ยน”

แพทย์เตือน "น้ำลายเอเลี่ยน" ของเล่นฮิตติดกระแสบางชนิดมีสารอันตราย

วันที่ 06 กรกฎาคม พ.ศ. 2558 เวลา 19:58:46 น.

ถูกใจ แชร์ 15 พัน Tweet

จากกรณีที่มีเด็กนำวัตถุคล้ายเยลลี่เหลว หรือที่เรียกกันว่า น้ำลายเอเลี่ยน มาเล่นและปั้นเป็นรูปต่างๆ ล่าสุด แพทย์โรงพยาบาลรามาฯเตือนให้เล่นอย่างระมัดระวังเพราะที่วางจำหน่ายอยู่บางยี่ห้อมีสารพิษที่ทำให้เกิดอันตรายถึงขั้นเสียชีวิต

นายแพทย์ศักดา อาจองค์ วัลลิภากร อาจารย์ประจำศูนย์วิจัยเพื่อสร้างเสริมความปลอดภัยและป้องกันการบาดเจ็บในเด็ก คณะแพทย์ศาสตร์ โรงพยาบาลรามาธิบดี ได้ออกมาเตือนว่า สไลม์ (Slime) หรือที่กลุ่มเด็กๆเรียกกันว่าน้ำลายเอเลี่ยน จริงๆแล้วมีวัตถุประสงค์ไว้ดูดละอองฝุ่นตามซอกคีย์บอร์ดคอมพิวเตอร์ แต่ด้วยคุณสมบัติที่สามารถยืดหยุ่นได้ และมีสีสันสวยงาม ทำให้กลุ่มเด็กๆนำไปใช้เป็นของเล่น

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(4.2) งานแถลงข่าว “ปัญหาที่พบจากการใช้ยาโปรโคดิลและยาทรามาดอลในหมู่วัยรุ่น”

ข่าวประชาสัมพันธ์

PR NEWS

ปัญหาที่พบจากการใช้ยาโปรโคดิลและยาทรามาดอลในหมู่วัยรุ่น

หน่วยเวชศาสตร์ผู้ป่วยนอกเด็กและวัยรุ่น ภาควิชากุมารเวชศาสตร์ คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล จัดงานแถลงข่าว "ปัญหาที่พบจากการใช้ยาโปรโคดิล (procodyl) และยาทรามาดอล (tramadol) ในหมู่วัยรุ่น" โดยมี อ.พญ.จิราภรณ์ อรุณากูร อาจารย์ภาควิชากุมารเวชศาสตร์ คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล ดร.นพ.ศักดา อาจองค์ หน่วยระบาดวิทยาระบาดวิทยา คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล และศ.นพ.วินัย วนานุกูล หัวหน้าศูนย์พิษวิทยา คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล ร่วมแถลงข่าวให้ข้อมูลในครั้งนี้ด้วย เมื่อวันที่ 20 กรกฎาคม 2558 ณ ห้องประชุมศูนย์วิจัยเพื่อสร้างเสริมความปลอดภัยและป้องกันการบาดเจ็บในเด็ก ชั้น 3 อาคารบำบัดน้ำเสีย คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล

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RESEARCH ARTICLE Open Access

Risk prediction score for death of traumatised and injured children

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Abstract

Background: Injury prediction scores facilitate the development of clinical management protocols to decrease mortality. However, most of the previously developed scores are limited in scope and are non-specific for use in children. We aimed to develop and validate a risk prediction model of death for injured and Traumatised Thai children.

Methods: Our cross-sectional study included 43,516 injured children from 34 emergency services. A risk prediction model was derived using a logistic regression analysis that included 15 predictors. Model performance was assessed using the concordance statistic (C-statistic) and the observed per expected (O/E) ratio. Internal validation of the model was performed using a 200-repetition bootstrap analysis.

Results: Death occurred in 1.7% of the injured children (95% confidence interval [95% CI]: 1.57–1.82). Ten predictors (i.e., age, airway intervention, physical injury mechanism, three injured body regions, the Glasgow Coma Scale, and three vital signs) were significantly associated with death. The C-statistic and the O/E ratio were 0.938 (95% CI: 0.929–0.947) and 0.86 (95% CI: 0.70–1.02), respectively. The scoring scheme classified three risk stratifications with respective likelihood ratios of 1.26 (95% CI: 1.25–1.27), 2.45 (95% CI: 2.42–2.52), and 4.72 (95% CI: 4.57–4.88) for low, intermediate, and high risks of death. Internal validation showed good model performance (C-statistic = 0.938, 95% CI: 0.926–0.952) and a small calibration bias of 0.002 (95% CI: 0.0005–0.003).

Conclusions: We developed a simplified Thai pediatric injury death prediction score with satisfactory calibrated and discriminative performance in emergency room settings.

Keywords: Logistic regression, Pediatric trauma and injury score, Prediction score, Injured child, Pediatric injury, Bootstrap

Background

On a global scale, injury is one of the most burdensome problems and the second most common cause of emergency department visits in children [1,2]. The mortality rate of injured children has decreased in developed countries, but the decrease has been slow and minimal in South East Asian developing countries. In Thailand, it has accounted for almost half of all causes of deaths since the 1990's, and approximately 25% of deaths in children (overall average = 2.37–25.7/100,000 population) [3-6].

The Thai trauma care system was developed in the year 2000 to improve quality of care, reduce morbidity and mortality rates, and reduce the cost of injury treatment [7,8]. Factors associated with survival of injured children include individual characteristics (e.g., age, gender, weight, and underlying diseases), pre-hospital factors (e.g., injury mechanisms, anatomic injured regions, cause of injury, duration of transportation, and quality of first aid), and hospital factors (e.g., trauma center type, trauma care team experience, quality of emergency care, and the patient's physiologic reserve at arrival). These factors were used to develop clinical prediction scores to predict injury severity and survival probability, and decrease the number of post-injury fatal outcomes. Emergency care personnel use these scores to prioritize proper treatment and management, allocate the trauma center

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type, physician, and team, and guide decisions about treatment interventions.

The Trauma Injury Severity Score (TRISS) [9-12] is the most well-known prediction score. It incorporates the Revised Trauma Score (RTS) [13] and the Injury Severity Score (ISS) [14]. However, the TRISS is adult-based and thus unsuitable for use in children [15-17]. The Pediatric Age Adjusted TRISS score (PAAT) [18] was developed by modifying the TRISS to be more specific for use in children. However, this score has some limitations because it has not been externally validated, does not use adjusted variable weighting, and only uses the three most severely injured body regions (out of a possible six), even though multiple regions may be injured. The New Injury Severity Score (NISS) [19-22] addresses this problem by summing the scores of the three most severe injuries regardless of body region, but does not account for the relative effect on outcome that injury of one body region may have compared with another. The Pediatric Trauma Score (PTS) [23,24] was designed to improve triage and management of injured children. Unfortunately, this score performs poorly for cases of blunt abdominal trauma, because it does not include body region. Given the poor performance of previously developed prediction scores, an alternative approach for score development was investigated by considering original variables individually rather than scoring them before including them in the equations. This approach accounts for the fact that different variables have different effects on survival. Logit model results were used to weight individual variables. We also considered for inclusion some variables (i.e., duration of transportation, type of injury, pre-hospital airway management) that are not included in the previously developed scores, but that may be relevant for our clinical setting.

The aim of this study was to develop and validate a simplified Thai pediatric trauma and injury prediction score of death. A scoring scheme and risk stratifications were created, and their performance was compared with the original [23] and modified PTSs [24-26].

Methods

Study design and setting

A multicenter cross-sectional study was performed during April 2010 to October 2012. The study was organized by the Thai Taskforce of Pediatric Injury, a collaboration between Ramathibodi Hospital (Bangkok), the Bureau of Epidemiology, the Ministry of Public Health (MOPH), and trauma care centers registered with the National Pediatric Injury and Trauma Registry of Thailand (NPIRT). Thirty-four trauma care centers (12 (47%), 11 (28%), and 11 (25%) hospitals representing trauma care levels I, II, and III–IV, respectively) participated in the study. The trauma care levels were classified based on the MOPH National Master Plan 1998–2009 [27].

Selection of participants

Children aged 0–18 years who presented at the emergency services of collaborating hospitals with the following trauma or injury were included in the study: falling, being struck by or against, cut or pierce, gunshot wound, animal bite, transport injury, injury from child abuse, burn or scald, firearm-gun, foreign body aspiration, and drowning or near drowning. The study was approved by the Institutional Review Boards (IRBs) of the Faculty of Medicine Ramathibodi Hospital and the MOPH.

Data collection and processing

Before the study was initiated, the research objectives and the roles of the collaborating sites were described to doctors and nurses that attended a collaborative meeting organized by our research team. Descriptions of pediatric injury and trauma, and the study variables and their measurements were standardized. The data were collected at the collaborative sites and were then transmitted to the central NPIRT database (http://nrpi.mahidol.ac.th), where all trauma cases were registered. The registration forms included patient demographic data, pre-hospital data, injury factors and their associated risks (type and mechanism of injury, site of injury, and injured body region), the Glasgow Coma Scale (GCS), vital signs, diagnosis-disposition, and outcome. Web-databases were constructed using PHP version 5.2.9 (PHP Group, Chittagong, Bangladesh) and MySQL client version 5.0.51a (Oracle Corporation, Redwood Shores, CA USA) software. Data were directly entered from individual trauma care centers in real-time. A quality control program for data entry was created based on possible values, variable codes, and cross-checks to verify and validate data. Data were checked by summarizing and cross-tabulating between relevant variables. The local collaborative sites were contacted when data were incorrect or missing, and the original medical records were consulted to determine the correct values.

Variable and outcome measures

The outcome of interest was death related to injury or trauma within 30 days. The six domains of predictive variables were collected which were

- Demographic and general data including age, sex, weight, height, occupation, and geographic region.
- Pre-hospital data were transport types and duration, prior communication, and trauma care level.
- Mechanism of injury including surgical perspective mechanism (i.e., blunt, penetrating, or both) and physiological mechanism (i.e., gravity related injury, velocity related injury, or both).

- Trauma related injury regions including brain and head/neck, face, thorax, abdomen, upper or lower extremities and external soft tissue injury.
- Airway management which were intervention, airway adjuncts (e.g., oxygen supplementation and positive ambulatory bag, etc.)
- GCS and vital signs including GCS, Pulse rate (PR), systolic blood pressure (SBP) and respiratory rate (RR).

The route of transportation was sub-group based on modes of transportation in Thailand. Own transport defined as transported by the patient or their parent, non-ambulance group was transported by non-ambulance services or organized by a charity or a foundation supervised by EMTs or paramedics, and ambulance service was supervised by doctors, emergency physicians, and registered or emergency nurses.

Vital signs were measured at the emergency room and classified as follows [28]:

The SBP was defined as abnormal if SBP <60 for neonates, <70 for infants, <70 + (2 × age in years) for 1–10 years and <90 mmHg for >10 years. Otherwise it was classified as normal. PR was classified as tachycardia if PR >190 for ≤2 years, >140 for >2-10 years, and >100 beats/min for >10 years. Bradycardia was defined as PR < 60 beats/min. Pediatric Basic and Advanced Life Support criteria were used to classify RR as normal or tachypneic [29]. Consciousness consisted of awake, response to verbal stimulus, response to painful stimulus, and unresponsiveness. The original and the modified PTS were calculated using variables identified by Tepas et al. [23,25] and the modified Pediatric Polytrauma score 2012 [26].

Primary data analysis

Mean and standard deviation (SD) were used to describe continuous variables if data were normal distribution, otherwise median and ranges were used. Frequency and percentage were used to describe categorical data. An overall death rate along with its 95% confidence interval (95% CI) was estimated. Data analysis consisted of 2 phases as follows;

Derivation phase

The 21 independent variables were included in a data set that was used to develop risk prediction of death. A simple logistic regression analysis was used to evaluate the association between mortality and each of the variables. Variables with a p-value < 0.10 were included in a multivariate logistic model. The likelihood ratio (LR) test with backward elimination of variables was used to determine the most parsimonious model. Calibration and discrimination performance of the final model was then assessed. For calibration performance, a goodness of fit of the final model was assessed using the Hosmer-Lemeshow test [30]. A ratio of observed to expected values (O/E) was also estimated. A receiver operating characteristic curve (ROC) analysis was used to estimate discriminative performance, and the C-statistic was estimated.

The coefficients of the variables included in the final model were used to create scoring schemes. Total scores were calculated by summing the coefficients of all significant variables. The ROC analysis was applied to calibrate score cut-offs by estimating a likelihood ratio positive (LR^+) for each distinct score cut-off. The prediction scores were then classified into risk stratification for ease of application in clinical practice [31].

Validation phase

Because the death rate was quite low, all data were included in the 200-repetition bootstrap model used for internal validation. For each sample, the final logistic model resulting from the derivation phase was constructed, and parameters (i.e. predicted probability and the C-statistic) were estimated. Correlations between the observed and predicted values were assessed using the Somer'D correlation statistic (D_{boot}). Model calibration was then assessed using D_{orig}-D_{boot}, where D_{orig} was the Somer'D correlation obtained from the derived data. A value close to 0 implied an optimistic calibration. Discrimination was also assessed by comparing the C-statistics results of the original model with the bootstrap modelling results [32-35].

Score performance was compared with the pre-existing PTSs using ROC curve analysis. Net reclassification improvement (NRI) and integrated discrimination improvement (IDI) statistics were also applied [36,37]. These measures allowed us to analyze benefit gains and losses when using our prediction scores compared with the PTSs scores. All analyses were performed using STATA 12.0 software (College Station, TX, USA) [38]. A P-value <0.05 was considered to be statistically significant.

Results

Characteristics of study subjects

The data from 43,561 injured children who presented at the emergency medical services of the 34 participating hospitals were entered and retrieved from the NPIRT databases during the study period. Of these, 13,382 (31%), 11,750 (30%), 7,529 (17%), 4,638 (11%), 3,430 (8%), and 2,832 (7%) injured children were from the north-eastern, southern, central, eastern, northern, and Bangkok areas of Thailand, respectively (Additional file 1: Table S1).

The mean age of the children was 11.4 ± 5.5 years, median weight was 45 kg (range = 7–76), and 71% were male (Table 1). Approximately 92% of them were injured while in their residential areas, and 39% were transferred to the hospital by ambulance. 47% had prior communication

Table 1 Descriptive characteristics of children

Characteristics	N (%)
Number of subjects	43,561
Demographic data	
Age, years, mean ± SD	11.37 + 5.52
Sex	
Male	30,883 (70.96)
Female	12,678 (29.10)
Weight, kg, median (min–max)	45 (7–76)
Occupation	
Parent care	7,513 (17.25)
Student	25,790 (59.25)
Other	10,258 (23.50)
Region	
Bangkok	2,832 (6.50)
Central	7,529 (17.28)
North	3,430 (7.87)
North-east	13,382 (30.72)
East	4,638 (10.65)
South	11,750 (26.97)
Injury location	
Resident province	40,210 (92.33)
Non-resident province	3,342 (7.67)
Pre-hospital information	
Transfer route	
Own transport	12,483 (28.66)
Non-ambulance	14,137 (32.45)
Ambulance	16,941 (38.89)
Prior communication	
Yes	23,120 (53.07)
No	20,441 (46.93)
Trauma level	
I	20,492 (47.04)
II	12,441 (28.56)
III	7,220 (17.57)
IV	3,408 (7.82)
Pre-hospital support	
Not needed	22,248 (51.07)
Not provided	2,812 (6.46)
Provided	18,498 (42.47)
Injury types and mechanisms	
Injury Mechanisms	
Blunt	31,482 (72.27)
Penetrating	5,940 (13.64)
Both	1,943 (4.46)
Non-classified	4,196 (9.63)
Physical mechanisms	
Velocity-related	1,528 (8.75)
Gravity-related	8,191 (19.44)
Both	22,003 (52.21)
Non-classified	10,368 (24.60)
Types of injury	
Transportation	19,928 (45.75)
Falling	7,902 (18.14)
Poisoning	461 (1.06)
Animal bite or sting	1,641 (3.77)
Struck by or against	3,426 (7.86)
Cut or pierce	3,502 (8.04)
Burn or scald	1,005 (2.31)
Fire gun or explosion	1,582 (3.63)
FB aspiration or suffocation	1,359 (3.12)
Drowning or submersion	355 (0.81)
Abuse, assault, or neglect	2,400 (5.51)
Object-related injury	
Chemical or food product	801 (1.84)
Home or office, work place	12,730 (29.22)
Sports equipment	639 (1.47)
Weapons	2,047 (4.70)
Transportation-related	20,317 (46.64)
Natural objects (animal)	3,362 (7.72)
Miscellaneous	3,664 (8.41)
Length of stay, days, median (min-max)	2 (0–63)
Outcomes	
Major outcome	
Survival	42,821 (98.30)
Death	740 (1.70)
Short term disabilities	
Outcome	
Major	1,862 (4.40)
Minor	3,624 (8.40)
None	37,334 (87.20)

with the referral hospitals before transportation. Approximately 49% of the children received first aid at the trauma site scene, and 87% were provided appropriate assistance. Blunt injury (72%) was the most common mechanism of injury, followed by penetrating injury (14%). The three most common injuries were transportation (46%), falling (18%), and cut and pierce (8%) injuries.

The estimated overall death rate was 1.7% (95% CI: 1.57–1.82). The death rate was highest for children from the eastern region of Thailand (2.41%, 95% CI: 1.97–2.85), and lowest in Bangkok (0.78%, 95 CI: 0.45–1.10). Drowning was the highest cause of death (8.0%), followed by weapon, fire-gun, bomb-explosion, or firework injury (2.6%).

Derivation phase

The entire data set (n = 43,561 children) was used to derive the risk prediction score of death. The results of a univariate analysis revealed that 20 variables were significantly associated with risk of death (Table 2). Five variables exhibited multi-collinearity, so 15 variables were simultaneously included in the multivariate logistic model. Only 10 variables were significant and thus were retained in the final model (Table 3; logit equation presented in Additional file 1). The model displayed good fit to the data (Hosmer-Lemeshow Chi square = 13.64, d.f. = 5, p = 0.092; O/E ratio = 0.86, 95% CI: 0.70–1.02). The model was also effective at discriminating between dying and surviving children (C-statistic = 0.938, 95% CI: 0.929–0.947; read Figure 1).

Magnitude of association was described using the odds ratio (OR) (Table 3). Children aged 1–5 and 6–12 years were at a 1.9 (95% CI: 1.4–2.6) and 3.0 (95% CI: 2.0–4.3) higher odds of death, respectively, than children aged 13–18 years. The odds of death for intubated children was about 10.9 (95% CI: 8.6–13.7) greater than the odds of death for non-intubated children. Children that received adjunct airway and support ventilation had a higher odds of death (OR = 3.3, 95% CI: 2.4–4.6) than children with non-airway support management.

The physical mechanism and region of injury domains were also significantly associated with death. Gravity, velocity, and both physical mechanisms were 2.0 (95% CI: 1.4–3.0), 1.3 (95% CI: 1.0–1.7), and 1.4 (95% CI: 1.1–1.9) times higher odds of death, respectively. Head (OR = 5.0, 95% CI: 4.1–6.1) and abdominal (OR = 5.0, 95% CI: 4.0–6.5) injuries were most strongly associated with the odds of death, followed by injury to the thorax (OR = 4.6, 95% CI: 3.5–6.0).

The odds of death for children with GCS < 9 was greater than the odds of death for children with a GCS ≥ 9 (OR = 4.0, 95% CI: 3.2–5.1). Abnormal PR, RR, and SBP were significantly associated with death. Children with bradycardia (OR = 11.3, 95% CI: 7.5–17.0) and tachycardia (OR = 2.2, 95% CI: 1.8–2.8) had a significantly higher odds of death than children with a normal PR. Compared with children with normal RR and SBP, children with an abnormal SBP and RR had a 5.0 (95% CI: 3.9–6.4) and 2.2 (95% CI: 1.5–3.1) times higher odds of death, respectively.

The total risk score (0–15.16) was created by summation of all coefficients for the variables that contributed to the final model (Table 4). For simplicity, and for easier application in clinical practice, the total risk score was classified into four stratifications according to its performance and distribution. The cut-offs were <1.02, ≥1.02, ≥1.96, and ≥3.06, which represented very low, low, intermediate, and high risks of death, respectively (Table 5). The LR^+s for these corresponding risk stratifications were 1.26 (95% CI: 1.25–1.27), 2.47 (95% CI: 2.42–2.52), and 4.72 (95% CI: 4.57–4.88), respectively. The positive predictive values (PV^+) for these four risk groups were 1.88% (95% CI: 1.74–2.04), 3.64% (95% CI: 3.36–3.94) and 6.73% (95% CI: 6.20–7.29), respectively.

Validation phase

The 200-replication bootstrap model yielded estimated D_{boot} and D_{origin} coefficients of 0.873 (95% CI: 0.872–0.875) and 0.872 (95% CI: 0.863–0.881), respectively, and a percentage error of 0.20%. The estimated bias was low, at 0.0017 (95% CI: 0.0005–0.0030), which indicated that the model was internally well-calibrated. The estimated O/E ratio for the bootstrap data were 0.86 (95% CI: 0.70–1.02), and the C-statistic was 0.938 (95% 95% CI: 0.926–0.952).

Comparison of performances of prediction models

We compared our model to the original PTS developed by Tepas et al. [23,25] and the recently modified PTS, the Pediatric Polytrauma score 2012 [26]. The C-statistics for our score and the two other scores were 0.938 (95% CI: 0.929–0.947), 0.876 (95% CI: 0.862–0.891) and 0.874 (95% CI 0.860–0.888), respectively. Compared with the other two models, our model was significantly more likely to accurately discriminate between dying and surviving children (p < 0.001, Table 6).

The NRI was estimated by comparing our model to the two alternate models. The probability of death estimated from each model was classified using the previously estimated score cut-offs (Additional file 1: Tables S2 and S3). The reclassification tables were constructed by separately cross-tabulating the alternate model scores versus our scores by dying and surviving groups. Our model improved the classification of children in both the dying and surviving groups. The percent of reclassification improvements (RI) from the Tepas 1987 and the Pediatric Polytrauma score 2012 were 13.57% and 4.42% in the death group, with a loss of 2.9% and a gain of 5.6% in the survival group, respectively (Table 6). The NRIs were 16.2% (95% CI: 11.22–21.20) and 1.48% (95% CI: −3.67–6.63) for the Tepas 1987 and the Pediatric Polytrauma 2012 scores, respectively. This result indicated that compared with the Tepas 1987 model, the discrimination of our model was statistically superior. However, it was not an improvement on the Pediatric Polytrauma 2012 model.

Table 2 Factors associated with death, pediatric trauma and injury: univariate analysis

Factors	Group				
	Death n (%)	Survival n (%)	OR	95% CI	P-value
Demographics domain					
Age, years					
0–5	113 (1.2)	9,342 (98.8)	1.8	1.4–2.4	<0.001
6–12	131 (1.2)	10,478 (98.8)	3.01	2.1–4.3	
13–19	496 (2.1)	23,001 (97.9)			
Sex					
Female	175 (1.4)	12,503 (98.6)	1		0.001
Male	565 (1.8)	30,318 (98.2)	1.3	1.1–1.6	
Weight, kilograms					
≤25	147 (1.2)	12,335 (98.8)	1		<0.001
26– 45	134 (1.3)	9,909 (98.7)	1.1	0.9–1.4	
46–55	227 (2.1)	10,504 (97.8)	1.8	1.5–2.2	
>55	232 (2.3)	10,073 (97.8)	1.9	1.6–2.4	
Pre-hospital domain					
Duration of transport, hours					
≤ 1	142 (1.7)	8,312 (98.3)	1.2	0.9–1.5	
1–2	299 (2.0)	14,443 (98.0)	1.5	1.2–1.8	
2–3	138 (1.6)	8,555 (98.4)	1.2	0.9–1.5	
>3	161 (1.4)	11,511 (98.6)	1		0.001
Airway management domain					
No intervention	224 (0.6) 81	38,704 (99.4)	1		<0.001
Adjuncts	(3.9)	1,975 (96.1)	7.1	5.5–9.2	
Intubation	435 (16.9)	2,141 (83.1)	35.1	29.7–41.5	
Mechanisms and injury regions domain					
Velocity-, Gravity-related mechanism					
Velocity	41 (2.6)	1,541 (97.4)	3.0	2.0–4.3	<0.001
Gravity	97 (1.2)	8,160 (98.8)	1.3	1.0–1.8	
Both	510 (2.2)	22,844 (97.8)	2.5	2.0–3.1	
None	92 (0.9)	10,276 (99.1)	1		
Mechanism of injury					
Penetrating	69 (1.2)	5,871 (98.8)	1		<0.001
Blunt	536 (1.7)	30,946 (98.3)	1.5	1.1–1.9	
Both	56 (2.9)	1,887 (97.1)	2.5	1.8–3.6	
Non-classified	79 (1.9)	4,117 (98.1)	1.6	1.2–2.3	
No. of injured sites					
0	82 (2.2)	3,636 (97.8)	1		<0.001
1	168 (0.7)	25,519 (99.4)	0.3	0.2–0.4	
2	159 (1.8)	8,579 (98.2)	0.8	0.6–1.1	
≥3	331 (6.1)	5,087 (93.9)	2.9	2.3–3.7	
Trauma body regions					
Brain, head,neck					
Yes	527 (4.8)	10,355 (95.2)	7.8	6.6–9.1	<0.001
No	213 (0.6)	32,466 (99.4)	1		

Table 2 Factors associated with death, pediatric trauma and injury: univariate analysis *(Continued)*

Face					
Yes	43 (1.5)	2,903 (98.5)	0.8	0.6–1.2	0.298*
No	697 (1.7)	39,918 (98.3)	1		
Thorax					
Yes	124 (13.1)	821 (86.9)	10.3	8.4–12.6	<0.001
No	616 (1.4)	42,000 (98.5)	1		
Abdomen, pelvis					
Yes	143 (7.6)	1,743 (92.4)	5.6	4.7–6.8	<0.001
No	597 (1.4)	41,074 (98.6)	1		
Musculoskeletal					
Yes	161 (0.9)	18,045 (99.1)	0.4	0.3–0.5	<0.001
No	579 (2.3)	24,776 (97.7)	1		
External soft tissues					
Yes	171 (1.0)	16,196 (99.0)	0.5	0.4–0.6	< 0.001
No	569 (2.1)	39,918 (97.9)	1		
Wound types					
Large, open (major)	449 (2.7)	16,195 (97.3)	2.0	1.5–2.7	<0.001
Small, closed (minor)	247 (1.0)	23,466 (99.0)	0.8	0.5–1.0	
None	44 (1.4)	3,160 (98.6)	1		
Fracture types					
Open, multiple	115 (4.0)	2,756 (96.0)	2.5	2.0–3.0	<0.001
Single	198 (1.3)	14,962 (98.7)	0.8	0.7–0.9	
None	427 (1.7)	25,103 (98.3)	1		
Severity domain					
Total GCS In-Hospital					
<9	389 (18.6) 351	1,700 (81.4)	26.8	22.9–31.4	<0.001
≥9	(0.9)	41,121 (99.1)	1		
Vital sign domain					
PR					
Bradycardia	66 (15.1)	370 (84.9)	16.4	12.4–21.7	<0.001
Tachycardia	291 (3.8)	7,313 (96.2)	3.7	3.1–4.3	
Normal	383 (1.1)	35,138 (98.9)	1		
SBP					
Abnormal	164 (7.7)	1,960 (92.3)	5.9	5.0–7.1	<0.001
Normal	576 (1.4)	40,861 (98.6)	1		
RR					
Tachypnea	611 (2.1)	28,986 (97.9)	2.3	1.9–2.7	<0.001
Normal	129 (0.9)	13,835 (99.1)	1		
Consciousness (AVPU)					
Awake	313 (0.8)	39,722 (99.2)	1		<0.001
Verbal	33 (2.8)	1,161 (97.2)	3.6	2.5–5.2	
Pain stimulus	30 (7.4)	377 (92.6)	10.1	6.8–14.9	
Unresponsiveness	364 (19.0)	1,561 (81.1)	29.6	25.0–35.0	

Table 3 Results for multivariate logistic regression analysis of factors associated with the outcome variable, death

Factors	Coefficient	SE	P-value	OR (95% CI)
Age, years				
≤ 5	0.65	0.16	<0.001	1.9 (1.4–2.6)
6 – 12	1.09	0.19	<0.001	3.0 (2.0–4.3)
13 – 19				1
Airway management				
ET intubation	2.39	0.12	<0.001	10.9 (8.6–13.7)
Adjuncts	1.21	0.16	<0.001	3.3 (2.4–4.6)
None				1
Physical mechanism				
Velocity-related	0.24	0.14	0.08	1.3 (1.0–1.7)
Gravity-related	0.71	0.20	<0.001	2.0 (1.4–3.0)
Both	0.36	0.15	0.013	1.4 (1.1–1.9)
None				1
Head-neck injury				
Yes	1.61	0.10	<0.001	5.0 (4.1–6.1)
No				1
Thorax injury				
Yes	1.52	0.14	<0.001	4.6 (3.5–6.0)
No				1
Abdomen-pelvis injury				
Yes	1.62	0.13	<0.001	5.0 (4.0–6.5)
No				1
GCS				
<9	1.40	0.12	<0.001	4.0 (3.2–5.1)
≥9				1
PR				
Bradycardia	2.42	0.21	<0.001	11.3 (7.5–7.0)
Tachycardia	0.80	0.11	<0.001	2.2 (1.8–2.8)
Normal				1
SBP				
Abnormal	1.61	0.12	<0.001	5.0 (3.9–6.4)
Normal				1
RR				
Abnormal	0.79	0.21	<0.001	2.2 (1.5–3.1)
Normal				1

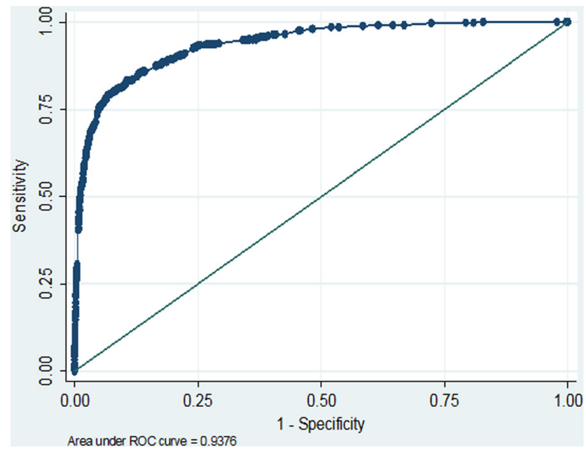

Figure 1 Receiver-operator characteristic (ROC) curve, Thai Pediatric Trauma and Injury Score, derivation data set.

Discussion

Thirty-four hospitals across Thailand contributed data for a cross-sectional study of 43,561 injured and traumatized children. The most common injuries were transportation, falling, and cut and pierce injuries. Blunt injury was the most common mechanism of injury. The estimated overall death rate was 1.7%. The highest death rate occurred in the eastern region of Thailand (2.4%), and the lowest death rate occurred in Bangkok (0.78%). Drowning (8.0%) was the most common cause of death, followed by weapon, fire-gun, bomb-explosion, or firework injury (2.6%), and transportation (2.4%). The major causes of injured child death in Thailand were transportation (46%), falling (18%), and cut and pierce (8%) injuries. These results differ from results for the U.S., where transportation (48%), suffocation (19%), and drowning (13%) injuries represent the major causes of death for individuals 0–19 years in age [39]. In Europe, the major causes of death for individuals 0–19 years in age were transportation (23%), drowning (17%), and poisoning (7%) injuries [40].

The risk prediction score of death that was derived from our study indicated that 10 variables were significantly associated with death (age, intubation, physical mechanism, injury of head, abdomen, or thorax, GCS, PR, RR, and SBP). The derived model displayed a good fit to the data and discriminated dying from surviving subjects. The C-statistics were 0.938 (95% CI: 0.929–0.947), and 0.938 (95% CI: 0.926–0.952) for the derived and internally validated data, respectively. A simplified Thai pediatric trauma and injury scoring scheme was created, which indicated that children with a score >3 had a higher risk of death.

Emergency medicine has developed in Thailand since 2005, but the systems and services do not yet include all specialties, particularly specialties included in pediatric emergency medicine. Lack of human resources, medical equipment and supplies, low budgets, and lack of knowledge have contributed to this deficit. Most of the children that experience physical trauma and injury are treated by general or adult emergency physicians. A well-organized and maintained trauma/injury data registry

Table 4 Thai pediatric trauma and injury scoring scheme

Factors	Score
1) Age, years	
≤ 5	0.65
6–12	1.09
≥13	0
2) Airway	
Intubation	2.39
Adjuncts	1.21
No intervention	0
3) Physical Mechanisms	
Pure velocity	0.24
Pure gravity	0.71
Both	0.36
None	0
4) Head-Neck injury	
Yes	1.61
No	0
5) Thoracic injury	
Yes	1.52
No	0
6) Abdomen-pelvis injury	
Yes	1.62
No	0
7) GCS	
<9	1.40
≥9	0
8) Pulse rate	
Bradycardia	2.42
Tachycardia	0.80
Normal	0
9) Respiratory rate	
Abnormal	0.79
Normal	0
10) Systolic blood pressure	
Abnormal	1.61
Normal	0
Total	0–15.16

for children still needs to be established, which would aid clinical decision-making for treatment management allocations. Our study should lead to the establishment of a data registry that includes the important variables necessary to create risk prediction models and severity grading systems. The risk prediction model should include user-friendly software to encourage health personnel in emergency settings to use it in routine practice.

Ours versus previous risk scores

Few previous risk scores have been specifically developed for children (e.g., PTS [23-26], PAAT [18], NISS [19-22]). The PTS includes three variables that were included in our scoring system (i.e., airway, GCS, and SBP), but the other PTS variables were non-significant predictors in our model. Our model added seven significant variables (i.e., age, physical mechanism, three injured body regions (head-neck, thorax, and abdomen-pelvis), PR, and RR). Inclusion of individual body regions, and thus multiple injuries with different weights, was also considered based on the results of the logistic regression modeling. We also considered mechanism of injury, PR, and RR in our model. For PR, we considered bradycardia, tachycardia, and normal, which was more detail than simply using abnormal or normal PR. Therefore, our risk score was superior to the PTS [23] and to the other score, which are modified PTS score cut offs [24-26].

Although the NISS was specifically developed for children by modifying the ISS, it has not often been included in the TRISS [9-12]. This low use may be because NISS coding is complex, and the comprehensive detailed requirements of this system make it impractical for use as a triage tool.

Risk factors for death

In our model, the association between airway management and death was similar to the PTS.

Children who were intubated had a risk of death 10 times greater than that of non-intubated children, and higher risk than other factors from multi-logit model (Table 3). The airway manipulation should be urgently performed to restore oxygenation and ventilation due to poor physiological reserve in children. These evidences were supported by Schafermeyer [41] which showed that aggressive airway and hemodynamic resuscitation were essential to critically injured child. Woosley et al. [42] emphasized that airway and ventilation were the first priority to improvement of thoracic injury in children. Likewise of severe traumatic brain injury, Boer et al. [43] showed the association of adequate airway management, prevention of hypoxia and hypo-hypercapnia were major components of trauma care improvement. Avarello et al. [44] and Brindis et al. [45] have also suggested aggressive resuscitation which included intubation was indicated to injured patient to improving their results.

Consciousness (measured by GCS) was also an important variable to predict death as an outcome. This result was similar to Cicero et al. [46] who found that only the GCS and Glasgow motor component could predict pre-hospital and on-arrival death. We considered vital signs by categorizing them as low, normal, and high, which was a more detailed approach than the abnormal and normal

Table 5 Risk classification of death, thai pediatric trauma and injury score

Score cut-off	Risk groups	Score development discrimination capacities					
		Outcome		Sensitivity (%)	Specificity (%)	LR^+(95% CI)	PV^+(%)
		Death	Survival				
<1.02	Very low	1	8,559				
≥1.02	Low	25	16,862	99.84	20.61	1.26 (1.25–1.27)	1.88 (1.74–2.04)
≥1.96	Intermediate	42	8,244	95.90	61.24	2.47 (2.42–2.52)	3.64 (3.36–3.94)
≥3.06	High	566	7,845	89.3	81.00	4.72 (4.57–4.88)	6.73 (6.20–7.29)

LR^+, likelihood ratio positive; PV^+, positive predictive value.

categories used by the PTS. As expected, for PR we found that bradycardia was associated with a greater odds of death than tachycardia (i.e., an approximately 11 times (bradycardia) and 2 times (tachycardia) higher risk of death than a normal PR). The effects of low values and high values were similar for the RR and SBP variables, so we combined them as abnormal RR and SBP. PR increased after the child was injured, which was an indication for early treatment administration and intervention. If management was delayed and the body could not continue to compensate, bradycardia would occur, blood pressure would drop, and shock would result.

Age was an important predictor of death. The odds of death were about 2 to 3 times higher for the children from the ≤5 and the 6–12 age groups than they were for the children from the 13–19 year age group. Only the PAAT has accounted for age effects via the Age-specific Pediatric Trauma Score (ASPTS). This age effect trend contrasted with Nance et al. [47], who found that compared with an older age of 13–15 years, a younger age had a protective effect. This difference might be explained by differences in exposure for the different age groups (i.e., dissimilar based line of physiologic reserve among age group, different types of trauma and injury result in differential injury severity and risk of death). Different countries also have different vehicle and road traffic safety regulations, which may indirectly affect trauma and injury risk in children.

Previous prediction scores included conventional mechanisms of injury (e.g., blunt and penetrating injuries), but these were not significant for our population. Physical mechanisms of injury (i.e., velocity and gravity) were significantly associated with death in our study and were included in our score. There was a greater odds of death for gravity-, compared with velocity-related injury.

The body regions head-neck, thorax, and abdominal-pelvis, were also important risk factors. These injured regions moderately affected the odds of death, with ORs of approximately 4.6–5.0. Our model considered injured regions individually and allowed the data from the logistic model to indicate which regions represented a significant risk, and how they should be weighted in the final score. Among six injured regions, only three of them were significant risk factors. The face, soft tissue, and musculoskeletal regions were not included. The weights of 1.61, 1.62, and 1.52 were applied to the head-neck, abdominal-pelvis, and thorax regions, respectively. Unlike other scores (e.g., AIS, ISS and TRISS), our score does not require additional calculations. This characteristic will reduce error at the trauma site scene.

Calibration of scoring cutoff

The ROC curve analysis was used to estimate score cut-offs. The discrimination capability of each score was identified using LR^+, which was a ratio of sensitivity versus 1-specificity. This parameter is useful for the selection of new diagnostic tests because it incorporates both sensitivity and specificity [48]. Unlike positive predictive value, LR^+ does not depend on the prevalence/incidence of the event of interest. The LR^+ indicates the degree to which a score cut-off would increase the pretest probability (or prevalence) of death. The User's Guide for Evidence-based Medicine [49] specifies that LR^+ Values of ≥10, 5–10, 2–5, and 1–2 should be respectively classified as conclusive, moderate, small but sometimes important, and very small changes in pretest probability of death. An examination of our results suggested that 3 cut-offs, ≥1.02, ≥1.96, and ≥3.06, with the respective LR^+s

Table 6 Comparison of model performance

Models	ROC Area	95% CI	Survival RI	Death RI	NRI (95% CI)
Our model	0.938	0.929–0.947	-	-	-
Tepas (1987)	0.876	0.862–0.891	+0.0564	+0.1057	+0.1621 (0.1122–0.2120)
Pediatric Polytrauma (2012)	0.874	0.860–0.888	–0.0294	+0.0442	+0.0148 (–0.0367–0.0663)

NRI, net reclassification improvement; *RI*, reclassification improvement.

of 1.26, 2.47, and 4.72, should be used. We designated these cutoffs as low, intermediate, and high risk of death, respectively. Children in the high risk group were approximately five times more likely to die than survive. Although none of our LR^+ Values were as high as 10, they moderately shifted the pretest probability of death from 1.5% to 6.7%.

Use of the Thai pediatric trauma and injury score

We encourage staff in emergency settings to use our score in routine practice among internally validated sites. Score estimation requires the measurement of 10 variables, and it is easily calculated (Table 4). The risk classification feature of our score should aid in the determination of whether patients should be transferred from, or treated at, a particular trauma care center, given the acute care facilities, equipment, and health care personnel. Only a patient with a low risk classification should be treated at a trauma care level III–IV hospital. A patient is classified as at intermediate risk classification may be treated (with close observation) at a level II hospital or transferred to a level I facility.

The outcomes will be compared and explored to find gap for improvement, and bring to develop the guidelines for trauma management of injured children in future. Within the scope of our study was developed injury prediction score of death for Thai injured children. This phase was only conducted among 34 multisite centers across Thailand with internal validation. We have not performed an external validation to ensure that the benefits of our score in different countries or networks have not been tested. The external validation is a next priority. A cross-sectional study that includes data from at least five provinces (one province for each region) will be collected using the same methods used in the score development phase. Development of portable personal computer software for score assessment is also necessary for widespread use of the score. Software development may be performed in parallel with the external validation phase or may be delayed until the results of external validation are complete. Before transfer to the user, the software should be tested for errors and for user satisfaction.

Limitations

Some of the limitations indicated that the level of trauma care should be assessed and standardized. Most hospitals have been classified according to the size instead of available facilities. Improvements in transportation time will also improve the quality of trauma care in Thailand. A standardized trauma and injury transportation policy should be implemented. Development of the policy should include assessment of the availability of pediatric staff in emergency medicine, ambulance services for children, specialized medical instruments, and knowledgeable medical personnel. Consideration of these aspects will help policy makers to plan proper allocation of resources.

Conclusions

A 10-variable risk prediction score of death was developed and validated. The variables included in the score were age, intubation, physical mechanism, head, abdomen, and thorax injury, GCS, PR, RR, and SBP. These variables are simple to assess and measure in routine practice. The scoring scheme is simple to calculate and interpret. Children with a high risk classification require prompt emergency treatment and management. Development of error-free and user-friendly software for installation in portable electronic is necessary so that widespread use of the score can be implemented.

Additional file

Additional file 1: Table S1. Collaborating hospitals by trauma care level (I–IV) and region. **Table S2.** Comparison with the Tepas 1987 model. **Table S3.** Comparison with the Pediatric Polytrauma Score 2012. S4. Logistic regression equation.

Abbreviations

AIS: Abbreviated injury scale; ASPTS: Age-specific pediatric trauma score; C-statistic: Concordance statistic; CI: Confidence interval; GCS: Glasgow coma scale score; IDI: Integrated discrimination improvement; IRBs: Institutional review boards; LR: Likelihood ratio; MOPH: Ministry of public health; MySQL: My-structured query language; NISS: New injury severity score; NPIRT: National pediatric injury and trauma registry of Thailand; NRI: Net reclassification improvement; O/E ratio: Observed per expected ratio; OR: Odds ratio; PAAT: Pediatric age adjusted TRISS score; PHP: Personal home page; PR: Pulse rate; PTS: Pediatric trauma score; PV+: Positive predictive value; RI: Reclassification improvements; ROC: Receiver operating characteristic curve; RR: Respiratory rate; RTS: Revised trauma score; SBP: Systolic blood pressure; TRISS: Trauma injury severity score.

Competing interests

All authors declare that they have no competing interests.

Authors' contributions

SV, AP, GS, and AT contributed to the study concept and design. SV, PT, and AP were involved in the process of data acquisition. SV and AT performed data analysis, interpretation of results, and drafted the manuscript. SV and AT critically revised the manuscript. All authors participated in writing the pre-submission versions of the article and contributed substantially to its revision. All authors read and approved the final manuscript.

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The Nationwide Survey of Child Abuse by National Pediatric Injury and Trauma Registry of Thailand (NPIRT)

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Study Objective

Child abuse was top five rank causes of preventable premature death in Thai children. However, the master of national database of child injury integrated with well-designed child abuse database has not been established and successful implementation in Thailand. We aimed to develop the prototype of multicenter national injury database and surveillance of child injury in Thailand with consists of comprehensive of child abuse database.

Methods

Our National Injury Database (NPIRT) included all injured children participated from 34 emergency services across country during 2010-2012. The descriptive analytic of child injury surveillance such as age group, sex, pre-hospital factors and support, vital signs, GCS, mechanism and type of injuries included with child abuse components and outcome were analyzed.

Results

Of these 43,516 from NPIRT, The incidence of child abuses occurred 2,400 cases (5.7 %), Male: Female 1.4: 1. The death rate of child abuse was higher in male than female. Mean age 15.3 + 3.32 years. 92% of children were injured mainly within their residential areas. Only One-third were transferred by ambulance. About 37% had prior communication with the referral hospitals and healthcare worker before transportation. 34% of children had initial first aid at scene and 29% were provided appropriately. The mainly mechanism of child abuses were physical blunt injury (51%) followed by penetrating (5%). Most of common injuries were physical abuse (2,309 cases, 95%), and following with sexually abused (91 cases, 5 %). The overall child abused death was 9 per 1,000 victims.

Conclusions

The NPIRT included with child abuse information was provided as the nationwide comprehensive injury database of Thailand. It was a useful tool to identify the incidence all of death in Thai injured children. It can explore the causes of injury child death integrated with child abuse injury information, their association factors and high risk of injury mechanism that can incorporate to future preventive strategy.

KEY WORDS: INJURY DATABASE, PEDIATRIC INJURY, CHILD DEATH, NPIRT, TYPE OF INJURY, CHILD ABUSE

The Profile of Pediatric Patients Visit Emergency Department at Urban University Hospital in Thailand

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Background: *There is an absence of data describing pediatric patients who visit Emergency Department (ED) in Thailand. Therefore, this report creates a profile of pediatric emergency room visit at a university hospital in Thailand.*
Material and Method: *The retrospective data of the pediatric patient aged less than 15 years that visited ED at Ramathibodi Hospital, Mahidol University, Bangkok, Thailand between fiscal year (FY) 2002 and 2011 were reviewed. The Electronic Medical Record Tracking was extracted. Demographic characteristic, acuity level, timing, and presumptive diagnosis were reviewed.*
Results: *During the 10 years of the data collection, 122,037 pediatric patient visited ED, thus, approximately 12,000 visits per year. Pediatric patients account for an average of 18% of hospital patients. Medical condition accounted for 95.21% of the visits followed by trauma at 4.77%, and death at 0.02%. The triage categorized patients into critical, emergency, urgency, and non-emergency, consisting of 0.6% as critical patients, 37.6% as emergency patients, 52.5% as acute illness, and 9.3% as non-emergency patients. The three most common diagnosis were upper respiratory tract infection, acute febrile illness, and acute gastroenteritis. Patient usually visited ED in the evening shift 44% (4 p.m. to midnight), followed by morning shift 40% (8 a.m. to 4 p.m.), and overnight shift 16% (midnight to 8 a.m.). There were two highest peaks of ED visit, in June, during the rainy season, and in January, during the winter.*
Conclusion: *Pediatric patients attending the emergency service were mostly for medical conditions. Acute illnesses were the major group of pediatric patients. A small proportion of visits in ED were true emergencies.*

Keywords: *Pediatric emergency, Emergency service, Emergency medicine, EMSC, EDIS*

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Emergency department (ED) is the essential and important front line of medical care provided by the hospital[1]. The ED takes care of patient of all ages, 24 hours per day, 7 days a week, in all specialties. According to characteristic, a hospital with a General ED serves all ages and types of patient, while a hospital with a pediatric ED takes care only of children. The perspectives and modalities of emergency care for children are different from adult. Understanding the epidemiological and clinical data of children emergencies will help plan for an effective emergency care for children. Furthermore, this information could help identify common illnesses likely to present at ED enabling early intervention to prevent morbidities and mortalities among pediatric emergency services[2-4]. From current US report, children accounted for 4 to 10% of all emergency medical services at an ED[5]. A few reports from Asia showed that children comprise of 25 to 32% of total ED visit[6,7]. There is a large difference in number between the US and Asian reports. In Thailand, there is a lack of updated report and published epidemiological data of pediatric patient in emergency care and visits.

The objective of the present study was to report the characteristics and trend of pediatric emergency department visits over a 10-year period at an urban university hospital in Thailand.

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Material and Method

Study design and population

A retrospective analysis of the Electronic Medical Record (EMR) of the ED from the Faculty of Medicine Ramathibodi Hospital, Mahidol University of the children aged 0 to 15 year between 2002 and

2011 was done. The faculty of Medicine, Ramathibodi Hospital is a 939-bed urban teaching university hospital in Bangkok, Thailand. There are three main health services building (Main building provides general care and emergency services, Queen Sirikit Building provides general care and transplantation, and Somdech Phra Debaratana Building provides comprehensive care and advanced services).

The ED is located in the main building, providing the emergency medical services and prehospital care for both adult and pediatric patients with 24-hour service. For ED, the electronic clinical data record includes all patient data, investigations, radiographic reports, and finding. This data is entered into the in-house software system called Rama-EDIS and Patient Tracking system.

Data collection

Data was extracted from Rama-EDIS and Patient Tracking System included the demographic data as well as the clinical characteristic (medical or surgical condition), triage acuity (four levels for triage categories, triage level 1 for crisis condition, triage level 2 for urgent condition, triage level 3 for acute illness and triage level 4 for non-urgent or non-acute illness), diagnosis, time of the day, and distribution of patients by month.

Data analysis

The data was analyzed using descriptive statistics, including mean and standard deviation (SD). Numbers, percentage, and proportion were also analyzed for clinical and demographic characteristics. Comparison of demographic data and interested parameters between groups of patients were evaluated by Mann-Whitney U, Fisher's exact or Chi-square test. A p-value <0.05 was considered statistically significant. The statistical analysis was performed using STATA 13.

Ethical approval

The present study was conducted in accordance with the principles of the 1975 Declaration of Helsinki and was approved by the Ethical Clearance Committee on Human Rights Related to Researches Involving Human Subjects, Faculty of Medicine, Ramathibodi Hospital, Mahidol University (Protocol ID 04-56-16, MURA2013/296).

Results

During 10 years of the present review, 122,037 pediatric patients visited the ED, averaging 12,204 visits per year. Most patients were male (M:F = 1.25:1). The trend of ED visit was decreasing from 13,689 visits (FY 2002) to 9,234 visits (FY 2011), see Table 1. The proportion of pediatric patient ranged from 13.54% to 19.63% with average 17.76% of total patient visiting ED.

Medical and surgical conditions: Medical condition was attributed to 116,192 cases (95.21%) and trauma was 5,823 cases (4.77%), see Fig. 1.

Triage and acuity: The ED, Ramathibodi Hospital has been using Triage and acuity Software (Maleewan V, et al) for more than 15 years, customized to four levels according to the emergency level. The triage categories level 1 was assigned to real crisis condition, triage level 2 for urgent condition, triage level 3 for acute illness, and triage level 4 for non-urgent or non-acute illness. The most frequent was triage level 3 (52.5%), followed by triage level 2 (37.6%), triage level 4 (9.3%), and level 1 (0.6%), see Table 2.

Diagnosis: The most common diagnosis of ED visits were acute nasopharyngitis (ICD10; J02),

Table 1. Characteristic of pediatric patient visit emergency department (ED)

Year (n)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Total medical cases	13,038	12,717	12,945	12,950	12,580	11,543	11,587	10,459	9,840	8,533	116,192
Critical	161	113	72	52	45	55	44	51	36	21	650
Emergency	5,936	5,369	5,179	4,712	4,261	4,009	4,023	3,554	3,611	3,024	43,678
Urgency	6,372	6,032	6,435	6,775	6,841	6,089	6,316	5,842	5,320	5,007	61,029
Non-emergency	569	1,203	1,259	1,411	1,433	1,390	1,204	1,012	873	481	10,835
Total trauma cases	644	570	620	535	597	525	593	521	518	700	5,823
Total death	7	2	2	1	2	2	1	3	1	1	22
Total pediatric cases	13,689	13,289	13,567	13,486	13,179	12,070	12,181	10,983	10,359	9,234	122,037
Total ED cases (percent)	69,729 (19.63)	71,170 (18.67)	71,608 (18.95)	71,717 (18.80)	70,564 (18.68)	66,260 (18.22)	66,857 (18.22)	65,612 (16.74)	65,586 (15.79)	68,198 (13.54)	687,301 (17.76)

followed by unspecified fever (ICD10; XX) and gastroenteritis (ICD10; A09), see Fig. 2.

Timing: The working hours of emergency physicians and nurses in ED were divided into eight hours per shift, three rotated shifts a day. The morning shift was from 8 a.m. to 4 p.m., evening shift was from 4 p.m. to midnight, and the night shift was from midnight to 8 a.m. of the next day. Most pediatric patients significantly visited ED at evening shift 44%, then morning shift 40%, and night shift 16% respectively (p-value <0.05).

Seasonal variation: Distributed by the month, there were two peak months of ED visit, in June, during rainy season, and in January, during winter, see Fig. 3.

Discussion

There are not many reports on the characteristics or epidemiologic data of pediatric emergency service at ED in both developed and developing countries[5-7]. Types of ED responsible to take care of children are ED of children hospital or pediatric emergency section within general ED. In Thailand, there is only one children hospital, Queen Sirikit National Institute of Child Health. Because of this, most of the pediatric emergency cares take place within the general emergency department as in our hospital. To date, there is no report about profile or characteristics of pediatric ED visit among emergency services in Thailand. The present study is the first reported profile of pediatric emergency visit in Thailand, in the setting of pediatric ED in the general emergency department.

The present study showed that the proportion of pediatric patient visiting ED averages 17.76% of the total ED visit. The National Hospital Ambulatory Medical Care Survey done in United States between 1997 and 2000 showed 110.9 million ED visits by children aged less than19 years, and Pediatric patients constituted 27.3% of all ED visits during that time[5]. A report from the South Korean National Emergency Department Information System (NEDIS) analyzed the pediatric visits (<19 years old) between 2008 and 2010. It reported that 2,072,664 children visited

Table 2. Triage categorize for medical conditions

Medical condition: (n = 116,192 patients)	n (%)
Triage level 1: Crisis condition	650 (0.6)
Triage level 2: Urgent condition	43,678 (37.6)
Triage level 3: Acute illness	61,029 (52.5)
Triage level 4: Non-urgent or non-acute illness	10,835 (9.3)

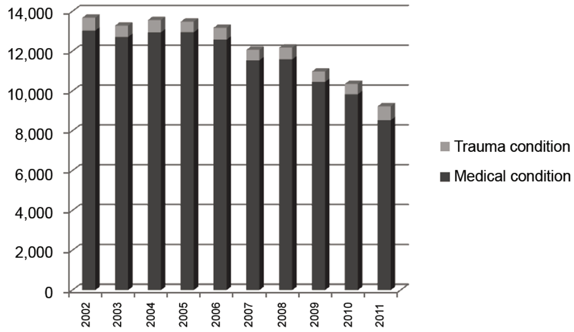

Fig. 1 Characteristic of medical and surgical condition of pediatric patient visit emergency department by year.

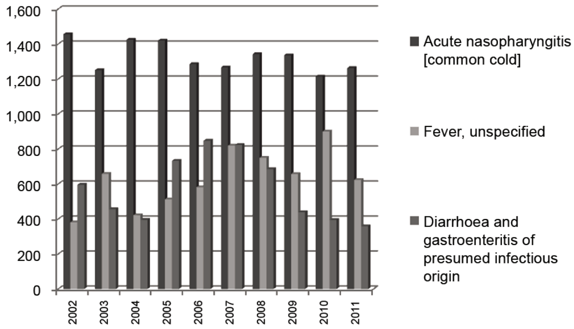

Fig. 2 The distribution of top 3rd rank of diagnosis in emergency visit during 10 years.

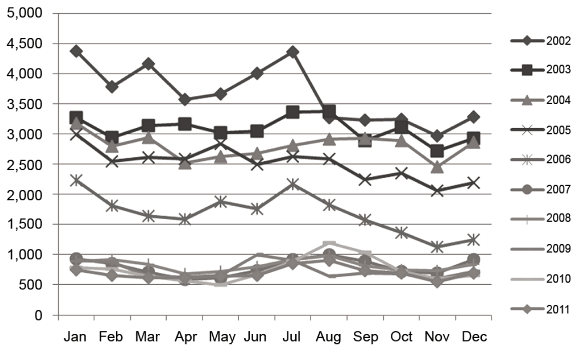

Fig. 3 Distribution of pediatric patient attended the emergency services by month.

124 EDs during the study period. It also stated that these visits were 31.2% of the total ED visits[6]. The report from the National Health Insurance Research Database of Taiwan stated that during the 10 years, between 2000 and 2009, children accounted for 25% of all emergency cases[7].

The trend of emergency department use in the United States increased substantially, both for adult and children, from 90 to 110 million between 1992 and

2002[14]. This is in contrast to our report that the children using emergency department had decreased from 13,689 visits in 2002 to 9,234 visits in 2011. This may be explained by the fact that our hospital has opened a new pediatric ambulatory office building that serves patients with insurance coverage, thus, allowing them to choose medical care that is different from the routine universal coverages provided by the government. The choices of pediatric emergency care are increasing after successfully introducing Emergency Medicine specialist in 2006. The physicians care and expertise also extend to the private hospital sector that provides a convenient service to parents of middle to higher income. The number of pediatric emergency visits may have decreased due to the coverage area that has been assigned as Emergency Facility Care Level by the Ministry of Public Health. Some of patients may be distributed to at least two specific pediatric emergency care, Queen Sirikit National Institute of Child Health and King Mongkut Military Hospital, which were nearby.

In the four-triage categories, the most visited was acute illness (52.5%) for real emergency. The crisis condition accounted for 0.6%, the other urgent condition was 37.6%, and non-urgent/non-acute illness was 9.3%. According to the trend of pediatric emergency department utilization, most of them are non-urgent care. Compare to the report from US study epidemiology of pediatric department at urban medical center, nearly half of pediatric emergency visits were for non-urgent care (46.0%), and other 42.0% sought urgent care exclusively, 12% received both urgent and non-urgent care[8]. Our report showed that the medical conditions composed of more than 95% of all visits while surgical complaint was about 5%. Compared to the report from South Korea, the ED visits with medical condition were 71%, whereas surgical conditions were 39%[6]. This may be explained by that they included the data from some EDs that have a trauma center.

From the present study, the most common diagnoses were acute respiratory tract infection (common cold), fever, and gastroenteritis. Most of them were non-emergency visit. Compared to reports from US, common non-emergent visits included mild asthma, viral syndromes, otitis media, allergy, or minor injury[15]. In Asia, the report from South Korea showed that the most important complaint was fever (37.4%), whereas many older children presented with abdominal pain (15.4%)[6]. The report from India showed that the highest complaints were gastrointestinal and respiratory illnesses (23% each), neurological emergencies (16%), and neonatal problems (15.6%)[9-11]. Recently, the report from Taiwan showed acute upper airway infection, fever, and acute gastrointestinal illness as the most common diagnoses among all non-hospitalized children, similar to our study. Of these 4.5% required subsequent hospitalization, and their most common diagnosis was fluid/electrolyte disorder, upper/lower airway infection, and acute gastrointestinal illness[7].

About work hour shifts, our study showed that pediatric patient visited ED during evening time, more than morning and nighttime. These finding may be explained by the location of our hospital, which is located at the urban center and most parents work during daytime and brought their children to ED after working hour. The second reason was the parent perceived attitude that they received faster service than in the morning shifts due to crowding patients. This has been reflected from survey reports.

There are strong seasonal variations in clinical presentation at ED. There are two peak periods, which are the winter and the rainy season. January and June are the most active months at the ED. Compared to the study from India[9-11], the maximum number of patients were seen in the monsoon months of July and August. The awareness of seasonal variation in the number and incidence of common pediatric emergencies is important for planning as well as preventive action of common illness.

There were few reported death at ED. Our report indicated 0.02% (22 cases from 122,037 patients in 10 years) mortality rate. A study from Egypt[12] reported overall mortality rate was 0.8%. Study from India[10] reported about 2% of patients died within 24 hours of hospitalization from ED. The study from Turkey[16] reported the net mortality rate was 2.9%, infectious diseases being the most common cause of mortality. Both studies reported the death after admission to the hospital but do not report death at ED.

Preparation and improvement of the quality of care in ED is based on the characteristic of patients who visit ED[17]. The epidemiologic and clinical data will help to initiate guideline for practice and strategy to promote first-line emergency service for children at ED[18,19]. The epidemiological result from the present study will help towards pediatric emergency plan as well as initiate guideline of common pediatric emergency problem and quality improvement of pediatric emergency care in the future.

Conclusion

We reported the profile of pediatric emergency room visit, most were acute illness. Real emergency, critical conditions were making up a small proportion. The clinical data will help in setting up pediatric emergency's strategy plan to improve the pediatric emergency care, both in academic and service prioritized on teaching and training both undergraduate medical students and postgraduate physicians.

Limitations

The present study had some limitations. First, our study was reported from a single institute at the university hospital. The data may not represent the other ED settings. Other limitation was due to extracting data from EMR where some data such as cause of death could not be explored in-depth.

What is already known on this topic?

The overall picture of EMSC (Emergency Medical Services of Children) in Thailand has not been established despite that the Emergency Medicine training has been initiated for more than five years already. We still lack a database of children who visited to emergency services in the aspect of descriptive characteristics of diseases that lead these patients to Emergency visit. Baseline characteristic and amount of patients in each shift is useful to anticipate the resource requirement for emergency management, based on time of the day and the season. We need to know the factors that are used to prepare and improve the quality of care in ED.

What this study adds?

The present study described EMSC in Thailand, which is one small part of the general emergency service. The amount of EMSC in this urban area is nearly one fourth of the overall emergency services, which is less than in rural area. The reason could be due to the well-developed ambulatory pediatric care in urban area and the density of medical care and services. The services provided to patients differ because of the number of patients, the rate of arrival and the staff available. Furthermore, seasonal variations, epidemic, school academic calendar, and holidays affects the demand for the service. By using this database, the mortality and quality of emergency service in different areas can be anticipated along with labor, facility of healthcare equipment, and professionalism. The results of this 10 years study may show a big picture of EMSC may help improve the direction and policies of services in the future.

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Potential conflicts of interest

None.

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ข้อมูลพื้นฐานการรับบริการด้านการแพทย์ฉุกเฉินของกลุ่มผู้ป่วยเด็กที่เข้ารับบริการในโรงพยาบาลระดับมหาวิทยาลัยในประเทศไทย

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วัตถุประสงค์: *เพื่อทบทวนและวิเคราะห์ข้อมูลย้อนหลังข้อมูลพื้นฐานของกลุ่มผู้ป่วยเด็ก อายุน้อยกว่า 15 ปี ที่เข้ารับบริการด้านการแพทย์ฉุกเฉิน ระดับโรงพยาบาลมหาวิทยาลัย ตั้งแต่ พ.ศ. 2545 ถึง พ.ศ. 2555 (10 ปี)*

วัสดุและวิธีการ: *การศึกษาวิจัยแบบทบทวนย้อนหลังข้อมูลการเข้ารับบริการการแพทย์ฉุกเฉินของผู้ป่วยเด็ก 122,037 ราย ที่แผนกเวชศาสตร์ฉุกเฉิน คณะแพทยศาสตร์ โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล โดยใช้ข้อมูลที่บันทึกจากเวชระเบียนอิเล็กทรอนิกส์ฉุกเฉินจากระบบที่ออกแบบไว้โดยเฉพาะสำหรับผู้ป่วยเด็ก ทั้งในด้านข้อมูลทั่วไป ระดับความรุนแรงของการรักษา ระยะเวลาและช่วงของการเข้ารับบริการ และข้อมูลการวินิจฉัย*

ผลการศึกษา: *อัตราการเข้ารับบริการโดยเฉลี่ยเท่ากับ 12,000 ครั้งต่อปี จากจำนวนผู้ป่วยเด็กฉุกเฉินทั้งสิ้น 122,037 ราย โดยคิดเป็นสัดส่วนเฉลี่ยร้อยละ 18 ของผู้ป่วยทั้งหมดที่เข้ารับการรักษาที่ห้องฉุกเฉินทั้งหมด พบผู้ป่วยส่วนใหญ่หรือร้อยละ 95.21 เป็นการเข้ารับบริการการแพทย์ฉุกเฉินจากการเจ็บป่วยด้วยโรคต่างๆ ส่วนน้อยร้อยละ 4.77 เข้ารับบริการจากอุบัติเหตุ พบอัตราการเสียชีวิตรวมร้อยละ 0.02 จากข้อมูลระดับการคัดกรองพบว่า ระดับวิกฤติพบร้อยละ 0.6 ระดับฉุกเฉินพบร้อยละ 37.6 เจ็บป่วยเฉียบพลันพบร้อยละ 52.5 และระดับไม่ฉุกเฉินพบร้อยละ 9.3 ตามลำดับ สาเหตุการหลักของเข้ารับบริการฉุกเฉิน 3 อันดับแรกในเด็กได้แก่ การติดเชื้อของระบบทางเดินหายใจส่วนบน ภาวะไข้ และการติดเชื้อของกระเพาะอาหารและลำไส้เฉียบพลัน สถิติพบว่าการเข้ารับบริการของผู้ป่วยเด็กฉุกเฉินส่วนใหญ่ในเวรกะเย็น (16:00 ถึง 24:00 น.)มากถึงร้อยละ 44 เวรกะเช้า (8:00 ถึง 16:00 น.) ร้อยละ 40 และส่วนน้อยร้อยละ 16 ในเวรกะดึก (24:00 ถึง 8:00 น.) ตามลำดับ ซึ่งพบความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ (p-value <0.05) พบอัตราการกระจุกตัวของผู้ป่วยเด็กเข้ารับบริการสูงสุดในสองช่วงเดือนคือ ในเดือนมิถุนายนหรือระหว่างฤดูฝน และเดือนมกราคม ซึ่งเป็นช่วงปลายฤดูหนาว*

สรุป: *ข้อมูลพื้นฐานของการรับบริการการแพทย์ฉุกเฉินในเด็กส่วนใหญ่ สาเหตุมาจากการเจ็บป่วยฉุกเฉินจากโรคต่างๆ โดยพบว่าระดับการเข้ารับบริการส่วนใหญ่อยู่ในระดับเจ็บป่วยแบบเฉียบพลัน มากกว่าการเจ็บป่วยแบบวิกฤติและฉุกเฉินจริงซึ่งพบเป็นกลุ่มน้อยที่เข้ารับบริการที่ห้องฉุกเฉิน*

The Study of Familial History and Associated Risks of Sexually Abused Children at Ramathibodi Hospital

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Background: *Nowadays, the incidence of sexual abuse in children is increasing especially in Thailand and the ASEAN countries. However, the study of risk factors in family history is limited.*
Objective: *Assess the significant family background and family history risks of sexually abused children.*
Material and Method: *This retrospective cross-sectional study used standard questionnaires to collect the general information of children who were sexually abused victims and explore their family history at the Parenting and Family Support Clinic, Department of Pediatrics, Ramathibodi Hospital, Mahidol University between 2011 and 2013.*
Results: *The majority of sexually abused children were aged 13 to 15 years (33 cases, 66%). Twelve children (24%) had underlying substances abuse and mood disorder in parental history, eleven (22%) had fathers with alcoholism problem, nine (18%) had mothers with mood disorder, and eight (16%) had both underlying conditions. There were 41 single families (82%). Twenty-nine cases (58%) had conflicting relationship between their parents. The significant risk factors such as baseline children's behaviors, abusers, family status, violent history in family background, underlying substances abused or mood disorder, and baseline relationships in family were studied to develop a decision matrix to see when urgent separation to save the child from sexually abuse event is required. The logistic regression was analyzed and demonstrated that parental physical violent history and age group 8 to 12 years were higher odds ratio 19.0 (95% CI: 2.62-137.52, p-value = 0.004), and 19.2 (95% CI: 2.15-171.82, p-value = 0.002) when compared to other groups.*
Conclusion: *Basic familial problems were commonly found in sexually abused children. Some of these factors are significant and can be applied as guidance for safety separation protocol for child safety in case of a sexually abused event.*

Keywords: *Background Family, Child Sexual Abuse, Abuse, Logistic Regression*

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Current advances in technology and communications in Western civilization have led to rapid progress in economic development and social changes. These may affect moral and ethical behavior in relation to domestic violence in the society. One important issue of these changes is the sexual abuse in children. Children sexual abuse will affect both the short and long-term children's physical and psychological health. Additionally, it will seriously burden to public health system.

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The worldwide prevalence of child sexual abuse was 0.9 to 45%[1-3]. Estimates of the prevalence of sexual abuse varied greatly depending on definitions and the way in which information was collected. The reported prevalence was different and it was very difficult to determine the exact number. The data from the Child Protection Fund (2008-2009) showed that children under 18 years who were sexually abused increased over time. The incidence of child sexual abused cases increased from 5,885 in 2008 to 6,398 cases in 2009 or an average of 18 cases per day.

Vallipakorn et al (2014) reported 2,400 cases (5.5%) of child abuse in the age range of 0 to 19 years from a multicenter study across Thailand between April 2010 and October 2012. The study found that 3.8% (91 cases) of overall abused and neglected were child sexual abuse. Of these cases, 43 (47.2%)

were unspecified abusers, 22 (24.2%) were abused by boyfriends, 19 were abused by strangers (20.9%), five were abused (5.5%) by relatives, and two were abused by father/stepfather (2.2%). No death was report in sexually abused children. All of these victims had reported the comorbid evidences of physical and psychological injuries. In these victims, 23 (25.3%) were classified as serious injury and had to be admitted in hospital. About 98.9% of cases showed minor disability, needed 10 to 14 days to recover, and needed long-term follow-up and support for psychological problems[4].

The reported incidence of sexual abuse of a child is usually less than the actual number because of the influence of culture in a society. The family or the victim will feel a sense of shame on the family lineage and the impact of living in a society, when a case of assault or sexual abuse occurs to one of family members. The short-term consequence of the victims of sexual abuse includes physical, emotional, and social development. Furthermore, there are many long-term problems such as increasing risk of psychiatric disorders. These affect individuals, families, and society, with even more damage to the economy and the community[5-7]. The associated factors of the occurrence of sexual abuse were family problems, disruption of family, and social background of the child's family or caregivers. These primary factors had significant risk of sexual abuse in children.

Bentovim A et al (1987) found that 75% of sexually abused children were abused by the people living in the family, 46% were the individual's father, and 27% were stepfather. Girls living with stepfather were six times more likely to be abused compared to girls living with their own father[8]. World Health Organization (2006-2010) reported that 80% of abused children were abused by parents or guardians. The risks of being abused were the low socioeconomic status, pathological mental or psychological problems, low education, the use of alcohol or illicit drugs, abuser had been abused in childhood, broken family, and violence from other family members[9].

Limsakul U, and the Ministry of Social Development and Welfare and Human Security of Thailand (2009) reported 71 cases of abused children and the impact of domestic violence. From these, 37 patients (44%) were victims of sexual abuse. Children aged 12 to 15 years had higher risk of injury and sexual abuse. Sixteen cases were sexually abused by their family members, four cases were abused by individual's fathers, and six cases were abused by stepfathers. In addition, children aged 10 to 14 years and 15 to 19 years had a higher rate of sexual abuse[10].

From the above, we realize that the problems of child sexual abuse in our country have become more serious and complicated. Several important associated risk factors were demonstrated within the family history and their background. Therefore, our objectives are to study the background of the families, and the associated risk factors of children being sexually abused to find the significant key factors. With these tools, we will recommend the help, the planning of the urgent separation of victim, and the prevention to eliminate future problems.

Definition

Sexual abuse is a form of child abuse in which an adult or older adolescent uses a child for sexual stimulation. Forms of child sexual abuse include asking or pressuring a child to engage in sexual activities (regardless of the outcome), indecent exposure (of reproductive organs, etc.) to a child with intent to gratify their own sexual desires, to intimidate, or to groom the child, physical sexual contact with a child, or using a child to produce child pornography[11,12].

Material and Method

The present study was retrospective cross-sectional study. It enrolled children ages 5 to 15 years old diagnosed of child sexual abuse, and their parents who visited the Parenting and Family Support Clinic, Department of Pediatrics, Faculty of Medicine, Ramathibodi Hospital, Mahidol University. The clinic provided services by multidisciplinary team consisting of pediatricians, child and adolescent psychiatrists, social workers, and pediatric nurses to manages and rehabilitates the sexually abused children and their family.

All of subjects were chosen as particular sample into the present study. The standard questionnaire was used as a tool for explore the family history and background. The main questionnaire consisted of two parts. The first part was asking about general information, e.g. the child's age, education, behavioral problems, and types and relation of person who sexually abused the child. The second part was a set of questions about characteristics and background of family, history of domestic violence in family, and the relationship among parents and children. The composition of the structures and language/meaning of questionnaires were proposed to three experts for consideration, revised for appropriate queries, and approved.

Data collection

The retrospective data collection was done after the approval of the Ethics Committee of Ramathibodi Hospital, Mahidol University (Certificated number 486/2555, ID 10-55-53). The social workers and assigned members collected information from anecdotal reports of children being sexually abused, and extracted the data into the social work, mental health, and clinical perspectives.

Statistical analysis

The interested factor of risks and background of family history were reviewed and collected from questionnaires. The descriptive analyses were done, and then some of factors related to outcome of safety protocol to separation of the sexually abused child from family as an urgent condition were selected and analyzed by univariate analysis. The significant factors from univariate analysis, which had a *p*-value <0.10, were further analyzed by multiple logistic regression analysis to find out significant association with the outcome (*p*-value <0.05). The analysis was done using STATA 13.0 software (College Station, TX, USA).

Results

Fifty sexually abused children attended the Parenting and Family Support Clinic, Department of Pediatrics, Ramathibodi Hospital, Mahidol University between January 2011 and December 2013. All the sexually abused children were girl victims (100%). The baseline characteristics of subjects had been described in Table 1. The mean aged was 11.88±3.13 years, median age 13 years (range = 5-15). About 33 cases (66%) were sexually abused teenage (13-15 years), followed by lowest age group 5 to 7 years (9 cases, 18%), and 8 to 12 years (8, 16%), respectively. Most of the abused were secondary school student (28 cases, 56%) with separated or divorced family status (32 cases, 64%).

The behavioral problems of the subjects that might be at risk to sexual abuse were truancy (36%), loafing behavior (30%), and learning problems (22%). The incidence of child sexually abuse was occurred more on single-family type than secondary or tertiary family types (42% vs. 8%).

The most common person who sexually abused children were boyfriends (36%) followed with strangers (24%), stepfather (22%), and relatives (12%). Sexually abused by individual's father in the present study reported only 6%. This might be different when compared with the incidences among ASEAN countries. Tang CS et al (2002) reported the prevalence of child sexual abuse at about 6%, and showed average age of the victims at the time of the sexual abuse was 11 years old. The majority had sexual abuse during their teenage years. Of these, 28% of abusers in this studied were strangers[13]. From this study, the most common person who children would consult after being sexually abused was mother (48%) and relative (32%).

We found that the relationship in family, especially between father and mother was the most common problem (58%). The relationship between the fathers and sons was estranged (60%), followed by neglected relationships (20%). The rapport between mothers and children were abandoned, neglected, and let loose (30%), followed by disaffected (26%). The history of verbal violence (26%) and physical violence (22%) were reported in parent's family history.

Most of the children selected to consult their mother after a sexual abuse event. Sixty-eight percent

Table 1. Baseline characteristics of 50 sexually abused children

Baseline characteristics	Number (%) or mean ± SD Total n = 50
Age (years), mean ± SD	11.88±3.13
Median (range)	13 (5, 15)
Age groups (years)	
5-7	9 (18)
8-12	8 (16)
13-15	33 (66)
Education	
Kindergarten	5 (10)
Primary School	7 (34)
Secondary School	28 (56)
Baseline of child behaviors	
Lying	6 (12)
Truancy	18 (36)
Loafing behavior	15 (30)
Learning problems	11 (22)
Family types	
Single	42 (84)
Secondary to tertiary	8 (16)
Family status	
Couple	18 (36)
Separated	25 (50)
Divorced	7 (14)

of familial reactions and responses for this situation were negative responses, rebuked (30%), concealed (24%), and neglected (14%). Only 32% of family responses were listening and helping the sexually abused children to cope with the problems. The management of children who were the victim of sexual abuse was to refer them to the responsible agency to look after their children, if there were any risks of serious outcome or the environment being unsafe for the children.

Twenty-six sexually abused cases (52%) were in the group of seriously abused that needed immediate separation of the children from their family by the Child Protection Organization/Units. Among the risk factors, we found the trend of the most severity of sexually abuse occurred by stranger and boyfriend (19 cases, 63% vs. 7 cases, 35%). Both groups needed urgent separation to the supportive care team after exploring the risks and their background. The relationship in family had shown to be a key factor to predict the urgency to separate child from family for safety. The present study found the significant factors that associated with urgent separation strategy to safe the child were age groups (p-value = 0.101), baseline of behaviors (p-value <0.001), type of abuser (p-value = 0.049), family status (p-value = 0.074), parental history of domestic violence (p-value <0.001), underlying behavior of parent such as substance abuse or mood disorder (p-value = 0.002), and the baseline of relationships in family, such as separation, argument, and argument with physical assault (p-value = 0.008) were associated with mode of management to separate child from family (26 cases, 100%, p-value <0.05). The association of baseline relationships in family showed a trend of those responses association when increasing of arguments and conflicts in family (Table 3). After univariate analysis, we included all the factors that were statistically significant (p-value <0.10) into the multiple logistic regression analysis to find a parsimonious model or factor(s) that helps make a decision to manage sexually abused children. The results showed that two significant factors were strongly associated with sexually abused children. They are the parental background history of physical domestic violence and age group. First, the parental background history of physical domestic violence had Odds ratio (OR) 19 times higher when compared with verbal domestic violence and no domestic violence in family history (p-value = 0.004, 95% CI: 2.62-137.52). The second significant factor was age group and the age 8 to 12 years showed OR 19.2 times higher when

Table 2. Family-based information of the sexually abused children

Studied factors	Number (%) Total n = 50
Abusers	
Father	3 (6)
Step father	11 (22)
Cousin/relative	6 (12)
Strangers	12 (24)
Boyfriend	18 (36)
Choices of consultation	
Mother	24 (48)
Cousin/relatives	16 (32)
Teacher	5 (10)
Neighbor	2 (4)
Friends	3 (6)
Intimacy of children with family member	
Father	2 (4)
Mother	30 (60)
Both	3 (6)
Relatives	10 (20)
None	5 (10)
Relational to family members	
Family relationship	
Loving great camaraderie	2 (4)
Incompatible	11 (22)
Controversy, but it is not assault	29 (58)
Conflict and controversy with mayhem	8 (16)
Child-Father relationships	
Loving great camaraderie	4 (8)
Disaffected/estranges	30 (60)
Let loose abandoned, neglected	11 (22)
Conflict and controversy	5 (10)
Child-Mother relationships	
Loving great camaraderie	10 (20)
Disaffected/estranges	14 (28)
Let loose abandoned, neglected	15 (30)
Conflict and controversy violent modes	11 (22)
Parent history of domestic violent	
Physical violent	11 (22)
Verbal violent	13 (26)
None	26 (52)
Behavior response after sexual abuse	
Concealed	12 (24)
Rebuke	15 (30)
Listen and help	16 (32)
Negligent	17 (14)
Helping method after sexual abuse	
More close	11 (22)
More attentive	13 (26)
Sent to agency's responsibility units	26 (52)

compared with other age groups (p-value = 0.008, 95% CI: 2.15-171.82). This mean that children with a parental history of physical domestic violent would have a greater risk of 19 times and 19.2 times when the age group was 8 to 12 years of being sexually abused. Therefore, they need urgent separation from family when compared to no parental history and verbal violence history in family, and other age groups (Table 4).

Discussion

The present study found that children are sexually abused as early as 8-year-old through late teenagers. Sixty percent (30 cases) are sexually abused by father, step-father, or relatives closed to family. Twenty percent (20 cases) are abused by strangers and boyfriends. Thirty-six percent (18 cases) are sexually abused by boyfriends with their collusion. The analyses of this child sexually abused database revealed that

Table 3. Univariate analysis among risk factors and management strategies (urgent separation vs. closed observation)

Risk factors	Urgent separation n = 26 (52%)	Closed observation n = 24 (48%)	Odds ratio (95% CI)	*p*-value
Age groups				
5-7	2 (22.2)	7 (77.8)	1	0.101
8-12	6 (75.0)	2 (25.0)	10.5 (0.69-159.69)	
13-15	18 (54.5)	15 (45.5)	4.2 (0.69-25.40)	
Baseline of child behaviors				
Lying	1 (16.7)	5 (83.3)	1	<0.001*
Truancy	17 (94.4)	1 (5.6)	85.0 (0.71-10,200.00)	
Loafing behavior	4 (26.7)	11 (73.3)	1.8 (0.15-22.31)	
Learning problems	4 (36.4)	7 (63.6)	2.9 (0.21-38.70)	
Abused by				
Family member/relatives	7 (35.0)	13 (65.0)	1	0.049*
Non family member	19 (63.3)	11 (36.7)	3.2 (0.93-11.11)	
Family types				
Secondary to tertiary	2 (25.0)	6 (75.0)	1	0.132
Single	24 (57.1)	18 (42.9)	4.0 (0.67-23.73)	
Family status				
Couple	7 (38.9)	11 (61.1)	1	0.074
Separated	17 (68.0)	8 (32.0)	3.3 (0.86-12.74)	
Divorced	2 (28.6)	5 (71.4)	0.6 (0.09-4.38)	
Parent history of domestic violent				
None	6 (23.1)	20 (76.9)	1	<0.001*
Physical violent	8 (72.7)	3 (27.3)	8.9 (1.40-56.37)	
Verbal violent	12 (92.3)	1 (7.7)	40.0 (2.00-799.32)	
Underlying of parents				
None	15 (39.5)	23 (60.5)	1	0.002*
Alcoholism or mood disorder	11 (91.7)	1 (8.3)	16.9 (1.49-190.53)	
Baseline relationships in family				
Loving great camaraderie	0 (0.0)	2 (100.0)	1	0.008*
Incompatible	2 (18.2)	9 (81.8)	0.2 (0.05-1.03)	
Controversy, no assault	17 (58.6)	12 (41.4)	1.4 (0.68-3.00)	
Conflict and with mayhem	7 (87.5)	1 (12.5)	7.0 (0.86-56.89)	

* p-value <0.05

Table 4. Multiple logistic regression analysis among risk factors and management strategies

Risk factors	Adjusted OR	95% CI	*p*-value
Parental history of physical violent	19.0	2.62-137.52	0.004
Age 8-12 years	19.2	2.15-171.82	0.008

74% (37 cases) have family disputes and 16% (8 cases) have evidences of physical abuses or assaults in the relationship between fathers and mothers.

In depth interview, the present study found that most children often felt a lack of shelter. The majority of children also have a closed relationship with the family as a dependent condition. Most families have frequent financial problems. The interviews reveal that most parents who took care of their families have to work and get more stress to earn enough money to support their families. Moreover, most of the families often lack the skills to encourage their children to grow up in both physically and mentally healthy. Those children were exposed to the physical and verbal violence or abusive environment in their family. The reports show that both parents usually had emotional and psychological problems, including judgment and responsibilities to the family.

The present study found that the sexually abused children had at least one behavioral problems. Truancy behavior was the majority of the problems, followed by learning problem, and loafing behavior. Because the present study was descriptive and analytical, without time incidence, we could not clarify whether these behaviors were the cause or the result of being sexually abused. However, we demonstrated statistically significant association between the trend of truancy behavior with sexually abused cases, and more association between truancy behavior with severely sexually abused cases that needed urgent separation from family (17 cases, 65.4%) (p-value <0.001). These results agree with results of previous researches such as studies of Caminis A et al (2007) and Teplin (2005), which found that sexual risk behavior correlated with other behavioral problems such as illegal behavior, truancy, substance abuse(14,15).

Parental history of substances abuse, alcoholism, or mood disorder are demonstrated as the higher risks associated with sexual abuse in children. The results showed 11 cases (22%) of father having alcoholism history, and nine cases of mother having mood disorder (18%) from psychological evaluation. This relevance to Norman R et al (2010) shown that poverty, alcohol, and substance abuse in parents, family rift, and domestic violence were risk factors of child being sexually abused(16). Similar to the study of the American Psychological Association (2011), it found the family characteristics of children being sexually abused were children without parents and live with stepfathers, their parents experienced violence in childhood, parents or caregivers used drugs and alcohol, economic problems, history of family abuse, marriage failure, and neglected children by their parents. These factors were at high risk of children being sexually abused(17).

In summary, we determine that the families with problems are often found in sexually abused children. Some of these problems or risks may associate to the children who were sexually abused. The novel care of sexually abused children should focus on the whole family, parental background, intrinsic and extrinsic factors within family, and relationships among parents and child as holistic approach. More support by multidisciplinary teams to provide the appropriate continuity care for abused children is required.

Conclusion

The present study show that family of sexually abused children had many problems and conflicts within family, such as their parents' divorce, socioeconomic problems, domestic violence, estranged relationship, child rearing problems (abandoned and neglected children), substance abuse problems of their father (alcohol and other substances), and mother with emotional and psychological problems. Some of these factors may cause a risk of serious episode up to fatal outcome or may impede the restoration of the child health back to normal. They reveal important concepts of care for these children consisting of professional approaches and exploring the family background and risks. The multidisciplinary work should begin with the evaluation of the child safety and well prepared emergency separation if any evidence of high risks of sexually abused or predisposed to morbidity-mortality outcome is found. A following step to help restore and strengthen the families tie to allow the child going back to normal as soon as possible should be done with the help of the multidisciplinary team.

Because sexual abuse is not only a civil problem of children or family, it is regulated by the UN Declaration on the Rights of Children, which is an international issues affecting the nation integrity. It is important that public and private sector stakeholders focus on developing and rehabilitating tangible holistic approach to cover all children, families, communities, and society.

The present study had some limitations. First, the population was relatively small due to the nature of epidemiology of sexually abused victims. Second, this study was only of sexually abused children who had been rescued and came to the hospital for treatment, which did not represent the children who were sexually abused in the general community. Therefore, some cases may not have been helped in the hospital. Finally, the present study had no control group except severity within abused group only. The control group may make a difference in a child's condition, the family of the sexually abused, and children who have not been sexually abused. Therefore, future research should plan to collect widely data ranges from the population or reviews from child abuse report from community, including from child death record. The control groups of other child abuse should be selected from a wider range of locations such as hospitals or community agencies. Additional research would make the data more accurate and could be applied in healthcare practices to find better ways to help, rehabilitate, and prevent children from being sexually abused.

What is already known on this topic?

The effects of sexual abuse on the incidence of depression and had been published in Journal of Boromarajonani College of Nursing, Bangkok, Volume 27 Issue 2; May-August 2005. The study used a 27-questions questionnaire self-report and the Children's Depression Inventory (CDI) by Maria Kovacs, adapted from Beck Depression Inventory. In the future, the correlation between childcare of sexually abuse child and child safety will be studied.

What this study adds?

Benefit of this study is to evaluate the family-based information for helping the sexually abused children. The family problems, such as mental health problems or substance abuse needs psychiatric treatment and social rehabilitation leading to empathy and intimacy within the family. Therefore, children can return to their own families and prevent repetitive incidences.

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Potential conflicts of interest

None.

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การศึกษาประวัติภูมิหลังและความสัมพันธ์ของปัจจัยเสี่ยงในครอบครัวของเด็กที่ถูกทารุณกรรมทางเพศที่โรงพยาบาลรามาธิบดี

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ภูมิหลัง: *ปัจจุบันการศึกษาปัจจัยเสี่ยง รวมถึงภูมิหลังและประวัติครอบครัวที่เกี่ยวข้องกับการทารุณกรรมทางเพศของเด็กยังมีจำกัด แม้อุบัติการณ์การเกิดมีแนวโน้มเพิ่มขึ้นทุกวันโดยเฉพาะอย่างยิ่งในประเทศไทยและกลุ่มประเทศอาเซียน*

วัตถุประสงค์: *การศึกษานี้เป็นการศึกษาแบบตัดขวาง โดยการทบทวนเวชระเบียนและแบบประเมินของเด็กที่ถูกทารุณกรรมทางเพศย้อนหลัง เพื่อประเมินภูมิหลัง ประวัติครอบครัว ปัจจัยพื้นฐานของเด็ก และปัจจัยเสี่ยงจากประวัติครอบครัว รวมถึงศึกษาความสัมพันธ์ระหว่างปัจจัยเหล่านี้กับความเสี่ยงในการถูกทารุณกรรมทางเพศและความปลอดภัยของเด็ก*

วัสดุและวิธีการ: *โดยแบบสอบถามมาตรฐานสองส่วนหลัก ส่วนแรกนำมาใช้ในการเก็บรวบรวมข้อมูลทั่วไปของเด็กที่ถูกทารุณกรรมทางเพศ และส่วนที่สองนำมาสำรวจภูมิหลังของประวัติครอบครัวของเด็กที่ถูกทารุณกรรมทางเพศ ที่คลินิกส่งเสริมการเลี้ยงดู ภาควิชากุมารเวชศาสตร์ คณะแพทยศาสตร์ โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล ระหว่าง พ.ศ. 2554 ถึง พ.ศ. 2556*

ผลการศึกษา: *ผู้ป่วยเด็กส่วนใหญ่ที่ถูกล่วงละเมิดและทารุณกรรมทางเพศ มีอายุระหว่าง 13-15 ปี (33 ราย, 66%), 12 ราย (24%) ของเด็กที่พบ พบว่ามีประวัติใช้สารเสพติดและมีความผิดปกติของอารมณ์ของบิดามารดา เด็ก 11 ราย (22%) มีบิดาที่มีปัญหาโรคพิษสุราเรื้อรัง, 9 ราย (18%) มีมารดาที่มีความผิดปกติทางอารมณ์ และ 8 ราย (16%) มีทั้งสองปัญหาร่วมกัน นอกจากนี้พบว่า 42 ราย มีลักษณะแบบครอบครัวเดี่ยว (84%) 29 ราย (58%) พบความขัดแย้งในครอบครัวของความสัมพันธ์ระหว่างบิดามารดา จากการศึกษาพบปัจจัยความเสี่ยงที่สำคัญ เช่น พฤติกรรมพื้นฐานของเด็ก ประเภทผู้ทารุณกรรม สถานะครอบครัว ประวัติความรุนแรงในครอบครัวของบิดามารดา การใช้สารเสพติดและความผิดปกติของอารมณ์ รวมถึงความสัมพันธ์พื้นฐานภายในครอบครัว ซึ่งพบความสัมพันธ์อย่างมีนัยสำคัญ ระหว่างปัจจัยต่าง ๆ เหล่านี้กับมาตรการแยกเด็กออกจากครอบครัวเพื่อช่วยให้เด็กปลอดภัยจากเหตุการณ์การถูกล่วงละเมิดและทารุณกรรมทางเพศ เมื่อวิเคราะห์ต่อด้วยวิธีถดถอยโลจิสติก พบว่าปัจจัยเสี่ยงที่สำคัญ คือ ประวัติใช้ความรุนแรงในครอบครัว ซึ่งผู้ปกครองเคยมีประวัติครอบครัวได้รับการทารุณกรรมทางกายมาก่อน และช่วงอายุ 8-12 ปี โดยพบว่ามีความเสี่ยงสูงอย่างมีนัยสำคัญทางสถิติ โดยมี odds ratio 19.0 (95% CI: 2.62-137.52, p-value = 0.004) และ 19.2 (95% CI: 2.15-171.82, p-value = 0.002) ตามลำดับ เมื่อเทียบกับช่วงอายุอื่น ๆ และกลุ่มที่ไม่มีประวัติการใช้ความรุนแรงทางกายในครอบครัว*

สรุป: *พื้นฐานปัญหาครอบครัวเป็นปัจจัยและความเสี่ยงที่พบมากในเด็กที่ถูกทารุณกรรมทางเพศ ปัจจัยบางอย่างที่มีความสำคัญและสามารถนำมาประยุกต์ใช้ในการกำหนดแนวทางการจัดการเพื่อเฝ้าระวังและดำเนินการแยกเด็กออกจากครอบครัว เพื่อให้เกิดความปลอดภัยของเด็กที่ถูกทารุณกรรมทางเพศมากที่สุด*

ระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียม
The Severity and Mortality Forecasting System of Pediatric Injuries using Artificial Neural Networks

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บทคัดย่อ

ในปัจจุบันเมื่อเกิดอุบัติเหตุกับเด็กขึ้น ผลการรักษานั้นจะแปรผันตามความรุนแรงของการบาดเจ็บและความสามารถในการวินิจฉัยของผู้รักษา ซึ่งทำให้ผลรักษาไม่แน่นอน เพื่อลดช่องว่างดังกล่าวจึงได้คิดค้นพัฒนางานวิจัยชิ้นนี้เพื่อพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียมแบบหลายชั้น (Neural Networks Multi-Layer Perceptrons) โดยใช้การเรียนรู้แบบ Back Propagation เพื่อช่วยในการตัดสินใจและช่วยลดความผิดพลาดอันเนื่องมาจากการวินิจฉัยและการรักษาของบุคลากรทางการแพทย์ต่ออาการบาดเจ็บที่เด็กได้รับ ซึ่งข้อมูลที่นำมาใช้ในการเรียนรู้มาจากฐานข้อมูลการเฝ้าระวังการบาดเจ็บ (National Registry of Pediatric Injury ; Rama PedISS) โดยเครือข่ายเฝ้าระวังการบาดเจ็บในเด็กแห่งประเทศไทย (Thai Injury Task Force of Pediatric Injury, Thailand; TTFPI) โดยความร่วมมือของคณะแพทยศาสตร์ รพ.รามาธิบดี, โรงพยาบาลระดับต่าง ๆ ทั่วประเทศไทยทั้งหมด 34 แห่ง และสำนักระบาดวิทยา กระทรวงสาธารณสุข โดยนำข้อมูลจากเว็บไซต์ http://www.pts.mahidol.ac.th โดยผลลัพธ์ที่ต้องการจะถูกแบ่งเป็น 4 ระดับดังนี้ โอกาสเสียชีวิตต่ำ โอกาสเสียชีวิตต่ำถึงปานกลาง โอกาสเสียชีวิตปานกลางถึงสูง โอกาสเสียชีวิตสูง โดย และผลการทดสอบความแม่นยำของข้อมูล จากข้อมูลทั้งหมด 42,144 ชุดข้อมูล พบว่าโมเดลที่ใช้มีความแม่นยำสูงถึง 99.26%

คำสำคัญ: พยากรณ์ ความรุนแรง ชีวิตเด็ก อุบัติเหตุ โครงข่ายประสาทเทียม

Abstract

This research was conducted to categorize the Severity and Mortality Forecasting System of Pediatric Injury by Artificial Neural Networks Multi-Layer Perceptions learning by Back Propagation algorithm . To help in decision-making and reducing the errors due to severity discrimination skill in the treatment of injuries of medical personnel to cope and manage to injured children. The training data set was used to learn from the National Registry of Pediatric Injury (Rama PedISS), Collaborated among Thai Injury Task Force of Pediatric Injury (TTFPI), which collaborate among Ramathibodi Hospital Medical Scholl, 34 Provincial Hospitals across Country, and Bureau of Epidemiology, Ministry of Public Health (MOPH). The data source was retrieved from http://www.pts.mahidol.ac.th. The interested results are divided into four levels by risk of severity and fatality, as low, low to moderate, moderate to high, and high mortality level. The RapidMiner Version 5 Software shows results of the tests and the accuracy of the model *with the set of data yield a high accuracy performance to 99.26%.*

Keyword: Pediatric Injury, Artificial Neural Networks, Multi-Layer Perceptrons

1. บทนำ

อุบัติการณ์การบาดเจ็บในเด็กมีแนวโน้มเพิ่มสูงมากขึ้นทุกปี เมื่อเกิดการบาดเจ็บหรืออุบัติเหตุในเด็ก การรักษาพยาบาล ที่มีความรวดเร็ว คัดกรองและการวินิจฉัยที่แม่นยำ การจำแนกการบาดเจ็บอย่างถูกต้อง ตลอดจนถึงความพร้อมของสถานบริการและบุคลากรเป็นสิ่งจำเป็นที่จะช่วยให้เด็กที่ได้รับบาดเจ็บรอดพ้นจากอันตรายและเกิดภาวะแทรกซ้อน ทุพลภาพให้น้อยที่สุดเท่าที่สามารถทำได้ พบว่าในบางครั้งปัญหาหลายประการส่งผลกระทบกับการดูแลผู้ป่วยเด็กที่ได้รับการบาดเจ็บ เช่น การวินิจฉัยอาการบาดเจ็บอาจไม่แม่นยำเท่าที่ควร ทั้งนี้ขึ้นอยู่กับประสบการณ์ ความรู้และชำนาญของผู้วินิจฉัย ปัจจัยเกี่ยวเนื่องกับอุบัติเหตุ เช่นกลไกการบาดเจ็บ เชิงกลและฟิสิกส์ รวมถึงอาการหรือสัญญาณชีพต่าง ๆ ที่สำคัญและจำเป็นและควรต้องประเมินหรือขาดไม่ได้ จึงอาจทำให้การวินิจฉัยเกิดผิดพลาดมีสูงและแน่นอนย่อมส่งผลต่อการรักษาและผลลัพธ์ที่ตามมา จากปัญหาดังกล่าว ทำให้ผู้วิจัยเกิดแนวคิดในการพัฒนาระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุ โดยใช้โครงข่ายประสาทเทียม เข้ามาช่วยในการพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็ก ซึ่งคาดหวังว่าผลลัพธ์และประโยชน์ที่ได้จะช่วยลดโอกาสการเสียชีวิตในเด็กให้มีปริมาณน้อยลงจากเดิมและนำไปสู่แนวคิดขั้นสูงในเชิงการแพทย์ฉุกเฉินต่อไป

2. ทฤษฎีและงานวิจัยที่เกี่ยวข้อง

2.1 โครงข่ายประสาทเทียมแบบหลายชั้น

เป็นรูปแบบประเภทหนึ่งของโครงข่ายประสาทเทียมที่มีโครงสร้างเป็นแบบหลายๆชั้น เหมาะสำหรับงานที่มีความซับซ้อนได้ผลเป็นอย่างดี ซึ่งมีกระบวนการเรียนรู้แบบมีผู้สอน (Supervise) และใช้ขั้นตอนการส่งค่าย้อนกลับ (Back Propagation) สำหรับการฝึกฝนกระบวนการส่งค่าย้อนกลับ โดยการคำนวณหาค่าผลลัพธ์(Output) พร้อมกับปรับปรุงค่า Weight และ Bias [1],[2]

2.2 ตัวแปรทางการแพทย์

เป็นกลุ่มของตัวแปรที่มีนัยสำคัญที่ใช้ในการพยากรณ์โอกาสในการเสียชีวิตในเด็กไทยจากการศึกษาเรื่องการสร้างระบบคะแนนประเมินการบาดเจ็บ [3] โดยแบ่งเป็นกลุ่มตัวแปรกลุ่มหลักได้ 4 ประเภทคือ ข้อมูลทั่วไป อวัยวะที่ได้รับการบาดเจ็บ สัญญาชีพ และกลไกการบาดเจ็บ ซึ่งเป็นตัวแปรที่มีนัยสำคัญทางสถิติและสอดคล้อง ซึ่งรวมเป็นตัวแปรดังตารางที่ 1 โดยให้ผลตรงกับประชากรเด็กประเทศไทยมากที่สุด โดยอาจครอบคลุมไปถึงแถบเอเชียเนื่องจากมีวัฒนธรรม ประเภทการบาดเจ็บ และระดับความเจริญของประเทศคล้ายคลึงกัน

2.3 งานวิจัยที่เกี่ยวข้อง

ผู้วิจัยได้ทบทวนและปริทัศน์งานวิจัยที่สอดคล้องกับวัตถุประสงค์ของงานวิจัยนี้ ทั้งเรื่องการใช้โครงข่ายประสาทเทียมและด้านการแพทย์ฉุกเฉิน กุมารเวชศาสตร์ฉุกเฉินด้านการบาดเจ็บและอุบัติเหตุ เพื่อเป็นแนวทางในการวิจัยดังต่อไปนี้

โครงข่ายประสาทเทียมเป็นอัลกอริทึมที่มีความสามารถหลากหลายมาก ทั้งการพยากรณ์ การจัดกลุ่ม การแบ่งกลุ่ม ฯลฯ และเป็นอัลกอริทึมที่มีความสามารถเรียนรู้ได้เอง รองรับความผิดพลาดได้สูง โดยโครงข่ายประสาทเทียมนี้นิยมใช้ในการแก้ปัญหาเกี่ยวกับโรคหรือภาวะต่าง ๆ เช่น ในหลายการศึกษาก่อนหน้านี้ เช่น การใช้โครงข่ายประสาทเทียมแบบหลายชั้นจำแนกประเภทของมะเร็งเม็ดเลือดขาว แล้วนำมาเปรียบเทียบกับอัลกอริทึมต้นไม้ตัดสินใจและอัลกอริทึมเนอีฟเบย์ ผลที่ได้คือ การจำแนกประเภทของมะเร็งเม็ดเลือดขาวโดยใช้โครงข่ายประสาทเทียมแบบหลายชั้น พบให้ความถูกต้องมากที่สุด ผลรองลงมาคือเนอีฟเบย์ [4] นอกจากนี้ยังมีการศึกษาในเรื่องระบบการคัดกรองความเสี่ยงโรคเบาหวานโดยใช้โครงข่ายประสาทเทียมเช่นกัน ผลการทดสอบพบว่าได้ผลที่ยอมรับได้จากการทดสอบด้วยผู้เชี่ยวชาญและได้รับความพึงพอใจในระดับดีจากผู้ใช้งานจริง [5] มีการนำแนวคิดไปพัฒนาเป็นระบบวิเคราะห์โรคมะเร็งเต้านมด้วยวิธีเรเดียลเบซิสฟังก์ชันเน็ตเวิร์คซึ่งเป็นวิธีหนึ่งของโครงข่ายประสาทเทียม ผลที่ได้มีค่าความถูกต้องมากกว่า 85 เปอร์เซ็นต์ [6] การศึกษานำโครงข่ายประสาทเทียมมาใช้แยกผู้ป่วยโรคพาร์กินสันจากผู้ป่วย

โรคที่มีลักษณะการสั่นใกล้เคียง ซึ่งจากการวิจัยพบว่าให้ความถูกต้อง 88.89 เปอร์เซ็นต์ [7] และเมื่อไม่นานมานี้ได้มีการนำระบบการพยากรณ์โครงข่ายประสาทเทียมไปใช้กับผู้ป่วยโรคหัวใจก็สามารถใช้ได้ผลดีเช่นกัน โดยผลการทดสอบอยู่ในระดับดี [8] ในซีกโลกตะวันตกได้มีการนำโครงข่ายประสาทเทียมไปประยุกต์ใช้กับเกณฑ์การคำนวณอาการบาดเจ็บเช่นเดียวกัน แต่เป็นโครงข่ายประสาทเทียมแบบชั้นเดียว [9]

ในการสร้างเกณฑ์การให้คะแนนจากอาการบาดเจ็บในเด็กนั้น หลาย ๆ องค์กรด้านการแพทย์ต่างให้ความสำคัญ ได้มีการตีพิมพ์ในวารสาร Journal of Trauma-Injury Infection & Critical เรื่อง The Pediatric Trauma Score as a Predictor of Injury Severity: An Objective Assessment โดยทำการศึกษาจากเด็กจำนวน 615 คน เพื่อสร้างระบบการให้คะแนนอย่างคร่าวเพื่อช่วยในการดูแลบริหารจัดการผู้ป่วยเด็กที่ได้รับการบาดเจ็บหรืออุบัติเหตุ [10] นอกจากนี้ในประเทศไทยก็มีได้ผู้จัดทำเกณฑ์ลักษณะเดียวกันขึ้นแต่ใช้ สารสนเทศมาจัดการเพิ่มความคล่องตัวและแม่นยำมากขึ้น ในงานวิจัยชื่อว่า Computerized Database and Decision Support Model for Pediatric Injury in Thailand ซึ่งนำมาใช้ในการพัฒนาต้นแบบการเก็บตัวแปรการบาดเจ็บในเด็กที่ห้องฉุกเฉิน [11] และรายงานเรื่อง Computerized-Database Model for Pediatric Injury โดยนำเกณฑ์หลายอย่างเหล่านี้ มาใช้ในการพัฒนาต้นแบบในการเก็บปัจจัยและตัวแปรที่สำคัญของการบาดเจ็บในห้องฉุกเฉิน เพื่อทำรายงานมาตรฐานรายงานโรค 19 หมวด สำหรับกระทรวงสาธารณสุข และสนับสนุนเชิงป้องกันสำหรับผลิตภัณฑ์หรือวัตถุที่สัมพันธ์กับอุบัติเหตุ และปัจจัยอื่น ๆ อย่างเป็นมิติ ตามแนวหลักการของ NOMESCO Classification External Cause of Injuries [12] และในต่อมาได้มีผู้คิดเกณฑ์การวัดระดับการบาดเจ็บสำหรับเด็กเพื่อใช้สำหรับประเทศไทยโดยเฉพาะโดยแบ่งเป็นกลุ่มตัวแปรกลุ่มหลักได้ 4 ตัวแปรและอาจประยุกต์ใช้ครอบคลุมกว้างไปถึงแถบเอเชียเนื่องจากมีวัฒนธรรม ประเภทการบาดเจ็บ และระดับความเจริญของประเทศคล้ายคลึงกัน [3]

จากงานวิจัยที่กล่าวมาจึงได้มีแนวคิดต่อยอด ในการนำแนวคิดโครงข่ายประสาทเทียมแบบหลายชั้น มาเป็นโมเดลในการพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุ และใช้ตัวแปรทางการแพทย์ที่ได้มีการแบ่งเป็นกลุ่มตัวแปรเป็น 4 กลุ่มที่ใช้สำหรับประเทศไทยเพื่อให้ได้ผลลัพธ์ที่ดีที่สุดสำหรับผู้บาดเจ็บในประเทศไทย

3. ขั้นตอนดำเนินงานวิจัย

3.1 การเก็บรวบรวมข้อมูล

ในการพัฒนาระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียมนั้น ผู้พัฒนาได้ทำการศึกษาปัญหาการรักษาจากแพทย์ผู้เชี่ยวชาญทางด้านอุบัติเหตุและฉุกเฉินในเด็ก พบว่า การรักษาเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุแต่ละครั้งนั้นมีผลการรักษาที่แตกต่างกันขึ้นอยู่กับความรวดเร็วในการวินิจฉัยประเมินความรุนแรงของการบาดเจ็บ ความพร้อมของทรัพยากรเครื่องมือและประสบการณ์ของแต่ละบุคคลที่ทำการรักษาทำให้ผลการรักษาแตกต่างกัน จึงได้ขอความร่วมมือจากคณะทำงานในการเก็บข้อมูลการบาดเจ็บระดับชาติ Thai Injury Task Force of Pediatric Injury แห่งประเทศไทย โดยนำข้อมูลจริงจากระบบบันทึกและเฝ้าระวังการบาดเจ็บในเด็กกว่า 42144 ชุดข้อมูล จากระบบ National Registry of Pediatric Injury ; Rama PedISS จากเว็บไซต์ http://www.pts.mahidol.ac.th ซึ่งเป็นเว็บไซต์ท่า (Web portal) สำหรับรวบรวมและทำการจัดเก็บข้อมูลของเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุในประเทศไทย ของคณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดลได้จัดทำขึ้นร่วมกับสำนักโรคไม่ติดต่อ กระทรวงสาธารณสุข (IS, MOPH) และศูนย์เฝ้าระวังและวิจัยการบาดเจ็บในเด็กแห่งประเทศไทย (CSIP) โดยนำข้อมูลที่ถูกบันทึกลงไปยังเว็บไซต์นี้ มาเป็นข้อมูลที่ใช้ในการพัฒนาระบบในครั้งนี้

3.2 การวิเคราะห์และออกแบบระบบ

ในการพัฒนาระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียมนั้น ได้นำกลุ่มตัวแปรหลัก 4 ประเภทคือ ข้อมูลทั่วไป อวัยวะที่ได้รับการบาดเจ็บ สัญญาชีพ และกลไกการบาดเจ็บ มาทำการให้ค่าถ่วงน้ำหนักของเกณฑ์ต่างๆ [3] ดังตารางที่ 1

ตารางที่ 1 : แสดงถ่วงค่าถ่วงน้ำหนักของตัวแปรที่ใช้ในการพยากรณ์

ตัวแปร	คำตอบ	ค่าถ่วงน้ำหนัก
1) Age (Years)	< 5 6-12 >12	0 1 2
2) Airway	No Manipulation Adjuncts Intubation	0 1 2
3) Physic Mechanism	None Pure Velocity Pure Gravity Both	0 1 2 3
4) Headneck	None Injured	0 1
5) Thorax	None Injured	0 1
6) Abd-Pelvis	None Injured	0 1
7) Glasgow Coma Score	< 9 > 9	1 2
8) Systolic Blood Pressure	Normal Abnormal	0 1
9) Pulse Rate	Normal Tachycardia Bradycardia	0 1 2
10) Respiratory Rate	Normal Abnormal	0 1

โดยค่าถ่วงน้ำหนัก ได้จากการวิเคราะห์เพื่อให้ได้ค่าสัมประสิทธิ์ของแต่ละตัวแปร และนำมาถ่วงน้ำหนักให้เหมาะสมและง่ายต่อการให้คะแนนอย่างถูกต้องยุติธรรม [3]

ซึ่งจะนำค่าน้ำหนักที่ได้เข้าประมวลผลในแบบจำลองโครงข่ายประสาทเทียมแบบหลายชั้น โดยค่า Input ทั้งหมดจะนำเข้ามาคำนวณ [1] ตามสูตร (1)

$$A = (x * w) + b \quad (1)$$

เมื่อ A คือ ผลการคำนวณ x คือ ค่า Input ที่เข้ามา w คือ ค่าน้ำหนักและ b คือ ค่าไบเอส จากนั้น ก็นำค่าที่ได้เข้าสู่ ฟังก์ชั่นกระตุ้น (Transfer Function) แบบ Log Sigmoid [1]โดยคำนวณได้จากสูตร (2)

$$1.0 / (1.0 + \exp(-1.0 * A)) \quad (2)$$

โดยผลคำตอบของระบบจะแบ่งเป็น 4 ระดับดังนี้ โอกาสเสียชีวิตต่ำ โอกาสเสียชีวิตต่ำถึงปานกลาง โอกาสเสียชีวิตปานกลางถึงสูง โอกาสเสียชีวิตสูง ซึ่งผลที่ได้จะช่วยในการตัดสินใจการรักษาของบุคลากรทางการแพทย์ต่อไป

3.3 สร้างแบบจำลอง

การสร้างแบบจำลองของโครงข่ายประสาทเทียมแบบหลายชั้น ได้ใช้วิธี 10 Fold-Cross Validation ในการแบ่งข้อมูลจำนวน 42,144 ชุดข้อมูล สำหรับเป็นชุดการเรียนรู้ และชุดทดสอบ แล้วนำเข้าโปรแกรม RapidMiner Version 5 เพื่อหาแบบจำลองที่ดีที่สุด โดยจำนวนรอบการเรียนรู้ (Training cycles) จะเริ่มตั้งแต่ 100 และเพิ่มขึ้นไปเรื่อยๆ พร้อมทั้งปรับค่าอัตราการเรียนรู้ (Learning rate) และค่าโมเมนตัม (Momentum) ด้วย

3.4 พัฒนาระบบ

ทำการพัฒนาระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียมนั้นด้วยภาษา PHP version 5.2.9 ร่วมกับฐานข้อมูล MySQL version 5.0.51a

3.5 การทดสอบระบบ

ด้านการทดสอบความถูกต้องของระบบ โดยทำการวัดประสิทธิภาพของการพยากรณ์ข้อมูล จากค่าความแม่นยำ (Accuracy) [3] ซึ่งคำนวณได้จากสูตร (3)

$$Accuracy = (TP + TN)/(TP + FP + FN + TN) \quad (3)$$

True Positive (TP) คือ สิ่งที่ระบบควรทำนายว่าจริง และระบบทำนายว่าจริง

True Negative (TN) คือ สิ่งที่ระบบทำนายว่าไม่จริง และระบบทำนายว่าไม่จริง

False Positive (FP) คือ สิ่งที่ระบบควรทำนายว่าไม่จริง แต่ระบบทำนายว่าจริง

False Negative (FN) คือ สิ่งที่ระบบควรทำนายว่าจริง แต่ระบบทำนายว่าไม่จริง

4. ผลการดำเนินงาน

4.1 ผลการสร้างแบบจำลอง

จากผลการสร้างแบบจำลองโครงข่ายประสาทเทียมแบบหลายชั้น และใช้ใช้วิธี 10 Fold-Cross Validation ในการแบ่งข้อมูลจำนวน 42,144 ชุดข้อมูล แล้วนำเข้าโปรแกรม RapidMiner ผลที่ได้ดังตารางที่ 2

ตารางที่ 2 : แสดงผลการทดสอบเพื่อสร้างแบบจำลอง

จำนวนชั้น	รอบการเรียนรู้	ค่าความแม่นยำ
1	100	93.7
1	200	93.76
1	300	93.78
2	100	99.13
2	200	99.26
2	300	99.25
3	100	98.98
3	200	97.17
3	300	95.52

จากผลการทดสอบพบว่าแบบจำลองที่มีชั้นซ่อน 2 ชั้น ขนาด 8 , 8 ค่า จำนวนรอบการเรียนรู้ 200 รอบ ค่า อัตราการเรียนรู้ 0.3 และค่าโมเมนตัม 0.2 ให้ค่าความแม่นยำ สูงที่สุด คือ 99.26%

4.2 ผลการพัฒนาระบบ

การพัฒนาระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียมนั้นได้ทำการออกแบบหน้าจอหลักดังภาพที่ 1 และผลที่ได้จากการพยากรณ์จากระบบดังภาพที่ 2

ภาพที่ 1 : หน้าจอหลัก

จากหน้าจอจะแสดงหน้าจอสำหรับป้อนข้อมูลที่จำเป็นในการพยากรณ์โดยผู้ใช้ระบบจะต้องกรอกข้อมูลให้ครบถ้วนทุกหัวข้อ

ภาพที่ 2 : ผลที่ได้จากการพยากรณ์จากระบบ

จากหน้าจอจะแสดงผลการพยากรณ์ โดยจะแสดงเป็นระดับของความรุนแรงพร้อมแถบสีบอกสถานะเพื่อช่วยในการแยกประเภทความรุนแรงได้อย่างรวดเร็ว

5. สรุปผล อภิปรายผล และข้อเสนอแนะ

จากการพัฒนาระบบพยากรณ์ความรุนแรงและโอกาสเสียชีวิตในเด็กที่ได้รับบาดเจ็บหรืออุบัติเหตุโดยใช้โครงข่ายประสาทเทียมนั้นได้ค่าความแม่นยำมากสุดถึง 99.26% ซึ่งเป็นความถูกต้องที่สูงมาก จึงทำให้การพยากรณ์โอกาสเสียชีวิตมีความแม่นยำมากขึ้น ซึ่งระบบนี้จะถูกนำไปใช้ในระบบการแพทย์ฉุกเฉินในเด็ก เพื่อเป็นเครื่องมือในช่วยเหลือเด็กที่ได้รับบาดเจ็บต่อไป เพื่อเพิ่มโอกาสรอดชีวิตให้สูงมากขึ้น โดยทั้งนี้ตัวแปรทางด้านการแพทย์นั้น ในอนาคตอาจมีการเปลี่ยนแปลงได้เพื่อให้เกิดความเหมาะสม เที่ยงตรง จึงควรมีการปรับปรุงเพื่อให้เกิดความทันสมัยและเหมาะสมมากขึ้นใน Phase ถัดไป หรืออาจต่อยอดระบบด้วยอัลกอริทึม IFLN เพื่อให้สามารถเพิ่มหรือลด ตัวแปรทั้งแกนตั้ง (ชนิดของตัวแปรและค่าสัมประสิทธิ์หรือการถ่วงคะแนนโดยน้ำหนักความสำคัญ) และแกนนอน (ตัวแปรร่วม อื่น เช่น ระดับความน่าจะเป็นต่อการเสียชีวิตหรือรอดชีวิตจกตัวแปรด้านศักยภาพของบุคลากรหรือสถานพยาบาล) ในอนาคต

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