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Development and Evaluation of On-site Triage Algorithm for Trauma Patients

By

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ABSTRACT

Introduction: Trauma triage protocols are important because they identify, at the injury scene, patients with major injuries requiring transfer to a Level I trauma center, from those with non-major injuries who could be treated at Levels II and III trauma centers. The Pre-hospital Index (PHI) is a physiological injury severity measure which may be used as a trauma triage tool.

Purpose: The purpose of the present study was to: 1) prospectively evaluate the predictive ability of the PHI in identifying trauma patients with major versus non-major injuries, and 2) develop a trauma triage scale which incorporates, along with the PHI, a subset of the variables age, body region injured, mechanism of injury, comorbidity, and time between 911 call and departure of the ambulance from the injury site, so as to improve the predictive ability of the PHI-based triage instrument.

Methods: This study was based on 1,291 trauma patients treated in Montreal between April 1993 and December 1996. A patient was considered to have major injuries if the patient died within seven days since hospital admission, had an intensive care unit admission within seven days, or major surgery performed within four days. Three hypothetical trauma triage protocols were developed using logistic regression analysis; where the model that describes the data best was selected according to Bayes factor approximation. In detecting major versus non-major injuries, sensitivities, specificities, positive and negative predictive values were calculated for all the cutoff points of the PHI and the triage protocols. Also, areas under the Receiver Operating Characteristic (ROC) curves were calculated and compared for these instruments.

Results: The trauma triage protocol which included the variables age, body region injured, mechanism of injury, comorbidity, and PHI produced the best combination of sensitivity and specificity; of 0.95, and 0.24, respectively. This algorithm underwent a significant improvement over the PHI (area under the ROC curve: 0.76 versus 0.66, $p < 0.05$).

Conclusion: An improvement in the predictive ability of the PHI-based triage instrument was introduced after the addition of the variables age, body region injured, mechanism of injury, and co-morbidity.

Résumé

Introduction. Les protocoles de triage sont d'une grande utilité car ils permettent de distinguer, sur le lieu même de l'accident, les patients gravement atteints qui doivent être transportés vers un centre de traumatologie de niveau I des patients souffrant de blessures légères qui peuvent être traités dans des centres de niveau II et III. L'indice préhospitalier (IPH) est une mesure de la gravité des lésions physiologiques qui peut faire fonction d'outil de triage des victimes de traumatismes.

But. La présente étude visait : 1) à estimer au moyen d'une évaluation prospective la valeur de prévision de l'IPH en tant qu'outil permettant de distinguer les patients grièvement blessés des blessés légers; 2) à concevoir une échelle de triage comprenant, outre l'IPH, un sous-ensemble de variables (âge, région du corps lésée, mécanisme de la lésion, comorbidité, intervalle entre l'appel au service 911 et le départ de l'ambulance du lieu de l'accident) permettant d'améliorer la valeur de prévision de l'instrument de triage fondé sur l'IPH.

Méthodes. L'étude a été réalisée auprès de 1 291 victimes de traumatismes traitées à Montréal entre avril 1993 et décembre 1996. Ont été rangés parmi les grands blessés les patients qui sont décédés dans les sept jours suivant leur admission à l'hôpital, qui ont été admis à l'unité des soins intensifs dans les sept jours suivant l'accident ou qui ont subi une intervention chirurgicale importante dans les quatre jours suivant celui-ci. Trois protocoles de triage hypothétiques ont été conçus selon une méthode d'analyse de régression logistique où le modèle décrivant le plus exactement les données a été sélectionné par approximation du facteur de Bayes. Pour distinguer les grands blessés des blessés légers, on a calculé la sensibilité, la spécificité et les valeurs positive et négative des points de démarcation de l'IPH et des protocoles de triage. On a également calculé et comparé les courbes caractéristiques de receveur (CCR) de ces instruments.

Résultats. Le protocole de triage qui comprenait les variables âge, région du corps lésée, mécanisme de la lésion, comorbidité et IPH a offert le meilleur amalgame de sensibilité et de spécificité, (respectivement 0,95 et 0,24). Cet algorithme a subi une amélioration importante par rapport à l'IPH (région sous la courbe CCR : 0,76 contre 0,66 $p < 0,05$).

Conclusion. L'ajout des variables âge, région du corps lésée, mécanisme de la lésion et comorbidité a permis d'améliorer la valeur de prévision de l'instrument de triage fondé sur l'IPH.

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Statement of Originality

The thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief, this thesis contains no material previously published or written by any person, except where reference is made in the context of this thesis. The hypothesis of this thesis was my own. The literature review, methods, design, statistical analysis, and writing of the thesis were my responsibility, although I was guided by my thesis committee.

This thesis was undertaken to evaluate the Pre-Hospital Index (PHI) in distinguishing patients with major injuries from patients with non-major injuries, and to develop and evaluate a trauma triage protocol for the population of Montreal -- the first statistically derived trauma triage protocol for this population. This work is considered an advancement in the literature since it developed a trauma triage protocol which used new statistical techniques -- Bayes factor approximation that considers the liklihood of the model (probability of the data given the model) -- thus, improving the methods used previously -- methods that depend on the significance of the variables in the model -- in developing trauma triage protocols.

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List of Abbreviations

ACS	American College of Surgeons
AIS	Abbreviated Injury Scale
ASCOT	A Severity Characterization of Trauma
AUC	Area Under Curve
BIC	Bayesian Information Criterion
CNS	Central Nervous System
CRAMS	Circulation, Respiration, Abdomen, Motor, and Speech
EMS	Emergency Medical Services
GCS	Glasgow Coma Score
GMR	Glasgow Motor Response
ISS	Injury Severity Score
LD50	Severity of injury lethal to 50% of the patients so injured
MAIS	Maximum AIS
MTOS	Major Trauma Outcome Study
NPV	Negative Predictive Value
PHI	Pre-hospital Index
PPV	Positive Predictive Value
PTS	Pediatric Trauma Score
ROC	Receiver Operating Characteristic
RTS	Revised Trauma Score
T-RTS	Triage Revised Trauma Score
TRISS	Trauma Score and Injury Severity Score

TS	Trauma Score
TTR	Trauma Triage Rule
VSS	Vital Signs Scores

CHAPTER 1.

STATEMENT OF THE PROBLEM AND RATIONALE

1.1. Definition of Trauma

Trauma is the medical term used to describe injury. It is defined as damage that results from exposure to physical energy that is beyond the body's resilience (1).

1.2. Impact of Trauma

In Canada, trauma is the leading cause of death for individuals under 45 years of age, and the third cause of death after heart disease and cancer, for all ages combined (2,3). Also, in Canada, trauma is the leading cause of short-term and long-term disability (4).

Because trauma is the leading cause of death for young individuals, the Person Years of Life Lost (PYLL) due to trauma is very high. For individuals under the age of 65, trauma accounts for more PYLL than do heart disease and cancer combined (5).

In 1993, the direct costs spent for trauma-related health care and compensation in Canada exceeded $7 billion (6). In Quebec, it is estimated that 4,000 individuals die every year due to trauma and another 10,000 suffer severe disability. Also, in Quebec, approximately 100,000 hospital admissions are trauma related (2,7).

1.3. Trauma as a Disease

Like other diseases, trauma exhibits three factors which are necessary for the occurrence of injury: 1) the host -- the living organism that becomes injured, 2) the agent -- the carrier of the physical energy, and 3) the environment -- the surroundings where the interaction between the host and the agent occurs (8).

To conceptualize how an injury occurs, it is important to recognize the three different injury phases: pre-injury, injury, and post-injury. The pre-injury phase is the time which follows the release of the physical energy before the occurrence of the injury. Even though the energy has been released at this time, injury does not have to occur. The probability of occurrence of the injury depends on the ability of the host to maintain equilibrium with the physical energy. This probability increases if the physical energy exceeds the capability of the individual to reach equilibrium, depending on both the individual's abilities and the overwhelming increase in the existing physical energy. The time interval during which the physical energy is transferred to the host is called the injury phase. Waller (8) pointed out that the severity of the injury depends on the rate of energy transfer, characteristics of the tissue injured, and characteristics of the agent that is transferring the energy (8). The post-injury phase is the time that precedes the injury phase. Once the injury has occurred, the seriousness and the consequence of the injury depend in large part on the provision of adequate care immediately after the injury's occurrence (8).

1.3.1. Trauma Outcomes

Mortality and disability are the two major outcomes of severe injuries. Even though the rate of severe disability is more than four times that of death, trauma research until now has focussed mainly on trauma deaths.

Almost half of all impairments due to injuries result in a reduction in the amount or kind of work, or inability to continue to work. Statistics have shown that approximately 72% of all disabilities due to injuries are deformities or other orthopaedic disabilities, 8% are hearing disabilities, and 7% absence of extremities in whole or in part. Visual impairments account for 5% of all trauma disabilities, and complete or partial paralysis of extremities account for 1% (9).

Trunkey (10) classified trauma deaths into three categories: 1) "immediate deaths", constituting 50% of all trauma deaths, 2) "early deaths", constituting 35% of all deaths, and 3) "late deaths" which account for 15% of all trauma deaths (10). "Immediate deaths" are those that occur within two hours after the injury. These deaths occur due to lacerations of the brain, the brain stem, the upper spinal cord, the heart or a major blood vessel. "Early deaths" occur between two hours and seven days after the occurrence of the injury, and they are usually due to: major internal haemorrhages of the head, the respiratory system, or the abdominal organs, or to multiple injuries associated with significant blood loss. "Late" deaths occur a week or more after the injury. They are usually caused by infection or multiple organ failure (10, 11).

1.4. Interventions Against Trauma

Interventions againstt trauma may be implemented at the pre-injury phase, the injury phase, and the post-injury phase.

Interventions at the pre-injury phase focus on preventing the agent from releasing the physical energy, thus preventing the injury from occurring. Examples of such interventions would be educational programs and legislation for injury prevention (8).

Interventions during the injury phase, focus on reducing the energy transfer from the agent to the host, and thus reducing the seriousness of the injury (8).

Interventions at the post-injury phase, or after injury occurrence, focus on reducing the probability of death or disability after injury. Once the injury has occurred, prompt and adequate surgical and medical care is crucial. It is essential that patients with severe injuries -- especially those with internal haemorrhages to the heart, respiratory system or abdominal organs -- be transferred within 30-60 minutes (known in trauma research as the "golden hour"), of the time of the injury to a hospital which is properly equipped to care for severely injured patients. Although the majority of "immediate deaths" are non-preventable, the prevention of "early deaths" depends on prompt and adequate care, whereas the prevention of "late deaths" depends on long-term in-hospital care (8, 10).

Therefore, in order to prevent "early deaths", it is essential that an organized trauma care system be available for the care of trauma patients. This system should identify patients with severe injuries, who are at high risk of mortality or disability, and

transport them promptly to an appropriate hospital that is qualified to care for patients with severe injuries.

1.4.1. Historical Background of Trauma Care

The idea of organized trauma care systems goes back to the ancient Greeks when soldiers were carried to barracks or ships to be cared for, and during the Napoleonic wars where "flying hospitals" ("*ambulance volante*") were designed for the treatment of injured soldiers (10).

The importance of providing prompt and definitive care as soon as possible after the injury, thereby reducing trauma mortality, was also recognized from experience in the World Wars I and II, in Korea, and in Vietnam (10). During World War I, the time between injury occurrence and surgical intervention ranged between 12-18 hours, with a reported mortality rate of 8.5%. During World War II, the time to definitive care was reduced to 6-12 hours and the mortality rate dropped to 5.8%. However, during the Korean conflict, injured soldiers were taken from the battlefield to a mobile army surgical hospital (MASH), thus reducing the time between injury and surgical intervention to 2-4 hours, with a mortality rate reduction to 2.4% (10). Time to definitive care again was reduced during the Vietnam war to 65 minutes, and the mortality rate dropped to 1.7%. Although the decrease in trauma mortality could not be attributed solely to the reduction of time to definitive care, because of the ecological bias as well as the different variables which could have confounded this relation, this hypothesis led to the development of trauma care systems for the public that were later supported by several studies (10).

1.4.2. Development of Trauma Care Systems

More attention has been devoted to trauma since the National Academy of Sciences / National Research Council (NAS/ NRC) published a report, in 1966, declaring trauma the neglected disease of modern society (12). This report addressed the need for Emergency Medical Services (EMS) systems and outlined the guidelines for an improved trauma care program. In 1973, the EMS systems Act called for the development of EMS systems throughout the USA, where as a result, 303 regional EMS geographic areas were developed (13).

In 1986, the American College of Surgeons (ACS) outlined the four necessary components of a trauma system: 1) access to care, 2) pre-hospital care, 3) in-hospital care, and 4) rehabilitation. Access to care includes an organised system which receives all inquiries requesting trauma care assistance (e.g. 911 calls), along with the awareness of the community of how to use this system. Pre-hospital care consists of the ambulances/ helicopters and the emergency medical personnel that will be dispatched to the scene of injury both to provide pre- hospital care to the injured patients and to transport these patients to the appropriate hospitals after co-ordination and communication with the hospitals. In-hospital care includes emergency physicians, surgeons, surgical nurses, anesthesiologists, intensive care facilities, and other facilities capable of providing adequate care to severely injured patients. Rehabilitation means access to rehabilitation for patients with severe injuries after their initial treatment (14).

Trauma care systems have been shown to reduce trauma mortality and disability (15, 16, 17, 18, 19, 20, 21). This is achieved first by reducing the time between injury

occurrence and definitive care, and second by providing a high level of care, as patients with severe injuries should have access to multi-specialty trauma teams and technology -- such as emergency physicians, surgeons, surgical nurses, anesthesiologists, intensive care facilities, and other specialties.

1.4.2.1. Regionalised Trauma Care Systems

Regionalised trauma care systems are one type of trauma care system. They require both: 1) designation of hospitals, and 2) pre-hospital emergency medical services.

These systems designate hospitals according to three levels: Level I trauma centers, Level II trauma centers, and Level III trauma centers. According to the American College of Surgeons (ACS) recommendations, Level I trauma centers have the highest level of care. They are hospitals which have 24-hour coverage of emergency services of physicians, surgeons, anaesthesiologists, intensive care facilities, surgical nurses along with other specialties available within 30 minutes. Level II trauma centers have 24-hour coverage of emergency physicians with other services including surgeons 24-hour on call or available within 30 minutes. However, Level III trauma centers have no 24-hour coverage, and medical and surgical services are on call only (14).

The responsibilities of the pre-hospital emergency medical services are to: 1) respond to the alert (the 911 call seeking health assistance); 2) assess/ diagnose the cause of injury at the site; 3) treat at the scene of injury (treatment could be: applying the advanced life support [ALS] approach, where patients are stabilized by initiation of intravenous fluid replacement [IV], intubation, application of pneumatic antishock

garment, and administration of medications, on the one hand, and/ or applying the basic life support (BLS) approach, on the other hand, where only immobilization, wound dressing, fracture splinting, and oxygen administration are provided at the scene of injury); 4) apply a triage protocol which identifies patients with major trauma requiring treatment at Level I trauma center, from those with non-major trauma who could be treated at Level II/ III trauma centers; and 5) transport patients to the appropriate hospitals.

1.4.2.1.1. Triage Protocols

Field triage is the sorting of trauma patients, in the pre-hospital setting, according to the severity of their injuries. This sorting of trauma patients may be done by following a triage protocol. A triage protocol is composed of variables associated with trauma mortality and disability, that could be identified at the scene of injury. According to these protocols patients are classified as having severe injuries if they satisfy specific criteria based on these variables.

Implementation of triage protocols is a necessity, since these protocols identify patients with severe injuries that could be life threatening or result in disability, so as to transfer them to Level I trauma centers, where multi-specialty trauma teams can be rapidly assembled to care for these patients, thus increasing their chance of survival and lowering the probability of disability by minimizing the time from injury to adequate definitive care. These protocols also identify patients with non-severe injuries so that they could be transferred to Level II and III trauma centers. It is important that patients with

non-severe injuries, who do not require services unique to a Level I trauma center, be transferred to Levels II and III centers, first in order to prevent the overcrowding of Level I trauma centers with non-severe cases, and second to minimize inefficiency and excessive cost by ensuring optimal use of resources.

The American College of Surgeons (ACS) classified injuries into three different categories: 1) severe injuries that are immediately life threatening comprising 5% of all injuries. 2) urgent injuries (15% of all injuries) which are not immediately life threatening, but could result in death and significant disability if adequate care was not provided within a short time since injury occurrence (60 minutes), and 3) non-urgent injuries comprising 80% of all injuries (14). Hence, according to the ACS classification of injury severity, approximately 20% of all injured patients would require transfer to a Level I trauma center, whereas the other 80% of patients could be treated at Levels II and III trauma centers.

1.4.2.1.1.1. Under-triage and Over-triage

The classification of patients at the site of injury as having severe versus non-severe injuries, through the application of triage protocols at the site, will result in the misclassification of injury severity for a certain proportion of patients. Thus, it is expected that a proportion of patients with severe injuries will be classified as having non-severe injuries and thus be transferred to Levels II and III trauma centers, whereas another proportion of patients with non-severe injuries will be classified as having severe injuries and thus be transferred incorrectly to a Level I trauma center.

Under-triage occurs when trauma patients with injuries that could be life threatening or could lead to disability are misclassified as having non-severe injuries and thus are not transferred to Level I trauma centers. Under-triage is the proportion of patients (of all patients triaged to non- Level I trauma centers) that require Level I trauma center. Insufficiently sensitive triage protocol results in too many victims not being transported to high level trauma centers, possibly leading to an increase in trauma mortality (22,23).

Over-triage occurs when patients with non-severe injuries are misclassified as having severe injuries and thus are transferred to a Level I trauma centers. This is the proportion of patients (of all patients triaged to Level I trauma centers) who did not require Level I trauma center care. The use of triage protocols which lack specificity result in too many victims being transported to these centers. This leads to an inefficient utilization of resources, and thus excessive costs (22,23), as well as less availability of such resources to severely injured patients.

An ideal triage protocol with a zero percent rate of both under- and over-triage is non- existent. By increasing the sensitivity of a specific triage protocol (decreasing the under-triage rate), the specificity decreases (the over-triage rate increases) and vice versa. Thus the aim is to determine what sensitivity and what specificity would be acceptable. From an ethical point of view, there is no doubt that the under-triage rate should be lower than the over-triage rate, since a decrease in the trauma mortality is of more importance than a decrease in the inefficient utilization of resources. The American College of Surgeons Committee on Trauma (ACSCOT) suggested that a 50% rate of over-triage may

be necessary to maintain an acceptable under-triage rate (24). It has been suggested by Kundson that field triage protocols should keep the under-triage rate below 5% and over-triage rate below 50% (25).

1.4.2.1.1.2. Requirements of Triage Protocols

A basic component of an effective triage protocol is a reliable and quick assessment of injury severity that can be applied in the field by emergency medical technicians.

Injury severity measures to be used for triage should be easy to use at the site of injury, fast to administer, be accurate with low false positive and low false negative rates, and have good reliability. These measures are applied as soon as possible after the occurrence of the injury, since their main objective is that severely injured patients be identified and thus transported to a Level I trauma center, while avoiding overcrowding of these centers with patients of non-severe injuries.

Triage protocols should include variables that could be quickly identified at the site of injury and that affect trauma outcomes. Several authors have suggested that these protocols should address not only the physiologic status of the patients, but also the anatomic injury status and the injury mechanism, so as to yield a highly sensitive tool (26, 27, 28, 29, 30, 31, 32, 33).

The following section will present the different variables that could be identified at the scene of injury and that are associated with trauma mortality and disability.

1.4.2.1.1.3. Pre- hospital Factors that Affect Trauma Mortality and Disability

Injury Severity

By far, injury severity is the variable that best predicts death and disability. Measurement of injury severity is necessary for: 1) description of injury severity, 2) adjustment of injury severity in research, and 3) patient triage. Injury severity measures may be divided into three types of scales: 1) anatomical, 2) physiological, and 3) composite (34,35, 36,37). A more detailed description of injury severity is presented in Chapter 2 of this thesis.

Anatomical scales such as the Abbreviated Injury Scale (AIS)/ Injury Severity Score (ISS) require information which is not available at the scene of injury. The data for these scales are obtained from physical examination, investigative procedures, surgical intervention and, in fatal cases, post mortem examination. Anatomical scales are stable over time and are not affected by treatment. These scales cannot be used for triage since the data required are not readily available at the scene, and because they do not measure the physiologic state of the patient at the time of injury (34,35,38).

On the other hand, physiological scales of injury severity such as the Trauma Score (TS) and Pre-hospital Index (PHI), measure the acute response to injury. These scales are used to facilitate decision on the immediate management of trauma patients, since the data required are available at the site of injury, and because these scales reflect the physiologic state of the patient at the scene of injury. They are unstable over time and are affected by treatment. The information required to calculate these scales could be easily obtained by non- physicians (34,35,38).

Composite scales such as the Trauma Score and Injury Severity Score (TRISS), and A Severity Characterization of Trauma (ASCOT), are methods of trauma scoring which combine physiological, anatomical and other factors. Such scales allow trauma care evaluation. They accurately relate to the patients' outcomes than when any of the anatomical or physiological scores are used alone (39,40).

Age

Trauma deaths occur more often in younger individuals. An autopsy study showed that 59% of the 425 trauma deaths in San Francisco in 1972 were patients below the age of 50 (41). Another study, also in San Francisco, revealed that, of 437 trauma deaths, 65% were patients below 51 years of age, and 27% were between ages of 21 and 30 (11).

Although trauma deaths occur more often in younger individuals, the probability of dying once injured is higher for older individuals. Injury death rates are lowest for ages 5-14, and highest for ages 75 and older (42). Baker showed that for the same injury severity, death rates were higher for individuals above 70 years of age. Also, individuals 50-69 years old had higher death rates than individuals below 49 years of age. However, age related differences in the mortality rate were observed mostly among patients with less severe injuries (43).

LD50 is defined as a severity of injury lethal to 50% of the patients so injured. An age-dependent relationship was discovered by Bull (44), where for ages 15-44 the LD50 was an Injury Severity Score (ISS) of 40. It was higher than for ages 45-64, where the LD50 was an ISS of 29, and higher still than for ages above 65, where the LD50 was an

ISS of 20 (44).

Body Region Injured

The main causes of "immediate deaths" according to Trunkey are lacerations of the brain, brain stem, spinal cord, heart or one of the major blood vessels. "Early deaths" are mostly caused by severe internal haemorrhage of the brain, respiratory system, or abdominal organs; or due to severe blood loss as a result of multiple injuries. On the other hand, the cause of "late deaths" is infection, or multiple organ failure (10).

Baker found that, of the 437 trauma deaths, the cause of death in 50% of the autopsies was brain injury; 17% of the trauma deaths were due to injuries to the heart, 12 % to haemorrhage, 10% to sepsis, 6% to lung injuries, and 3% to liver injuries (11).

Several studies have shown that patients with brain injuries are at a higher risk of dying than patients with other body region injuries (11,45,46). Also, patients with penetrating injuries to the head/ neck, abdomen, thorax, or spinal cord are at a high risk of having severe injuries requiring immediate surgical intervention (11,25,47,48,49).

Mechanism of Injury

Motor vehicle crashes, falls from an elevation above 15 feet, and firearm wounds are the three major mechanisms of injury associated with a high probability of dying (8,11,50).

Baker found that of the 437 autopsies studied in San Francisco, 32% of the trauma deaths were due to gunshot, 28% to falls, and 18% to motor vehicle related injuries (11).

In a study by Knopp *et al.*; the Positive Predictive Value (PPV) for predicting patients with severe injuries (defined by an Injury Severity Score [ISS] above 15), was 40% for extrication time of more than 30 minutes, 22.4% for ejection from a vehicle, 21.4% for fatality in same vehicle, 19.0% for space intrusion, 17.9% for pedestrian versus auto, and 14.3% for falls of more than 15 feet (51).

In a study by Rogers *et al.* describing the patterns of injury and death rates of vehicular related trauma patients, admitted to the Regional Trauma Unit of Sunnybrook Health Science Centre in Toronto, the death rate for the pedestrian group was 20%, for motorcycle 18%, and for the passenger-vehicle group 11% (52).

According to a study by Kundson *et al.*, the sensitivity and specificity in identifying patients with major injuries (defined if the patient died, had a length of hospital stay above three days, a Trauma Score (TS) of 14 or less, or ISS above 15) from motor vehicle accidents above 40 mph were 24% and 72%, respectively. Motorcycle accidents above 20 mph had a sensitivity in detecting major injuries of 9% and a specificity of 94%; auto versus pedestrian accident above 5 mph had a sensitivity of 16% and a specificity of 81%; and major assault had a sensitivity of 6% and a specificity of 89% (25).

Time to Definitive Care

Time between injury occurrence and definitive care consists of pre-hospital time and in-hospital delays. Pre-hospital time consists of three components: 1) response time (the time between request for ambulance [911 call] and ambulance arrival at the scene of

injury); 2) scene time (the time spent at the site of injury); and 3) travel time (the time taken to transport the patient from the site of injury to the hospital).

According to Trunkey, prompt definitive surgical intervention is crucial for patients with haemorrhages. For patients with severe haemorrhage (rate of blood loss above 180 millilitre per minute), the patient would lose more than half of his blood volume within 20 minutes of the injury, thus prompt surgical intervention is critical. In minor injuries (rate of blood loss less than 30 millilitre per minute), the patient could wait for an hour or more before surgical intervention (10).

Several studies have shown that increased pre-hospital time is associated with increased trauma mortality (53,54,55). In a study conducted by Sampalis *et al.*, scene time above 60 minutes was associated with a significant three-fold increase in the risk of dying, after controlling for age, injury severity, mechanism of injury, pre-hospital care, and level of in-hospital care (56).

Pre-existing Medical Conditions

It has been shown by several authors that co-morbidity increases the risk of dying in injured patients. In a study undertaken by Milzman *et al.*, a significant association was seen between pre-existing disease and mortality ($p < 0.03$), after controlling for age and injury severity of patients. The authors showed that mortality rates were increased by 18% for patients with two or more pre-existing diseases; compared to patients with no pre-existing disease. Patients with renal disease had a mortality rate increase of 38%. The increase was 20% for patients with malignancy, and 18% for patients with cardiac disease

-- all of which were statistically significant (57).

After adjusting for injury severity, age, and the hospital at which the patient was admitted, Morris *et al.* showed that the relative odds of dying with the presence of cirrhosis was 4.5; congenital coagulopathy 3.2, ischemic heart disease 1.8, chronic obstructive pulmonary disease 1.8, and diabetes 1.2 (all of which were statistically significant) (58). The same authors showed that after adjusting for injury severity and age of patient, obesity, hypertension, psychosis, and alcohol or drug problems prolonged hospital stay. The mean length of hospital stay was 69% higher for patients with pre-existing chronic conditions than those without (59).

In a study by Goldberg, after adjusting for the patient's age, sex, injury severity, type of hospital, along with a malignant neoplasms, influenza, pneumonia, and emergency tracheotomy, the only variable that was significantly associated with mortality was ischemic heart disease and other forms of heart diseases (28).

1.5. Present Study

1.5.1. Trauma Care in Montreal

Emergency medical care in Montreal is controlled and coordinated by Urgence santé, a non-profit organization. All 911 emergency calls seeking health assistance are received by operators at the base of Urgence santé. These operators follow a specific flow chart to determine the severity of the injury of the patient, and hence the resources to be dispatched to the site. If the system does not perceive the injury as severe, emergency medical technician with a driver and an ambulance are dispatched to the scene of injury.

If the injury is severe, a physician employed by Urgence santé is requested for dispatching with an emergency medical technician, a driver and an ambulance.

Prompted by a study which was undertaken in 1987 to evaluate pre-hospital care in Montreal, one which found excess trauma related mortality in that area (60), two regional Level I trauma centers, as well as 7 Level II trauma centers were designated in the Montreal area in 1993.

In June 1995, a triage protocol which depends on the Pre-hospital Index (PHI) was introduced by Urgence santé. In addition to the unsatisfactory compliance rate of this protocol, no studies have addressed the protocol's effectiveness in identifying the patients with major injuries requiring treatment at a Level I trauma center.

1.5.2. Rationale for the Present Study

In Montreal, a regionalised trauma care system was established in 1993. Although the literature describes several triage protocols that have been developed and are being used in several North American states, application of one of these protocols to the population of Montreal may not be appropriate, without further study, since triage protocols can perform better on the population in which they were developed than when applied to new populations (61). Thus, there is a need for the development and evaluation of a triage protocol for the pre-hospital management of trauma patients in Montreal. This protocol should be able to identify patients with major injuries for the transfer to Level I trauma centers, and those with non-major injuries who could be treated at Levels II and III trauma centers.

The purpose of this study is to assess the ability of the Pre-hospital Index (PHI) to identify major trauma cases that require treatment exclusively at Level I trauma centers, and to distinguish those who could be treated at Levels II and III centers, as well as to develop a trauma triage protocol that improves the predictive power of the PHI-based triage instrument.

1.5.3. Objectives of the Present Study

The objectives of the study are:

1- To assess the predictive validity of the PHI in its use as a trauma triage instrument.

2- To establish a triage protocol which incorporates, along with the PHI, variables easy to identify at the scene of injury (age, body region injured, mechanism of injury, comorbidity, and time between 911 call and departure of ambulance from the scene of injury) in order to improve the accuracy of the PHI-based triage protocol.

CHAPTER 2.

REVIEW OF THE LITERATURE

2.1. Injury Severity Measures

The major adverse outcomes of severe injuries are disability and, ultimately, death. Although the majority of "immediate deaths" (those that occur within two hours since injury occurrence) are non-preventable, "early deaths" that occur between two hours and seven days after injury occurrence -- and are usually due to major internal haemorrhages of the head, the respiratory system, the abdominal organs, or are due to multiple injuries associated with significant blood loss -- could be prevented. They are preventable if those patients are transferred within a short period of time after injury occurrence (usually within an hour) to a hospital qualified to care for patients with severe injuries.

In order to prevent "early deaths" (around 35% of all trauma deaths) and to reduce disability due to trauma, it is important to identify, at the scene of injury, the patients with severe injuries who are at high risk of dying or suffering disability, so as to transfer them promptly to a Level I trauma center. Identification of these patients at the scene of injury may be done by the application of a measure which correlates well with death and disability.

Injury severity measures help us predict the risk of death by determining the anatomical damage or the physiological deterioration of the patient. These measures are

divided into three types of scales: anatomical scales, physiological scales, and composite scales. The choice of scale depends on the purpose of its usage.

2.1.1. Anatomical Injury Severity Scales

Anatomical injury severity scales are measures which reflect the anatomical damage to the body as a result of the injury. The data required to calculate these measures are obtained from physical examination, investigative procedures, surgical intervention, and, in fatal cases, post-mortem examination. These scales are stable over time and are not affected by treatment. By way of example, a patient with an internal haemorrhage to the brain would have the same anatomical injury severity score if this measure was calculated within an hour or three days since injury occurrence, regardless of any treatment offered to the patient.

Because the information required for the calculation of the scores of the anatomical scales is not readily available at the injury site, and since these scales do not measure the physiological deterioration of the patient, such scales cannot be used in field triage. Thus these scales cannot be used in distinguishing patients into those whose severe injuries put them at high risk of dying or suffering disability, and thus requiring transfer to Level I trauma center, from those who could be treated at Levels II and III trauma centers. Anatomical scales are used as descriptive measures of injury severity, as well as in the adjustment of injury severity in research. The Abbreviated Injury Scale (AIS), and the Injury Severity Score (ISS) are two examples of such scales.

Abbreviated Injury Scale (AIS)

In 1971, after the collection of information on several motor vehicle crashes, a specialized team composed of engineers, physicians and crash investigators -- sponsored by The American Medical Association, The Association of Automotive Medicine, and The Society of Automotive Engineers -- created the first Abbreviated Injury Scale (AIS). The purpose of the AIS was to create a system that rates tissue damage in motor vehicle crashes, so as to evaluate vehicle design with respect to the incidence of injury occurrence (62).

In 1976, the first AIS dictionary was published listing more than 500 injury descriptions (62). Several changes in the AIS dictionary took place through different revisions. The last revision, the AIS 90, had a listing of more than 1,200 injuries (63).

Each injury description is a unique 6-digit numerical code in addition to the last digit which constitutes the AIS severity score. The first digit identifies the body region injured, the second digit identifies the type of anatomic structure, the third and fourth digits identify the specific anatomic structure, the fifth and sixth digits identify the level of injury of that specific body region and anatomic structure.

The severity score, the last digit, is classified as: 1 for minor injuries, 2 for moderate, 3 for serious, 4 for severe, 5 for critical, 6 for un-survivable injuries, and 9 for unknown. Table 1 summarizes the rules used for assigning the values for injury description (63).

The AIS ranks the severity of individual injuries only, and does not assess the combined effect of multiple injuries. In a study conducted by Baker where 2,128 motor

vehicle crash victims were analysed, the authors found that the variation in mortality explained by the maximum AIS score (MAIS), the most commonly used measure of the AIS at that time, was only 25% (43). Thus, the desire to evaluate the severity of motor vehicle victims with multiple injuries, led to the development of the Injury Severity Score (ISS) (43,64).

Injury Severity Score (ISS)

The Injury Severity Score (43) which was developed by Baker *et al.* in 1974 from the AIS (64) is the most widely used anatomic injury severity index. This score was developed to evaluate overall severity of motor vehicle victims who have sustained injury to more than one area of the body.

The ISS was developed based on the analysis of 2,128 motor vehicle victims seen at eight Baltimore hospitals for the study years 1968 and 1969.

The ISS is defined as the "sum of the squares of the highest AIS grade in each of the three most severely injured areas" (43). This definition was based on the following observations: 1) the percentage of patients who died increased with an increase in the AIS grade of the most severe injury; 2) the relationship between the AIS and mortality was not linear but rather quadratic; 3) injuries in second and third body regions, for patients with identical AIS grades for the most severe injury, increased the risk of death with the quadratic relationship being still applicable.

The ISS ranges between 1 and 75, however, there is variation in the frequency of occurrence of the different scores of the ISS; ISS of 9 and 16 are common, 14 and 22 are

unusual, and 7 and 15 are unattainable. By convention, a patient with an AIS code of 6 for any injury is automatically assigned an ISS of 75 (43).

Several studies have been undertaken to evaluate the ability of this scale to predict mortality. In the analysis of 2,128 motor vehicle crash victims, the ISS was able to identify 49% of the variation in mortality as compared to the 25% variation when the MAIS was used (43). Studies have also shown that for trauma patients, the proportion of death increases with an increase in the ISS (43,65,66,67).

Other studies reported a positive association between the ISS and the mean length of hospital stay of trauma patients (65,66). Also, when the ISS was retrospectively applied to 1,333 trauma patients, the mean ISS was significantly higher for trauma patients with permanent disability versus those with no permanent disability (66).

On the other hand, in a study conducted on 814 trauma patients, the authors reported a lack of complete correlation between the ISS and the resources that severely injured patients require at the hospitals (fluid resuscitation, invasive central nervous system monitoring, and surgical intervention) (68).

2.1.2. Physiological Scales

For an injury severity measure to be used as a triage instrument, three conditions are required. The injury severity measure should be 1) easy to calculate at the scene, 2) fast to administer, and 3) correlate well with death and disability. Physiological scales are the injury severity measures used in field triage. These scales reflect the acute response of the body to the injury by measuring the physiological status of the patients at the scene of

injury -- which is a measure of the risk of dying for the patient at that time.

The Trauma Index, Trauma Score, CRAMS scale, Pre-hospital Index, and Trauma Triage Rule are the physiological injury severity measures developed and evaluated so as to be used in the triage of trauma patients. In this section, a review of these different physiological scales will be presented. A more detailed review of the studies which evaluated these scales will be described in the next section.

Trauma Index

The Trauma Index was developed in 1971 in an attempt to classify trauma patients and grade the severity of their injuries (69). A list of over 60 variables was considered. After the analysis of 133 trauma patients, 25 variables were selected in such a way that these variables were associated with subsequent care of trauma patients and could be obtained with minimal equipment, without patient cooperation, and by a non-physician. These 25 variables were grouped into five major components: body region injured, type of injury, cardiovascular status, central nervous system, and respiratory status.

A score is given to each of these components; a score of 1 is given to "minimal" injury severity, 3 or 4 for "moderate" injury severity, and 6 for "severe" injuries (Table 2). The total of the scores constitute the Trauma Index.

Trauma Score (TS), Triage- Revised Trauma Score (T-RTS), Revised Trauma Score (RTS), and Pediatric Trauma Score (PTS)

Trauma Score (TS)

The Trauma Score (TS) was first described in 1981 by Champion *et al.* It is a modification by consensus physician peer review of the Triage Index (TI) to include systolic blood pressure and respiratory rate, thus adding to its face validity (70). The TI is a measure of injury severity derived from a multivariate analysis of a data set of 1,084 patients treated at the Washington Hospital Center (71). It is composed of five components: respiratory expansion, capillary refill, eye opening, verbal response, and motor response. For each patient, a code between 0 and 4 -- 0 indicating normal functioning and 4 physiological deterioration -- is assigned to the five components of the TI. To calculate the TI, coded measurements of the components of this index are multiplied by weights derived from a logistic regression analysis of 1,084 trauma patients, with the outcome being defined as death of the patient, within the initial hospitalization after injury (Table 3). The negative of the summation of these products constitute the TI.

Although the TS was designed to evaluate trauma care and not to be used in field triage, the TS emerged as one of the scales mostly used in field triage (70,32).

The TS is composed of three major variables: 1) respiratory status (respiratory rate, respiratory effort); 2) cardiovascular functioning (systolic blood pressure, capillary refill); and 3) neurologic functioning measured by the Glasgow Coma Scale (GCS). Developed in 1974, GCS measures the neurological state of trauma patients (72). The

components of the GCS are eye opening, motor response, and verbal response. The scores of these variables range from 1 to 6, and the addition of these scores constitutes the GCS which ranges from 3 to 15; 15 represents normal consciousness (Table 4).

To calculate the TS, all individual parameters are evaluated and given a score between 0 and 5; the addition of these scores constitutes the value of this index (Table 5). The highest TS is 16, indicating least physiologic deterioration, and the lowest value is 1, indicating lack of neurologic, respiratory, and cardiovascular function. Table 6 shows the probability of survival for each value of the TS as determined in the study by Champion, 1981 (70). Trauma patients with a TS of 12 or less had a probability of survival less than 90% following injury. Consequently, Champion *et al.* suggested that trauma patients with a TS of 12 or less be transferred to a trauma center for the provision of prompt definitive care (70).

Triage-Revised Trauma Score (T-RTS) and Revised Trauma Score (RTS)

The TS was revised in 1989, eliminating the use of capillary refill, and respiratory expansion which are difficult to assess at the site of injury. Two versions of the revised Trauma Score were developed (73). One for field triage, yielding a Triage-Revised Trauma Score (T-RTS), and another, the Revised Trauma Score (RTS), developed for use in the control of injury severity, as well as in the evaluation of trauma care.

For the calculation of the T-RTS, the coded values of the Glasgow Coma Scale (GCS), systolic blood pressure, and respiratory rate (Table 7), derived from the analysis of 2,166 trauma patients, are added. This yields the values of this index, which ranges

between 0 and 12. When applied to this data set, a T-RTS less than 12 identified 96.9% of fatally injured patients.

To calculate the RTS, coded measurements of respiratory rate, systolic blood pressure, and GCS are multiplied by weights derived from a regression analysis (Table 7) of more than 25,000 patients in the Major Trauma Outcome Study (MTOS) (39,73,74). The sum of these products constitutes the RTS. The RTS ranges from 0 to 7.8408. The Major Trauma Outcome Study (MTOS) was initiated by the American College of Surgeons in 1982 to study injury severity and outcome, and to evaluate trauma care systems. This study aggregates information on patients' demographics, injury severities, and outcome characteristics (providing information on ISS, TS, RTS, age, outcome, and length of hospital stay). In 1988, more than 140 (150,000 patients) Levels I and II North American trauma centres collaborated in that study.

Pediatric Trauma Score (PTS)

The PTS was developed in 1987 (75). It was recommended for use in the triage of pediatric trauma patients by the Advanced Life Support course (American College of Surgeons) (76). The components of this scale are size of the child, airway, systolic blood pressure, central nervous system, skeletal fractures, and cutaneous injury. Each of these components is scored +2, +1, or -1 and the sum constitutes the PTS (Table 8).

The PTS ranges from -6 to 12, with the lowest values reflecting severe injuries. Patients with a PTS of 7 or less are at increased risk of mortality and thus require transfer to pediatric trauma centre (75).

CRAMS Scale

The acronym "CRAMS" represent: Circulation, Respiration, Abdomen, Motor and Speech. This scale, which was not based on any statistical analysis, was developed in 1982, in an attempt to simplify the TS used for field triage (77).

Scores of 0, 1, or 2 representing: severely abnormal, mildly abnormal, or normal functioning respectively, are assigned to the five components of the CRAMS scale (Table 9). The sum of the scores constitutes the CRAMS scale.

The CRAMS scale ranges between 0 and 10, lowest scores being severe injuries. A CRAMS score of 9 or 10 defines minor trauma, whereas a score of 8 or less defines major trauma.

Pre-hospital Index (PHI)

The Pre-hospital index (PHI) is a physiological measure of injury severity developed from a statistical analysis of 313 injured patients (78). It consists of the four components: systolic blood pressure, pulse rate, respiratory status, and level of consciousness. The PHI is calculated by assigning a value between 0 and 5 to the vital signs, with 0 indicating normal functioning and 5 maximum physiological deterioration (Table 10). An additional four points are added for the presence of penetrating abdominal or thoracic trauma. The PHI could range between 0 and 24. A PHI between 0 and 3 indicates minor injury, between 4 and 8 moderate injury, and more than 8 major injury.

Trauma Triage Rule (TTR)

The TTR was developed in 1990, from a regression analysis of 1,004 trauma patients. For the development of this scale, major trauma was defined based on treatment resources that patients with severe injuries would require. Thus the definition of major trauma was if: 1) surgery with positive findings was performed (non- orthopaedic); 2) more than 1,000 ml of in-fluid hospital resuscitation was required; 3) there was transfusion to maintain a systolic blood pressure above 89 mm Hg; 4) Central Nervous System monitoring (invasive) with a positive CT scan of the head; or 5) death due to trauma. This scale assigns a patient to have major trauma thus requiring transfer to trauma center, if the patient had a systolic blood pressure less than 85 mmHg, Glasgow Coma Score less than 5, or penetrating injury to the head, neck, or trunk (79).

2.1.3. Composite Scales

Composite scales are methods of trauma scoring which combine physiological, anatomical and other factors. These scales relate to patients' outcomes more than when any of the anatomical or physiological scores are used alone. Composite scales are not used in field triage since the data required for their calculation cannot be assessed at the site of injury. However, these scales are used in trauma care evaluation. The Trauma Score and Injury Severity Score (TRISS), and A Severity Characterization of Trauma (ASCOT) are examples of such scales (39,40).

Trauma Score and Injury Severity Score (TRISS)

TRISS (39) is one of the first methods used to combine physiologic (TS) and anatomic (ISS) components. It also includes age and presence of penetrating injury. The four elements

-- TS, ISS, age, and presence of penetrating injury -- provide a probability of survival, Ps, ranging from 0 (certain death) to 1 (certain survival). This probability is used for the evaluation of the outcome of trauma care.

The probability of survival for a patient may be estimated from a logistic regression model, where:

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

$e=2.72$

$b= b_0 + b_1(TS) + b_2(ISS) + b_3(Age)$

Age=0 if the patient is less than 55 years old; otherwise Age=1

b_0 is the constant of the logistic regression model; b_1, b_2, and b_3, are coefficients for blunt and penetrating injuries (Table 11), indicating the increase in the logit of the outcome (survival) for a unit increase in TS, ISS, and age, respectively, derived from the regression analysis when applied to the Major Trauma Outcome Study (MTOS).

A modification of the TRISS was undertaken with the Triage-Revised Trauma Score (T-RTS) replacing the TS, thus resulting in a more accurate prediction of the outcome. The coefficients b_0, b_1, b_2, and b_3 of the modified regression model for blunt and penetrating injuries are shown in Table 11 (39).

A Severity Characterization Of Trauma (ASCOT)

ASCOT is a physiological and anatomical characterization of injury severity which was developed in 1990 (40). ASCOT uses the parameters of the Triage-Revised Trauma Score (T- RTS) to describe the physiological characteristics of the injury, with age categorised into five levels, along with the Anatomic Profile (AP) parameters (A, B, and C) to describe the anatomical characteristics of the injury (Table 12). AP component A summarizes all serious injuries to the head, brain and spinal cord; B summarizes all serious injuries to the thorax and the front of the neck; C summarizes all other serious injuries (being defined as injuries with AIS >2). These summaries were generated from both mathematical derivation and the judgement of experienced trauma surgeons.

Probability of survival is calculated according to the regression model, with patients being separated into blunt and penetrating injuries:

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

$K=k_1+k_2G+k_3S+k_4R+k_5A+k_6B+k_7C+k_8 Age$

G= GCS, S=systolic blood pressure, R= respiratory rate, A,B,C =AP parameters

The values of the coefficients of this regression model $k_1, k_2, k_3, k_4, k_5, k_6, k_7$, and k_8, derived from the MTOS data, are shown in (Table 12) for blunt and penetrating injuries.

2.2. Review of the Studies which Evaluated the Performance of Different Trauma Triage Instruments

Several studies were undertaken to evaluate the performance of different triage

instruments in identifying patients with major injuries versus patients with non-major injuries. This section is divided into two subsections. The first is a review of studies which evaluated the performance of the different physiological scales in their use as triage instruments (2.2.1.); Table 13 presents a summary of these studies. The second is a review of the studies which evaluated the performance of different triage protocols that used a combination of physiological scales and time independent variables (age, mechanism of injury, body region injured, or other variables associated with death and easy to obtain at the site of injury) (2.2.2.); Table 14 presents a summary of these studies.

While reviewing each study, a criticism (if applicable) of the study will be presented. At the end of each subsection, the studies will be summarized.

2.2.1. Review of the Studies which Evaluated the Different Physiological Injury Severity Measures

In this section, a review of the studies which evaluated the performance of the physiological injury severity measures in predicting patients with major injuries is presented. It should be noted that two important issues should be considered in the evaluation of the internal validity of these studies: 1) definition of major trauma, and 2) time at which the variables required to calculate the physiological measures were gathered.

With respect to the definition of major trauma, it should be clear that a patient with major injuries is one who has a life threatening injury, or who could have died or suffered severe disability if not transferred to a Level I trauma center within a short period

of time since injury occurrence. What is special about a Level I trauma center is the availability of multi-specialty trauma teams with surgeons, anesthesiologists, surgical nurses, intensive care facilities, and other facilities available over 24-hour basis. Therefore, trauma patients who require intensive care unit admission or surgery to be performed (other than orthopaedic surgery or plastic surgery) are the patients who may not have survived had they been transferred to a non-Level I trauma center. Therefore, these patients and others who die due to trauma could be classified as having major injuries.

Because the physiological measures are not stable over time and since they are dependent on any treatment that may be given to the patient, it would be best if the components of these indices were assessed at the scene of injury, when the decision of whether to transport the patient to a Level I trauma center or not is being made. This would allow for testing the validity of these indices in their use in field triage.

2.2.1.1. Review of the Study Which Evaluated the Trauma Index

The Trauma Index, one of the first injury severity measures developed, was evaluated in 1971 (69). In an analysis of 357 patients, 84% of the patients had a Trauma Index between 0-7, 14% had scores between 8-18, and 2% had scores above 18. In this study, death was the only outcome of interest to the authors. For patients with a Trauma Index below 18, the death rate was 0%; whereas for those with a Trauma Index above 18, the death rate was 50% (4 patients out of 8 patients died). Neither the sensitivity, nor the specificity were reported in this study.

2.2.1.2. Review of the Five Studies which Evaluated the TS, RTS, and PTS Instruments

In the first study, the TS was prospectively evaluated (80) on 1,106 trauma patients admitted to the trauma center at San Francisco General Hospital. Ninety-three percent of the deaths occurred among trauma patients with a TS of 14 or less. The sensitivity, specificity, positive predictive value, and negative predictive value of the TS (cutoff value 14 or less) in predicting death were, 0.9, 0.8, 0.3, 0.9; whereas for the prediction of an ISS of 20 or more these statistics were 0.63, 0.88, 0.52, and 0.92.

Although the ISS has been shown to be associated with death (43,65,66,67), this measure is not a true measure of death, intensive care unit or operating room admission (68), therefore, more valid results would have resulted if the definition of major trauma in this study was in terms of these variables.

The second study was undertaken on 250 children injured in Southern Alabama and transported to a hospital, which had an emergency department and emergency physician (81). The object of the study was to assess the predictive validity of the Pediatric Trauma Score (PTS) in identifying pediatric patients with severe injuries. In detecting patients with major injuries (defined if the patient died during the hospital stay), the sensitivity and specificity of the PTS (with a cutoff value of 8) were 0.96 and 0.99. The positive predictive value was 0.98, and the negative predictive value was 0.97. Again in this study, death was the only criterion used to define major injuries.

The third study was conducted (82) on 1,334 children (less than 14 years old) admitted to the Children's Medical Center in Washington DC, in order to compare the

abilities of the Trauma Score (TS), Revised Trauma Score (RTS), and Pediatric Trauma Score (PTS) in identifying children with major injuries. Also, in this study, major trauma was defined in terms of ISS above 15, rather than death, intensive care unit or surgery intervention. A TS (cutoff value of 14) had a sensitivity and a specificity of 0.72 and 0.75, respectively, with a positive predictive value and a negative predictive value of 0.32 and 0.94, respectively. The RTS (cutoff value of 11), yielded a sensitivity, specificity, positive predictive value, and negative predictive value of 0.78, 0.63, 0.25, and 0.95, respectively, whereas; these statistics were 0.78, 0.75, 0.33, and 0.95 for the PTS (cutoff value of 8). There was no statistically significant difference between the TS and the PTS in predicting major trauma. Nevertheless, while the RTS had the same sensitivity, the specificity and the positive predictive value of the RTS were lower than those of TS and PTS.

In the fourth study (83), the performance of the motor response component of the Glasgow Coma Score (GCS), the Glasgow Motor Response (GMR) (which ranges from 1 to 6, with 6 being normal motor response), was compared to the performance of the TS in identifying trauma patients who require transfer to trauma centers. Fifty-two percent of the 56,827 patients, obtained from the North Carolina Trauma Registry, and gathered around 6 years period, had complete data and thus were included for this analysis. The sensitivity of a GMR of 5 or below (those who cannot follow commands) in identifying patients who died or had ISS above 20 was 58%, whereas for a TS of 12 or less, the sensitivity was 53%. However, the sensitivity of the GMR and the TS in identifying death at emergency room, or direct admission to operating room, or intensive care unit were 23% and 19%.

The fifth study was conducted on 65 trauma patients (84) in order to compare the performance of the Trauma Score (TS) with the Vital Signs Scores (VSS) used by ambulance paramedics in New South Wales. The VSS is a modification of the TS: 1) skin colour substitutes capillary refill of the TS; 2) levels of respiratory expansion are satisfactory versus unsatisfactory (codes 1 and 0, respectively) as compared to normal, versus shallow/ retractive for the TS; and 3) level of consciousness is modified from the Glasgow Coma Scale (GCS). The mortality rate for patients with a TS below 12 was 0%. However, this was 4.4% for a VSS score below 12. For a TS of 12 or more, the mortality rate was 61.5 % versus 30 % for the VSS. A stepwise logistic regression analysis of the TS, VSS, and a combination of their components was done. The TS had a better predictive ability for mortality than any of the combinations of the components of the VSS.

In this study, the authors did not report the sensitivity and specificity of these indices. Also, the loss of power due to the small sample size, and the definition of major injuries with death being the only criterion, raises questions about the credibility of this study. Finally, no comparison of the performance of the TS and the VSS can be made, because these scores were obtained at different times (TS was calculated in the emergency department whereas the VSS was calculated while transporting the patient to the hospital). According to the results, the TS had a better predictive ability for mortality than the VSS. However, this is somewhat expected because the TS was calculated a little later than the other scale.

2.2.1.3. Review of the Two Studies which Evaluated the CRAMS Scale

The first study was undertaken by Clemmer *et al.* (85) to prospectively evaluate the CRAMS scale in its use as a triage criteria. Included in the study were 2,110 trauma patients gathered over seven months period in Salt Lake County. In this study, a respiratory rate greater than 35 breaths per minute was added to the abnormal or shallow category defined by the original CRAMS scale published by Gormican. In predicting death, the sensitivity, specificity, positive predictive value and negative predictive value of the CRAMS calculated at the site of injury (cutoff 6) were 0.96, 0.98, 0.62 and 0.99, respectively. The sensitivity and the specificity for intensive care unit admission were 0.27 and 0.96; for surgery the figures were 0.13 and 0.95, respectively.

The second study was undertaken by Gormican (77) to determine if the CRAMS scale could accurately differentiate between patients with major and minor injuries. Five hundred paramedic trauma transports seen at Scripps Base Station in California were included in the study. Major injury was defined if a patient died in the emergency department or went directly to the operating room for general surgery or neurosurgery; minor injury was defined if the patient was discharged home from the emergency department; and intermediate injury if the patient was admitted to the hospital without surgery, or with surgery other than general or neurosurgery. The sensitivity and the specificity of the CRAMS (cutoff value of 8 or less) in determining major and minor injuries (without considering patients with intermediate injuries) were found to be 92%, and 98%, respectively. If we were to combine intermediate injuries with minor injuries, the specificity would drop to 0.90.

In this study, definition of major trauma was in terms of death in the emergency room, or direct transfer from the emergency room to the operating room. A broader definition of major trauma to include death due to trauma in the hospital and intensive care unit admission may have yielded different results.

2.2.1.4. Review of the Four Studies which Evaluated of the PHI scale

Upon the development of the PHI, this scale was prospectively validated by Koehler on 388 trauma patients seen at the Butterworth Hospital Emergency Department, Michigan (78). In identifying patients who died within 72 hours of injury occurrence, or who required general or neurosurgery to be performed within 24 hours, this index (cutoff value of 4) had sensitivity, specificity, positive predictive value and negative predictive values of 0.94, 0.95, 0.46 and 0.99, respectively.

A second study was conducted by Koehler *et al.* (86) for the prospective evaluation of the PHI, applied to 3,581 trauma patients transported to the emergency department of 14 different hospitals (2 of which were designated as Level I trauma centers). A PHI of 4 or more had a sensitivity of 92.7% in detecting patients who died or who had surgery within four hours of hospital admission, and a specificity of 93.3%. The positive predictive value and the negative predictive values were 52.1%, and 99.4%, respectively.

Another study was conducted by Plant *et al.* (87) in Calgary, Canada, where ambulance protocols mandate the transfer of patients with a PHI of 4 or more to trauma centers, to assess the effectiveness of the PHI in its use as a triage tool. Six hundred and

twenty-one patients with an Injury Severity Score (ISS) of 16 or more, seen at Calgary's two adult trauma centers, were identified and included in the study. In this study, the highest PHI before admission to the trauma center was used instead of the one calculated at the scene. A PHI of 4 or more had a sensitivity and a specificity of 81% and 61% for either death within 72 hours, or surgery within 4 hours. However, these statistics are misleading, because the population of which they were calculated belongs to patients seen at trauma centers with ISS of 16 or above.

The fourth study was conducted by Sampalis *et al.* (88) to evaluate the predictive validity and internal consistency of the PHI, calculated at the scene, in its use as a triage instrument. Considered for the analysis were 628 patients with major injuries for whom a physician was requested to be dispatched to the injury site. Major trauma was defined if the patient died due to trauma, had a length of hospital stay of more than three days, was admitted to the intensive care unit, or had surgery. The sensitivity, specificity, positive predictive value, and negative predictive value (cutoff point of 4) were 83%, 67%, 64%, and 85%, respectively. Internal consistency was measured by Cronbach's alpha. The overall alpha for the PHI was 0.72, which value increased to 0.76 when the level of consciousness was removed form the calculation of the PHI.

2.2.1.5. Review of the Two studies which Evaluated the TTR Scale

With the development of the TTR, this scale was tested on a cohort of 1,004 trauma patients. The authors reported a sensitivity of 92% and a specificity of 92% in identifying patients who underwent: 1) operative procedure (non-orthopaedic) with

positive findings within 48 hours after admission (positive findings defined as traumatic injuries which are life threatening if not treated); 2) in-hospital fluid resuscitation of more than 1,000 ml; 3) transfusion to maintain a systolic blood pressure of more than 89 mm Hg; 4) invasive central nervous system monitoring with a positive CT scan or elevated intra-cranial pressure; or 5) trauma related death (79).

Another prospective study was undertaken by Fries *et al.* (89) to test the accuracy of both the paramedic judgment and the Trauma Triage Rule (TTR) in identifying trauma patients who require transfer to trauma centers. At the injury site, paramedics evaluated the seriousness of the injury of 653 trauma patients and recorded the values of the variables required for the TTR calculation. The definition of major trauma was the same as that used by Baxt in the previous study (79). The sensitivity, specificity, positive predictive value, and negative predictive value of the paramedic judgment were 91%, 60%, 24.6%, and 98%, respectively. Whereas the TTR had a sensitivity of 88%, a specificity of 86%, a positive predictive value of 47.1%, and a negative predictive value of 98%. The combination of the TTR and the paramedic judgment resulted in a sensitivity of 100% and a specificity of 75%, respectively. In this study, the paramedics had to report the TTR variables at the same time they reported their judgement. Thus, such a judgement could have been influenced by the evaluation of the variables of the TTR.

2.2.1.6. Review of the Three Studies which Evaluated the Different Physiologic Injury Severity Measures

A retrospective study was undertaken on 5,130 trauma patients in Nebraska (31) to evaluate the performance of the TS and the CRAMS scale. Both a TS of 12 or less, and a CRAMS score of 8 or less identified all trauma patients who died in the emergency department or who died before arrival to the hospital. A TS of 12 or less had a sensitivity, specificity, positive predictive value, and negative predictive value (in identifying patients who died in the emergency room or before arrival to the hospital, or who were transferred from the emergency department to the operating room) of 0.48, 0.78, 0.1, and 0.97, respectively. On the other hand, the sensitivity, specificity, positive predictive value, and negative predictive value of a CRAMS score of 8 or less were 0.34, 0.88, 0.12, and 0.96, respectively. Again in this study, a broader criterion for the definition of major trauma to include patients who died in the hospital due to trauma would have yielded more valid results.

Another study considered a cohort of 2,434 patients, treated by the San Diego County regionalised trauma system, for the evaluation of the TS, CRAMS, RTS, and the PHI in their use as triage instruments (90). In this study, major trauma was defined for death and ISS above 15 separately. According to the Receiver Operating Characteristic Curve (ROC), each of the four scales was able to predict mortality with a sensitivity of 85% or more, and a specificity of 85% or more. However, no scale was able to achieve a sensitivity and a specificity of more than 70% in predicting an ISS of 15 or greater.

Another study (23) aimed to compare the performance of the emergency medical

technicians' judgement (in identifying patients with major trauma) with the Revised Trauma Score (RTS), Pre-hospital Index (PHI), and CRAMS scales (23). Information on all the variables required for the calculation of these scales was collected at the site of injury. Of the 1,502 patients seen over 6 months period, 1,153 patients had complete data and were included in the study. The emergency medical technicians predicted the probability of patients' mortality on a scale of 0 to 100. In predicting patients who died or required general or neuro-surgical operation to be performed within two hours of arrival to the emergency department, there was no statistically significant difference in the emergency medical technicians' mortality estimate (area under ROC curve =0.94 $\pm$ 0.02), PHI (area under ROC curve =0.96 $\pm$ 0.01), CRAMS scale (area under ROC curve =0.95 $\pm$ 0.02). However, the RTS area under ROC curve (0.90 $\pm$ 0.03) was significantly lower than that of the PHI, CRAMS, and emergency medical technicians' scale. In this study calculation of the CRAMS, PHI, and the RTS was not done at the scene of injury, but the emergency medical technicians had to identify the values of all the variables for these scales at the site. Thus the judgement of the emergency medical technicians could have been influenced by such calculations.

2.2.1.7. Summary of the Studies which Evaluated the Performance of the Different Physiologic Injury Severity Measures

The indices from the studies presented above cannot be compared because of 1) differences in the populations on which the scales were applied; 2) differences in the definition of major trauma; and 3) differences in the time when the information of the

variables required for the calculation of the indices were gathered.

Although some of these studies reported acceptable accuracy of the indices in predicting major trauma, others showed extremely disappointing results (Table 13). The sensitivity of the TS in predicting major trauma ranged from 0.9, with a specificity above 0.8 in detecting only patients who died due to trauma (80), to 0.48 with a specificity of 0.78 in detecting patients who died at the emergency room or before reaching the hospital, or who were directly admitted to the operating room (31). The rest of the studies which evaluated the TS had a sensitivity ranging from 0.53 in predicting death or ISS above 20 (83), to a sensitivity above 0.85 in detecting trauma deaths (90). The two studies which compared the performance of the TS to the RTS had contradictory results. In the study conducted on 1,334 children (82), the RTS seemed to be doing better than the TS in predicting trauma patients with ISS above 15. However, in the study conducted on 1,502 patients (23), the area under the ROC curve for the TS was significantly higher than that of the RTS (in predicting death or surgery within 2 hours). The PTS showed a sensitivity, specificity, positive predictive value, and negative predictive value above 0.95 in predicting pediatric patients who died in the hospital due to trauma (81). However, in this study, these statistics were for predicting death only, and the sample size was small (250, out of which 13 deaths occurred). The sensitivity and specificity of the PTS, in predicting trauma patients with ISS above 15, in another study were 0.78 and 0.75, respectively (82).

As for the CRAMS scale, the sensitivity of this index ranged from 0.96 in detecting only trauma deaths (85) to 0.92 in predicting deaths in emergency room, or direct admission to operating room (77), to 0.34 in detecting death before arrival to the

hospital, death in emergency room, or direct admission from emergency room to the operating room (31).

The TTR was evaluated in two studies (79, 89). The sensitivity and specificity were 0.92 in one study (79), and 0.88 and 0.86 in the second study (89). The major injuries in these studies were defined if: 1) surgery was performed (non-orthopaedic) with positive findings; 2) more than 1,000 ml of in-fluid hospital resuscitation was required; 3) transfusion was given to maintain a systolic blood pressure above 89mm Hg; 4) central nervous system monitoring (invasive) with a positive CT scan of the head, or 5) death due to trauma.

The PHI had a sensitivity which ranged from 0.81 (in identifying trauma patients who died within 72 hours, or who had surgery performed within four hours), with a specificity of 0.61 (87), to 0.94 (in defining death or surgery) with a specificity of 0.95 (78). In one study, the PHI had a sensitivity of 0.93, and a specificity of 0.93 when applied to 3,581 patients (in detecting patients who died or had surgery within 4 hours) (86). In another study, the sensitivity and the specificity were 0.83 and 0.67 respectively (in detecting death, length of hospital stay above three days, intensive care unit admission, or surgery) (88), whereas both sensitivity and specificity were above 0.85 (in identifying death) when the PHI was applied to 2,434 patients (90) .

Although no definite conclusion can be made after the review of these studies, it is apparent that even though the sensitivity of the indices was as low as 0.13, all of these scales in the studies reviewed had acceptable specificities (all specificities were above 60%). Also, the PHI and the TTR had the most consistent and highest sensitivity and

specificity in predicting injury severity of trauma patients. The studies which evaluated these two indices had acceptable internal validity in terms of definition of major trauma, and the time when the variables of the indices were evaluated. However, although the TTR seems to have promising results, only two studies evaluated this scale.

In the next section, a review of the studies which developed and evaluated the combination of time independent variables (mechanism of injury, body region injured, and age) with the physiological scales will be presented.

2.2.2. Review of the Studies which Developed and Evaluated Triage Protocols Composed of Physiological and Time Independent Variables

A prospective study (91) was conducted on 1,063 trauma patients to evaluate a standard triage criterion, used in Oregon, to identify patients who require transfer to trauma centers and to assess if the addition of emergency medical technicians' perception add to the accuracy of this triage criterion. In Oregon, the standard triage criterion for the transfer of patients to trauma centers requires the patient to have one or more of a list of 12 mandatory conditions, and/ or 10 discretionary conditions. These conditions are composed of physiologic measures, one of which is the GCS, mechanism of injury, and body region injured characteristics.

. The emergency medical technicians' perception was categorized into four levels -- A patient with: 1) minor injury, 2) acute, 3) life- threatening, or 4) needed resuscitation. For the study's purpose, a patient was classified to have major trauma, if the patient had a major surgery within six hours after hospital admission, or had intensive care unit

admission within three days after hospital admission, or an Injury Severity Score (ISS) of 16 or more, or death. The sensitivity of the standard triage criteria was 87% and the specificity was 27%. Areas under ROC curves increased from 0.83 for the standard triage criteria to 0.88 when the emergency medical technicians' perception was added ($p < 0.001$).

A prospective study (92), was conducted on 8,891 trauma patients transported to the seven trauma centers (one Level I trauma center, and six Level II trauma centers) in Dade County, Florida, so as to evaluate the efficacy of the triage guidelines suggested by Champion and the report of the Conference on Injury Severity Scoring and Triage (32,93). These triage guidelines require information on physiological measure (TS), mechanism of injury, and body region injured variables.

Thirty percent of the patients transferred to a trauma center (Levels I and II), according to this triage protocol, had major trauma -- defined if the patient died in the emergency room, had surgery, or was admitted to the intensive care unit. The overall positive predictive value of the triage system was 30%. The highest positive predictive value was 92% for the TS criterion (cutoff value of 12). This value was 22% for high energy dissipation, and 48% for penetrating trauma.

In this study, there was no information on patients who did not satisfy the criteria for transfer to a trauma center; thus, we neither know the percentage of the false negatives (patients with major injuries missed by this triage protocol), nor the percentage of the true negatives (patients with minor injuries correctly identified by the triage protocol). Therefore, neither the sensitivity nor the specificity could be calculated for the triage

guidelines. Also, the criteria for defining major trauma included only death at the emergency department. Of the 468 patients who died in the hospital, only 219 patients died in the emergency room and were considered to have had major trauma.

Knopp *et al.* conducted a study (51) on 1,473 trauma patients transported by the Fresno County Central California emergency medical system. The objectives of the study were to: 1) determine the specific mechanisms of injury or body region injured that predict patients with Injury Severity Score (ISS) above 15; 2) determine the best combination of the Trauma Score (TS), mechanism of injury, and body region injured that will increase the accuracy of predicting patients with ISS above 15, than if any of the criterion was used separately.

The authors reported that a TS of 12 or less had a positive predictive value of 0.76 in identifying patients with an ISS above 15. This TS cutoff value resulted in an over-triage rate (defined as the number of patients with an ISS below 15 who met the triage criteria divided by the total number of trauma patients with an ISS of 15 or less) of 1.5% and an under-triage rate (defined as the number of patients with an ISS of more than 15 missed by the triage criteria divided by the total number of trauma patients who had an ISS of more than 15) of 29.9%.

The positive predictive value for predicting an ISS above 15 was 100% for spinal injury, 100% for amputation, 60% for penetrating torso injury, 37.5% for burns, 40% for extrication time of more than 30 minutes, 22.4% for ejection, 21.4% for fatality in same vehicle, 19.5% for proximal long-bone fracture, and 19.0% for space intrusion. A combination of these conditions along with a TS of 12 or less produced an over-triage

rate of 12.8% and an under-triage rate of 10.3% with a positive predictive value of 33%.

The purpose of another study (25), which included 500 trauma patients seen at the San Jose Hospital, California, was to assess the ability of the Trauma Score (TS), CRAMS, and mechanism of injury, to identify trauma patients with serious injuries.

A TS of 12 or below had a sensitivity of 24%, with a specificity of 100% in identifying trauma patients with major injuries, defined if the patient died, was hospitalised for more than three days, had a TS calculated at the emergency room of 14 or less, or had an Injury Severity Score (ISS) above 15. This high specificity could be partially explained by the definition of major trauma which included a TS at the emergency room of 14 or less. On the other hand, a CRAMS of 8 or less had a sensitivity and specificity of 66% and 82%, respectively. When the sensitivity and specificity of certain mechanisms of injury were investigated, motor vehicle accident above 40 mph had the highest sensitivity (24%) with a specificity of 72%, motorcycle accident above 20 mph had a sensitivity of 9% and a specificity of 94%, auto versus pedestrian accident above 5 mph had a sensitivity of 16% and a specificity of 81%, and major assault had a sensitivity of 6% and a specificity of 89%. Combined with the CRAMS scale (8 as a cutoff point), these variables produced the highest sensitivity of 93%, with a specificity of 30%.

A study was undertaken (94) on 2,058 trauma patients, to develop a triage protocol which combines physiologic, mechanism of injury, and body region injured variables.

In this study, the TS was calculated at the emergency room and not at the scene of

injury. Also, the definition of major trauma was in terms of ISS only. The sensitivity and specificity of the TS (cutoff value 12), in identifying patients with ISS above 15, were 40.3% and 98.7% with a positive predictive value of 94.2% and a negative predictive value of 78.4%. However, in identifying patients with an ISS above 20, the sensitivity was 52%, specificity was 97.9%, positive predictive value was 88%, and negative predictive value was 87.5%. Triage guidelines which combined TS along with other physiologic variables, and mechanism of injury and body region injured characteristics were established, after determining the prevalence of major trauma for these variables. The sensitivity, specificity, positive predictive value, and negative predictive value of the triage guidelines in identifying patients with ISS above 15 were 86.3%, 92.1%, 83.2%, and 93.7%, respectively. For patients with an ISS above 20, these statistics were: 86.3%, 93.1%, 78.7%, and 95.9%, respectively.

Based on the analysis of 937 trauma patients transported to four of the hospitals in Southern California, Kane *et al.* developed and evaluated the performance of a two triage instruments that determine which patients should be transferred to trauma centers (27). Major trauma was defined if the patient had an ISS of 16 or more; or had cranial, neck, truncal injury or major vascular surgery within six hours of emergency room admission; or if the patient died within six hours since emergency room admission.

Demographics, body region injured and physiologic variables were assessed while the patient was still at the scene of injury. Two different techniques for analysis were performed: 1) multivariate logistic regression and 2) hierarchical modelling.

1) Logistic regression determined eight predictor variables. The rounding of the weights

of these variables to integers, and addition of constants were done, thus determining the ranks for the variables of the triage scale. The summation of these ranks determined the score of the scale to be used for this triage instrument, where a patient above an established cutoff score would be sent to a trauma center.

2) A hierarchical modelling was performed where logistic regression model was used to determine the one variable that predicted best which patients should be transferred to trauma centers. Patients who satisfied the criterion according to that variable were removed from the data set. This was then repeated where the next best predictive variable of the outcome was determined. The process was repeated on smaller data sets until the variables left in the model had all p values above 0.15. This technique resulted in a checklist. A patient is supposed to be transferred to a trauma center if the patient had any of the checklist items.

For both the generated scale as well as the checklist certain variables with high face validity were not included. However, certain variables with low-face validity were removed from the final model. For this reason, a revised scale and a revised checklist were created by adding variables of high-face validity and taking out variables with low-face validity.

Sensitivity, specificity, and positive predictive value were determined for the following six triage instruments: the Scale, the Checklist, the Revised Scale, the Revised Checklist, the Trauma Score (TS), and the CRAMS.

As for the Revised Scale, cutoff values of 6 and 7 were considered. The cutoff value of 6 yielded a sensitivity, specificity, and positive predictive value of 0.95, 0.37, and 0.16, respectively. For the cutoff value of 7, these statistics were 0.71, 0.86, and 0.38,

respectively. For the Revised Checklist, the highest sensitivity was 0.81, when all 12 variables were considered, the specificity and positive predictive value were 0.77, and 0.72, respectively. However, the highest specificity was 0.9, when the first six items were considered, yielding a sensitivity of 0.64, and a positive predictive value of 0.41. The CRAMS (cutoff value 8 or less) had a sensitivity of 0.72, a specificity of 0.86, and a positive predictive value of 0.38. The TS (cutoff value 12 or less) had a sensitivity of 0.17, specificity of 0.99, and positive predictive value of 0.64.

A study was conducted (95) to compare the performance of two triage instruments used in Orange County; the original instrument that was based on physiological variables only, and the revised one that added anatomic, mechanism of injury, and age criteria to the physiological variables. The results of triage by the original triage instrument for 743 trauma patients, seen in the field by paramedics and transferred to trauma centers, were compared to the results of triage of 1,793 patients transferred to trauma centers and for whom the revised triage instrument was applied, during its first-year of operation.

Major trauma had two definitions: 1) Injury Severity Score (ISS) of 10 or more, with length of hospital stay of three days or more, and 2) ISS above 15. The over triage rate was defined as the number of patients triaged to a trauma center according to the triage instrument, however, not satisfying the definition of major trauma, divided by the total number of patients triaged to a trauma centre. For the first and second major trauma definition, the over-triage rate for the original triage tool were 0.18. and 0.40, respectively. However, for the modified triage tools, the over-triage rates, for identifying patients with major trauma according to the first and second definitions, were 0.36, and 0.60, respectively. The difference of the over-triage rates for the original and the revised

tools were statistically significant ($p < 0.001$).

Since no information was available on patients triaged to non-trauma centers, rate of under-triage could not be assessed in this study. However, the authors defined the rate of under-triage as the ratio of non-central nervous system motor vehicular (non-CNS MVA) deaths in non-designated trauma centres divided by the total number of regional non-CNS MVA deaths times 100. According to the authors, non-CNS deaths were evaluated because studies have shown that these deaths are at high risk for prevention. The under triage rate for the original triage tool was 0.21, whereas for the revised tool this was 0.04 ($p < 0.05$).

A study was conducted (96) to compare the performance of 11 triage instruments when applied to 130 trauma patients from a semi-rural population in Washington state.

Patients with major trauma requiring transfer to trauma centre were defined if the patient had no vital signs at the sight of injury, died in the emergency department, or was admitted directly to the operating room (for surgery other than orthopaedic extremity injury) or to the intensive care unit. Five of the 11 triage instruments had a sensitivity above 0.70. Those instruments were, Kane's Revised Checklist, CRAMS scale, a combination of the Trauma Score (TS)\ Glasgow Coma Scale (GCS) \ and mechanism of injury, RSG (an abbreviation of the TS variables: respiratory\systolic pressure\ GCS), and the Pre Hospital Index (PHI). Both Kane's Revised Checklist and the CRAMS had the highest sensitivity 0.85. On the other hand, both the RSG and the PHI had the highest specificity among the five instruments -- 79% and 75%, respectively. The best negative liklihood ratios were for Kane's Checklist and the CRAMS scale and these values were 0.22 and 0.27, respectively. However, the RSG and the PHI had the highest positive

liklihood ratio.

2.2.2.1. Summary of the Studies which Developed and Evaluated the Performance of Triage Protocols Composed of Physiological and Time Independent Variables

The TS and the CRAMS scale are the two physiological injury severity measures which have been most extensively assessed for field triage after the addition of time independent variables (mechanism of injury, body region injured, and age) (92,51,94,27,96) (Table 14). In these studies, when the TS or the CRAMS scale was assessed separately for field triage, the sensitivity in identifying patients with major injuries was low relative to the calculated specificity. However, when time independent variables (mechanism of injury, body region injured, and age) were added to the field triage scale, the sensitivity increased, at the expense of the specificity.

In the study by Cottington (94), the sensitivity of the TS in detecting patients with ISS above 15 was 0.40 with a specificity of 0.99. This sensitivity increased to 0.86 and the specificity dropped to 0.92 after the addition of the mechanism of injury and body region injured variables to the TS. In the study by Kundson (25), the sensitivity and the specificity of the CRAMS scale -- in detecting death, length of hospital stay above three days, TS at emergency room below 15, or ISS above 15 -- were 0.66 and 0.82, respectively. However after the addition of the mechanism of injury variable these statistics were 0.93 and 0.30, respectively. In another study by Kane (27), when the CRAMS and TS were evaluated separately, the sensitivity of the two scales in detecting ISS above 15, surgery, or death were 0.72, and 0.17 with specificities of 0.86 and 0.99, respectively. However, after the addition of the time independent variables to the

physiologic variables, the Revised Scale and the Revised Checklist had a sensitivity of 0.95 and 0.81, with specificities of 0.37, and 0.77, respectively.

The same conclusion could be made from the two studies that reported over- and under-triage rates (51,95). The over-triage rate for a triage instrument with only physiological measures (95) was 0.18 in identifying patients with ISS of 10 or more and length of hospital stay of three days or more, with under-triage rate of 0.21. These values changed to 0.36 and 0.04 when the mechanism of injury and the body region injured were added to the physiological variables. Also, in the study by Knopp (51), the over-triage rate and under-triage rate of the TS were 1.5% and 29.9% (for identifying patients with ISS above 15); these values changed to 12.8% and 10.3% when mechanism of injury and body region injured variables were added to the TS index.

In the study by Hedges, after comparing the performance of 11 triage instruments, Kane's Revised Checklist, which is a combination of physiologic and time independent variables (mechanism of injury, body region injured), had the highest sensitivity with a relatively good specificity (0.85, and 0.65, respectively).

One may conclude that in order to obtain a more sensitive triage scale and thus be able to identify a larger proportion of trauma patients with major injuries who are at increased risk of dying or having disability and who require transfer to Level I trauma center, triage protocols which are composed of time independent variables and physiological measures should be used.

2.3. The Present Study

After reviewing the studies which developed and evaluated different triage instruments (previous section), it is obvious that more work needs to be done in this area, for better identification of patients with major injuries to be transferred to a Level I trauma center, as opposed to patients with less serious injuries who could be treated at Levels II and III trauma centers.

The objectives of the present study are to evaluate the PHI in its use as a field trauma triage instrument for the population of Montreal. The study also aims to develop and to evaluate three triage protocols. These protocols will incorporate, along with the PHI, variables which are associated with death and disability, and which are easy to obtain at the scene of the injury (mechanism of injury, body region injured, age, comorbidity, and time between 911 call and departure of the ambulance from the site of injury), so as to improve the predictive ability of the triage protocol, which is based on the PHI alone.

For this study, the PHI is the index of choice among the physiological indices reviewed because this scale 1) is easy to calculate at the scene of injury; 2) has proven consistently to be a valid physiological injury severity scale (78,86,87,88,90,23,96); and 3) is currently used in Montreal by Urgence santé as a criterion for the triage protocol.

In order to improve the validity of the present study over previous studies, the following aspects will be considered:

1) Reduction of information bias by using a valid definition for patients with major injuries that targets patients who are at increased risk of dying or having severe disability

if not treated at Level I trauma center .

2) Reduction of information bias by considering the PHI when calculated at the site, time when the decision for transfer is being made .

3) Use of appropriate statistical methods.

CHAPTER 3.

RATIONALE AND METHODS

3.1. Rationale and Study Objectives

3.1.1. Rationale

A non-profit organization, Urgence santé, was established in 1981 to provide emergency medical care in both Montreal and Laval (Quebec), an area of 1,200 km^2 with a population of two million individuals. In 1997, Urgence santé had 150 ambulances, and employed 70 physicians and 700 emergency medical technicians. Depending on the time of the day and the day of the week, between 80 and 100 ambulances have standby positions at specific locations in the city.

All 911 emergency calls seeking emergency medical assistance are received by operators at the central location of Urgence santé. These operators follow a specific flow chart to determine the severity of the injury of the patient, and hence the resources that should be requested to the scene of injury. If the injury is not perceived by the system to be severe, an emergency medical technician with a driver and an ambulance are dispatched to the scene of injury; whereas if the injury is severe, a physician employed by Urgence santé is requested for dispatch with an emergency medical technician, a driver and an ambulance.

In 1987, a cohort study was undertaken to evaluate trauma care in Montreal. This study was based on 360 severely injured patients transported by Urgence santé, between

March 1987 and April 1988, to the nearest hospital with an available emergency room. The results of this study showed 81% excess in mortality when compared to the Major Trauma Outcome Study (MTOS), which aggregates information on demographic, injury severity, and outcome characteristics for patients treated at Levels I and II North American trauma centres. Prompted by the results of this study, trauma care became a priority for the Quebec Government. In 1993, four regional Level I trauma centers were established in Quebec (Montreal General Hospital, Sacré coeur Hospital, Charles Lemoyne, and Enfant Jésus Hospital). Also in Quebec, 35 hospitals were designated as Level II trauma centers, and 24 as Level III trauma centers. In Montreal and Laval, the area within which pre-hospital care is covered by Urgence santé, two hospitals were designated as Level I trauma centers -- Montreal General Hospital, and Sacré Coeur -- and seven hospitals as Level II trauma centers -- Maisonneuve- Rosemont, Général Juif, Verdun, Santa Cabrini, Jean Talon, Hotel Dieu, as well as Cité de la santé. However, none of the hospitals was designated as Level III trauma centers. Leves I trauma centers have 24-hour per day coverage of trauma team with surgical staff. Other specialties including neurosurgery are available within 30 minutes. On the other hand, Levels II trauma centers have 24 hour coverage of emergency room physicians, and all other specialties are available within 30 minutes. The terms Level I, II, and II trauma centers were used in order to keep our terminology comparable with that in most of the literature. However, in Canada the trauma centers are classified as Tertiary, Secondary, and Primary. Tertiary trauma centers are equivalent to Level I trauma centers in the U.S. Secondary trauma care centers are not similar to the U.S. Level II trauma centers because they do not have all the required facilities, specialties, and technology to treat patients with major trauma. Similarly, Primary trauma centers are not equal to the Level III centers since only emergency care is available.

Since the implementation of regional trauma care centers in Montreal, Urgence

santé has designed training sessions for employed emergency medical technicians and physicians, focussing on rapid stabilization and scene-time reduction. Also, a triage protocol (Figure 1) based on the Pre-Hospital Index (PHI), a physiologic injury severity measure, was introduced in June 1995. Before the introduction of this protocol, trauma victims were generally transferred to the nearest hospital with an emergency room. According to this protocol, however, a patient is considered to have major trauma and thus should be transferred to a Level I trauma center (Montreal General Hospital or Sacré Coeur) if: the patient has a PHI of 4 or more, or the injury is from a high impact velocity. The patient should also have vital signs and one of the following: a penetrating trauma, significant injury to the cranium, or unconsciousness. High impact velocity is defined by examples such as: fall from an elevation of over seven metres, death of another person in a motor vehicle crash, ejection from a vehicle, deformation of the motor vehicle, intrusion in the vehicle, or a hit while walking or cycling more than 35 km/hr. On the other hand, patients with a PHI below 4 who do not have a high impact velocity trauma are transferred to the closest hospital (designated trauma center or non-designated trauma center); the rest of the trauma patients are transferred to a Level I or II trauma center.

Before the introduction of the triage protocol, and between October 1994 and June 1995, 34% of the patients with major trauma who required transfer to a Level I trauma center, based on the definition of major trauma in the protocol (Figure 1), were transferred correctly to Level I trauma centers. Although the introduction of this protocol has increased the chance that patients with major injuries be transferred to Level I trauma centers, compliance with the protocol is not completely satisfactory. Urgence santé's statistics also show that between July 1995 and March 1997 (after the introduction of the protocol), 16% of the patients with major injuries requiring transfer to a Level I trauma center were transferred to a non-designated trauma hospital, 16.4% were transferred to a Level II trauma center and only 68% of those patients with major injuries were transferred correctly to a Level I trauma center. In addition to the unsatisfactory compliance rate of

this protocol, no studies have dealt with the protocol's effectiveness in identifying patients with major injuries from those with non-major injuries.

The rationale of this study was that development, evaluation and thus implementation of an effective triage protocol for the pre-hospital management of trauma patients in Montreal, at this point in time and after the designation of trauma care centers in 1993, are necessary.

At the time of injury occurrence, the variables available at the scene that may be associated with injury outcomes (mortality and disability) are: age, mechanism of injury, body region injured, time interval between 911 call and departure of the ambulance from the site of injury, comorbidity, and vital signs. A combination of these variables should be used in order to develop a sensitive triage protocol able to distinguish patients with severe injuries requiring transfer to a Level I trauma center, from patients with non-severe injuries who could be treated at Levels II and III trauma centers.

The first objective of this study was to assess the ability of the PHI to identify major trauma cases that exclusively require treatment at Level I trauma centers, and to distinguish those that could be treated at Levels II for the population of Montreal. The second objective was to develop a trauma triage protocol that improves the predictive power of the PHI -- in distinguishing patients with major trauma from those with non-major trauma -- by incorporating along with this index one or more of the variables: age, mechanism of injury, body region injured, time interval between 911 call and departure of ambulance from the site of injury, and comorbidity.

The PHI is a physiologic injury severity measure based on: pulse rate, level of

consciousness, respiratory status, systolic blood pressure, and presence of penetrating injury. This index, and not another physiologic measure, was used as a criterion for the triage protocol that was developed and evaluated because, first, the PHI has proven to be a valid and reliable triage protocol (86,78.88,87,96,90,23); and, second, since this index is the basis of the triage protocol used by Urgence santé in Montreal.

3.1.2. Study Objectives

The objectives of the study were:

1) To assess the predictive validity of the PHI in its use as a trauma triage instrument;

2) To establish a triage protocol which incorporates, along with the PHI, variables that are readily available at the scene of injury (age, body region injured, mechanism of injury, time interval between 911 call and departure of ambulance from the site of injury, and comorbidity) in order to improve the predictive ability of the PHI-based triage protocol.

3.2. Methods

3.2.1. Study Design

The study proposed included patients above 15 years of age, transferred by Urgence santé to either of the two Level I trauma centers (Montreal General Hospital or Sacré Coeur) between April 1993 and December 1996. The inclusion criteria for the patients in this study were:

1) patients who were transferred by Urgence santé from the scene of the injury to either the Montreal General Hospital or Sacré Coeur;

2) patients who were alive upon their arrival to the hospital; and

3) patients who either died at the emergency room, or were admitted to the hospital.

To avoid confounding the results with the level of hospital care, the hospitals designated as Level I trauma centers in the Montreal area (Montreal General Hospital, and Sacré Coeur) were the only hospitals considered for the analysis. It should be noted that even before the designation of these two hospitals as Level I trauma centers in 1993, both hospitals had the personnel and level of care compatible with Level I trauma centers (56).

For this study's purpose, patients were identified at the time of the 911 call and were followed up until death or hospital discharge. The 911 call was used as a proxy for the time of injury occurrence, since it is the most reliable and available time closest to the injury's occurrence.

3.2.2. Data for the Study

Urgence santé operators who receive 911 emergency calls seeking health assistance record information on: the date and time of the 911 call, nature of the injury, and the resources that have been requested to the scene of injury. This information is conveyed to the dispatchers who organize and coordinate the dispatch of the physicians, as well as standby ambulances and emergency medical technicians closest to the site of injury. The dispatchers record the time the ambulance was dispatched, time of arrival at the scene, time of departure from the scene, and time of arrival at the hospital.

At the site of the injury, emergency medical technicians record the patients'

demographic information, injury characteristics, as well as several vital signs including those required for the calculation of the PHI.

All the information gathered by Urgence santé operators, dispatchers, and emergency medical technicians, are entered in data files at Urgence santé.

In 1993, a trauma registry was developed in Quebec, with its base at the Montreal General Hospital. Information on patients' demographics, injury characteristics, pre-hospital care, hospital admission status, diagnosis, intensive care unit (ICU) admission, surgical procedures performed, length of hospital stay, and discharge status of the patient is being gathered for trauma patients treated in Quebec hospitals. This information is abstracted from hospital charts by medical archivists at each hospital, and is entered in a data base.

For the purpose of this study, linkage of Urgence santé data files and the trauma registry data files for patients transferred to the Montreal General Hospital and Sacré Coeur was done. This linkage was based on the authorization number given by Urgence santé to each of the trauma patients. For patients on whom this linkage was not successful, the files were linked based on combinations of the variables: name of the patient, date of birth, gender, date the 911 call was made, code of the ambulance that transferred the patient from the injury site to the hospital, and the hospital to which the patient was transferred to.

3.2.3. Study Variables

Study variables were obtained from either Urgence santé data files or from the

data in the trauma registry. In this section, these variables are listed separately depending on the source from which they will originate:

The variables that were identified from Urgence santé data files are:

1) date/ time of 911 call;

2) time of dispatch of the ambulance to the scene of injury;

3) time of arrival of the ambulance to the scene of injury;

4) time of departure of the ambulance from the scene of injury;

5) comorbidity: cardiovascular disease, diabetes, epilepsy, hypertension, and respiratory problems, and

6) vital signs required for the calculation of the PHI (evaluated at the scene): pulse rate, level of consciousness, respiratory status, systolic blood pressure, presence of penetrating injury.

From this data set, time interval between 911 call and departure of the ambulance from the scene of injury, and the PHI were determined.

The variables identified from the trauma registry data files were following:

1) death at emergency room;

2) hospital admission (was the patient admitted to the hospital?);

3) date/ time of hospital admission;

4) surgery performed;

5) type of surgery;

6) date/ time of surgery;

7) intensive care unit admission;

8) date/ time of intensive care unit admission;

9) Abbreviated Injury Scale (AIS) for each of the injuries;

10) age of the patient;

11) mechanism of injury: being the driver of a car, passenger in a car, driver of a motorcycle, cyclist, pedestrian, fall above 15 ft, fall below 15 ft, firearm, stabbing, knife, blunt object, and other;

12) body region injured: head, neck, face, abdomen, thorax, spine, upper, and lower extremities;

13) presence of penetrating injuries;

14) death;

15) date/ time of death; and

16) date/ time of hospital discharge.

From the Quebec registry, the following variables were determined:

1) Injury Severity Score (ISS);

2) length of hospital stay;

3) time between hospital admission and intensive care unit admission;

4) time between hospital admission and surgical intervention; and

5) time between hospital admission and death.

3.3. Statistical Methods

3.3.1. Outcome Variable

An injury was defined as being major if it was: 1) life threatening, or 2) could

have been life threatening, or could have resulted in severe disability, if adequate care was not provided to the patient within a short period of time since its occurrence (usually within an hour). Adequate care referred to multi-specialty trauma teams with surgeons, anesthesiologists, surgical nurses, intensive care unit facilities as well as other facilities. Level I trauma centers are the hospitals which have 24-hour coverage of all of these services. Thus, an injury was defined as being major if: 1) it was life threatening, or 2) could have been life threatening, or resulted in severe disability if treatment at Level I trauma center was not available within short period of time since the injury's occurrence.

According to the literature, several authors have defined major trauma differently. Baxt 1989 (90), Ramenofsky 1988 (81), Morris 1986 (80), and Clemmer 1985 (85) used the definition of death during hospitalization as the criterion for defining patients with severe injuries. Eichelberger 1989 (82), Knopp 1988 (51), Cottington 1988 (94), and West 1986 (95) used an ISS above 15 as the basis for the definition of major injuries. On the other hand, the following authors used one or more of the variables death, ISS, surgery, and intensive care unit admission to define major injuries: Meredith 1995 (83), Gormican 1982 (77), Koehler 1986, 1987 (78,86), Plant 1995 (87), Sampalis 1996 (88), Baxt 1990 (79), Fries 1994 (89), Ornato 1985 (31), Emerman 1991 (23), Simmons 1995 (91), Kreis 1988 (92), Kundson 1988 (25), Kane 1985 (27), and Hedges 1987 (96).

Using the variable death as the only criterion for the definition of major injuries is very crude, in the sense that even if the patient did not die but required intensive care unit admission or surgical intervention within a specific period of time, this patient may die if not treated at a Level I trauma center which has 24-hour coverage of surgeons, surgical

nurses, and intensive care unit facilities -- unlike Levels II and III trauma centers. Also, the use of ISS above a specific cutoff value is not a valid measure for defining major injuries because the ISS does not correlate well with hospital resource utilization such as intensive care unit admission, or admission to operating room for surgery (68). Thus a trauma patient could be defined to have major injuries if this patient either died, or received intensive care unit or surgical intervention within a specific period of time.

For the purpose of our study, patients with severe injuries were so defined (Figure 2) if they conform to any of the following:

1) death at the emergency department or death within seven days after hospital admission;

2) surgical intervention within four days after hospital admission (non-orthopaedic, non-plastic);

3) intensive care unit admission within seven days after hospital admission.

All other patients were classified as having non-severe injuries.

Each patient was classified as having severe or non-severe injuries defined according to the above criteria. The predictive validity of the PHI and the three developed trauma triage protocols were assessed by evaluating the performance of these protocols if calculated at the scene of injury, in identifying patients with severe versus non-severe injuries defined according to this criteria.

3.3.2. Description of the Statistical Procedures Used in this Study

The statistical methods that were used in this study are presented in this section.

3.3.2.1. Sensitivity, Specificity, Positive, and Negative Predictive Values

For the different cutoff values of each of the PHI and the trauma triage protocols, the sensitivity, specificity, positive predictive value, and negative predictive value were calculated. These statistics were calculated based on the 2 X 2 tables created for the different cutoff values of these triage indices. The two variables (shown below) for these tables were: 1) the triage protocol, calculated from variables measured at the scene of injury, and dichotomized at a specific cutoff value, thus indicating a positive test if the score is above or equal to that cutoff value, or a negative test if the score is below that cutoff value, 2) patients with actually major or non-major injuries defined according to the criteria defined previously (Figure 2).

Triage protocol	Actual	
	Major injury	Non major injury
Positive test (>= cutoff value)	a	b
Negative test (< cutoff value)	c	d

a: represents true positives;

b: represents false positives;

c: represents false negatives; and

d: represents true negatives.

Sensitivity = a/a+c

Defined as the proportion of patients with major injuries who have a positive score.

Specificity = d/b+d

Defined as the proportion of patients with non-major injuries who have a negative score.

Positive predictive value= a/a+b

Defined as the proportion of patients with positive score who have major injuries.

Negative predictive value= d/c+d

Defined as the proportion of patients with negative score who have non-major injuries.

Sensitivities and specificities are validity measures, since they are characteristics of the triage protocol; whereas positive predictive values and negative predictive values are not true tests of validity because they depend on the prevalence of the outcome "major injuries" in the population studied. The disadvantage of calculating these statistics is that dichotomization of the triage instrument has to be done, resulting in loss of information.

Sensitivities, specificities, positive predictive values, and negative predictive values range between 0 and 1. The closer these values are to 1, the higher is the discrimination ability (in the classification of severe versus non-severe injuries) of these instruments.

3.3.2.2. Receiver Operating Characteristic Curves

Receiver Operating Characteristic (ROC) curves for the different triage protocols will be graphed. These curves are graphical representations of the sensitivity and

specificity across the range of different cutoff values for each of the triage instruments; the y-axis represents the sensitivity and the x-axis represents 1- specificity. The main advantages of these curves are that no simplification of the triage instrument is required and thus no information is lost, the tradeoff between sensitivity and specificity is clearly illustrated, and the choice of an "optimum" cutoff value is facilitated.

The ROC curve is plotted using maximum likelihood estimation with the usual assumption that the outcome measured (score of the triage instrument) is independent from patient to patient (97).

3.3.2.3. Area Under the ROC Curve

The area under the ROC curve will be calculated for the different triage protocols. This statistic is a method used to reduce the ROC curve into a single summary measure of diagnostic accuracy. The area under the curve ranges between 0 and 1, and is interpreted as the probability that a randomly selected "positive" and "negative" subjects will be correctly classified by the test. A value less than 0.5 indicates a non-informative instrument (accuracy less than random chance guessing), and a value of 1 indicates a perfectly informative instrument in its ability to discriminate major from non-major injuries (97,98).

The area under the curve may be calculated either by a parametric or a non-parametric approach. One parametric approach assumes that the curve is generated from two normal distributions, with different means and standard deviations. The first normal distribution represents the test results on a continuous scale for patients with actual major

injuries, the other normal distribution is the similar curve for patients with actual non-major injuries. The area can then be calculated directly from knowledge of the normal distribution parameters, the area calculated this way is represented by Az. On the other hand, the non-parametric approach assumes that the curves do not follow any pre-specified distribution (97,98). The non-parametrically calculated area is represented by A. The bias in the estimates of the area under curves, using the parametric approach for data that does not follow the bi-normal distribution, has been found to be minimal in general (99). A study which calculated simulations of a large number of data sets developed from bi-normal and non bi-normal distribution with different degrees of departure from bi-normality, found that the bias of the estimates of the area under curves calculated using the parametric approach and the non- parametric approach was typically very small (99).

In order to determine if the difference in the areas under two ROC curves of two different triage protocols could be attributed solely to random chance, a critical ratio z could be calculated according to the following formula (100):

$z = (A_1 - A_2) / sqt(SE_1^2 + SE_2^2 - 2rSE_1SE_2)$,

Where:

A_1 is the observed area under the ROC curve of the first trauma triage index;

A_2 is the observed area under the ROC curve of the second trauma triage index;

SE_1 the estimated standard error of A_1;

SE_2 the estimated standard error for A_2; and

r: the estimated correlation between A_1 and A_2 (calculated based on both the average of the two areas under ROC curves, and the average of r_N and r_A -- where

r_N is the Pearson correlation coefficient of the two indices for truly negative cases, and r_A is the Pearson correlation coefficient of the 2 indices for truly positive cases) (100).

3.3.2.4. Multivariate Logistic Regression

Multivariate logistic regression analysis describes the mean or the expected value of the outcome as a logistic function of a set of predictor variables X1, X2,...Xk. For this type of regression, the outcome is a random dichotomous variable.

Three trauma triage protocols were developed based on multivariate logistic regression analysis. For each of the triage protocols, the model that describes the data best was selected based on Bayes factors (101). The dependent variable for all these models was the dichotomous variable; presence of major injuries (defined if the patient: died within seven days of hospital admission, or had surgical intervention within four days of hospital admission (non-orthopaedic, non-plastic), or had intensive care unit admission within seven days of hospital admission, Figure 2). Depending on the model studied, the independent variables were a subset of the following categorical variables:

1) mechanism of injury;

2) body region injured;

3) time between 911 call and departure of the ambulance from the scene;

4) age of the patient;

5) Pre-hospital Index (PHI); and

6) comorbidity.

3.3.2.5. Bayes Factors

The major difficulties of using sequential automated model selection (backward selection, forward selection and stepwise model selection) for selecting the model which fits the data best are that: 1) depending on the order in which the variables are put in the model, different models will be selected; 2) one out of many possible models will be selected, ignoring the uncertainty in the final model selected; 3) p-values from the final model are virtually impossible to interpret correctly, since the sample space of models and parameter values is large; and 4) when the sample size is very large, it is expected that a portion of the variation will be explained by almost any independent variable included in the model. Thus, if the data set is large enough, all the variables in the model will be "significant" and thus selected (101).

A Bayesian approach may be devised to deal with these drawbacks. In particular, we will use Bayes factors which we now briefly describe. Suppose we have data D, and wish to compare two models, M1 with v1 variables and M2 with v2 variables. The following quantities can be defined from Bayes theorem:

$P(M2 \mid D) / P(M1 \mid D) = [P(D \mid M2) / P(D \mid M1)]\ [P(M2) / P(M1)]$, where

$P(M2 \mid D) / P(M1 \mid D)$ = Posterior odds of Model 2 compared to Model 1,

$P(D \mid M2) / P(D \mid M1)$ = B21=Bayes factor for M2 against M1, where

$p(D \mid M_k)$= integrated likelihood for model k

$P(D|M1) = \int P(D \mid v1, M1)\, P(v1 \mid M1) dv1 = \int (\text{likelihood} \ \ \text{prior}) dv1$

P(M2) / P(M1) = Prior odds (prior odds=1, represents no prior preference for M1 over M2).

By way of example, suppose that B21= 9, then given that one of the two models is correct (Model 1 or Model 2), there is a 90% chance (9 to 1 ratio) that the correct model is M2, and a 10% chance it is Model 1, assuming there is no prior preference for M1 or M2.

The Bayesian Information Criterion (BIC), which is an approximation to the Bayes factor will be used (101). The comparison of each models with a baseline null model (M_0) is done according to the formula:

$BIC_k = -X^2_{k0} + p_k \log n$

Where:

BIC_k = BIC for model M_0 against model M_k

X^2_{k0} = Liklihood Ratio Test statistic for testing model M_0 against model M_k

p_k= the number of independent variables in model M_k

n= sample size

The smaller the value of the BIC_k , the better the fit of M_k compared to M_0. Thus, when comparing two models, the smaller the BIC value of the model, the more that model is preferred to the other one.

Once the BIC values of the two models M_k and M_j have been calculated, Bayes factors could be approximated according to the following formula (101):

$B_{jk} = \exp [(BIC_k - BIC_j) / 2]$, where

B_{jk} = approximate Bayes Factor for model M_j against model M_k.

BIC_k = the BIC of model k, with M_0 (the null model) being the baseline model.

BIC_j = the BIC of model M_j, with M_0 being the baseline model.

As an example, if the difference in the BIC values of models M_k and M_j (with the null model being the baseline) is 6, the Bayes Factor as calculated according to the above formula is 20. Thus, there is a 95.2% chance that the correct model is model M_k and a 4.8% chance that it is M_j, given that one of these two models is correct.

3.3.3. Statistical Softwares Packages Used for the Study

Three different software packages were used for analysing the data of this study:

1) The SPSS computer application was used to perform the descriptive statistics, and the logistic regression models (102).

2) The LABROC software was used for the creation of the ROC curves of the triage protocols and the areas under these curves (103). Using the maximum liklihood estimation, this software determines the parameters required for the creation of the ROC curves. Also, using the parametric approach, this software calculates the area under the ROC curve with its Standard Error.

3) The Excel computer package was used to calculate of the sensitivity, specificity, positive and negative predictive values, with 95% Confidence Intervals around these statistics, for the different cutoff points of the triage protocols. This software was also used for graphing the ROC curves (104).

3.3.4. Statistical Methods to Address the Study Objectives

3.3.4.1. Descriptive Statistics of Patients' Characteristics

As a first step, descriptive statistics on the demographics, injury, and in-hospital characteristics of the patients was performed.

Data on the components of the PHI collected by emergency medical technicians at the scene of the injury were used to compute the on-site score of the PHI. It is expected that a certain percentage of patients will have missing data on one or more of the components of the PHI. These patients were discarded from the analysis. However, patients' characteristics were compared for the group of patients with missing PHI and the one with complete data on all the components of the PHI, in order to identify any differences among the two groups. One possible explanation for having missing information on the variables required for the calculation of the PHI could be that emergency medical technicians did not want to spend time evaluating these variables for patients with major injuries, or contrary to this, they did not feel the need for evaluating these variables for patients with non-severe injuries.

Descriptive statistics of patients' characteristics stratified by the outcome -- major versus non-major injuries defined by our criteria (Figure 2) -- were performed.

3.3.4.2. Statistical Methods to Address the First Objective of the Study

First objective: Assess the predictive validity of the PHI trauma triage instrument

The proportion of patients with major injuries was evaluated for the different

values of the PHI, and for the four PHI categories (0, 1-3, 4-7, and > 7) -- selected based on a review of the literature (78,86,87,88).

To assess the predictive validity of the PHI in identifying patients with major injuries and non-major injuries, we calculated sensitivity, specificity, positive and negative predictive values, with 95% confidence intervals for all the PHI cutoff values. Major injury was identified if the patient had a PHI above or equal to that cutoff, non-major injury if the patient had a PHI below that cutoff value. A Receiver Operating Characteristic (ROC) curve was graphed, and the area under the curve with its Standard Error were determined.

3.3.4.3. Statistical Methods to Address the Second Objective of the Study

Second objective: To establish a triage protocol which, along with the PHI, incorporates variables easy to identify at the scene of injury to improve the predictive ability of the PHI based triage protocol

To meet the second objective of the study, three trauma triage protocols -- decided on before we looked at the data -- were developed based on logistic regression modelling. Sensitivity, specificity, positive predictive value, and negative predictive value for all of the cutoff values of these three triage protocols were calculated. For each of these protocols ROC curve was graphed and the area under the curve were determined.

3.3.4.3.1. First Trauma Triage Protocol

Multivariate logistic regression models were performed where the outcome

variable was patients with major injuries (defined by our criteria, Figure 2), and the independent variables were a subset of the following: PHI, age, body region injured, mechanism of injury, time between 911 call and departure of the ambulance from the scene, and comorbidity (all of which was entered as polychotomous variables). The best model, that determined the variables of the scale used for this triage protocol was selected using approximate Bayes factor calculated from the BIC. For each patient, the summation of the regression coefficients (determined from the selected regression model) constituted the score of this scale.

Sensitivities, specificities, positive and negative predictive values were determined for all the cutoff values of the scale of this triage protocol. Patients with a score above or equal to this specific cutoff value were considered to have major injuries, whereas patients with a score below this specific cutoff value was considered to have non-major injuries. A Receiver Operating Characteristic (ROC) curve was graphed, and the area under the curve, with its Standard Error, were calculated.

3.3.4.3.2. Second Trauma Triage Protocol

The PHI was categorized into four levels: 0, 1-3, 4-7, and 8-24. In this protocol, patients with a PHI of 0 were considered to have non-major injuries, whereas patients with a PHI between 8-24 were considered to have major injuries. This was done because the literature shows that the sensitivity and specificity in identifying patients with major and non-major injuries for the PHI categories 0 and above 7 are high relative to the other PHI values (78,86,87,88). Patients with a PHI ranging between 1-7 were considered to lie

in a grey area in terms of injury severity. Therefore, separate analysis was performed for patients with PHI between 1-3 and for those with PHI between 4-7. For each group, logistic regression analysis was performed with the dependent variable being major injury defined by our criteria (Figure 2); and the independent variables being a subset of age, body region injured, mechanism of injury, time between 911 call and departure of the ambulance from the scene of injury, and comorbidity. Using the BIC, the best model was selected for each of the two PHI categories (1-3, 4-7), thus determining the variables of the two different scales to be used for each of these categories. Summation of the regression coefficients constituted the scores of these scales.

The proportion of truly negative injuries was calculated for patients with PHI of 0, and the proportion of truly positive injuries was calculated for patients with PHI 8-24. Sensitivity, specificity, positive predictive value, and negative predictive value (with 95% Confidence Intervals) were calculated for the different cutoff values of the two new scales developed for patients with PHI 1-3 and for patients with PHI 4-7. For each scale, an ROC curve was graphed, and the area under the curve with its Standard Error were calculated.

3.3.4.3.3. Third Trauma Triage Protocol

For easiness of use, dichotomization in terms of predictiveness of having major trauma, was performed for each of the following variables: mechanism of injury, body region injured, time between 911 call and departure of the ambulance from the site, and comorbidity. This was done based on a regression model with the dependent variable

being major injuries (Figure 2); and the independent variables being PHI, age, body region injured, mechanism of injury, time between 911 call and departure of the ambulance from the scene, and comorbidity.

Because the death rate for the same injury severity, has been shown to be higher in older individuals than in younger ones (43,44), logistic regression analysis was performed separately for individuals below 65 years of age and those 65 or older. This is the cutoff used in nearly all dichotomous classification of age in relation to trauma. The outcome for these regression models was major injuries, defined by our criteria (Figure 2); whereas, the independent variables were PHI (entered as a categorical variable), body region injured, mechanism of injury, time between 911 call and departure of the ambulance from the scene, and comorbidity -- all of which were entered as dichotomous variables. The best model for each of the two age groups as selected using the BIC (Bayes factor approximation), thus determining the variables of the two different scales to be used for each of these categories. The summation of the regression coefficients (of the scales determined from the selected models) constituted the scores of these scales.

Sensitivities, specificities, positive predictive values, and negative predictive values, with 95% Confidence Interval, were calculated for all the cutoff values of these scales. Also, ROC curves were plotted, and the area under the curve was calculated for each of the two age categories.

CHAPTER 4.

RESULTS

4.1. Description of the Group of Patients

4.1.1 Patients' Demographics, Injuries, and In-hospital Characteristics

Between April 1993 and December 1996, a total of 2,847 trauma patients were identified by the Quebec trauma registry to be transferred by Urgence santé to the emergency department of either the Montreal General Hospital or Sacré Coeur (2,088 patients were transferred to the Montreal General Hospital, and 759 patients to Sacré Coeur). Of the 2,847 patients, 30 patients died at the emergency department of the Montreal General Hospital and 34 at the emergency department of Sacré Coeur; the remaining patients were admitted to the hospital to which they were transferred to.

Table 15 shows the descriptive statistics of patients' characteristics. Sixty percent of these patients were males, and the average age was 52 years (SD= 23). Thirty-two percent of the patients had injuries due to a fall below 15ft, whereas 13% of all the injuries were the result of a fall above 15 ft. Twenty-eight percent of the patients had injuries as a result of a motor vehicle crash; 12% were due to firearms, or stabbing, and 8% result from blows with a blunt object. A total of 975 patients (34%) had injuries to the head or neck, 797 patients (28%) sustained injuries to the face, and 571 patients (20%) had injuries to the thorax. The proportion of patients with injuries to the abdomen, spine, and extremities were 12% (326 patients), 9% (262 patients), and 75% (2,148 patients),

respectively. Seven percent of all patients (199 patients) had a penetrating injury to the thorax, abdomen, pelvis, head, neck, or spine.

When calculated from the data available at the injury site, the average PHI was 2.2 (SD 4.4). Also, from information gathered by Urgence santé technicians at the injury scene, 8% of the patients had a history of cardiovascular diseases, 3% had diabetes, 1% had epilepsy, 8% had hypertension, and 3% had a history of respiratory problems (Table 15).

From information gathered at the hospital, 1,467 patients (52%) required at least one surgery to be performed during the hospital stay. However, 655 (23%) patients required a surgery (non-orthopaedic, or non-plastic) to be performed within four days since hospital admission. Also, 26% of the patients (742 patients) were admitted to the intensive care unit within seven days of hospital admission. Of all the patients, 153 patients (5%) died at the emergency department or within seven days of hospital admission. The average ISS and hospital stay were 11.4 (SD= 10), and 14.2 days (SD= 24), respectively. Fourty-five percent of all patients (1,274 patients) had major injuries -- defined according to the criteria shown in Figure 2-- (Table 15).

4.1.2. Distribution of the Variables Required for the Calculation of the PHI

Fourty-five percent of the 2,847 trauma patients (1,291 patients) had vital signs, required for the calculation of the PHI and measured at the scene of injury; whereas 55% of the 2,847 patients (1,556 patients) were missing one or more of the vital signs required for the PHI calculation. Table 16 shows the frequency distribution of the vital sign

variables required for the calculation of the PHI. Eighty-three percent of the patients had a systolic blood pressure above 100; 10% had a systolic blood pressure between 86 and 100; and 7% had a blood pressure below 86. Respiratory status was normal for 86% of the patients, but for 14% of the patients this was laboured, shallow, less than 10 per minute, or the patient required intubation. Eighty-one percent of the patients had a normal level of consciousness, while 19% were confused, combative, or said no intelligible words. The pulse rate for 92% of the patients was above or equal to 120; for 8% of the patients it was below this value. Ninety-seven patients (8%) had at least one penetrating injury to the head, neck, abdomen, pelvis, thorax, or spine.

A score ranging from 0 to 5 was given for each patient, to each of the four variables; systolic blood pressure, respiratory status, level of consciousness, and pulse rate. These scores were added -- with four points if the patient had a penetrating injury to the head, neck, abdomen, pelvis, thorax or spine -- thus constituting the PHI value (78).

4.1.3. Patients' Characteristics by PHI

Descriptive statistics of the patients' characteristics were evaluated separately for patients for whom the PHI could have been calculated at the site (1,291), and for patients on whom one or more variables required for the PHI calculation was missing (1,556) (Table 17). In this Table, no significant difference in the demographics, injury, and in-hospital characteristics was found, thus suggesting that the group of patients for whom we were able to calculate the PHI may be considered a random sample of the patients transferred by Urgence santé to the Montreal General Hospital or Sacré Coeur during this

period of time. Therefore, the rest of this chapter will consider only the 1,291 trauma patients for whom a PHI could be calculated at the site of the injury.

4.1.4. Patients' Characteristics by Major Injuries

Table 18 shows the distribution of the 1,291 trauma patients' characteristics stratified by major injuries as defined according to Figure 2. Sixty-six percent of the patients with major injuries were males, compared to only 58% of the patients with non-major injuries. Fourty-nine percent (283 patients) of the patients with major injuries were between the ages 15 and 45, 19% (107 patients) were between the ages 46 and 64, and 32% (186 patients) were patients above 64 years of age. In terms of the mechanism of injury, patients with major injuries were more likely to be injured by firearms or stabbing (19%), compared to those with non-major injuries (10%); whereas patients with injuries due to falls of less than 15 ft, or due to a blunt injuries were more likely to have non-major injuries (47%), compared to those with major injuries (31%). As for the body region injured, patients with major injuries were more likely to have head or neck injuries (44%) when compared to the non-major injuries category (27%), face injuries (32% vs 26%), thorax injuries (29% vs 14%), abdomen or pelvic injuries (19% vs 6%), and spine injuries (12% vs 8%). Of the 576 trauma patients with major injuries, 73 (13%) had penetrating injuries to the thorax, abdomen, pelvis, head, neck, or spine region. Of the 715 patients with non-major injuries, 24 patients (3%) had penetrating injuries to any of the above regions. The proportion of patients with major injuries transferred to the Montreal General Hospital was 72%; whereas for patients with non-major injuries this

proportion was 73%. The mean ISS and PHI for patients with major injuries were 15.1 (SD=12), and 3.8 (SD= 5.8), respectively; whereas for patients with non- major injuries, these statistics were 7.6 (SD= 5), and 1.0 (SD= 2), respectively. Patients with major injuries had an average length of hospital stay of 18 days (SD= 25); this was 11 days (SD= 14) for patients with non-major injuries. Also, the average time between 911 call and departure of the ambulance from the scene for patients with major injuries was 30 minutes (SD= 15), compared to 31 minutes (SD= 15) for patients with non-major injuries.

Therefore, the results of Table 18 suggest that patients with major injuries were more likely than patients with non-major injuries to be males, have injuries due to motor vehicle crash, firearm, or stabbing, sustain injuries to the head, neck, face, thorax, abdomen, pelvis, or spine, as well as have high ISS and PHI values.

4.2. Results Addressing the First Objective of the Study

***First objective:* Assess the Predictive Validity of the PHI Trauma Triage Instrument**

The proportion of patients with major injuries and with non-major injuries was calculated for the different cutoff values of the PHI (Table 19). A consistent increase in the proportion of major injuries when the PHI score increased was not seen. However, when the four categories of the PHI were considered, the proportion of major injuries increased from 34% for patients with a PHI of 0 to 44% for patients with a PHI of 1-3, to 70% for patients with a PHI of 4-7, to 87% for patients with a PHI above 7 (Table 20).

Sensitivities, specificities, positive predictive values, and negative predictive values with 95% Confidence Interval were calculated for the different cutoff values of the PHI (Table 21). A cutoff value of 3 (patients with a PHI of 3 or more were considered to have major injuries, but patients with a PHI below 3 were considered to have non-major injuries) produced a sensitivity, specificity, positive predictive value, and negative predictive value of 0.46, 0.78, 0.63, and 0.64, respectively. However, for a cutoff value of 4, these statistics were 0.35, 0.91, 0.77, and 0.64, respectively. The ROC curve was plotted (Figure 3), and the calculated area under the ROC curve of the PHI was 0.66 (SE= 0.02).

4.3. Results Addressing the Second Objective of the Study

Second objective: ***To establish a triage protocol which incorporates, along with the PHI, variables that are readily available at the scene of injury (age, body region injured, mechanism of injury, time interval between 911 call and departure of the ambulance from the site of injury, and comorbidity) to improve the predictive ability of the PHI-based triage protocol***

4.3.1. Recoding of the Variable: Time between 911 Call and Departure of the Ambulance from the Scene

Twenty-seven percent of the 1,291 patients had missing data for the variable time between 911 call and departure of the ambulance from the scene of injury. Table 22 shows the frequency distribution of patients' characteristics stratified by the 3 categories

of time (time below 40 minutes, above or equal to 40 minutes, and time missing). Overall, the group of patients for whom the time variable was missing had similar demographic, injury and in-hospital characteristics to those for whom time was less than 40 minutes. Thus, for the patients who had the time value missing, substitution of the value less than 40 minutes was done.

4.3.2. Development of the Three Trauma Triage Protocols

With respect to the second objective of the study, three triage protocols were developed based on logistic regression analysis (best models were selected according to Bayes factors approximation). Summation of the regression coefficients of the selected models produced different scales with positive and negative decimal values. For each scale, values consisting of integers and ranging between 0 and 24, so as to relate to the scores of the PHI, were sought. Thus, the transformation of the scales that were developed directly from logistic regression analysis was performed. In order to check for any loss of information due to this transformation, the area under the ROC curve was calculated separately for the original scale and the transformed scale.

4.3.2.1. First Trauma Triage Protocol

4.3.2.1.1. Selection of the Model for the First Trauma Triage Protocol

Logistic regression analysis was performed with the dependent variable being major injury (defined according to Figure 2), and the independent variables all or a subset of the following variables:

1) age: 15-44, 45-64, and above 64;

2) mechanism of injury: driver, passenger, motorcycle, cyclist, pedestrian, fall above 15 ft, fall below 15 ft, firearm or stabbing, blunt object, or other;

3) body region injured: head or neck, face, thorax, abdomen or pelvis, spine, and upper or lower extremities;

4) time between 911 call and departure from the scene: below 40 minutes, and above 39 minutes;

5) comorbidity: cardiovascular diseases, diabetes, epilepsy, hypertension, and respiratory problems; and

6) PHI: 0, 1-3, 4-7, and above 7.

Sixty-four different logistic regression models were tested ($64=2^6$ possible models, 6 being the number of independent variables in the full model). The Bayesian Information Criterion (BIC), an approximation to the Bayes factor (Chapter 3, Section 3.3.2.5), was calculated for each of the regression models. The model with the lowest BIC value (the one that describes the data best) was the one selected for this protocol. The two regression models which had the lowest BIC values were:

Model	BIC value	Independent variables included in the model
1	**-226.65**	**age, body region injured, mechanism of injury, PHI, comorbidity**
2	**-224.36**	**age, body region injured, mechanism of injury, PHI**

The Bayes factor approximation for Model 1 against Model 2 was 3.2, when calculated according to the following formula (Chapter 3, Section 3.3.2.5.):

$B_{12} = \exp [(BIC_2 - BIC_1) / 2]$, where

B_{12} = approximate Bayes factor for model M_1 against model M_2

BIC_2 = the BIC for Model 2; with M_0 (the null model) being the baseline model

BIC_1 = the BIC for Model 1; with M_0 being the baseline model

A Bayes factor approximation for Model 1 against Model 2 of 3.2 suggests that Model 1 has a 76% chance of being the correct model, compared to 24% for Model 2, given that one of these two models is correct. Thus, the first model was the one selected for the first triage protocol.

Table 23 shows the results of the regression model selected for the first triage protocol with the independent variables being: age, body region injured, mechanism of injury, comorbidity, and PHI. When compared to patients between 15 and 44 years of age, the Odds Ratio for having major injuries for patients who were between 45 and 64 years of age was 0.91 (95% Confidence Interval= 0.66- 1.29). For patients above 65 years of age, this was 1.83 (95% Confidence Interval= 1.26- 2.64). The Odds Ratio for having major injuries for patients with injuries to the abdomen or pelvis was 2.46 (95% Confidence Interval= 1.60- 3.79), when compared to those without this type of injury. The Odds Ratio for patients with injuries to the thorax was 1.54 (95% Confidence Interval= 1.10- 2.15), this was 1.66 (95% Confidence Interval= 1.06- 2.61) for spine injuries, 1.61 (95% Confidence Interval= 1.18- 2021) for head or neck injuries, 1.06 (95% Confidence Interval= 0.78- 1.45 for extremities, and 0.95 (95% Confidence Interval= 0.69- 1.29) for face injuries. The odds of having major injuries for patients injured by a

blunt object, or as a result of being a passenger in a car, when compared to driving a car, were less than 0.50 separately (neither was significant at alpha = 0.05). However, this was 0.63 (95% Confidence Interval= 0.39- 1.03) for a fall below 15 ft, 0.71 (95% CI=0.41-1.23) for being a pedestrian hit by a motor vehicle, 0.80 (95% Confidence Interval= 0.48-1.34) for fall of 15 ft or more, and 0.89 (95% Confidence Interval= 0.33- 2.36) for riding a bicycle. On the other hand, the Odds Ratio of having major injuries after adjusting for the other variables was 1 for driving a motorcycle, or having a wound as a result of firearm or a stab (compared to driving a car) --Both Odds Ratios were not significant at alpha equals to 0.05). The odds of having major injuries for patients with cardiovascular diseases, diabetes, epilepsy, hypertension, and respiratory problems, compared to patients without these health conditions, were: 1.23 (95% Confidence Interval= 0.79- 1.88), 1.70 (95% Confidence Interval= 0.93- 3.12), 1.15 (95% Confidence Interval= 0.42- 3.13), 0.89 (95% Confidence Interval= 0.58- 1.37), and 0.69 (95% Confidence Interval= 0.35- 1.35), respectively. After adjusting for age, mechanism of injury, body region injured, and comorbidity, the Odds Ratio of having major injuries for patients with a PHI of 1- 3, 4-7, and above 7, compared to patients with a PHI of 0, were: 1.34, 2.95, and 8.45 respectively -- all of which were significant at an alpha of 0.05.

Therefore, according to this regression model, the levels of each of the variables with the highest prediction of major injuries were: patients 65 years of age or above, injuries to the abdomen or pelvis, injuries due to firearm or stab, patients with history of diabetes, and a PHI above 7.

4.3.2.1.2. Development of the First Trauma Triage Protocol

For each patient a value equal to the beta coefficient (Table 23) was given to each of the variables age, body region injured, mechanism of injury, comorbidity, and PHI. A value of 0 was given to the reference levels: age (15- 44) , mechanism of injury (driving a car), and PHI (0). The summation of these coefficients produced a score which ranged from -1.36 to 4.84. Transformation of the score, where the value was multiplied by 3 after the addition of 1.36, was performed. Rounding of this score to a zero decimal point number produced the first protocol with ranges of values between 0 and 19.

4.3.2.1.3. Evaluation of the First Trauma Triage Protocol

Sensitivities, specificities, positive predictive values, and negative predictive values of the different cutoff values of this protocol are shown in Table 24. At a cutoff value of 4, this protocol had a sensitivity of 0.95, a specificity of 0.24, a positive predictive value of 0.50, and a negative predictive value of 0.86. Whereas at a cutoff value of 5, these values were 0.85, 0.42, 0.54, and 0.77, respectively. The Receiver Operating Characteristic (ROC) curve was plotted (Figure 4); the area under the curve, calculated for the first protocol, was 0.74 (SE= 0.01).

In order to check for any loss of information as a result of the transformation performed on this protocol (addition of 1.36, multiplication of 3, and rounding of the score to a zero decimal point number), the area under ROC curve was calculated for the original protocol that ranged from -1.36 to 4.84. This area was 0.74 (SE= 0.01), which was not different from the one calculated after the transformation (area under ROC

curve= 0.74, SE= 0.01).

4.3.2.2. Second Trauma Triage Protocol

For the second trauma triage protocol, the PHI was categorized into four levels: 0, 1-3, 4-7, and above 7. Patients with a PHI of 0 were considered to have non-major injures (defined according to Figure 2); whereas patients with a PHI above 7 were classified as having major injuries. As for patients with a PHI ranging between 1-7 (patients considered to lie in a grey area in terms of injury severity predictiveness), separate analysis was performed for patients with a PHI between 1-3 and those with a PHI between 4-7. Using logistic regression analysis, two scales were developed for this protocol, one for each of the PHI categories 1-3, and 4-7.

4.3.2.2.1. Selection of the Models for the Second Trauma Triage Protocol

For each of the PHI categories 1-3 and 4-7, all possible regression models were performed where the dependent variable was major injuries and the independent variables were all or a subset of the variables: age, body region injured, mechanism of injury, time between 911 call and departure of the ambulance from the scene, and comorbidity (all of these variables had the same definition as the ones used in the first triage protocol). The BIC value (with the null model being the reference model) was calculated for each of the regression models, and the model with the lowest BIC value was the one selected.

4.3.2.2.1.1. Selection of the Model for Patients with a PHI Between 1 and 3

For the group of patients with a PHI between 1-3, the three lowest BIC values were for the regression models which included the following variables:

Model	BIC value	Independent variables included in the model
1	-34.89	**body region injured, mechanism of injury, comorbidity, age**
2	-34.40	**body region injured, mechanism of injury, comorbidity**
3	-32.38	**body region injured, mechanism of injury, comorbidity, age, time**

The Bayes factor approximation for Model 1 against Model 2 was 1.3, suggesting a 56.5% chance that Model 1 is correct as compared to Model 2, which has a 43.5% chance of being correct (assuming that either Model 1 or Model 2 is the correct one). The Bayes factor approximation for Model 1 against Model 3 was 3.7, suggesting 78.7% chance that Model 1 is the correct model as compared to a 21.3% chance for Model 3 (again, assuming that either Model 1 or Model 3 is the correct model). Bayes factor approximation shows some evidence that Model 1 is better supported by the data compared to Model 3, leaving the choice of model selection to be between Model 1 or Model 2. Although there was not strong evidence to suggest that Model 1 is preferable to Model 2, Model 1 -- which included the variables age, body region injured, mechanism of injury, and comorbidity -- was the model of choice for patients with a PHI between 1-3.

The model selected for patients with a PHI between 1 and 3 (Table 25), shows that the odds of having major injuries for patients who were 45-64 years old, when compared to patients whose ages range between 15 and 44, was 1.26 (95% Confidence Interval= 0.63- 2.50). For patients who were 65 years or older, this was 2.05 (95%

Confidence Interval= 0.86- 4.82). The Odds Ratio of having major injuries for patients with injuries to either the thorax, abdomen or pelvis, spine, and head or neck were: 1.81 (95% Confidence Interval= 0.86- 3.80), 2.03 (95% Confidence Interval= 0.67- 6.22), 1.63 (95% CI=0.70- 3.79), and 1.79 (95% Confidence Interval= 0.92- 3.48), respectively (the reference level being not having an injury to that particular body region). On the other hand, the Odds Ratio of having major injuries for patients with injuries to the face or extremities was 1.3 (not significant at an alpha of 0.05). With respect to the mechanism of injury, the odds of having major injuries for driving a motorcycle, a fall above 15 ft, firearm or a stab compared to driving a car were: 1469.3 (95% Confidence Interval= 0.00- $2.5*10^{15}$) --6 patients belonged to this category; all of them had major injuries --, 2.30 (95% Confidence Interval= 0.77- 6.87), and 3.00 (95% Confidence Interval= 0.98- 9.18), respectively. The odds of having major injuries for patients with cardiovascular diseases or diabetes were: 2.13 (95% Confidence Interval= 0.66- 6.93), and 2.14 (95% Confidence Interval= 0.63- 7.21), respectively, when compared to patients without this health problem; whereas for epilepsy, hypertension, or respiratory problems, this was less than 0.8 (not significant at alpha = 0.05).

Therefore, according to this regression model, the following levels were highly predictive of having major injuries (defined according to Figure 2): being 65 or older, having an injury to the pelvis or abdomen, having an injury as a result of driving a motorcycle, and a history of either cardiovascular diseases, or diabetes.

4.3.2.2.1.2. Selection of the Model for Patients with a PHI Between 4 and 7

For the group of patients with a PHI between 4 and 7, the two lowest BIC values were for the following models:

Model	BIC value	Independent variables included in the model
1	**-25.55**	**body region injured, mechanism of injury, comorbidity**
2	**-24.83**	**body region injured, mechanism of injury, comorbidity, age**

The Bayes factor approximation for Model 1 against Model 2 was 1.4, suggesting a 58.3% chance that Model 1 is the correct model versus 41.7% chance that Model 2 is correct (assuming that either Model 1 or Model 2 is the correct model). Thus, the model of choice for patients with a PHI between 4 to 7 was the one which constituted of the variables: body region injured, mechanism of injury, and comorbidity.

The model selected for patients with a PHI between 4 and 7 (Table 26), shows that the Odds Ratio of having major injuries for patients with abdominal or pelvic injuries was 6.45 (95% Confidence Interval= 2.02- 20.42); for patients with spine injuries this value was 4.03 (95% Confidence Interval= 0.76- 21.24); for head or neck injuries 2.84 (95% Confidence Interval= 1.04- 7.69); for thorax injuries 1.53 (95% Confidence Interval= 0.62- 3.79); and for face and extremities, the Odds Ratios were 0.82 (95% Confidence Interval= 0.31- 2.18) and 1.24 (95% Confidence Interval= 0.54- 2.89), respectively. When compared to driving a car, being a passenger in a car, or driving a motorcycle produced very high Odds Ratios (3,884 and 1767, respectively). The Odds Ratio of having major injuries for riding a bicycle, being a pedestrian hit by a motor vehicle, fall above 15 ft, fall below 15 ft, firearm or stab, and for blunt object, compared

to driving a car, were 1.23 (95% Confidence Interval= 0.09- 15.92), 2.20 (95% Confidence Interval= 0.19- 25.04), 1.03 (95% Confidence Interval= 0.24- 4.48), 0.37 (95% Confidence Interval= 0.05- 2.46), 0.94 (95% Confidence Interval= 0.23- 3.86), and 0.86 (95% Confidence Interval= 0.16- 4.64), respectively. Patients with injuries as a result of other mechanisms (other than the ones specified, e.g. burns, strenous movements) had an Odds Ratio of 1.39 (95% Confidence Interval= 0.08- 23.39) for having major injuries, when compared to driving a car. Patients with cardiovascular diseases (compared to patients with no cardiovascular diseases) had an Odds Ratio of having major injuries of 1,663 (95% Confidence Interval= 0.00- $4.6*10^{54}$); whereas the Odds Ratio of having major injuries for patients with diabetes, hypertension, and respiratory problems were 3.44 (95% Confidence Interval= 0.00- $1.94*10^{73}$), 4.18 (95% Confidence Interval= 0.38- 46.56), and 0.55 (95% Confidence Interval= 0.04- 7.15), respectively.

According to this model, having an injury to the abdomen or pelvis, being injured as a passenger in a car, or having a history of cardiovascular diseases were highly predictive of having major injuries.

4.3.2.2.2. Development of the Two Scales of the Second Trauma Triage Protocol

Two scales, one for patients with a PHI 1-3 and another for patients with a PHI 4-7, were developed separately from each of the two selected regression models.

4.3.2.2.2.1. Development of the Scale for Patients with a PHI Between 1 and 3

For patients with a PHI between 1 and 3, the summation of the beta coefficients (Table 25) produced scores which ranged between -1.58 and 9.90. These scores were multiplied by 2 after the addition of 1.58. The final value to a zero decimal point was then rounded producing a scale, for patients with a PHI between 0 and 3, which ranged from 0 to 23.

4.3.2.2.2.2. Development of the Scale for Patients with a PHI Between 4 and 7

A scale for patients with a PHI between 4 and 7 was developed based on the regression coefficients of the selected regression model (Table 26) for this category of patients. The values of this scale ranged between -1.38 and 9.32. Transforming the scale, by adding 1.38 to each of the scores, and rounding the final value of the score to a whole integer produced a scale between 0 and 11.

4.3.2.2.3. Evaluation of the Second Trauma Triage Protocol

This section consists of four sub-sections; 1) evaluation of the two PHI categories: 0, and greater than 7; 2) evaluation of the scale developed for patients with a PHI between 1-3; 3) evaluation of the scale developed for patients with a PHI between 4-7; and 4) evaluation of the overall second triage protocol.

4.3.2.2.3.1. Evaluation of the Two PHI Categories: 0, and Greater than 7

The proportion of patients with non-major injuries (defined according to Figure 2), for patients with a PHI of 0 (considered to have non-major injuries according to this protocol) was 0.66. Whereas for patients with a PHI above 7 (defined to have major injuries according to this protocol), the proportion of patients with major injuries, was 0.87 .

4.3.2.2.3.2. Evaluation of the Scale Developed for Patients with a PHI Between 1 and 3

Sensitivities, specificities, positive predictive values, and negative predictive values for the different cutoff values of the scale developed for patients with a PHI between 1 and 3 are shown in Table 27. At a cutoff value of 5, this scale produced a sensitivity of 0.88 with a specificity of 0.33, a positive predictive value of 0.51, and a negative predictive value of 0.79. These statistics were 0.69, 0.63, 0.59, and 0.72 for a cutoff value of 6. The ROC curve for this scale is shown in Figure 5. The area under the ROC curve, after the transformation, was 0.72 (SE= 0.03). This statistic was 0.73 (SE= 0.03) before the transformation.

4.3.2.2.3.3. Evaluation of the Scale Developed for Patients with a PHI Between 4 and 7

Table 28 shows sensitivities, specificities, positive predictive values, and negative predictive values for the different cutoff values of the triage scale, developed for patients

with a PHI between 4 and 7. For a cutoff value of 2, these statistics were 0.98, 0.16, 0.74, and 0.80, respectively. For a cutoff value of 3, they were 0.72, 0.59, 0.81, and 0.47, respectively. The ROC curve is shown in Figure 6, and the area under the ROC curve for this scale was 0.75 after the transformation (SE= 0.04). The area under the curve for this scale before the transformation was 0.77 (SE= 0.04).

4.3.2.2.3.4. Evaluation of the Overall Second Triage Protocol

The overall sensitivity, specificity, positive predictive value, and negative predictive value for the second triage protocol, using a cutoff value of 5 for the scale developed for patients with a PHI between 1-3, and a cutoff value of 2 for the scale developed for patients with a PHI between 4 and 7, were: 0.52, 0.79, 0.66, and 0.67. According to this protocol, patients were defined to have major injuries if a patient had: 1) a PHI between 1 and 3, with a value of 5 or more for the first scale, or 2) a PHI between 4 and 7, with a score of 2 or more for the second scale, or 3) a PHI above 7.

4.3.2.3 Third Trauma Triage Protocol

Two different scales were developed for this protocol, one for patients below 65 years of age (881 trauma patients), and another for patients 65 years old or above (410 patients). For each age group, all possible regression models were performed, where the dependent variable was major injuries defined according to Figure 2, and the independent variables were: body region injured, mechanism of injury, comorbidity, PHI and time, all of which were re-categorized as shown in the next section.

4.3.2.3.1. Re-categorization of the Independent Variables

In order to develop the third trauma triage protocol, dichotomization of the independent variables body region injured, mechanism of injury, and comorbidity (shown below) was done after testing a regression model which included all the independent variables: age, body region injured, mechanism of injury, comorbidity, PHI, and time between 911 call and departure of the ambulance from the injury site (Table 29) -- the outcome for this model was major injuries defined according to Figure 2.

The categories of the independent variables:

body region injured: injuries to any of the following body regions: spine, head, neck, thorax, abdomen, or pelvis (yes/ no);

mechanism of injury: driver of a car, a motorcycle, a bicycle, firearm, stab, or fall above 14 ft (yes/ no);

comorbidity: history of cardiovascular disease or diabetes (yes/ no);

time between 911 call and departure of the ambulance from the scene: Above 39 minutes (yes/ no); and

PHI: 0, 1-3, 4-7, and above 7.

4.3.2.3.2. Selection of the Models of the Third Trauma Triage Protocol

4.3.2.3.2.1. Selection of the Model for Patients Below 65 Years of Age

For patients below 65 years of age, the two models with the lowest BIC values were:

Model	BIC value	Independent variables included in the model
1	**-188.97**	**body region injured, mechanism of injury, PHI**
2	**-186.12**	**body region injured, mechanism of injury, PHI, time**

Bayes factor approximation for Model 1 against Model 2 was 4.1, suggesting 80.4% chance that Model 1 is correct, against a 19.6% chance that Model 2 is correct (assuming that either Model is correct). Thus, Model 1-- which included the variables body region injured, mechanism of injury, and PHI -- was the model selected for developing the trauma triage scale for patients below 65 years of age.

Table 30 shows the results of the regression model selected for patients below 65 years of age. The odds of having major injuries for patients with injuries to the thorax, abdomen, pelvis, spine, head, or neck was 2.3 times higher than the odds of having major injuries for patients with no injuries to any of these body regions (significant at alpha = 0.05). The Odds Ratio for having major injuries for patients whose injuries were due to driving a car, a motorcycle, fall above 15 ft, stab, or firearm was 1.76 (95% Confidence Interval= 1.29- 2.42); whereas the Odds Ratio for having major injuries for patients with a PHI of 1-3, compared to a PHI of 0, was 1.45 (95% Confidence Intervals=2- 2.06). It was 3.18 (95% Confidence Interval= 2.03- 5.01) when patients with a PHI of 4-7 were compared to those with a PHI of 0, and it increased to 15.31 (95% Confidence Interval= 7.14- 32.93) for patients with a PHI above 7.

4.3.2.3.2.2. Selection of the Model for Patients Above 64 Years of Age

For patients above 64 years of age, the three lowest BIC values were for the following models:

Model	BIC value	Independent variables included in the model
1	-13.57	PHI, comorbidity
2	-13.39	PHI
3	-12.06	PHI, comorbidity, mechanism of injury

The Bayes factor approximation for Model 1 compared to Model 2 was 1.1, suggesting a 52% chance that Model 1 is the correct one, compared to a 48% chance that Model 2 is the correct model (given that either Model 1 or 2 is the correct one). Whereas the Bayes factor of Model 1 against Model 3 was 2.0, suggesting a 67% chance that Model 1 is the correct model compared to Model 3, which has a 33% chance of being correct (assuming either Model 1 or Model 3 is the correct one). The first model which included the variables comorbidity and PHI was the model of choice for patients above 64 years of age.

The results of the selected model for patients above 64 years of age are shown in Table 31. The odds of having major injuries for patients with diabetes or cardiovascular diseases was 45% higher than that of patients with no history of either disease (significant at alpha = 0.05). The Odds Ratio of having major injuries for patients with a PHI of 1-3 compared to a PHI of 0 was 1.42 (95% Confidence Interval= 0.82- 2.46); it was 4.50 (95% Confidence Interval= 1.72- 11.71) for patients with a PHI of 4-7 compared to patients with a PHI of 0, and 4.01 (95% Confidence Interval= 1.39- 11.57) for patients

with a PHI above 7.

4.3.2.3.3. Development of the Scales for the Third Trauma Triage Protocol

4.3.2.3.3.1. Development of the Scale for Patients Below 65 Years of Age

For patients below 65 years of age, summation of the regression coefficients (Table 30) produced a scale which ranged from 0 to 4.12. The scores of this scale were multiplied by 3, and the final values were rounded to a zero decimal point number, producing a scale from 0 to 12.

4.3.2.3.3.2. Development of the Scale for Patients Above 64 Years of Age

The summation of the regression coefficients of the model selected for patients 65 years of age or above (Table 31) produced a scale between 0 and 1.41. The scores of this scale were multiplied by 8, and the final values were rounded to a zero decimal point number, producing a scale which ranged between 0 and 15.

4.3.2.3.4. Evaluation of the Third Trauma Triage Protocol

4.3.2.3.4.1. Evaluation of the Scale Developed for Patients Below 65 Years of Age

Sensitivities, specificities, positive predictive values and negative predictive values (with 95% Confidence Interval around these statistics) for the different cutoff values of this scale are shown in Table 32. At a cutoff value of 2, the sensitivity, specificity, positive predictive value, and negative predictive value were 0.91, 0.33, 0.52, and 0.82, respectively. At a cutoff value of 3, these statistics were, 0.76, 0.61, 0.61, and

0.76, respectively. The ROC curve was plotted (Figure 7), and the area under the curve calculated after the transformation was 0.76 (SE= 0.02), which was not different from the one calculated before the transformation (area under ROC curve= 0.76, SE= 0.02).

4.3.2.3.4.2. Evaluation of the Scale Developed for Patients Above 64 Years of Age

Sensitivities, specificities, positive predictive values, and negative predictive values, for the scale developed for patients above 64 years of age, are shown in Table 33. At a cutoff value of 1, the sensitivity, specificity, positive predictive value, and negative predictive value were 0.56, 0.56, 0.52, and 0.61, respectively. The ROC curve was plotted (Figure 8), and the area under the ROC curve for the scale developed for this group of patients was 0.60 (SE= 0.03) before and after the transformation.

4.3.2.3.4.3. Evaluation of the Overall Third Trauma Triage Protocol

The overall sensitivity, specificity, positive predictive value, and negative predictive value for the third triage protocol were 0.80, 0.36, 0.50, and 0.70, respectively. According to this protocol, patients were considered to have major injuries if: 1) the patient was below 65 years of age, with a score for the scale developed for this age group above 1, or 2) if the patient was above 64 years of age, with a score for the scale developed for this age group above 1.

4.4. Conclusion of the Results

Table 34 shows the sensitivities, specificities, positive predictive values, negative

predictive values, and the areas under the ROC curves of the PHI and the three trauma triage instruments. For these triage instruments, the cutoff points which acquired the highest sensitivity, with a specificity above 15%, were selected. High sensitivity in predicting major injuries for these triage instruments was desired for ethical reasons, where it is more important to identify patients with major injuries, so as to be transferred to Level I trauma centers, than it is to identify patients with non-major injuries for their transfer to a Level II trauma center.

According to the results of this study (summarized in Table 34), the first trauma triage protocol seems to be the index with the highest predictive ability in identifying patients with major injuries. Although the results of the two scales developed for patients with a PHI between 1 to 3 and 4 to 7 were similar to the first triage protocol, the evaluation of the overall second triage protocol showed disappointing results. This is because according to this protocol, patients with a PHI of 0 were considered to have non-major injuries, however, 34% of these patients sustained major injuries (Table 19). With respect to the third trauma triage protocol, the results of the scale developed for patients who were below 65 years of age was similar to the first triage protocol. However, the scale developed for patients above 64 years of age had a very low predictive ability.

In conclusion, the first triage protocol developed in this study demonstrated the highest sensitivity with an acceptable specificity when compared to the PHI, the second and the third trauma triage protocols.

CHAPTER 5.

DISCUSSION

5.1 Summary of the Study's Findings

Implementation of an effective trauma triage protocol for the area of Montreal, has become necessary after the establishment of a regionalized trauma care system in 1993. These protocols identify patients with severe injuries that could be life-threatening, or result in disability, for transfer to a Level I trauma center, where multi-specialty trauma teams can be rapidly assembled to care for these patients. Also, triage protocols identify trauma patients with non-severe injuries (who do not require services unique to a Level I trauma center), for transfer to Levels II and III centers, thus avoiding overcrowding Level I trauma centers with non-severe cases and minimizing the inefficiency and excessive cost by insuring optimal use of resources. The purpose of this study was to assess the ability of the PHI trauma triage instrument to identify patients with major versus non-major injuries (Figure 2), and to develop a trauma triage protocol that improves the predictive power of the PHI-based trauma triage instrument.

A total of 1,291 trauma patients transferred and treated at the two Level I trauma centers in Montreal were included in this study. Using logistic regression analysis, three hypothetical trauma triage protocols were developed. The variables which constituted the scales of these triage protocols (a subset of the independent variables: body region injured, mechanism of injury, age, PHI, comorbidity, and time between 911 call and

departure of the ambulance from the injury site) were selected by using Bayes factor approximation, where the model that described the data best was selected. The values of these scales were based on the regression coefficients of the selected models. Sensitivities, specificities, positive predictive values, and negative predictive values for the different cutoff values of the PHI and the three triage protocols were evaluated. Also, the area under the Receiver Operating Characteristic (ROC) curves were calculated for these instruments.

A summary of the evaluation of the PHI and the 3 trauma triage protocols -- in their use as field trauma triage instruments-- is presented in this section.

5.1.1. The PHI Trauma Triage Instrument

In our study, a PHI of 1 or above was able to identify 55% of the patients with major injuries (where major injury was defined according to Figure 2), whereas a PHI below 1 identified 71% of the patients with non-major injuries (Table 21). The area under the ROC curve of the PHI was 0.66 (SE=0.02), suggesting that if we were to randomly select a person with major injuries and another one with non-major injuries, the probability that the PHI correctly classifies these individuals in terms of injury severity (defined according to Figure 2) is 66% (Table 21).

5.1.2. The First Trauma Triage Protocol

At a cutoff value of 4, the sensitivity, specificity, positive predictive value, and negative predictive value of the first triage protocol (which consisted of the variables:

age, body region injured, mechanism of injury, comorbidity, and PHI) were 0.95, 0.24, 0.50, and 0.86, respectively; whereas at a cutoff value of 5, these estimates were 0.85, 0.42, 0.54, and 0.77, respectively (Table 24). Therefore, if we were to use this hypothetical protocol as a trauma triage instrument (cutoff point of 4), we would be able to identify 95% of the patients with major injuries (defined according to our criteria, Figure 2), whereas 76% of the patients with non-major injuries would be misclassified as having major trauma.

Compared to the PHI at cutoff value of 1, the first triage protocol at cutoff value of 4 was able to identify an additional 40% of the patients with major injuries; whereas an additional 47% of the patients with non-major injuries were incorrectly identified as having major injuries. Also, the area under the ROC curve of this trauma triage protocol was significantly higher (at an alpha of 0.05) than that of the PHI-based trauma triage instrument (0.74 vs 0.66 -- Table 34); suggesting an improvement in the predictive ability -- of major injuries -- of this trauma triage protocol over the PHI.

5.1.3. The Second Trauma Triage Protocol

The sensitivity, specificity, positive predictive value, and negative predictive value of the second triage protocol were 0.52, 0.79, 0.66 and 0.67, respectively (Table 34). These values were obtained when patients were classified to have major injuries if they had a PHI above 7; or a PHI between 1-3 with a score of 5 or above for the scale developed for this group of patients (this scale consisted of the variables: age, body region injured, mechanism of injury, and comorbidity); or a PHI between 4-7 with a score

of 2 or above for the scale developed for this group of patients (this scale consisted of the variables: body region injured, mechanism of injury, and comorbidity). The low sensitivity of this triage protocol was expected since all patients with a PHI of 0 were considered to have non-major injuries, and since 34% of the patients with a PHI of 0 had major injuries. Therefore, if this hypothetical trauma triage protocol was to be applied, 48% of the patients with major injuries will be classified incorrectly as having minor trauma. The area under the ROC curve of each of the two scales developed for this protocol was not significantly different (alpha = 0.05) from that of the PHI (Table 34).

5.1.4. The Third Trauma Triage Protocol

The sensitivity, specificity, positive predictive value, and negative predictive value of the overall third trauma triage protocol (cutoff value of 1 for each of the scales developed for patients below 65 years of age and those 65 years old or above) were 0.80, 0.36, 0.50, and 0.70, respectively (Table 34). The scale developed for patients below 65 years of age (which consisted of the variables body region injured, mechanism of injury, and PHI) had a sensitivity and a specificity of 0.93 and 0.27, respectively (cutoff value of 1), with an area under the ROC curve significantly higher than that of the PHI (0.76 vs 0.66 -- Table 34). However, the scale developed for patients above 64 years of age (the variables PHI, and comorbidity were the variables selected for this scale) had a sensitivity and specificity (cutoff value of 1) of 0.56 each. The area under the ROC curve for this scale was significantly lower than that of the PHI (0.60 vs 0.66 -- Table 34). This low performance could be due to the small sample size of this age group (410 patients), or

simply the result of unexplained variation of the outcome by the independent variables considered.

5.1.5. Conclusion of the Study's Findings

In conclusion, the first trauma triage protocol, when compared to the PHI, and the second and third triage protocols seems to be the trauma triage instrument which has the highest power in identifying patients with major injuries (sensitivity of the first triage protocol was 0.95, versus 0.55 for the PHI, 0.52 for the second protocol, and 0.80 for the third protocol -- Table 34). The tradeoff for this high sensitivity is a low specificity of 0.24. However, currently in Montreal, no protocol prohibits trauma patients from being transported to a Level I trauma center. Therefore, if we were to apply this hypothetical protocol in Montreal, we would be capturing 95% of the trauma patients with major injuries, and saving the cost of treating, at a Level I trauma center, 24% of the patients with non-major injuries (Figure 2) by transferring them to a Level II trauma center.

5.2. Comparison with Other Studies

A review of the data in the literature, summarised in Table 13, shows that although some of the trauma triage indices reported acceptable accuracy in predicting major trauma, others have shown extremely disappointing results. The sensitivity of the Trauma Score (TS) in predicting major trauma ranged from 0.90 in detecting trauma deaths (80) to 0.17 in predicting ISS above 15, surgery, or death (27). The rest of the studies which evaluated the TS had a sensitivity ranging from 0.48 in detecting death or

surgery (31), to 0.52 in detecting ISS above 20 (94), to 0.53 in predicting death or ISS above 20 (83), to a sensitivity above 0.85 in detecting trauma deaths (90). In one study (82), the Revised Trauma Score (RTS) seemed to be doing better than the TS in predicting trauma patients with ISS above 15. However, in another study (23), the area under the ROC curve for the TS was significantly higher than that of the RTS (in predicting death or surgery). The Pediatric Trauma Score (PTS) had a sensitivity above 0.95 in predicting death of pediatric patients (81). However, in another study, the sensitivity of the PTS, in predicting trauma patients with ISS above 15, was 0.78 (82). The specificities of all of these studies were above 60%.

As for the CRAMS scale, the sensitivity of this index ranged from 0.96 in detecting only trauma deaths (85) to 0.85 in predicting death, or direct admission to operating room or intensive care unit (96); to 0.72 in predicting death, surgery, or ISS above 15 (27); to 0.92 and 0.34 in predicting death or surgery (77,31). The specificity of the CRAMS scale in all of these studies, with the exception of the study conducted by Hedges (96), was above 80%.

The Trauma Triage Rule (TTR) and the Pre-hospital Index (PHI), had the most consistent predictive ability in predicting injury severity of trauma patients. The studies which evaluated these two indices had acceptable internal validity in terms of the definition of major trauma, and of the time when the variables of the indices were evaluated. Although the TTR seems to have promising results, only two studies evaluated this scale. In predicting death, surgery, in-fluid hospital resuscitation, transfusion, and central nervous system monitoring (79, 89), the sensitivity and specificity of the TTR

were 0.92 each in one study (79), and 0.88 and 0.86 in the other study (89). The PHI had a sensitivity and specificity above 0.92 in identifying trauma deaths or surgery (78,86); these statistics were 0.81 and 0.61 in predicting death or surgery (87), and 0.83 and 0.67 in predicting death, length of hospital stay, intensive care unit, or surgery (88). In another study, both the sensitivity and the specificity of the PHI were above 0.85 in identifying trauma deaths (90) .

The TS and the CRAMS scale are the two physiological injury severity measures which have been most extensively assessed for field triage after addition of the time independent variables: mechanism of injury, body region injured, and age (92,51,94,27,96) (Table 14). In these studies, when the TS, or CRAMS scale was assessed separately for field triage, the sensitivity in identifying patients with major injuries was low relative to the calculated specificity. However, when the time independent variables were added to the physiological scales, the sensitivity increased, the tradeoff being a decrease in the specificity.

In predicting ISS above 20, the sensitivity increased from 0.52 to 0.86 and the specificity dropped from 0.98 to 0.93, after the addition of the mechanism of injury and body region injured variables to the TS (94). In the study by Kundson (25), the sensitivity and specificity -- in detecting death, length of hospital stay above three days, TS at emergency room below 15, or ISS above 15-- were 0.93 and 0.30, respectively, after the addition of the mechanism of injury variable to the CRAMS scale. After the addition of the body region injured and mechanism of injury variables to the physiologic measures, the Revised Scale and the Revised Checklist had a sensitivity of 0.95 and 0.81-- with

specificities of 0.37, and 0.77, respectively -- in detecting ISS above 15, surgery, or death (27). In the study by Hedges, Kane's Revised Checklist had a sensitivity and specificity of 0.85 and 0.65, respectively (96).

In detecting similar outcomes, the sensitivity estimate of the PHI in our study was lower than the sensitivity of any of the studies which evaluated the performance of the PHI (78,86,88). This may be explained by the fact that the two studies conducted by Koehler (78,86) evaluated the PHI on the same population from which the PHI was derived. On the other hand, differences in the results obtained in this study and the one conducted by Sampalis in Montreal (88) may be explained by: 1) differences in the definition of major injuries in the two studies, 2) differences in the selection of the samples in the two studies -- the sample of patients studied by Sampalis consisted of trauma patients with severe injuries seen by physicians at the injury site, whereas the present study consisted of patients with severe and non-severe injuries treated at the injury site by physicians and emergency medical technicians, and 3) differences in the personnel evaluating the variables required for the calculation of the PHI -- in the study by Sampalis, physicians evaluated these variables, whereas in the present study these variables were evaluated by emergency medical technicians and physicians.

Also, the TTR (79, 89) and the CRAMS (77) had a better ability in predicting similar outcomes than the PHI in our study. However, the predictive ability of the TS and CRAMS (31) scales in identifying major injuries defined by death or direct admission to the operating room, was similar to that of the PHI in our study.

Similar to the previous studies (45,65,77,96) (summarized in Table 14), addition

of time independent variables to the PHI (physiologic injury severity measures) increased the sensitivity of the triage protocols, with the tradeoff being a decrease in the specificity. In our study, the first trauma triage protocol, compared to the second and third trauma triage protocols, had the highest predictive power in identifying patients with major injuries (defined according to Figure 2); where a sensitivity of 0.95 and a specificity of 0.24 were achieved. In predicting similar outcomes, these statistics were not much different from the ones reported for the index developed by Kundson (45). Although the sensitivity of the first trauma triage protocol developed in our study was higher than Kane's Revised Checklist, the specificity was considerably lower (65.96); however, the predictive ability of this protocol was higher than that developed by Simmons (52).

In conclusion, in our study the PHI-based trauma triage instrument had a low predictive ability in identifying major injuries (defined according to Figure 2) when compared to the physiological injury severity measures reviewed in the literature. However, the first trauma triage protocol developed -- that added time independent variables to the PHI -- demonstrated a predictive ability as good or better than the trauma triage instruments reviewed in the literature.

5.3. Limitations of the Study

5.3.1. Selection of patients treated at Level I trauma centers only

Trauma patients who have been transferred to and treated at either the Montreal General Hospital or Sacré Coeur (the only Level I trauma centers in Montreal), between April 1993 and December 1996, were considered in the study. Before June 1995, trauma

patients were transferred to the nearest hospital with an emergency room. However, after June 1995, Urgence santé introduced a triage protocol, based on the PHI, mandating trauma patients with major injuries (defined according to Figure 1), to be transferred to a Level I trauma center (compliance with this protocol was not satisfactory). For this study, only patients treated at Level I trauma centers were selected because at the time the study was conducted, only this data was available to us. But more importantly, we did not pursue addition of patients treated at Level II trauma centers because we thought that this might have the potential for confounding the results due to the differences in the levels of trauma care. So at the developmental stage of a trauma protocol, we believed it would be a good idea to restrict the study to patients treated at Level I trauma centers.

5.3.2. Missing Data on the PHI

Although the PHI was missing for 45% of the trauma patients, descriptive statistics of patients' demographics, injury and in-hospital characteristics were similar for the group of patients on whom a PHI was calculated at the scene, and the other group of patients for whom one or more of the variables required for the calculation of the PHI was missing, thus suggesting that the group of patients with a calculated PHI at the site is representative of the population of patients who have been transferred to either hospital.

5.3.3. Definition of major injuries

Because a gold standard for the definition of the outcome variable, major injuries, is unavailable, misclassification is of concern in all studies which develop and evaluate

trauma triage protocols. The question that should be asked is: Are we able to identify all the patients who may have died or have had severe disability had they not been treated at a Level I trauma center? In our definition of major trauma, we did not include only patients who died -- as was the case in the studies conducted by Baxt 1989 (90), Ramenofsky 1988 (81), Morris 1986 (80), and Clemmer 1985 (85), however, we used for the definition of major trauma a combination of the variables death, intensive care unit admission, and surgery intervention -- similar to the studies conducted by Meredith 1995 (83), Gormican 1982 (77), Sampalis 1996 (88), Simmons 1995 (91), and Kreis 1988 (92). Moreover, the definition of major injuries in this study was not based on the variable ISS -- as was the case in the studies by Eichelberger 1989 (82), Knopp 1988 (51), Cottington 1988 (94), West 1986 (95), Meredith 1995 (83), Simmons 1995 (91), Kundson 1988 (25), and Kane 1985 (27) -- because this index does not correlate well with intensive care unit admission or surgery intervention (68). This was confirmed when the proportion of patients with an ISS above 20 for patients who were defined as having major injuries (Figure 2) was found to be only 12% (149 patients). On the other hand, the proportion of patients who did not satisfy the definition of major trauma, but who had an ISS above 20, was 1.4% (18 patients).

Using such a conservative definition of major injuries -- death within seven days of hospital admission, admission to an intensive care unit within seven days, or surgery intervention within four days -- is important for ethical reasons where it is unlikely that patients with major injuries be classified as having non-major injuries. Nevertheless, it is possible that patients with non-major injuries will be misclassified as having major

injuries. Therefore, it is unlikely that patients who require treatment at a Level I trauma center will be classified as having non-major injuries that could be treated at Levels II and III trauma centers, but it is possible that patients with injuries that could be treated at Levels II or III trauma centers be misclassified as having injuries requiring treatment at Level I trauma centers.

5.3.4. Recoding of the variable time between 911 call and departure of the ambulance from the injury site for patients with a missing value for this variable

A cutoff value of 40 minutes was used for the variable time between 911 call and departure of the ambulance from the injury site. Replacement of the value time less than 40 minutes -- the average time= 31 minutes, median= 27 -- for 27% of the patients, who had data missing for the time variable, was performed after finding that the distribution of patients' demographics, injury and in-hospital characteristics for this group of patients -- those missing data on the time variable -- was similar to that for patients with time less than 40 minutes.

Replacement of the missing values of the time variable with a value less than 40 minutes could not have biassed the results of the triage protocols, because the variable time was not selected for any of the protocols.

5.4. Strengths of the Study

In this study, we were able to develop a trauma triage protocol which had a sensitivity of 95% and a specificity of 24% in detecting major injuries (defined according

to Figure 2). This triage protocol was composed of the variables: body region injured, mechanism of injury, age, comorbidity, and PHI. The variables required for the calculation of the PHI were evaluated at the injury site, thus reflecting the physiological condition of the patient at the scene of injury where the decision of whether to transfer the patient to a Level I or II trauma center is done.

Although there is no gold standard for the definition of major injuries, by extending the definition of major injuries to include death, and the use of services which are exclusive to Level I trauma centers, we were able to identify patients who might have died had they not been treated at level I trauma center.

In terms of the statistical analysis performed in this study, the use of the Bayes factor approximation which considers the liklihood of the data given the model in selecting the regression models that predict the data best (for the development of the triage protocols) was important because it addressed the major drawback of the sequential model selection technique in which selection of the variables in the final model depends on the significance of the variables in the model; p values are impossible to interpret in this context since the true sample space of models and parameter values is too large to be used in practice, and therefore the correct sample space is not used. The use of the BIC is also important for external validity, since it avoids over-fitting of the model to a particular data set. Also, using the coefficients of the independent variables of the selected logistic regression models to evaluate the rank of each of the levels of these variables (selected for the different triage protocols) is important since the effect of each of the variables was evaluated, after adjusting for the other variables.

5.5. Practical Implementation

The First Trauma Triage protocol consisted of the variables: age, body region injured, mechanism of injury, co-morbidity and the PHI. The variables which may be hard to assess at the injury site, if the patient was unconscious, are age and co-morbidity. For this reason, the variable age was categorised into the levels 16-44, 45-64, and above 64, rather than having to evaluate the exact age of the patient. With respect to the variable co-morbidity, and for the selection of the logistic regression model that constituted the First Trauma Triage Protocol, we considered the information that was gathered for this variable by the emergency medical technicians at the injury site, and not the ones identified from hospital records, to assess if this information is important in predicting major injuries. Of the 1,291 trauma patients considered in our study, emergency medical technicians identified 285 patients (22%) who had a history of either cardiovascular diseases, diabetes, epilepsy, hypertension, or respiratory problems. This is compared to 19% in the study conducted by MacKenzie 1989 (59), and 16% in the study conducted by Milzman 1992 (57). A next study should decide on what to do with patients for whom age and co-morbidity can not be assessed at the injury site.

Even though the calculation of these triage instruments was not done at the injury site. This should not affect the results of our findings, because it is not expected that Urgence santé technicians calculate the PHI or any other score at the scene. With programmable hand-held devices, all that the technicians will have to do is select the level of the variables for which the patient belongs, and the decision of whether the patient should be transferred to a Level I or II trauma center will be displayed on the

screen.

5.6. Generalizability

Triage protocols can perform better on populations in which they were developed (60) -- Montreal in case of the present study. If the First Trauma Triage Protocol is to be applied in a population other than Montreal, evaluation of the performance of the triage protocol in identifying trauma patients with severe and non-severe injuries for this population is a necessity. Even though this protocol was developed for the population of Montreal -- an urban city in the province of Quebec, the effectiveness of this protocol should be tested before its application in any other urban or rural area in Quebec. This is because the conditions that exist in these areas may not resemble those in Montreal. Therefore, validation of this protocol, as well as modification of it should be considered. Finally, application of this triage protocol on the population of Montreal should undergo continuous evaluation to account for any secular trends in the mechanisms or types of injuries over time in this area.

5.7. Recommendations for Further Research

A prospective evaluation of the first trauma triage protocol on a sample of patients treated at Levels I and II trauma centers, for the population of Montreal, is necessary. Also, a cost benefit study should be done to determine the cutoff value of the trauma triage instrument to be used, in order to balance the benefits of a correct decision against the costs of an incorrect decision.

Further research should evaluate the combination of trauma triage instruments. Because of the advanced technology, we do not need to limit our screening scales to simple calculable formulas. We may use more sophisticated measures that increase the predictive ability of the trauma triage instruments. These measures could be easily generated by emergency medical personnel, at the site of the injury, by using hand-held programmable devices. The low specificity of the first trauma triage protocol (developed in this study) led us to investigate further combination of this protocol with the two scales developed for the second and third protocols (the scale developed for patients with a PHI between 4-7, and the scale developed for patients below 65 years of age). A patient was defined to have non-major injuries if: 1) the patient had a score for the first trauma triage protocol below 4; 2) the patient had a PHI between 4-7 with a score below 2 for the scale developed for this group of patients; or 3) the patient was below 65 years of age, with a score below 1 for the scale developed for this group of patients. The sensitivity, specificity, positive predictive value, and negative predictive value for predicting major injuries (defined according to Figure 2, after combining the three triage protocols) were 0.88, 0.34, 0.52, and 0.59, respectively. When protocols 1 and 2 were combined (definition of non-major injuries was in terms of the first two conditions listed above), these statistics were 0.90, 0.32, 0.52, and 0.80; whereas the combination of protocols 1 and 3 (definition of non-major injuries was in terms of the first and third conditions listed above) yielded a sensitivity, specificity, positive predictive value, and negative predictive value of 0.91, 0.31, 0.52, and 0.81, respectively.

5.8. Conclusion

In this study, we were able to demonstrate that the addition of the variables age, body region injured, mechanism of injury, and comorbidity to the PHI-based trauma triage instrument increased the sensitivity of predicting major injuries (defined according to Figure 2), the tradeoff being a decrease in the specificity. Using logistic regression analysis, we were able to develop a trauma triage scale which had a sensitivity, specificity, positive predictive value, and negative predictive value of 0.94, 0.24, 0.50, and 0.86, respectively, with an area under the ROC curve of 0.74 (SE=0.01). Further research, however, should focus on the prospective evaluation of this trauma triage instrument for patients treated at Levels I and II trauma centers, for the area of Montreal.

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Tables

Table 1: The Abbreviated Injury Scale (AIS)

Injury description:

A B CD EF. G

A

Body region

1	Head
2	Face
3	Neck
4	Thorax
5	Abdomen
6	Spine
7	Upper extremity
8	Lower extremity
9	Unspecified

B

Type of anatomic structure

1	Whole area
2	Vessels
3	Nerves
4	Organs
5	Skeletal
6	Head

CD

Specific anatomic structure or nature

Assigned consecutive 2 digit numbers starting with 02

EF

Level

Assigned consecutive two digit numbers staring with 02

G

Severity Scores

1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Un-survivable
9	Unknown

Table 2: The Trauma Index

Variable	Score
Region	
Skin or extremities	1
Back	3
Chest or abdomen	4
Head or neck	6
Type of injury	
Laceration or contusion	1
Stab wound	3
Blunt	4
Missile	6
Cardio-vascular status	
External haemorrhage	1
BP < 100 , P > 100	3
BP < 80 , P > 140	4
Absent pulses	6
Central nervous system status	
Drowsy	1
Stupor	3
Motor or sensory loss	4
Coma	6
Respiratory status	
Chest pain	1
Dyspnea or hemoptysis	3
Evidence of aspiration	4
Apnea or cyanosis	6
Total Trauma Index	-------

Table 3: The Triage Index (TI)

Variable	Score	Regression Coefficient
Respiratory expansion		-0.52
Normal	0	
Shallow	2	
Retractive	2	
None	3	
Capillary refill		-0.64
Immediate	0	
Delayed	2	
Eye opening		-0.29
Spontaneous	0	
To voice	1	
To pain	2	
None	3	
Verbal response		-0.64
Oriented	0	
Confused	1	
Inappropriate words	2	
incomprehensible sounds	3	
None	4	
Motor response		-0.32
Obedience	0	
Withdrawal	1	
Flexion	2	
Extension	3	
None	4	

Table 4: The Glasgow Coma Scale (GCS)

Variable	Score
Eye opening	
Spontaneous	4
To voice	3
To pain	2
None	1
Verbal response	
Oriented	5
Confused	4
Inappropriate words	3
Incomprehensible words	2
None	1
Motor response	
Obeys command	6
Localizes pain	5
Withdraw (pain)	4
Flexion (pain)	3
Extension (pain)	2
None	1
Total Glasgow Coma Scale	-----

Table 5: The Trauma Score (TS)

Variable	Score
Respirations/min	
>=36	2
25-35	3
10-24	4
1-9	1
None	0
Respiratory expansion	
Normal	1
Shallow	0
Retractive	0
Systolic blood pressure, mmHg	
>=90	4
70-89	3
50-69	2
0-49	1
No pulse	0
Capillary refill	
Normal	2
Delayed	1
None	0
Glasgow Coma Scale	
14-15	5
11-13	4
8-10	3
5-7	2
3-4	1
Total Trauma Score	----

Table 6: Probability of Survival for the Different Values of the TS

TS	Percentage of Patients	Probability of Survival
16	66	0.99
15	14	0.98
14	6.3	0.95
13	3.4	0.91
12	2.8	0.83
11	1.3	0.71
10	1.6	0.55
9	0.49	0.37
8	0.24	0.22
7	0.24	0.12
6	0.49	0.07
5	0.00	0.04
4	0.12	0.02
3	0	0.01
2	3.2	0
1	0	0

Table 7: The Triage-Revised Trauma Score (T-RTS), and the Revised Trauma Score (RTS)

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

RTS = 0.9368(GCS) + 0.7326(Systolic blood pressure) + 0.2908(Respiratory rate)

Table 8: The Pediatric Trauma Score (PTS)

Variable	Score
Size of child	
>20	2
10-20	1
<10	-1
Airway	
Normal	2
Maintainable	1
Un-maintainable	-1
Systolic blood pressure	
>90	2
50-90	1
<50	-1
Central nervous system	
Awake	2
Obtunded/ Loss of consciousness	1
Decerebrate	-1
Skeletal fractures	
None	2
Closed fracture	1
Open/multiple fracture	-1
Cutaneous injury	
None	2
Minor	1
Major/penetrating	-1
Total PTS	-----

Table 9: The CRAMS Scale

Variable	Score
Circulation	
Normal capillary refill and blood pressure >100	2
Delayed capillary refill or blood pressure 85-10	1
No capillary refill or B blood pressure <85	0
Respirations	
Normal	2
Abnormal	1
Absent	0
Abdomen	
Abdomen and thorax non-tender	2
Abdomen or thorax tender	1
Abdomen rigid or flail chest	0
Motor	
Normal	2
Responds only to pain	1
No response	0
Speech	
Normal	2
Confused	1
No intelligible words	0
Total CRAMS	-----

Table 10: The Pre hospital Index (PHI)

Variable		Score
Systolic blood pressure	>100	0
	86-100	1
	75-85	2
	<75	3
Pulse rate	51-120	0
	>120	3
	<50	5
Respiratory status	Normal	0
	Laboured/ shallow	3
	<10 needs intubation	5
Level of consciousness	Normal	0
	Confused combative	3
	No intelligible words	5
Total PHI		----

Penetrating abdominal or chest injuries adds additional 4 points

Table 11: Values of the Regression Coefficients of the Probability of Survival Model for the TRISS

	Constant (b_0)	TS (b_1)	ISS (b_2)	Age (b_3)
Original Values				
Blunt	-1.6465	0.5175	-0.0739	-1.9261
Penetrating	-0.8068	0.5442	-0.1159	-2.4782
Modified Values				
Blunt	-1.2470	0.9544	-0.0768	-1.9052
Penetrating	-0.6029	1.1430	-0.1516	-2.6676

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

$b = b_0 + b_1(TS) + b_2(ISS) + b_3(Age)$

Age= 0 if the patient is less than 55 years old; otherwise Age=1

b_0 , constant of the logistic regression model

b_1, b_2, and b_3 are the regression coefficients of the variables TS, ISS, and age, respectively

Table 12: Values of the Regression Coefficients of the Probability of Survival Model for the ASCOT

variable	Blunt	Penetrating
Constant	-1.1570	-1.1350
G	0.7705	1.0626
S	0.6583	0.3638
R	0.2810	0.3332
A	-0.3002	-0.3702
B	-0.1961	-0.2053
C	-0.2086	-0.3188
Age	-0.6355	-0.8365

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

$K=k_1+k_2G+k_3S+k_4R+k_5A+k_6B+k_7C+k_8A$

G= GCS, S=systolic blood pressure, R= respiratory rate, A,B,C =AP parameters

A =0 if age between 0 and 45
A =1 if age between 55 and 64
A =2 if age between 65 and 74
A =3 if age between 75 and 84
A =4 if age >= 85

Table 13: Summary of the Studies which Evaluated the Performance of Different Physiological Injury Severity Measures in their Use as Triage Instruments

Referrence	*Index*	*Cutoff*	*Number*	*Major trauma*	*Sensitivity*	*Specificity*	*PPV*	*NPV*	*Comments*
Morris,1986	TS	14	1,106	ISS>=20	0.63	0.88	0.52	0.9	Definition of major trauma
				Death	0.9	0.8	0.3	0.9	
Ramenofsky,1988	PTS	8	250 Paediatric patients	Death	0.96	0.99	0.98	1	Definition of major trauma
Eichelberger,1989	TS	14	1,334	ISS>15	0.72	0.75	0.32	0.9	*Definition of major trauma
	PTS	8	children		0.78	0.75	0.33	1	*Indices calculated at ER
	RTS	11			0.78	0.63	0.25	1	
Meredith,1995	TS	12	29,550	Death or ISS> 20	0.53				Index calculated at ER
				Death at ER/ or direct admission for surgery or ICU	0.19				
Clemmer,1985	CRAMS	6	2,110	Death	0.96	0.98	0.62	1	Definition of major trauma
				ICU admission	0.27	0.96			
				Surgery	0.13	0.95			
Gormican,1982	CRAMS	8	500	Death in ER/ or direct admission for surgery or ICU	0.92	0.9			Definition of major trauma
Koehler,1986	PHI	4	388	Death (72 hours), general or neuro surgery (24 hours)	0.94	0.95	0.46	1	
Koehler,1987	PHI	4	3,581	Death, or surgery (4 hours)	0.93	0.93	0.52	1	
Plant,1995	PHI	4	621	Death (72 hours), or surgery (4 hours)	0.81	0.61			*Highest PHI used *Inclusion criteria: ISS > 16 *Misleading sensitivity, specificity

Table 13: (Continued) Summary of the Studies which Evaluated the Performance of Different Physiological Injury Severity Measures in their Use as Triage Instruments

Referrence	Index	Cutoff	Number	Major trauma	Sensitivity	Specificity	PPV	NPV	Comments
Sampalis,1996	PHI	4	628	Death, or hospital stay >3days, or ICUadmission, or surgery	0.83	0.67	0.64	0.85	
Baxt,1990	TTR		1,004	Surgery with positive findings (48 hours), IV fluid replacement >1000 ml, transfusion,invasive CNS monitoring, death	0.92	0.92			
Fries,1994	TTR		653	Surgery with positive findings (48 hours), IV fluid replacement >1000 ml, transfusion,invasive CNS monitoring, death	0.88	0.86	0.47	0.98	
Ornato,1985	TS	12	5,130	DOA, death in ER, direct admission to OR	0.48	0.78	0.1	0.97	Definition of major trauma
	CRAMS	8			0.34	0.88	0.12	0.96	
Baxt,1989	TS		2,434	Death	>0.85	>0.85			*Definition of major trauma
	RTS				>0.85	>0.85			*No scale was able to achieve
	CRAMS				>0.85	>0.85			a sensitivity and specificity
	PHI				>0.85	>0.85			above70% in predicting ISS >15
Emerman,1991	RTS		1,502	Death, or surgery (2 hours)					Lower area under ROC curve
	PHI								for RTS as compared to PHI
	CRAMS								and CRAMS

Table 14: Summary of the Studies which Developed and Evaluated Triage Protocols that Consisted of Physiological and Time Independent Variables

Referrence	Index	Cutoff	Number	Major trauma	Sensitivity	Specificity	PPV	NPV	Comments
Simmons,1995	Oregon triage criteria Physiologic/MOI/BRI/age		1,063	surgery (6 hours), ICU (3 days),ISS, >15, or death	0.87	0.27			
Kreis,1988	Physiologic/MOI/BRI/age TS Penetrating injuries High energy dissipation	12	8,891	Death in ER, surgery, ICU			0.3 0.92 0.48 0.22		*Inclusion criteria: patients who satisfied the triage criteria for major trauma *Sensitivity and specificity could not be calculated *Definition of major trauma
Knopp,1988	TS TS, MOI, BRI	12	1,473	ISS >15			0.76 0.33		***Over-triage Under-triage** 1.5% 29.9% 12.8% 10.3% *Definition of major trauma *No sensitivity, specitivity calculated
Kundson,1988	TS CRAMS CRAMS and MOI	12 8	500	death, hospital stay > 3 days, TS at ER <15, ISS >15	0.24 0.66 0.93	1 0.82 0.3			Definition of major trauma
Cottington,1988	TS TS, physiologic, MOI, BRI	12	2,058	ISS >15 ISS >20 ISS >15 ISS >20	0.4 0.52 0.86 0.86	0.99 0.98 0.92 0.93	0.94 0.88 0.83 0.79	0.78 0.88 0.94 0.96	*Definition of major trauma *TS calculated at ER
Kane,1985	Revised scale physiologic,MOI, BRI Revised checklist physiologic,MOI, BRI CRAMS TS	6 7 12 variables 6 variables 8 12	937	ISS >15, surgery (6 hours), death (6 hours), injury to cranium, trunk, or neck	0.95 0.71 0.81 0.64 0.72 0.17	0.37 0.86 0.77 0.9 0.86 0.99	0.16 0.38 0.72 0.41 0.38 0.64		

Table 14: (Continued) Summary of the Studies which Developed and Evaluated Triage Protocols that Consisted of Physiological and Time Independent Variables

Referrence	Index	Cutoff	Number	Major trauma	Sensitivity	Specificity	PPV	NPV	Comments	
									*Over-triage	Under-triage
West,1986	Original triage instrument		743	ISS >9,hospital stay>2days					0.18	0.21
	only physiologic variables			ISS > 15					0.4	
	Revised triage instrument		1,793	ISS >9,hospital stay>2days					0.36	0.04
	Physiologic, MOI, BRI			ISS > 15					0.6	
									*Different definition of major trauma for under-triage	
Hedges,198	Kane's revised checklist		130	No vital signs at	0.85	0.65			*Small sample size	
	TS/GCS/MOI			site, death in ER,	0.78	0.63			*Definition of major trauma	
	CRAMS	8		direct admission	0.85	0.54				
	RSG (Respiration/SBP/GCS)			to ER, or operating room	0.73	0.79				
	PHI	4			0.73	0.75				

Table 15: Patients' Characteristics

Variable	Number (%)
Total	2,847
Gender	
Male	1,699 (60)
Female	1,147 (40)
Missing	1 (0)
Mechanism of injury	
Driver	314 (11)
Passenger	121 (4)
Motorcycle	82 (3)
Cyclist	60 (2)
Pedestrian	238 (8)
Fall above 15 ft	374 (13)
Fall below 15 ft	903 (32)
Firearm, stab, knife...	354 (12)
Blunt object	238 (8)
Other	163 (6)
Missing	0 (0)
Body region injured	
Head/ neck	975 (34)
Face	797 (28)
Thorax	571 (20)
Abdomen/ pelvis	326 (12)
Spine	262 (9)
Upper/ lower extremities	2,148 (75)
Missing	0 (0)
Penetrating injury	199 (7)
Comorbidity	
Cardiovascular diseases	223 (8)
Diabetes	94 (3)
Epilepsy	40 (1)
Hypertension	217 (8)
Respiratory problems	76 (3)

Table 15: (Continued) Patients' Characteristics

Variable	Number (%)
Hospital	
Montreal General Hospital	2088 (73)
Sacré Coeur	759 (27)
ISS	
0-15	2.245 (79)
16-25	323 (11)
26-49	245 (9)
>=50	31 (1)
Missing	1 (0)
Surgery [1]	655 (23)
Intensive care unit admission [2]	742 (26)
Death [3]	153 (5)
Major injury [4]	1274 (45)

Variable	Mean (SD) Median	Missing (%)
Age	51.6 (23.2) 47	5 (0.2)
Time (minutes) [5]	31.0 (18.1) 27	839 (29.5)
ISS	11.4 (10.0) 9	1 (0)
PHI	2.2 (4.4) 0	1691 (59.4)
Hospital stay (days)	14.2 (24) 7.6	67 (2.4)

1= Surgery (non- orthopaedic, or plastic) within 4 days since hospital admission
2= Intensive care unit admission within 7 days since hospital admission
3= Death at emergency room or death within 7 days since hospital admission
4= Major injuries defined according to Graph 2
5= Time between 911 call and departure of the ambulance from the scene

Table 16: Frequency Distribution of the PHI Vital Signs Variables

Vital signs variables	N (%)	Score
Total	1,291 (100)	
Systolic blood pressure		
>100	1071 (83)	0
86-100	136 (10)	1
75-85	19 (2)	2
0-74	65 (5)	5
Respiratory status		
Normal	1112 (86)	0
Laboured/ shallow	138 (11)	3
Less than 10 min, needs intubation	41 (3)	5
Level of consciousness		
Normal	1050 (81)	0
Confused/ combative	118 (9)	3
Non intelligible words	123 (10)	5
Pulse rate		
Greater than or equal to 120	1193 (92)	0
51-119	47 (4)	3
Below 50	51 (4)	5

97 patients (8%) had penetrating injuries to the head/ neck, abdomen, thorax or spine, and thus were given an additional 4 points

Table 17: Patients' Characteristics by Presence of a PHI at the Site of Injury

Variable	PHI information available Number (%)	PHI information not-available Number (%)
Total	1,291 (45)	1,556 (55)
Gender		
Male	797 (62)	902 (58)
Female	493 (38)	654 (42)
Missing	1 (0)	0 (0)
Mechanism of injury		
Driver	142 (11)	172 (11)
Passenger	54 (4)	67 (4)
Motorcycle	41 (3)	41 (3)
Cyclist	22 (2)	38 (2)
Pedestrian	116 (9)	122 (8)
Fall above 15 ft	158 (12)	216 (14)
Fall below 15 ft	392 (30)	511 (33)
Firearm, stab	178 (14)	176 (11)
Blunt object	119 (9)	119 (8)
Other	69 (5)	94 (6)
Missing	0 (0)	0 (0)
Body region injured		
Head/ neck	444 (34)	531 (34)
Face	368 (29)	429 (28)
Thorax	266 (21)	305 (20)
Abdomen/ pelvis	152 (12)	174 (11)
Spine	121 (9)	141 (9)
Upper/ lower extremities	982 (76)	1,166 (75)
Missing	0 (0)	0 (0)
Penetrating injury	97 (8)	102 (7)
Comorbidity		
Cardiovascular diseases	123 (10)	100 (6)
Diabetes	50 (4)	44 (3)
Epilepsy	18 (1)	22 (1)
Hypertension	121 (9)	96 (6)
Respiratory problems	47 (4)	29 (2)

Table 17: (Continued) Patients' Characteristics by Presence of a PHI at the Site of Injury

Variable	PHI information available Number (%)	PHI information not-available Number (%)
Hospital		
Montreal General Hospital	936 (73)	1152 (74)
Sacré Coeur	355 (27)	404 (26)
ISS		
0-15	1,031 (80)	1,214 (78)
16-25	148 (12)	175 (11)
26-49	102 (8)	143 (9)
>=50	9 (1)	22 (1)
Missing	0 (0)	0 (0)
Surgery [1]	297 (23)	358 (23)
Intensive care unit admission [2]	313 (24)	429 (28)
Death [3]	70 (5)	83 (5)
Major injury [4]	576 (45)	698 (45)
Variable	**Mean (SD) Median**	**Mean (SD) Median**
Age	51.1 (23.0) 47	52.0 (23.4) 48
Missing (%)	4 (0.3)	1 (0.1)
Time (minutes) [5]	30.6 (15.4) 27	31.5 (20.2) 26
Missing (%)	354 (27.4)	485 (31.2)
ISS	11.0 (9.4) 9	11.7 (10.4) 9
Missing (%)	0 (0)	1 (0.1)
PHI	2.2 (4.4) 0	
Hospital stay (days)	13.7 (19.7) 7.6	14.5 (27.0) 7.6
Missing (%)	37 (2.9)	30 (1.9)

1= Surgery (non- orthopaedic, or plastic) within 4 days since hospital admission
2= Intensive care unit admission within 7 days since hospital admission
3= Death at emergency room or death within 7 days since hospital admission
4= Major injuries defined according to Graph 2
5= Time between 911 call and departure of the ambulance from the scene

Table 18: Patients Characteristics by Major Injuries

Variable	Major injuries Number (%)	Non-major injuries Number (%)
Total	576 (45)	715 (55)
Gender		
Male	381 (66)	416 (58)
Female	194 (34)	299 (42)
Missing	1 (0)	0 (0)
Mechanism of injury		
Driver	76 (13)	66 (9)
Passenger	15 (3)	39 (6)
Motorcycle	21 (4)	20 (3)
Cyclist	10 (2)	12 (2)
Pedestrian	57 (10)	59 (8)
Fall above 15 ft	75 (13)	83 (12)
Fall below 15 ft	141 (25)	251 (35)
Firearm, stab, knife...	110 (19)	68 (10)
Blunt object	37 (6)	82 (12)
Other	37 (6)	35 (5)
Missing	1 (0)	0 (0)
Body region injured		
Head/ neck	254 (44)	190 (27)
Face	183 (32)	185 (26)
Thorax	169 (29)	97 (14)
Abdomen/ pelvis	111 (19)	41 (6)
Spine	67 (12)	54 (8)
Upper/ lower extremities	413 (71)	569 (80)
Missing	1 (0)	0 (0)
Penetrating injury	73 (13)	24 (3)
Comorbidity		
Cardiovascular diseases	56 (10)	67 (9)
Diabetes	26 (5)	24 (3)
Epilepsy	7 (1)	11 (2)
Hypertension	45 (89)	76 (11)
Respiratory problems	16 (3)	31 (4)

Table 18: (Continued) Patients Characteristics by Major Injuries

Variable	Major injuries Number (%)	Non-major injuries Number (%)
Hospital		
Montreal General Hospital	416 (72)	520 (73)
Sacré Coeur	160 (28)	195 (27)
ISS		
0-15	370 (64)	661 (92)
16-25	102 (18)	47 (7)
26-49	95 (17)	7 (1)
>=50	9 (2)	0
Missing	0 (0)	0 (0)
Surgery [1]	297 (52)	0
Intensive care unit admission [2]	313 (54)	0
Death [3]	70 (12)	0

Variable	Mean (SD) Median	Mean (SD) Median
Age	51.0 (23.4) 46	51.0 (22.5) 48
Missing	4 (0.7)	0 (0)
Time (minutes) [4]	30.0 (15.4) 26	31.1 (15.3) 28
Missing	170 (29.5)	184 (25.7)
ISS	15.1 (11.7) 10	7.6 (5.0) 9
Missing	0 (0)	0 (0)
PHI	3.8 (5.8) 1	1.0 (2.0) 0
Hospital stay (days)	17.9 (25.1) 10	10.6 (13.6) 6
Missing	36 (6.3)	1 (0.1)

1= Surgery (non- orthopaedic, or plastic) within 4 days since hospital admission
2= Intensive care unit admission within 7 days since hospital admission
3= Death at emergency room or death within 7 days since hospital admission
4= Time between 911 call and departure of the ambulance from the scene

Table 19: Distribution of Major Injuries by PHI Cutoff Values

PHI	Major injuries N (%)	Non-major injuries N (%)
0	262 (34)	508 (66)
1	43 (49)	44 (51)
2	4 (36)	7 (64)
3	65 (41)	94 (59)
4	43 (71)	18 (30)
5	45 (76)	14 (24)
6	14 (58)	10 (42)
7	14 (67)	7 (33)
8	19 (70)	8 (30)
9	2 (50)	2 (50)
10	5 (83)	1 (17)
11	6 (100)	0
12	2 (100)	0
13	1 (50)	1 (50)
14	1 (100)	0
15	2 (67)	1 (33)
16	0	0
17	0	0
18	3 (100)	0
19	0	0
20	36 (100)	0
21	0	0
22	3 (100)	0
23	0	0
24	6 (100)	0

Table 20: Proportion of Patients with Major Injuries for the 4 PHI Categories

PHI category	Major injuries N (%)	Non-major injuries N (%)
0	262 (34)	508 (66)
1-3	112 (44)	145 (56)
4-7	116 (70)	49 (30)
Above 7	86 (87)	13 (13)

Table 21: Sensitivities, Specificities, Positive, and Negative Predictive Values for the Cutoff Points of the PHI (Area Under the ROC Curve= 0.66, SD= 0.02)

PHI cutoff point	Sensitivity (95% CI)		Specificity (95%CI)		PPV[1] (95% CI)		NPV[2] (95%CI)	
0	1.00	(1.00-1.00)	0.00	(0.00-0.00)	0.45	(0.42-0.47)		
1	0.55	(0.52-0.57)	0.71	(0.69-0.74)	0.60	(0.58-0.63)	0.66	(0.63-0.69)
2	0.47	(0.44-0.50)	0.77	(0.75-0.79)	0.62	(0.60-0.65)	0.64	(0.62-0.67)
3	0.46	(0.44-0.49)	0.78	(0.76-0.80)	0.63	(0.60-0.66)	0.64	(0.62-0.67)
4	0.35	(0.32-0.38)	0.91	(0.90-0.93)	0.77	(0.74-0.79)	0.64	(0.61-0.66)
5	0.28	(0.25-0.30)	0.94	(0.93-0.95)	0.78	(0.76-0.81)	0.62	(0.59-0.64)
6	0.20	(0.18-0.22)	0.96	(0.95-0.97)	0.79	(0.77-0.81)	0.60	(0.57-0.62)
7	0.17	(0.15-0.19)	0.97	(0.96-0.98)	0.83	(0.81-0.85)	0.59	(0.57-0.62)
8	0.15	(0.13-0.17)	0.98	(0.97-0.99)	0.87	(0.85-0.89)	0.59	(0.56-0.62)
9	0.12	(0.10-0.13)	0.99	(0.99-1.00)	0.93	(0.92-0.94)	0.58	(0.56-0.61)
10	0.11	(0.10-0.13)	1.00	(0.99-1.00)	0.96	(0.94-0.97)	0.58	(0.56-0.61)
11	0.10	(0.09-0.12)	1.00	(0.99-1.00)	0.97	(0.96-0.98)	0.58	(0.55-0.61)
12	0.09	(0.08-0.11)	1.00	(0.99-1.00)	0.96	(0.95-0.97)	0.58	(0.55-0.60)
13	0.09	(0.07-0.11)	1.00	(0.99-1.00)	0.96	(0.95-0.97)	0.58	(0.55-0.60)
14	0.09	(0.07-0.10)	1.00	(1.00-1.00)	0.98	(0.97-0.99)	0.58	(0.55-0.60)
15	0.09	(0.07-0.10)	1.00	(1.00-1.00)	0.98	(0.97-0.99)	0.58	(0.55-0.60)
16	0.08	(0.07-0.10)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.55-0.60)
17	0.08	(0.07-0.10)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.55-0.60)
18	0.08	(0.07-0.10)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.55-0.60)
19	0.08	(0.06-0.09)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.57	(0.55-0.60)
20	0.08	(0.06-0.09)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.57	(0.55-0.60)
21	0.02	(0.01-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.56	(0.53-0.58)
22	0.02	(0.01-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.56	(0.53-0.58)
23	0.01	(0.00-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.56	(0.53-0.58)
24	0.01	(0.00-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.56	(0.53-0.58)

1=Positive predictive value
2=Negative predictive value

Table 22: Patients' Characteristics by Time Between 911 Call and Departure of the Ambulance from the Injury Site

Variable	Time > 39 min Number (%)	Time < 40 min Number (%)	Time=missing Number (%)
Total	166 (13)	771 (60)	354 (27)
Gender			
Male	60 (36)	502 (65)	235 (66)
Female	106 (64)	268 (35)	119 (34)
Mechanism of injury			
Driver	19 (11)	85 (11)	38 (11)
Passenger	7 (4)	24 (3)	23 (7)
Motorcycle	0	23 (3)	18 (5)
Cyclist	0	15 (2)	6 (2)
Pedestrian	3 (2)	71 (9)	41 (12)
Fall above 15 ft	22 (14)	88 (11)	48 (14)
Fall below 15 ft	95 (57)	225 (29)	68 (19)
Firearm, stab, knife...	3 (2)	108 (14)	67 (19)
Blunt object	12 (7)	81 (11)	26 (7)
Other	5 (3)	51 (7)	19 (5)
Body region injured			
Head/ neck	32 (19)	284 (37)	128 (36)
Face	33 (20)	226 (29)	109 (31)
Thorax	20 (12)	149 (19)	97 (27)
Abdomen/ pelvis	9 (5)	91 (12)	52 (15)
Spine	12 (7)	71 (9)	38 (11)
Upper/ lower extremities	153 (92)	573 (74)	256 (72)
Penetrating injury	1 (1)	60 (8)	36 (10)
Comorbidity			
Cardiovascular diseases	30 (18)	67 (9)	26 (7)
Diabetes	14 (8)	28 (4)	8 (2)
Epilepsy	5 (3)	8 (1)	5 (1)
Hypertension	38 (23)	61 (8)	22 (6)
Respiratory problems	5 (3)	32 (4)	10 (3)
Hospital			
Montreal General Hospital	117 (71)	571 (74)	248 (70)
Sacré Coeur	49 (30)	200 (26)	106 (30)

Table 22: (Continued) Patients' Characteristics by Time Between 911 Call and Departure of the Ambulance from the Injury Site

Variable	Time > 39 min Number (%)	Time < 40 min Number (%)	Time=missing Number (%)
Surgery [1]	47 (28)	171 (22)	79 (22)
Intensive care unit admission [2]	21 (13)	200 (26)	92 (26)
Death [3]	3 (2)	39 (5)	28 (8)
Major injury [4]	67 (40)	339 (44)	170 (48)

Variable	Mean (SD) Median	Mean (SD) Median	Mean (SD) Median
Age	66.8 (22.7) 74	49.6 (22.4) 46	47.1 (21) 44
ISS	9.5 (5.4) 9	10.8 (9.4) 9	12.0 (10.8) 9
PHI	0.9 (2.3) 0	2.2 (4.2) 0	2.9 (5.3) 0
Hospital stay (days)	16.2 (17.7) 11.7	13.7 (21.5) 6.8	12.5 (16.6) 7.5

1= Surgery (non- orthopaedic. or plastic) within 4 days since hospital admission
2= Intensive care unit admission within 7 days since hospital admission
3= Death at emergency room or death within 7 days since hospital admission
4= Major injuries defined according to Graph 2

Table 23: The Logistic Regression Model Selected for the First Triage Protocol

Variable	B	SE	OR (95%CI)
Age			
45-64	-0.08	0.17	0.91(0.66-1.29)
>=65	0.60	0.19	1.83(1.26-2.64)
Body region injured			
Face	-0.06	0.16	0.95(0.69-1.29)
Thorax	0.43	0.17	1.54(1.10-2.15)
Abdomen/ pelvis	0.90	0.22	2.46(1.60-3.79)
Spine	0.51	0.23	1.66(1.06-2.61)
Head/ neck	0.48	0.16	1.61(1.18-2.21)
Extremities	0.06	0.16	1.06(0.78-1.45)
Mechanism of injury			
Passenger	-1.05	0.37	0.35(0.17-0.72)
Motorcycle	0.04	0.39	1.04(0.48-2.24)
Cyclist	-0.12	0.50	0.89(0.33-2.36)
Pedestrian	-0.34	0.28	0.71(0.41-1.23)
Fall >15ft	-0.22	0.26	0.80(0.48-1.34)
Fall < 15ft	-0.46	0.25	0.63(0.39-1.03)
Firearm, stab	0.13	0.28	1.13(0.66-1.97)
Blunt object	-0.69	0.29	0.50(0.28-0.89)
Other	-0.01	0.33	0.99(0.52-1.89)
Comorbidity			
Cardiovascular diseases	0.20	0.22	1.23(0.79-1.88)
Diabetes	0.53	0.31	1.70(0.93-3.12)
Epilepsy	0.14	0.51	1.15(0.42-3.13)
Hypertension	-0.12	0.22	0.89(0.58-1.37)
Respiratory problems	-0.37	0.34	0.69(0.35-1.35)
PHI			
1-3	0.29	0.16	1.34(0.98-1.83)
4-7	1.08	0.22	2.95(1.91-4.53)
>7	2.13	0.33	8.45(4.41-16.07)

Table 24: Sensitivities, Specificities, Positive, and Negative Predictive Values for the Cutoff Points of the First Triage Protocol (Area Under the ROC Curve= 0.74, SE= 0.01)

Cutoff point	Sensitivity (95% CI)		Specificity (95%CI)		PPV[1] (95% CI)		NPV[2] (95%CI)	
0	1.00	(1.00-1.00)	0.00	(0.00-0.00)	0.45	(0.42-0.47)		
1	1.00	(1.00-1.00)	0.00	(0.00-0.01)	0.45	(0.42-0.47)	1.00	(1.00-1.00)
2	1.00	(1.00-1.00)	0.01	(0.01-0.02)	0.45	(0.42-0.48)	1.00	(1.00-1.00)
3	0.99	(0.98-0.99)	0.09	(0.08-0.11)	0.47	(0.44-0.49)	0.89	(0.87-0.91)
4	0.95	(0.94-0.96)	0.24	(0.21-0.26)	0.50	(0.47-0.53)	0.86	(0.84-0.88)
5	0.85	(0.83-0.87)	0.42	(0.39-0.44)	0.54	(0.51-0.57)	0.77	(0.75-0.79)
6	0.64	(0.62-0.67)	0.67	(0.64-0.69)	0.61	(0.58-0.64)	0.70	(0.67-0.72)
7	0.51	(0.49-0.54)	0.80	(0.78-0.83)	0.68	(0.65-0.70)	0.67	(0.65-0.70)
8	0.43	(0.41-0.46)	0.88	(0.86-0.90)	0.74	(0.72-0.77)	0.66	(0.63-0.68)
9	0.36	(0.33-0.38)	0.92	(0.91-0.94)	0.79	(0.76-0.81)	0.64	(0.61-0.67)
10	0.29	(0.26-0.31)	0.96	(0.95-0.97)	0.85	(0.83-0.87)	0.63	(0.60-0.65)
11	0.21	(0.18-0.23)	0.97	(0.96-0.98)	0.86	(0.84-0.88)	0.60	(0.58-0.63)
12	0.15	(0.13-0.17)	0.98	(0.97-0.99)	0.86	(0.84-0.88)	0.59	(0.56-0.62)
13	0.09	(0.08-0.11)	0.99	(0.99-1.00)	0.91	(0.90-0.93)	0.58	(0.55-0.60)
14	0.06	(0.05-0.08)	0.99	(0.99-1.00)	0.90	(0.89-0.92)	0.57	(0.54-0.60)
15	0.04	(0.03-0.05)	1.00	(0.99-1.00)	0.89	(0.87-0.91)	0.56	(0.54-0.59)
16	0.02	(0.01-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.56	(0.53-0.59)
17	0.01	(0.00-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.56	(0.53-0.58)
18	0.00	(0.00-0.00)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.55	(0.53-0.58)

1=Positive predictive value
2=Negative predictive value

Table 25: Results of the Logistic Regression Model Selected for the Second Triage Protocol for Patients with a PHI Between 1 and 3

Variable	B	SE	OR (95%CI)
Age			
45-64	0.23	0.35	1.26(0.63-2.50)
>=65	0.71	0.44	2.05(0.86-4.82)
Body region injured			
Face	0.25	0.35	1.28(0.65-2.55)
Thorax	0.59	0.38	1.81(0.86-3.80)
Abdomen/ pelvis	0.71	0.57	2.03(0.67-6.22)
Spine	0.49	0.43	1.63(0.70-3.79)
Head/ neck	0.58	0.34	1.79(0.92-3.48)
Extremities	0.24	0.34	1.27(0.65-2.48)
Mechanism of injury			
Passenger	-0.72	0.72	0.49(0.12-2.00)
Motorcycle	7.29	14.40	$1469.3(0.00\text{-}2.6*10^{15})$
Cyclist	-0.06	1.03	0.94(0.13-7.09)
Pedestrian	0.00	0.58	1.00(0.32-3.12)
Fall >15ft	0.83	0.56	2.30(0.77-6.87)
Fall < 15ft	-0.07	0.53	0.93(0.33-2.63)
Firearm, stab	1.10	0.57	3.00(0.98-9.18)
Blunt object	-0.01	0.59	1.00(0.31-3.15)
Other	0.81	0.75	2.24(0.52-9.78)
Comorbidity			
Cardiovascular diseases	0.76	0.60	2.13(0.66-6.93)
Diabetes	0.76	0.62	2.14(0.63-7.21)
Epilepsy	-1.44	1.23	0.24(0.02-2.64)
Hypertension	-0.52	0.59	0.60(0.19-1.89)
Respiratory problems	-0.31	0.76	0.73(0.17-3.25)

Table 26: Results of the Logistic Regression Model Selected for the Second Triage Protocol for Patients with a PHI Between 4 and 7

Variable	B	SE	OR (95%CI)
Body region injured			
Face	-0.20	0.50	0.82(0.31-2.18)
Thorax	0.43	0.46	1.53(0.62-3.79)
Abdomen/ pelvis	1.86	0.59	6.45(2.02-20.42)
Spine	1.39	0.85	4.03(0.76-21.24)
Head/ neck	1.04	0.51	2.84(1.04-7.69)
Extremities	0.22	0.43	1.24(0.54-2.89)
Mechanism of injury			
Passenger	8.26	41.79	$3884.55(0.00\text{-}1.4*10^{39})$
Motorcycle	7.48	26.56	$1767.89(0.00\text{-}7.1*10^{25})$
Cyclist	0.20	1.31	1.23(0.09-15.92)
Pedestrian	0.79	1.24	2.20(0.19-25.04)
Fall >15ft	0.03	0.75	1.03(0.24-4.48)
Fall < 15ft	-1.00	0.97	0.37(0.05-2.46)
Firearm, stab	-0.06	0.72	0.94(0.23-3.86)
Blunt object	-0.15	0.86	0.86(0.16-4.64)
Other	0.33	1.44	1.39(0.08-23.39)
Comorbidity			
Cardiovascular diseases	7.42	60.43	$1662.7(0.00\text{-}4.6*10^{54})$
Diabetes	1.23	85.47	$3.44(0.00\text{-}1.94*10^{73})$
Hypertension	1.43	1.23	4.18(0.38-46.56)
Respiratory problems	-0.60	1.31	0.55(0.04-7.15)

Table 27: Sensitivities, Specificities, Positive, and Negative Predictive Values for the Cutoff Points of the Second Triage Protocol for Patients with a PHI Between 1 and 3 (Area Under the ROC Curve= 0.72, SE= 0.03)

Cutoff point	Sensitivity (95% CI)		Specificity (95%CI)		PPV[1] (95% CI)		NPV[2] (95%CI)	
0	1.00	(1.00-1.00)	0.00	(0.00-0.00)	0.44	(0.38-0.50)		
1	1.00	(1.00-1.00)	0.01	(0.00-0.02)	0.44	(0.38-0.50)	1.00	(1.00-1.00)
2	1.00	(1.00-1.00)	0.01	(0.00-0.03)	0.44	(0.38-0.50)	1.00	(1.00-1.00)
3	0.97	(0.95-0.99)	0.03	(0.01-0.06)	0.44	(0.38-0.50)	0.63	(0.57-0.68)
4	0.97	(0.95-0.99)	0.08	(0.04-0.11)	0.45	(0.39-0.51)	0.79	(0.74-0.84)
5	0.88	(0.84-0.92)	0.33	(0.27-0.39)	0.51	(0.44-0.57)	0.79	(0.740-.84)
6	0.69	(0.63-0.74)	0.63	(0.57-0.69)	0.59	(0.53-0.65)	0.72	(0.67-0.78)
7	0.40	(0.34-0.46)	0.89	(0.85-0.93)	0.74	(0.68-0.79)	0.66	(0.60-0.72)
8	0.25	(0.20-0.30)	0.95	(0.93-0.98)	0.80	(0.75-0.85)	0.62	(0.56-0.68)
9	0.14	(0.10-0.19)	0.99	(0.97-1.00)	0.89	(0.85-0.93)	0.60	(0.54-0.66)
10	0.11	(0.07-0.14)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.59	(0.53-0.65)
11	0.07	(0.04-0.10)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
12	0.06	(0.03-0.09)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
13	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
14	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
15	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
16	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
17	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
18	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
19	0.05	(0.03-0.08)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.58	(0.52-0.64)
20	0.04	(0.01-0.06)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.57	(0.51-0.63)
21	0.03	(0.01-0.05)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.57	(0.51-0.63)
22	0.02	(0.00-0.03)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.57	(0.51-0.63)
23	0.01	(0.00-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.57	(0.51-0.63)
24	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.56	(0.50-0.62)

1=Positive predictive value
2=Negative predictive value

Table 28: Sensitivities, Specificities, Positive, and Negative Predictive Values for the Cutoff Points of the Second Triage Protocol for Patients with a PHI Between 4 and 7 (Area Under the ROC Curve= 0.75, SE= 0.04)

Cutoff point	Sensitivity (95% CI)		Specificity (95%CI)		PPV[1] (95% CI)		NPV[2] (95%CI)	
0	1.00	(1.00-1.00)	0.00	(0.00-0.00)	0.70	(0.63-0.77)		
1	1.00	(1.00-1.00)	0.02	(0.00-0.04)	0.71	(0.68-0.78)	1.00	(1.00-1.00)
2	0.98	(0.96-1.00)	0.16	(0.11-0.22)	0.74	(0.71-0.80)	0.80	(0.74-0.86)
3	0.72	(0.65-0.78)	0.59	(0.52-0.67)	0.81	(0.78-0.87)	0.47	(0.39-0.54)
4	0.34	(0.26-0.41)	0.92	(0.88-0.96)	0.91	(0.89-0.95)	0.37	(0.30-0.44)
5	0.17	(0.11-0.23)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.34	(0.27-0.41)
6	0.09	(0.04-0.13)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.32	(0.25-0.39)
7	0.08	(0.04-0.12)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.31	(0.24-0.38)
8	0.08	(0.04-0.12)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.31	(0.24-0.38)
9	0.08	(0.04-0.12)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.31	(0.24-0.38)
10	0.07	(0.03-0.11)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.31	(0.24-0.38)
11	0.03	(0.00-0.05)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.30	(0.23-0.37)
12	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.30	(0.23-0.37)
13	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.30	(0.23-0.37)
14	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.30	(0.23-0.37)
15	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.30	(0.23-0.37)

1=Positive predictive value
2=Negative predictive value

Table 29: Logistic Regression Model with All of the Independent Variables Being Included

Variable	B	SE	OR (95%CI)
Age			
45-64	-0.08	0.21	0.92(0.61-1.39)
>=65	0.71	0.22	2.03(1.32-3.13)
Body region injured			
Face	0.03	0.18	1.03(0.72-1.47)
Thorax	0.50	0.21	1.65(1.09-2.49)
Abdomen/ pelvis	0.78	0.26	2.18(1.31-3.63)
Spine	0.65	0.27	1.92(1.13-3.25)
Head/ neck	0.44	0.19	1.55(1.07-2.25)
Extremities	-0.01	0.19	0.99(0.68-1.44)
Mechanism of injury			
Passenger	-1.04	0.48	0.36(0.14-0.91)
Motorcycle	0.02	0.52	1.02(0.37-2.83)
Cyclist	-0.05	0.59	0.95(0.30-3.02)
Pedestrian	-0.32	0.34	0.73(0.37-1.41)
Fall >15ft	-0.18	0.31	0.83(0.45-1.53)
Fall < 15ft	-0.46	0.29	0.63(0.36-1.11)
Firearm, stab	0.48	0.34	1.61(0.83-3.15)
Blunt object	-0.66	0.33	0.52(0.27-0.99)
Other	-0.23	0.38	0.79(0.38-1.67)
Time >= 40 minutes	0.13	0.20	1.14(0.77-1.69)
Comorbidity			
Cardiovascular diseases	0.14	0.25	1.15(0.70-1.88)
Diabetes	0.62	0.34	1.86(0.95-3.62)
Epilepsy	-0.12	0.62	0.89(0.26-2.99)
Hypertension	-0.34	0.25	0.71(0.44-1.16)
Respiratory problems	-0.12	0.38	0.89(0.42-1.87)
PHI			
1-3	0.30	0.19	1.36(0.93-1.96)
4-7	0.83	0.26	2.29(1.38-3.82)
>7	2.13	0.42	8.39(3.69-19.17)

Table 30: Results of the Logistic Regression Model Selected for the Third Triage Protocol for Patients Below 65 Years of Age

Variable	B	SE	OR (95%CI)
Body region injured	0.82	0.17	2.27(1.63-3.17)
Mechanism of injury	0.57	0.16	1.76(1.29-2.42)
PHI			
1-3	0.37	0.18	1.45(1.02-2.06)
4-7	1.16	0.23	3.18(2.03-5.01)
>7	2.73	0.39	15.31(7.14-32.93)

Table 31: Results of the Logistic Regression Model Selected for the Third Triage Protocol for Patients 65 Years of Age or Older

Variable	B	SE	OR (95%CI)
Comorbidity	0.37	0.22	1.45(0.94-2.23)
PHI			
1-3	0.35	0.28	1.42(0.82-2.46)
4-7	1.50	0.49	4.50(1.72-11.71)
>7	1.39	0.54	4.01(1.39-11.57)

Table 32: Sensitivities, Specificities, Positive, and Negative Predictive Values for the Cutoff Points of the Third Triage Protocol for Patients Below 65 Years of Age (Area Under the ROC Curve= 0.76, SE= 0.02)

Cutoff point	Sensitivity (95% CI)		Specificity (95%CI)		PPV[1] (95% CI)		NPV[2] (95%CI)	
0	1.00	(1.00-1.00)	0.00	(0.00-0.00)	0.44	(0.42-0.47)		
1	0.93	(0.91-0.94)	0.27	(0.25-0.30)	0.50	(0.48-0.53)	0.82	(0.80-0.84)
2	0.91	(0.89-0.92)	0.33	(0.31-0.36)	0.52	(0.49-0.55)	0.82	(0.79-0.84)
3	0.76	(0.73-0.78)	0.61	(0.59-0.64)	0.61	(0.58-0.63)	0.76	(0.74-0.78)
4	0.72	(0.69-0.74)	0.66	(0.63-0.68)	0.62	(0.60-0.65)	0.75	(0.72-0.77)
5	0.54	(0.51-0.56)	0.85	(0.83-0.87)	0.74	(0.71-0.76)	0.70	(0.67-0.72)
6	0.44	(0.41-0.46)	0.91	(0.89-0.92)	0.79	(0.77-0.81)	0.67	(0.64-0.70)
7	0.39	(0.36-0.42)	0.92	(0.91-0.94)	0.80	(0.77-0.82)	0.66	(0.63-0.68)
8	0.39	(0.36-0.42)	0.92	(0.91-0.94)	0.80	(0.77-0.82)	0.66	(0.63-0.68)
9	0.18	(0.16-0.20)	0.98	(0.98-0.99)	0.90	(0.88-0.91)	0.60	(0.57-0.63)
10	0.18	(0.16-0.20)	0.98	(0.98-0.99)	0.90	(0.88-0.91)	0.60	(0.57-0.63)
11	0.17	(0.15-0.20)	0.98	(0.98-0.99)	0.89	(0.88-0.91)	0.60	(0.57-0.63)
12	0.10	(0.08-0.11)	0.99	(0.98-1.00)	0.88	(0.87-0.90)	0.58	(0.55-0.61)
13	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.56	(0.53-0.58)
14	0.00	(0.00-0.00)	1.00	(1.00-1.00)			0.56	(0.53-0.58)

1=Positive predictive value
2=Negative predictive value

Table 33: Sensitivities, Specificities, Positive, and Negative Predictive Values for the Cutoff Points of the Third Triage Protocol for Patients 65 years of age or older (Area Under the ROC Curve= 0.60, SE= 0.03)

Cutoff point	Sensitivity (95% CI)		Specificity (95%CI)		PPV[1] (95% CI)		NPV[2] (95%CI)	
0	1.00	(1.00-1.00)	0.00	(0.00-0.00)	0.45	(0.43-0.48)		
1	0.56	(0.54-0.59)	0.56	(0.54-0.59)	0.52	(0.49-0.54)	0.61	(0.58-0.64)
2	0.56	(0.54-0.59)	0.56	(0.54-0.59)	0.52	(0.49-0.54)	0.61	(0.58-0.64)
3	0.56	(0.54-0.59)	0.56	(0.54-0.59)	0.52	(0.49-0.54)	0.61	(0.58-0.64)
4	0.24	(0.21-0.26)	0.93	(0 .91-0.94)	0.73	(0.71-0.76)	0.59	(0.57-0.62)
5	0.24	(0.21-0.26)	0.93	(0.91-0.94)	0.73	(0.71-0.76)	0.59	(0.57-0.62)
6	0.24	(0.21-0.26)	0.93	(0.91-0.94)	0.73	(0.71-0.76)	0.59	(0.57-0.62)
7	0.16	(0.14-0.18)	0.95	(0.94-0.96)	0.73	(0.71-0.76)	0.58	(0.55-0.60)
8	0.16	(0.14-0.18)	0.95	(0.94-0.96)	0.73	(0.71-0.76)	0.58	(0.55-0.60)
9	0.16	(0.14-0.18)	0.95	(0.94-0.96)	0.73	(0.71-0.76)	0.58	(0.55-0.60)
10	0.16	(0.14-0.18)	0.95	(0.94-0.96)	0.73	(0.71-0.76)	0.58	(0.55-0.60)
11	0.16	(0.14-0.18)	0.95	(0.94-0.96)	0.73	(0.71-0.76)	0.58	(0.55-0.60)
12	0.10	(0.08-0.11)	0.96	(0.95-0.97)	0.69	(0.67-0.72)	0.56	(0.54-0.59)
13	0.02	(0.01-0.02)	0.99	(0.99-1.00)	0.60	(0.57-0.63)	0.55	(0.52-0.58)
14	0.02	(0.01-0.02)	0.99	(0.99-1.00)	0.60	(0.57-0.63)	0.55	(0.52-0.58)
15	0.01	(0.01-0.02)	1.00	(1.00-1.00)	1.00	(1.00-1.00)	0.55	(0.52-0.58)

1=Positive predictive value
2=Negative predictive value

Table 34: Comparison Between the Different Triage Protocols

	Cutoff value	Sensitivity	Specificity	PPV[1]	NPV[2]	AUC[3](SE)
PHI	1	0.55	0.71	0.60	0.66	0.66(0.02)
First protocol	4	0.95	0.24	0.50	0.86	0.74(0.01)[5]
Second protocol						
PHI 1-3	5	0.88	0.33	0.51	0.79	0.72(0.03)
PHI 4-7	2	0.98	0.16	0.74	0.80	0.75(0.04)
Overall	(5,2)[4]	0.52	0.79	0.66	0.67	
Third Protocol						
Age <65	1	0.93	0.27	0.50	0.82	0.76(0.02)[5]
Age >64	1	0.56	0.56	0.52	0.61	0.60(0.03)[5]
Overall	(1,1)[6]	0.80	0.36	0.50	0.70	

1=Positive Predictive value
2=Negative predictive value
3=Area under the ROC curve
4=Cutoff value of 5 for the scale developed for patients with a PHI between 1-3
Cutoff value of 2 for the scale developed for patients with a PHI between 4-7
5=The area under the ROC curve is significantly different than the (alpha = 0.05)
6=Cutoff value of 1 for the scale developed for patients below 65 years of age
Cutoff value of 1 for the scale developed for patients above 64 years of age

Figures

Figure 1: Urgence Santé Triage Protocol

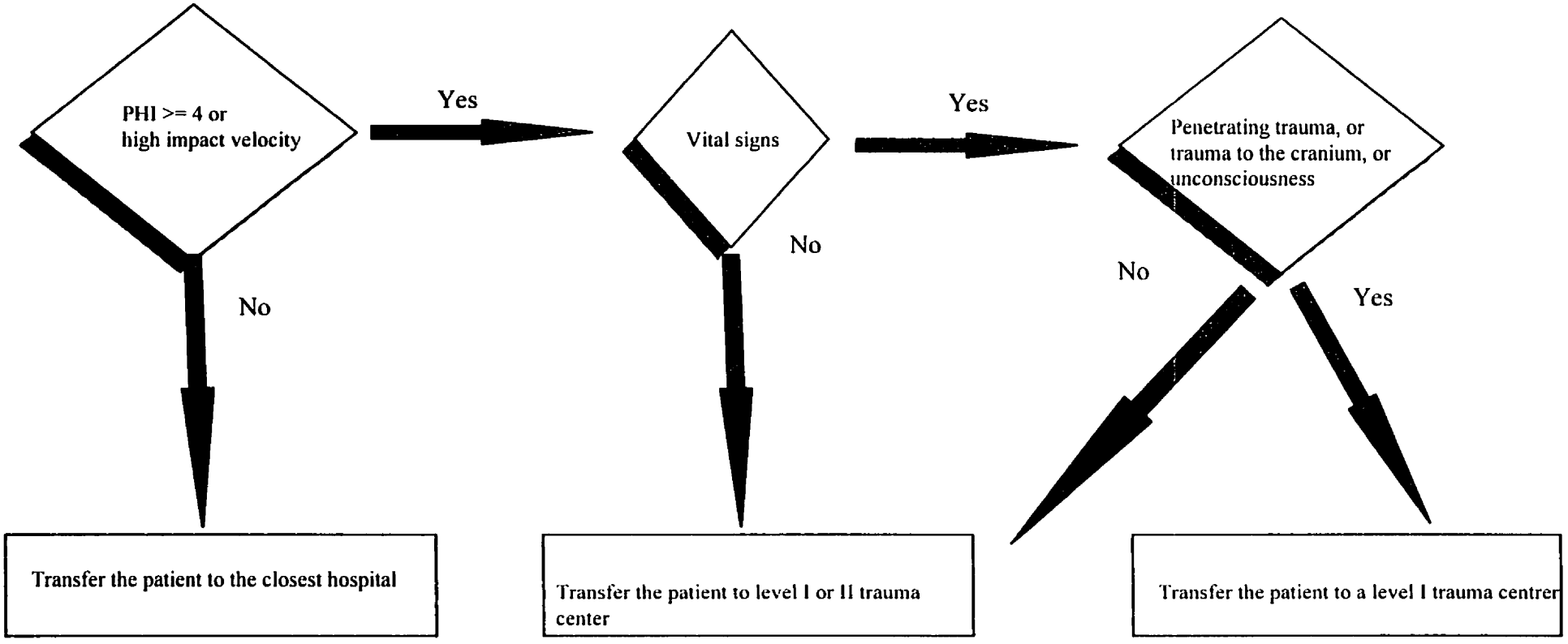

Figure 2: Definition of Major Trauma

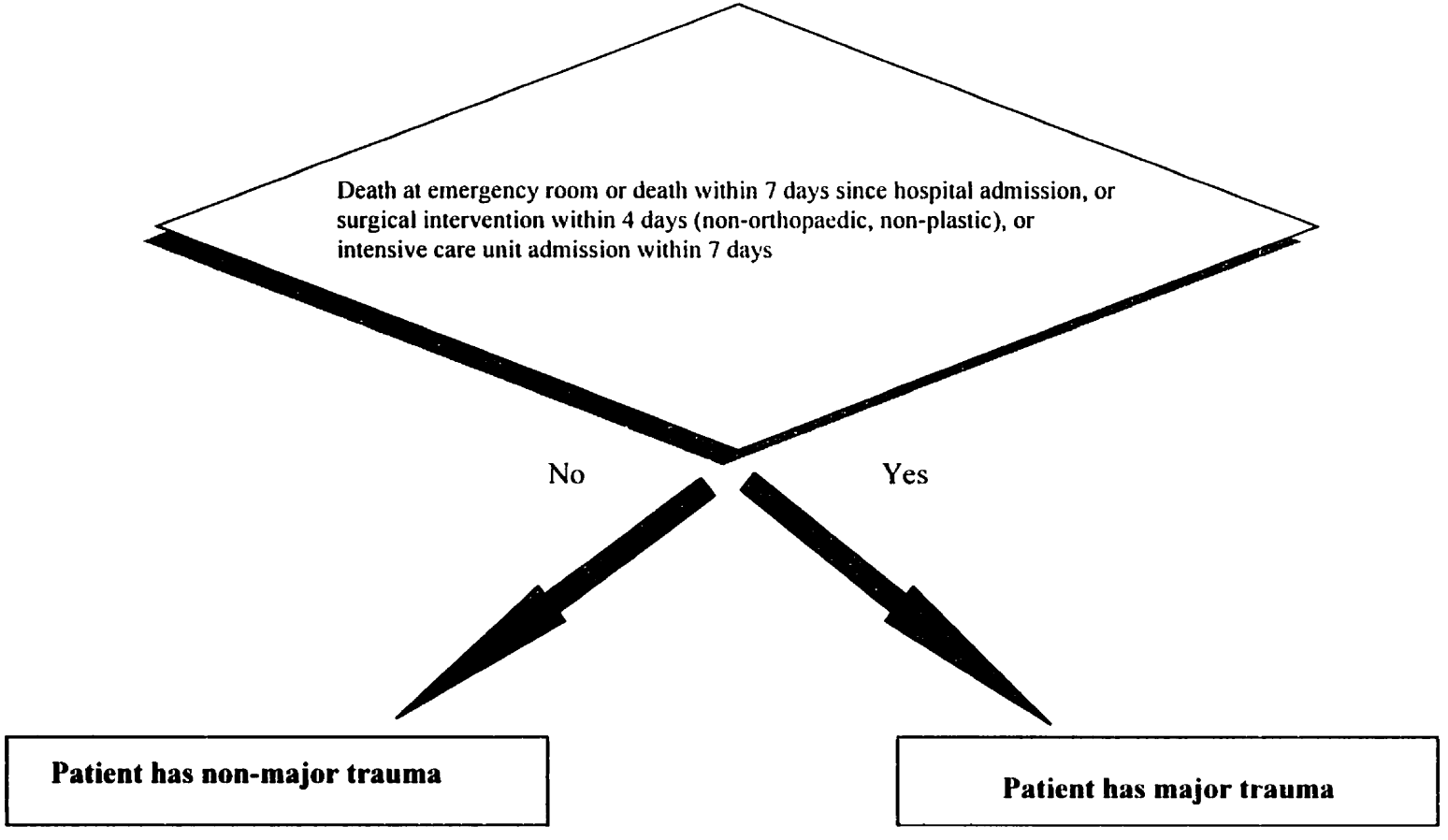

Figure 3: ROC Curve of the PHI

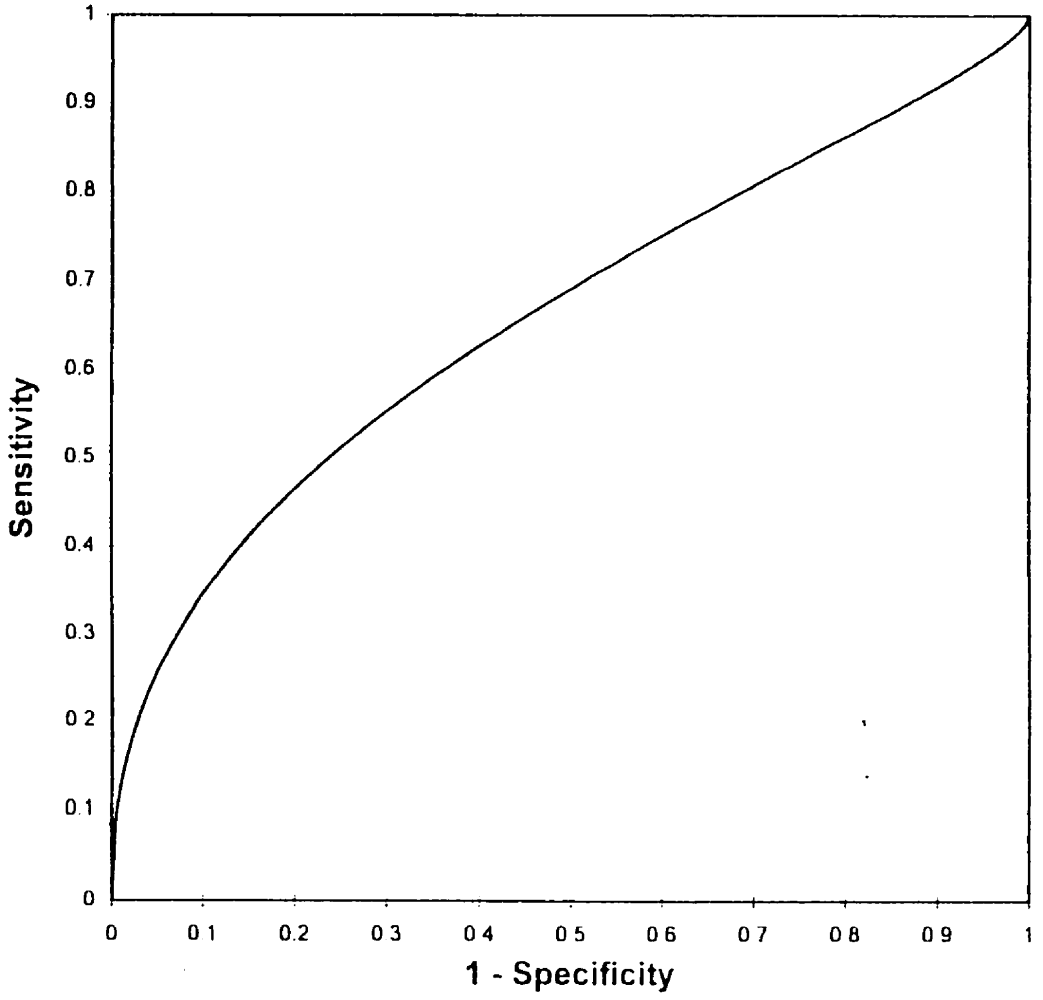

Figure 4: ROC Curve of the First Trauma Triage Protocol

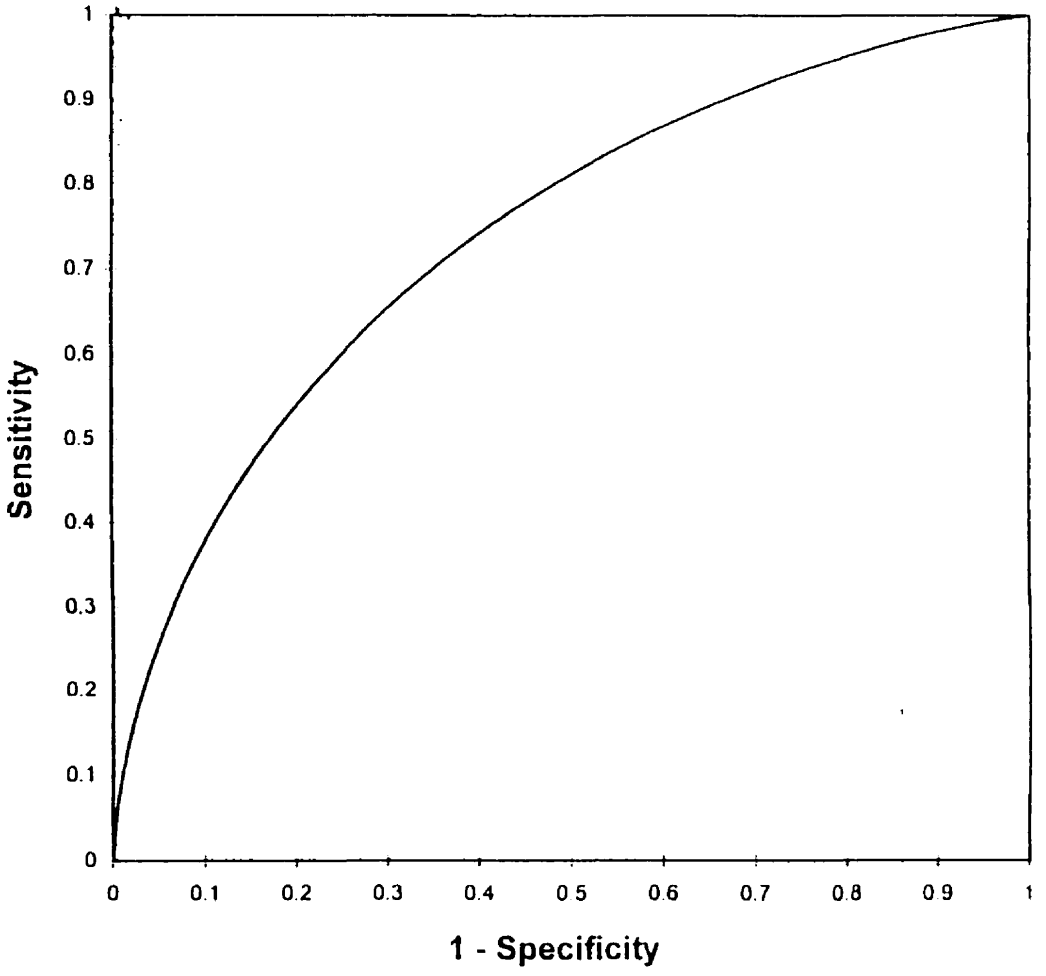

Figure 5: ROC Curve of the Second Trauma Triage Protocol (PHI 1-3)

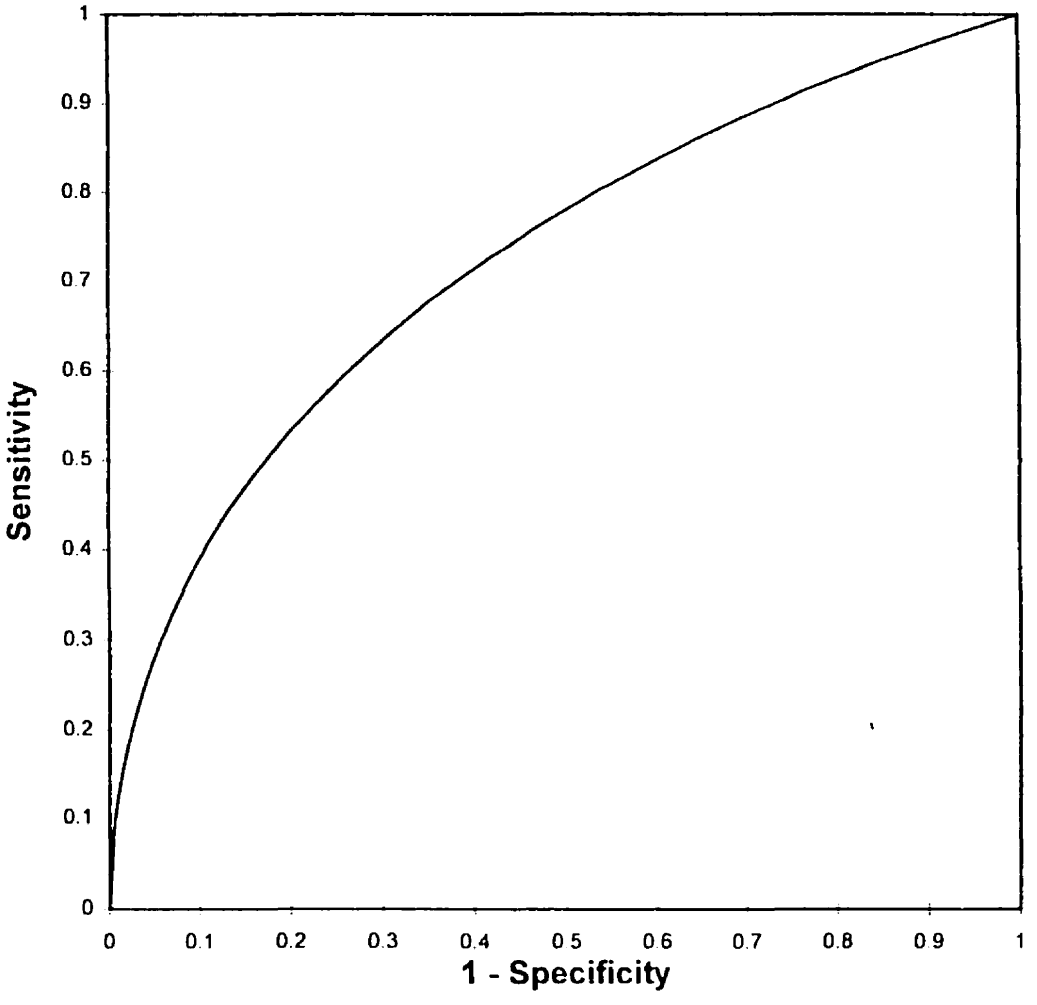

Figure 6: ROC Curve of the Second Trauma Triage Protocol (PHI 4-7)

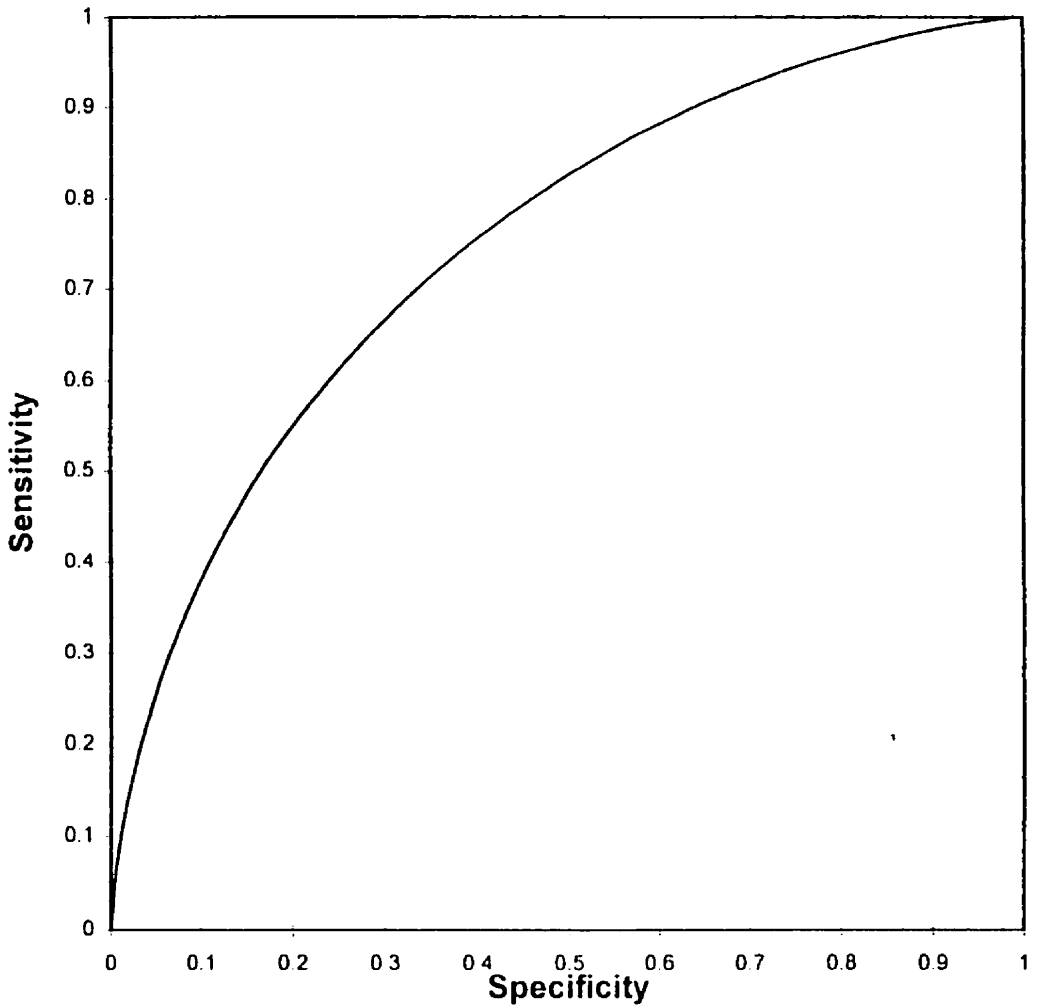

Figure 7: ROC Curve of the Third Trauma Triage Protocol (Ages Below 65 Years)

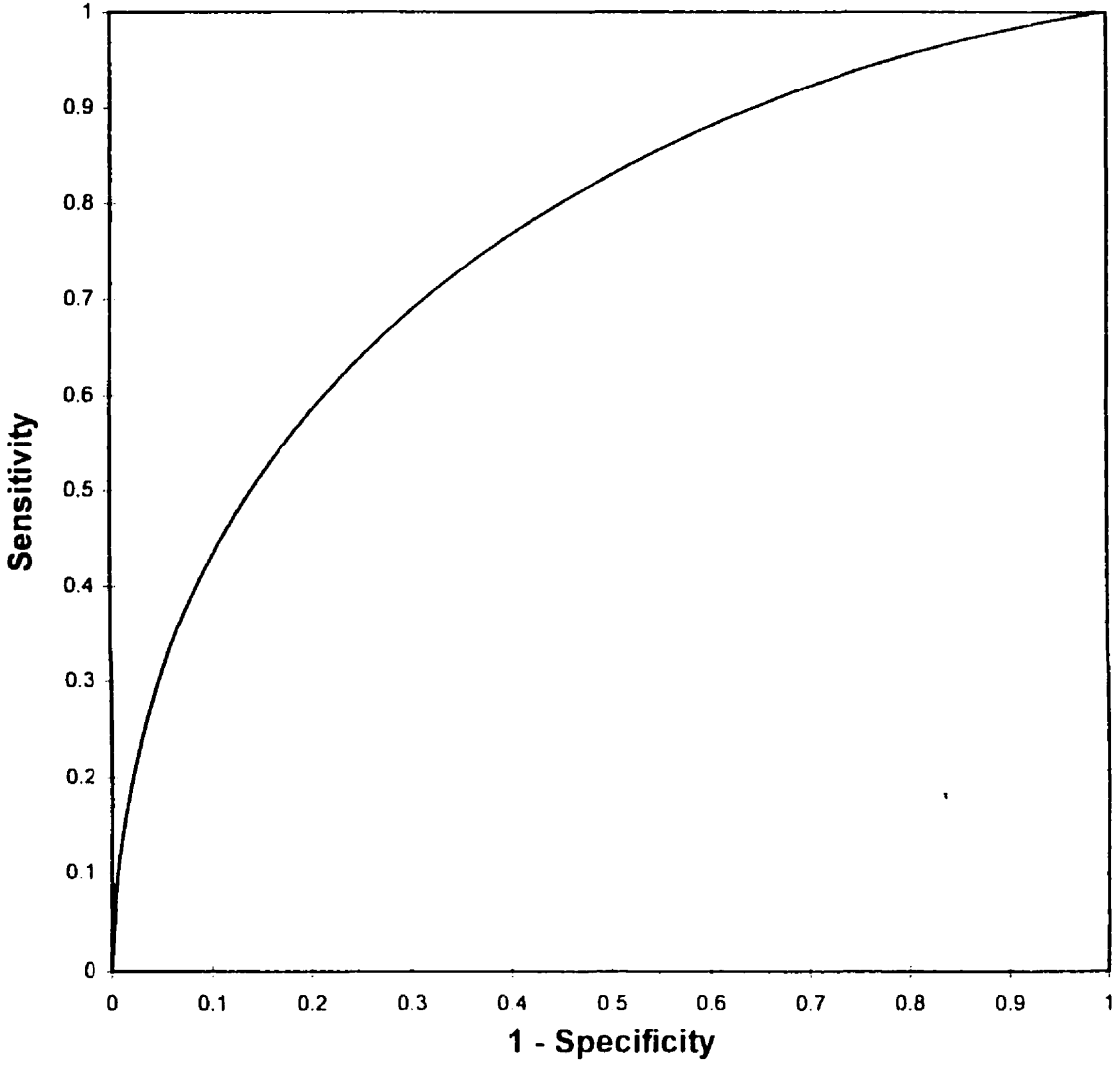

Figure 8: ROC Curve of the Third Trauma TRiage Protocol (Ages Above 64 Years)