The impact of time of admission on major complications and mortality in patients undergoing emergency trauma surgery

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Submitted 03-07-11. Accepted 03-12-10

Background Previous studies have shown a relationship between time of admission to hospital and mortality rates; however, it is uncertain whether such a relationship exists for patients requiring emergency trauma surgery.

Methods We included all trauma patients, except those with moderate to severe burns, who presented to a university-affiliated level 1 trauma center and underwent surgery, from 1995 until 2001 (n = 1044). We conducted univariate and multivariate analyses in which the dependent variables were in-hospital mortality and major complications, and the independent variables were the time of presentation to the trauma centre (nighttime vs. daytime, weekend vs. weekday, month of year, and year), age, sex, injury severity score, type of operative procedure, and total number of operative procedures.

Results None of the factors related to time of presentation were associated with major complications or mortality. Factors predictive of increased mortality were higher ISS (odds ratio 1.07; 95% confidence interval 1.03–1.08), older age (1.04; 1.03–1.07), operations involving the cardiovascular system (1.7; 1–2.6), "miscellaneous" operative procedures (1.8; 1.1–2.9), and major complications (2.4; 1.4–4.2).

Interpretation Time of presentation for emergency trauma surgery was not associated with differences in major complications or in mortality.

Trauma is responsible for the deaths of more North Americans aged 1–34 years than all other causes combined (Trunkey 1984, Health Division 1987–1990). Observational studies of trauma patients have suggested that a substantial proportion of in-hospital deaths were preventable (Ottoson and Krantz 1984, American College of Surgeons 1994). The efficiency of trauma care systems may be adversely affected by clinicians working late into the night, by reduced staff during the night, weekends or holiday seasons, or during certain months of the year that may be associated with increased rates of trauma admission. Each of these situations may place a strain on trauma systems (Bell and Redelmeier 2001, Claridge et al. 2001). Furthermore, Bell and Redelmeier (2001) have proposed criteria associated with greater risk of mortality for admittance to hospital on weekends, which patients admitted for emergency trauma surgery meet. Given the lack of available literature on the possible association between time of presentation for acute trauma surgery and major complications and mortality, we analysed data recorded in a trauma register over a 6-year period.

Methods

The data for this study came from the trauma registry of a Canadian university-affiliated, level 1 trauma center, and were available from its inception on April 3, 1995 to April 22, 2001. Our trauma centre admits the most severe trauma in its area, and all admissions present with an Injury Severity Score (ISS) of greater then 13. All individuals who sustain traumatic injuries are entered prospectively into the registry database (Collector software; Trianalytics, Baltimore, MD). Each day, the database management team reviews all emergency department triage records and identifies all the trauma patients from the previous day who underwent surgery. Patients' charts are reviewed, the relevant information abstracted, and queries clarified by the attending physician or paramedics. An experienced data entry clerk abstracts information on patient demographics, sustained injuries, treatment, postoperative course and hospital discharge status.

We included all patients in the trauma registry who underwent surgery within 48 hours of admission because of trauma. Time of admission was defined as the time patients arrived at the trauma center. Patients were excluded from our study if they presented at hospital with moderate to severe burns, as mortality derived from this subpopulation was deemed, a priori, to be a poor surrogate for quality of trauma management.

We defined major complications as multisystem organ failure, sepsis, respiratory distress syndrome, pneumonia, myocardial infarction, congestive heart failure, cardiac arrest, and disseminated intravascular coagulation. Two orthopedic trauma surgeons independently evaluated 50 cases recorded in the database to ensure interobserver reliability. The chance-corrected agreement for major complications was substantial (kappa = 0.82; 95% CI 0.69–0.95). One of the two abstractors assessed each of the remaining cases. All deaths that occurred after patients had been admitted to the trauma centre were captured for calculation of mortality rates.

We hypothesized that 8 variables predicted major complications and mortality: age; sex; ISS (which ranges from 1 to 75, with 1 representing the least severe) (Baker et al. 1974); time of presentation at the trauma centre (nighttime, between 7:01 p.m. and 6:59 a.m. vs. daytime, between 7:00 a.m. and 7:00 p.m.); day of presentation (weekend vs. weekday); month of presentation; year of presentation; total number of operative procedures; and type of operative procedure. The definition of daytime and nighttime reflects the day shift to night shift change in the hospital. We compared the distribution of major complications and patient mortality by year of presentation (1995–2001) using the chi-square test or the Fisher's exact test, depending on cell frequencies.

We created binary logistic regression models for each dichotomous outcome variable (major complications, and mortality). We tested each of the variables in univariate regressions models for significance, and any variable that resulted in a p-value of ≤ 0.10 was entered into multivariable regression models. As time of presentation was felt to be an important factor, relevant variables were included in the multivariable regression models for both major complications and mortality, regardless of significance in univariate models. For the purpose of the univariate models, month and year of presentation were treated as a single variable. The elevated, or reduced, risk of outcome for a given variable, as determined by regression analysis, was reported as an odds ratio (OR). As there is literature hypothesizing that July may be a high-risk month for admission to hospital emergency services (Claridge et al. 2001), this month was chosen as the reference month for all multivariable models. Moreover, as we were interested in the trends over time, 1995 was chosen as the reference year for all multivariable modeling. Goodness of fit for each multivariable regression model was determined by the Hosmer-Lemeshow (H-L) test. The H-L test measures predictive reliability by comparing the expected results with the actual results of the dependent variable (severe complications or mortality). The H-L is distributed approximately as χ^2 with 8 degrees of freedom. Values of H-L less than 15.5 indicate a statistically good fit at the 0.05 level of significance (Hosmer and Lemeshow 1980). For the purpose of the multivariable regression models for major complications and mortality, significance was assumed at $p \leq 0.05$.

Results

Initial analysis of the frequency distribution of the data revealed that data on age had been improperly coded for two subjects (the ages were implausible), leaving 1042 patients available for analysis. The mean age was 40 (13–95) years, and 140 (13%) were over 64. Of the 1044 patients included in the remaining analyses, 72% (754 of 1044) were male and the mean ISS was 26 (13–75). The 1044

Table 1. Operative procedures

Target of operative procedure	Frequency (%)
Musculoskeletal system	1854 (58)
Nervous system	367 (11)
Digestive system	200 (6.2)
Integumentary system	171 (5.3)
Respiratory system	149 (4.6)
Cardiovascular system	118 (3.7)
"Miscellaneous" procedures [a]	112 (3.5)
Nose, mouth and pharynx	69 (2.1)
Lymphatic system	64 (2.0)
Urinary system	59 (1.8)
Eye	46 (1.4)
Ear	7 (0.2)
Male genital system	4 (0.1)
Obstetric procedures	2 (0.1)
Female genital system	2 (0.1)
Endocrine system	2 (0.1)

[a] Operative procedures that could not be readily classified according to the 15 organ system categories were recorded as "miscellaneous" procedures.

patients underwent 3226 operative procedures which were classified according to the organ system targeted. The average number of operations per patient was 3.1 (SD 1.5), and only 11 patients underwent more than 5 procedures (Table 1).

There were 78 deaths (7.5%), yielding death rates of 4.7% (7/148) for 1995, 5.7% (9/158) for 1996, 11% (22 /198) for 1997, 7.8% (14/180) for 1998, 5.6% (10/180) for 1999, 8.3% (12/145) for 2000, and 11% (4/35) for the first 4 months of 2001. Differences in mortality by year of presentation did not reach significance ($p = 0.2$). 338 patients (32%) had major complications either during, or following, surgery.

Univariate analysis (Tables 2 and 3)

Sex was not a predictor of major complications, or mortality. Presentation during the nighttime versus daytime was not a significant predictor of major complications, but did significantly predict an elevated risk of mortality. Presentation at weekends versus weekdays was not associated with a higher risk of major complications, or of mortality. Neither month nor the year of presentation were significant predictors of major complications or mortality.

Multivariate analysis (Tables 2 and 3)

All significant variables, and all time of presentation-related variables, were entered into multiple regression models, and significant predictors of major complications and mortality were determined. The forward conditional model of variable entry was applied in each multivariable regression model. The H-L test was significant for major complications ($p = 0.04$), but not for mortality ($p = 0.6$). Therefore, the regression model for major complications was stopped after 3 steps (there were 4 in the original model), which was not significant for the H-L test ($p = 0.08$) indicating goodness of fit for the multivariable regression model.

Our multivariable regression model indicated that an increased risk of mortality was associated with operative procedures involving the cardiovascular system, operative procedures coded as "miscellaneous", and by major complications. In our adjusted model, presentation during the nighttime versus daytime was not a significant predictor of mortality. Operative procedures involving the musculoskeletal system were associated with a decreased risk of mortality. The risk of major complications rose with procedures involving the respiratory system, older age, and higher severity of injury.

Discussion

All patients included in our analysis underwent surgery, and operations involving certain systems were significant predictors of clinical outcome. We found an increased risk of mortality with operative procedures involving the cardiovascular system and "miscellaneous" procedures, and most strongly by the occurrence of major complications (Table 3). Given the influence of "miscellaneous" procedures on mortality, it would be worthwhile to attempt to further define this category in the future. Operative procedures involving the musculoskeletal system were associated with a decreased risk of mortality. The risk of major complications rose with procedures involving the respiratory system. As with previous analyses of trauma registries, we found that older age and higher severity of injury were predictive of increased major complications and mortality following trauma care (Brennan et al. 2002). Our study suggests that for patients requiring emergency trauma surgery, major complica-

Table 2. Predictors of major complications

Predictor	Univariate analysis OR (95% CI)	P-value	Multivariate analysis OR (95% CI)	P-value
Operation of the:				
Integumentary system	0.62 (0.45–0.86)	<0.01		0.05 [a]
Digestive system	1.41 (1.15–1.72)	<0.01		0.06
Lymphatic system	2.80 (1.68–4.65)	<0.01		0.1
Cardiovascular system	1.48 (1.11–1.98)	0.01		0.3
Respiratory system	2.18 (1.60–2.95)	<0.01	1.66 (1.20–2.30)	<0.01
Musculoskeletal system	0.90 (0.83–0.99)	0.03		0.9
Time of presentation:				
Year		0.1		0.3
Month		1		1
Weekend vs. weekday		0.9		0.8
Night vs. day		0.7		0.7
Other:				
ISS	1.09 (1.07–1.10)	<0.01	1.08 (1.07–1.10)	<0.01
Age	1.02 (1.01–1.02)	<0.01	1.02 (1.01–1.02)	<0.01
Number of operative procedures	1.10 (1.01–1.20)	0.03		0.2

OR – Odds ratio, 95% CI – 95% confidence interval, ISS – Injury severity score
[a] This variable was excluded from the regression model to maintain goodness of fit (see Methods section)

Table 3. Predictors of mortality

Predictor	Univariate analysis OR (95% CI)	P-value	Multivariate analysis OR (95% CI)	P-value
Operation of the:				
Digestive system	1.48 (1.14–1.93)	<0.01		0.4
Lymphatic system	2.70 (1.37–5.32)	<0.01		0.9
Cardiovascular system	1.98 (1.40–2.82)	<0.01	1.67 (1.09–2.57)	0.02
Respiratory system	2.28 (1.60–3.24)	<0.01		0.2
Nervous system	1.25 (0.99–1.58)	0.06		0.1
Musculoskeletal system	0.64 (0.52–0.78)	<0.01	0.78 (0.65–0.95)	0.01
“Miscellaneous” procedures	1.61 (1.02–2.54)	0.04	1.77 (1.06–2.94)	0.03
Time of presentation:				
Year		0.4		0.9
Month		0.6		0.9
Weekend vs. weekday		0.9		0.7
Night vs. day	1.69 (1.08–2.69)	0.03		0.06
Other:				
Age	1.04 (1.03–1.05)	<0.01	1.04 (1.03–1.07)	<0.01
ISS	1.08 (1.06–1.10)	<0.01	1.07 (1.03–1.08)	<0.01
Major complications	3.97 (2.03–7.78)	<0.01	2.42 (1.39–4.20)	<0.01

Abbreviations – see Table 2

tions and mortality are not associated with whether patients presented during the night or day, on a weekend versus a weekday, month of presentation, or year of presentation. In our analysis, sex was not a significant predictor of outcome following trauma care and this is consistent with other studies (West et al. 2000, Brennan et al. 2002, Croce et al. 2002, Rappold et al. 2002). The narrow confidence intervals surrounding many of our odds ratios provide greater confidence in these estimates of effect.

Our study has some limitations. We used administrative data that may have included coding errors or omissions (Wynn et al. 2001). The coding of surgeries by system in our database, as opposed to by procedure, limits interpretation of our results. The clinical usefulness of the ISS has been criticized (Rutledge 1996, Stephenson et al. 2002) and alternate systems for characterizing traumatic injury have been developed in an attempt to improve quantification of injury severity (Merideth et al. 2002). Due to the limitations of our data, we were unable to account for the impact of comorbidity, which has been shown to increase risk of mortality among trauma patients (Sacco et al. 1993, Brennan et al. 2002). Additionally, our study was restricted to the hospital phase of care and does not address pre-hospital access issues, the adequacy of emergency medical services' triage and transport, and post-hospital health status. The external validity of our findings is not clear, and our results may not be generalizable to other trauma centers. A national trauma registry that would link individual data from Canadian trauma centers has been proposed in order to develop clinical practice benchmarks (McLellan 1997), and efforts are under way to develop this resource (The Canadian Major Trauma Information Program).

Time of presentation for hospital-based care has been found to influence clinical outcomes. Specifically, patients seeking emergency care have been reported to be at higher risk of death if admitted to acute care hospitals in Ontario during the weekend as opposed to on a weekday (Bell and Redelmeier 2001). Variations in clinical outcome depending on month of presentation for trauma care has also been investigated, although the results to date have been inconclusive (Buchwald et al. 1989, Rich et al. 1990, 1993, Shulkin 1995, Claridge et al. 2001), and we have now investigated the effect of presenting for trauma surgery at nighttime versus daytime. Although previous studies have found significant reduction in morbidity and mortality following initiation of trauma care systems (Sampalis et al. 1992, 1995, Stewart et al. 1995, Simons et al. 1999, Simons and Kirkpatrick 2002), we found no decrease in mortality between inception of the registry (April 3, 1995) and April 22, 2001, and rates of severe complications have remained relatively stable over the past 7 years.

Our patient population fulfilled all the criteria put forward by Bell and Redelmeier (2001) as being associated with higher risks of mortality for admission to hospital at the weekend: the condition occurs frequently, high in-hospital mortality rate, critical first few days of hospitalization, treatable condition, care involving logistic difficulties, death which can be rapid, and patients typically receiving a substantial amount of care outside a critical care unit or emergency department. However, we did not demonstrate any association between weekend and weekday admissions and mortality or major complications. Emergency trauma units may have long been aware of these issues, and may have made conscious efforts to maintain consistent standards of care at all times. If this hypothesis is correct, it could be argued that our findings support the contention that strategic planning of hospital services can successfully overcome the variations in care that have been noted in general acute care admission to emergency departments in Ontario (Bell and Redelmeier 2001). Further research is required to explore this hypothesis and to uncover all the variables that avoid excessive mortality and major complications with weekend trauma care admissions. This should help to inform and improve areas in which there is an excess of these outcomes.

Dr. Jason Busse is funded by a Canadian Institutes of Health Research Fellowship Award. Dr. Mohit Bhandari is supported in part by a Clinical Scientist Fellowship from the Department of Clinical Epidemiology and Biostatistics, McMaster University. Dr. P.J. Devereaux is supported by a Heart and Stroke Foundation of Canada and Canadian Institutes of Health Research Fellowship Award. No funds were received for the preparation of this manuscript.
No competing interests declared.

We are grateful to Ms Stephanie Stacyk from the Hamilton Health Sciences Trauma Program, McMaster University, for assistance with the database. We are also grateful to Dr. Beate Hanson, Director, AO Clinical Investigation and Documentation, AO Institute, Davos, Switzerland, for assistance with data abstraction.

Jason W. Busse led the writing of the manuscript and, with Mohit Bhandari, developed the concept for the study. Mohit Bhandari and P.J. Devereaux contributed to the study design, in revising the manuscript, and in reviewing the final manuscript.

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