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The urban injury severity score (UISS) better predicts mortality following penetrating gunshot wounds (GSW)

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ABSTRACT

Background: The Injury Severity Score (ISS) and the New ISS (NISS) underscore injury severity after GSW. This study assesses the Urban ISS (UISS), which incorporates all injuries.
Methods: Complete trauma program registry (TPR) data and chart analyses were performed on 585 patients (pts) over 28 months. Factors analyzed included age, gender, ISS, NISS, UISS, time of admission, intent of injury, race, number GSW, weapon, and outcome.
Results: The 585 patients could be categorized within three groups. The first group included 98 pts with low ISS (1–2), no organ injuries, and early discharge; the second group included 47 patients with severe shock who died during operation; the third group of 442 pts were admitted after operation. All injury scores correlated ($p < 0.001$) with assault, number GSW, death, and length-of-stay (LOS). Death and LOS correlated closely with assault and the resultant number of GSW, best seen with UISS compared to ISS or NISS. Race and admission time did not correlate with death or LOS.
Conclusions: UISS correlates better than ISS and NISS in victims of inner-city firearm injuries.

Introduction

Firearm injuries, a common surgical challenge, present a wide spectrum of injury severity.[1] Dr. Susan Baker, in 1974, performed multiple mathematical correlations of national data on abbreviated injury scores (AIS) after blunt injury in order to develop what is now known as the Injury Severity Score (ISS); this provided the best fit, at that time, for correlating blunt injury severity with death and morbidity.[2] The highest AIS from three of six anatomic compartments was squared and added, yielding a score of 1–75. The ISS was widely accepted and was later applied to penetrating injury.[3] This application to penetrating wounds led to an underscoring of injury severity, especially in patients with multiple gunshot wounds to a single anatomic cavity causing multiple organ injuries within that cavity.[4] Osler, in 1997, created the New ISS (NISS), which allowed for the two highest AIS values from a single anatomic compartment to be included in the calculation.[4] This reduced but did not eliminate underscoring after penetrating wounds.[3,5] The present study was designed to evaluate a new scoring system called the Urban ISS (UISS), in which all organ injuries in all six anatomic compartments are included in the calculation so that patients with multiple injuries within a single anatomic compartment are not underscored.

Methods

A retrospective review of prospectively stored trauma program registry (TPR) data and complete chart analyses was performed on 585 patients with gunshot wounds (GSW) admitted to an inner-city trauma center over 28 months from 1/1/2012 through 4/30/2014. Factors assessed included reason for injury (assault, accident, law enforcement, or unknown); race; gender; age; time of admission (6 p.m.–6 a.m. versus 6 a.m.- 6 p.m.); weaponry (pistol, rifle, or shotgun); fate; length-of-stay (LOS); maximum AIS for each anatomic area; number of GSW; ISS, NISS, and UISS calculated by one author (CEL) to correct for well-known TPR errors.[6] The number of GSW after a shotgun wound was listed as one or two depending upon whether the weapon had a single or double barrel. The AIS was calculated for each injury in the classic anatomic compartments, namely, head and neck, chest, abdomen and pelvis, extremities, neurological system, and maxillo-facial. The severity of injury, or AIS, was categorized as 1-mild, 2-moderate, 3-serious, 4-critical, and 5-immediately life-threatening. The highest AIS score from three of these six anatomic compartments was squared and then added so that the final ISS ranged from 1 to 75. The NISS

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allowed for two injuries to be scored from the same anatomic compartment, but the final NISS would still be 1–75. The UISS scored all injuries in all six of the anatomic compartments, which were then squared and added so that the maximal score could be greater than 75. Assault, which included six suicide attempts, and six police GSW were grouped as "assault"; likewise, accidental and unknown cause of injury were grouped as Acc/Unk. Because these penetrating firearm wounds occurred primarily in African American (AA) pts, all other racial groups were defined as non-AA patients for statistical analyses between the two groups. The comparisons between the patient groups as related to AA patients versus non-AA patients, assault versus Acc/Unk, the numbers of GSW, and the time of patient arrival at the hospital, being daytime or nighttime, were made by Independent-Samples T Test, whereas the different correlations were made by linear regression analyses. This study was approved by the Institutional Investigational Review Board.

Results

The 585 patients were stratified into three groups. There were 98 patients with single (81 patients) or two (17 patients) superficial wounds not involving any organs and with an ISS of 1 or 2 who were discharged home. Most (74 patients) were male with an average age of 37 ± 6.2 years (15–92 years).

The remaining 487 patients were primarily male (442 patients) and had an average age of 36 ± 12.9 years SD. There were 405 AA patients (83.2%) and 82 non-AA patients (16.8%). The injury was caused by assault in 353 patients (72.5%), law enforcement activity in 6 patients (1.2%), accident in 66 patients (13.6%), and unknown in 62 patients (12.7%). Thus, the percent of patients with purposeful injury was 73.7% compared to 26.3% Acc/Unk injury. The weapon used was a pistol in 455 patients, a rifle in 9 patients, a shotgun in 20 patients, and unknown in 3 patients. Most patients (354) were admitted during the night hours (6 p.m.-6 a.m.) including 306 who survived and 48 who died compared to 133 patients admitted during the day hours including 117 who survived and 16 who died.

There were 47 patients who died in the ED (15 patients) or in the OR (32 patients); 42 (82%) were AA patients. The deaths in these 47 patients were caused by inability to control hemorrhage. These patients typically had multiple gunshot wounds (Average = 3.6), and their injuries were caused primarily by assault (43 patients). All three injury severity scores correlated ($p < 0.001$) with the number of GSW and averaged 32.4 ± 18.6 for ISS, 40.0 ± 11.8 for NISS, and 50.4 ± 22.6 for UISS. This included three patients with an ISS below 15 and 5 patients with an ISS of 15–24; 2 patients had an NISS of 15–24; all 47 patients had a UISS over 25 including 8 patients with a UISS over 75. The UISS was significantly higher ($P < 0.001$) than the NISS or the ISS. The statistical correlations were similar when the UISS, over 75 in these 8 patients, was capped at 75.

The reason for injury and the number of GSW with resultant high injury scores also affected outcome as measured by LOS and death in the 440 patients who survived operation (Fig. 1). The LOS was 4.5 ± 5.9 days, and the average injury scores were 9.1 ± 8.4 for ISS, 12.2 ± 10.9 for NISS, and 15.3 ± 14.9 for UISS. All three injury scores correlated ($p < 0.001$) with LOS; when the correlation curves of the three injury severity scores were compared, the UISS slope was significantly steeper than the ISS and the NISS (Fig. 1). There were 101 patients with three or more GSW (3–10) including 26 patients who died during operation and six of 75 patients who died after operation. These 101 patients had an average ISS of 16.3 ± 9.7, an NISS of 21.7 ± 12.1, and a UISS of 32.3 ± 17. For the 18 patients who were admitted but died after operation, the ISS averaged 25.5 ± 9.5, the NISS averaged 36.0 ± 14.8, and the UISS averaged 50.0 ± 20.5. This included 3 patients with an ISS below 15 and 4 patients with an ISS from 15 to 24 and 1 patient with an NISS of 18; all 18 deaths had a UISS over 25 including 2 patients with a UISS over 75. None of the three injury scores showed a significant correlation with LOS due to the high number of patients (11 of 18) who died within 72 h.

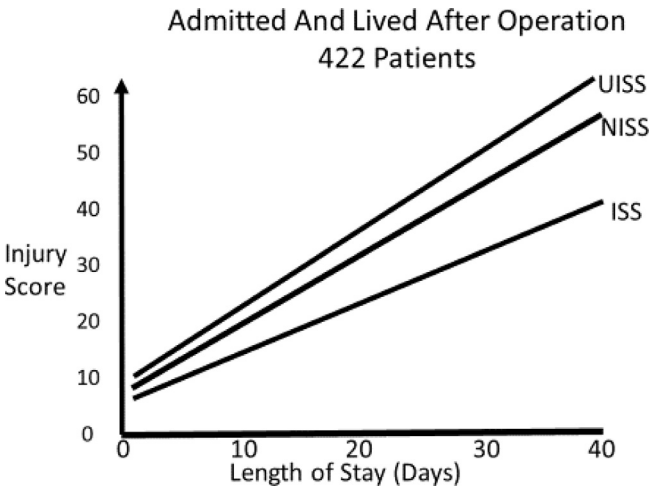

Fig. 1. All three injury scores correlated ($p < 0.001$) with LOS in the 422 patients who survived after emergency operation. The slope for UISS was significantly ($p < 0.001$) steeper than slopes for the ISS and NISS.

This relationship between number of GSW and LOS was not affected by race (Table 1). The 363 AA patients admitted to hospital after operation were younger than the 77 non-AA patients (35.1 ± 12.6 vs 39.5 ± 14.6; $p = 0.008$), but both groups had comparable LOS, which averaged 4.5 ± 6.5 days for AA patients and 5.6 ± 6.8 days for non-AA patients (Table 1). Both groups also had similar injury scores. Race did not affect mortality, which was 3.4% for the AA patients and 5.6% for the non-AA patients ($p = 0.46$). The injury scores were much lower in the 422 survivors, averaging 9.2 ± 8.7 for ISS, 12.3 ± 11 for NISS, and 14.35 ± 14.6 for UISS, but were similar for AA patients and non-AA patients (Table 1).

There were 359 patients injured by felonious assault, including 6 suicidal patients, or police action (assault) compared to 128 patients injured by accident or unknown (Acc/Unk) reason. When the patients with unknown reason for injury with only one GSW were analyzed, the injury scores were essentially identical with the 66 victims of accidental injury; therefore they were categorized as one group of 128 Acc/Unk victims, which could then be compared to the

Table 1
Demographics on 487 patients admitted after firearm injury.

	AA	Non-AA
Number of Pts	405 (83.2%)	82 (16.8%)
Reason for Injury		
Assault	359 (73.7%)	64 (78%)
Acc/Unk	134 (26.3%)	18 (22%)
Weapon		
Pistol	333	127
Rifle	8	1
Shotgun	16	4
Unknown	1	2
Gender		
Male	325	122
Female	33	12
Death (%)	3.4	5.6
LOS (days)	4.1	5.3

AA equals African American patients and non-AA is composed of Caucasian, Latino, and Native American patients. There were no significant differences in death and LOS between the two groups.

359 assault victims. Death and LOS were affected by reason of injury. The age (36.5 ± 12) was greater ($p = 0.007$) in the assault victims compared to the Acc/Unk injures (32.9 ± 12.4). All three injury scores were markedly elevated ($p < 0.001$) after assault, averaging 13.9 ± 13.4 vs 6.6 ± 6.2 for ISS, 18.5 ± 15.1 vs 8.1 ± 8.0 for NISS, and 24.9 ± 22.5 vs 8.2 ± 10.4 for UISS. Assault victims had more ($p < 0.001$) GSW (2.1 ± 1.6) compared to Acc/Unk injury (1.1 ± 0.9). A similar pattern was seen in the 300 assault victim survivors when compared to the 123 Acc/Unk victim survivors. Regarding the 59 patients who died after assault versus the 6 patients who died after Acc/Unk injury, only the UISS was significantly higher ($p = 0.018$) for the assault victims compared to the ISS ($p = 0.48$) and the NISS ($p = 0.18$). When the 72 assault victims with three or more GSW were compared to the 8 patients with unknown reason for injury with three or more GSW, the age and the three injury scores were similar. Both groups had very high injury scores, suggesting that these 8 patients were really assaulted; protection of the identity of a known assailant is often seen in an inner-city trauma center.

Time of day that the 487 patients arrived affected volume but not injury severity, death rate, or LOS. During the daytime hours from 6 a.m.–6 p.m., 133 patients with an average age of 34.5 years were admitted compared to 354 patients with an average age of 38.4 admitted during the nightshift from 6 p.m.–6 a.m. The average LOS was 4.4 days following daytime admission and 4.8 days following nighttime admission. ($p = 0.61$) The percent of patients who survived was the same in each group; 117 patients (88%) lived and 16 patients (12%) died after daytime admission compared to 306 (86.5%) survivors and 49 (13.5%) deaths after night admission (p-0.7 for survivors). The average GSW was 1.7 and 1.6 respectively for all patients admitted during these two time periods, whereas these averages rose to 3.3 and 3.7 respectively for those patients who died following the day admission and night admission respectively. Death occurred in 11 (69%) assault victims after daytime admission and 44 (89%) assault victims after night time admission.

The reason for injury was also evaluated as it relates to the site of injury. The percent of patients with injuries to multiple anatomic compartments was always greater in the assault victims due to the increased number of GSW. The percent of injuries for the assault and Acc/Unk subgroups was 10.2% vs 2.0% for head and neck, 25.6% vs 4.5% for the chest, 27.9% vs 4.7% for the abdomen, 44.5% vs 17.2% for the extremities, 7.2% vs 1.2% for the neurological system, and 6.0% ± 0.2% for maxillofacial injuries. Thus, the more common anatomic sites of injuries for both subgroups were the extremities, abdomen, and chest.

Discussion

Firearms in the United States cause 67% of homicides, 50% of suicides, and are used in 43% of robberies and over 20% of non-lethal assaults.[1] Each year 30,000–40,000 victims die of firearm injuries; this includes many children and teenagers.[1,7] Most deaths are caused by assaults (79%) in AA patients, whereas accidents are more common in children.[1,7] These mortality statistics do not highlight the number of patients with firearm related, life-changing disabilities from acute spinal cord injury, limb amputation, multiple organ failure, and the post-traumatic stress disorder.[1,8]

Many factors related to geography, gender, race, reason for injury, number of GSW, and injury severity affect outcome.[1,3,9,10] Most victims of firearm injury within an inner-city environment are young AA patients (69%) and the weapon is a pistol (92%). The ethnic background, in this study, reflects the citizens within the city trauma system region covered by the Detroit Receiving Hospital and will be different from that seen in a rural area.[1,9]

Within an inner city environment, death and LOS after GSW are functions of intent of injury, namely assault, resulting in an increased number of GSW and higher injury scores.[1] vol increases during the night hours (73%) versus the day hours (27%), but the severity of injury is similar. Thus, the hospital resources, including physician availability, must be available to treat the most severe injuries at all times of the day. Both assault victims and Acc/Unk victims were more likely to have injuries of the extremities, abdomen, and chest in contrast to a prior report that the assault victims more likely have head and neck injuries and Acc/Unk victims usually have extremity injuries.[1]

Prior reports suggest that AA patients fare less well than non-AA patients.[1,10] The data, in this study, demonstrate that outcome as judged by survival and LOS are not affected by race. Whether admitted during the day or nighttime hours, death and LOS varied closely with injury scores and were similar for AA patients and non-AA patients. Worse outcomes have also been reported in non-white Hispanic patients; the number of Latino patients was too small to evaluate as a separate group.[10]

Problem resolution of urban firearm violence is a multistep challenge including definition, prevention, provision of care, and evaluation of care to assist in ongoing performance improvement.[1,6] The data, in this study, define the challenge of inner-city firearm violence in a large northern United States city. Prevention efforts must be directed to societal issues such as job availability, early education, close relationships between law enforcement agencies and the citizenry, and legal efforts to reduce accessibility to weapons.[11,12] Clearly, this is not the focus of this report, which deals with the provision and assessment of care to better define the quality and, thereby, implement performance improvements.

Following the landmark paper by Baker in 1774, a myriad of injury scoring systems have evolved. These systems may utilize severity of anatomic injuries, associated physiologic derangements, and/or some combination of both.[1,3,4,6] Each scoring system has value within limitations depending on the purpose for which the system is being used. Over the years, the scoring systems looking at anatomic injury, namely the ISS and NISS, have remained the most frequently used systems for most TPRs, particularly as it relates to the American College of Surgeons (ACS) Verification Review Committee (VRC) and the Trauma Quality Improvement Program (TQIP). The VRC identifies a minor injury as having an ISS of 9 or less, a moderate injury with an ISS of 10–14, a major injury of 16–24, and life-threatening injury of 25 or greater.[6] This grading system helps define the need for a trauma team activation and helps determine when a bad outcome is expected or not expected.[6] This SYSTEM aids the trauma center peer review committee with the implementation of performance improvement. Both the ISS and the NISS are included within the TPR of trauma centers being surveyed by the VRC. The data, described herein, show that the UISS, when used for penetrating firearm injuries within an urban environment, provides a better estimate of injury severity as suggested by LOS and mortality rates than does the ISS or NISS. This improved estimate of morbidity and mortality in an urban environment parallels the military injury severity score (mISS) system, which better defines AIS of wounds encountered in an active military theater.[3] Similarly, the UISS would provide a better gage for severity of injury and quality analyses in an urban environment where the injuries are inflicted primarily with pistols during a purposeful assault. This is exemplified by the LOS statistic and the observation that eight of 65 deaths had ISS scores less than 25 and two of these deaths had NISS less than 25; three of these 65 deaths had ISS less than 15 and two had an ISS less than 10. All deaths had UISS scores over 25. A similar pattern likely will be seen with multi-center analyses with larger numbers of deaths.

The UISS system should not be difficult to implement. All charts of injured patients in all trauma centers are routinely analyzed, and all organ injuries are documented. The addition of specific injuries into the already six anatomic compartments on the TPRs would not be difficult and the tabulation of the UISS could be easily built into the TPR programs. Likewise, it would be quite simple to cap the UISS at 75 as there is no significant difference in the analyses when patients with a UISS greater than 75 are capped at 75. None of the patients who died during operation or following operation had UISS scores below 25. This bespeaks of the fact that the UISS would be more helpful in assessing performance improvement in an inner-city trauma center when reviewing patients with penetrating gunshot wounds.

This study has several limitations. First, the data come from one inner city trauma center that treats only adults and may not apply to suburban, rural, or pediatric trauma centers.[7,9,10] Next, there were no analyses done for the military injury severity score (mISS), which takes into account devastating injuries associated with military weapons. Since few were injured by high-velocity weapons or exploding bombs, the addition of mISS did not seem appropriate. Also, the low number of Latino patients did not allow for significant analyses in those patients; the findings, in this study, would likely reflect most Midwest Level I urban trauma centers. Finally, the use of the UISS creates the potential for the score to exceed 75, which could mandate a revision of current TPR; this could be circumvented by having a maximal score of 75 as is done with the mISS. When the 11 patients with UISS more than 75 were capped at 75, the statistical analyses were the same.

In conclusion, this study demonstrates that the most commonly used firearm weapon in an inner city trauma center is the pistol. The likelihood of death or increased LOS reflects the purpose of injury, namely assault, which leads to more GSW with higher injury scores. Resultant death or prolonged LOS are not related to the admission time of day or race. All three injury scores correlate significantly with death and with LOS in survivors; the UISS provided a better correlation for death and LOS than the ISS or NISS. For patients who survived operation but died after admission to the hospital, only the UISS correlated significantly with death, The use of UISS may provide a better tool for severity assessment in victims of inner-city firearms.

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Conflicts of interest

The authors of the paper have nothing to disclose or any conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.09.013.

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