



They only come out at night: Impact of time of day on outcomes after penetrating abdominal trauma☆

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ABSTRACT

Background: Patients who present at night following penetrating abdominal trauma are thought to have more severe injuries and increased risk for morbidity and mortality. The current literature is at odds regarding this belief. The purpose of this study was to evaluate time of day on outcomes following laparotomy for penetrating abdominal trauma.

Methods: Patients undergoing laparotomy following penetrating abdominal trauma over a 12-month period at a level I trauma center were stratified by age, sex, severity of shock, injury, operative complexity, and time of day (DAY = 0700–1900, NIGHT = 1901–0659). Outcomes of damage control laparotomy, ventilator days, intensive care unit length of stay, hospital length of stay, morbidity, and mortality were compared between DAY and NIGHT.

Results: A total of 210 patients were identified: 145 (69%) comprised NIGHT, and 65 (31%) comprised DAY. Overall mortality was 2.9%. Both injury severity and intraoperative transfusions were increased with NIGHT with no difference in morbidity (37% vs 40%, $P = 0.63$) or mortality (2.1% vs 4.6%, $P = 0.31$). Adjusting for sex, time of day, injury severity, and operative complexity, only abdominal abbreviated injury severity (odds ratio 1.46; 95% confidence interval 1.07–1.99, $P = .019$) and operative transfusions (odds ratio 1.18; 95% confidence interval 1.09–1.28, $P < .0001$) were identified as independent predictors of damage control laparotomy using multivariable logistic regression (area under the curve 0.96).

Conclusion: The majority of operative penetrating abdominal trauma occurs at night with increased injury burden, more operative transfusions, and increased use of damage control laparotomy with no difference in morbidity and mortality. Outcomes at a fully staffed and operational trauma center should not be impacted by time of day.

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INTRODUCTION

“Nothing good happens after midnight” is an old adage frequently used in everyday life. At most trauma centers, the weekend is revered as the busiest time, especially at night. There appears to be an overwhelming anecdotal consensus that sicker patients with a higher severity of injury come in more often as the sun goes down. Such patients are presumed to be at increased risk for both morbidity and mortality, and although that belief is commonly held, it is poorly supported. In fact, the

current literature is divided regarding the effect of time of day on trauma patient outcomes. Multiple countries including Japan, Canada, the United Kingdom, Germany, Brazil, and the United States have all performed retrospective studies using their trauma data banks over varied time frames attempting to confirm or refute the above belief [1–6]. However, none of these studies can agree if time of day truly impacts patient outcomes, and none have separated blunt from penetrating trauma.

The purpose of this study was to evaluate time of day on outcomes (morbidity and mortality) in patients following laparotomy for penetrating abdominal trauma. We hypothesized that overall injury burden would be greater in those patients presenting at night following penetrating abdominal trauma undergoing laparotomy; however, mortality would not be impacted by the time of day at initial presentation. Prior to this study, it was the authors’ belief that although it seemed like

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sicker, more injured patients tended to present at night, there were not a disproportionate number of deaths at night—in fact, it was our belief that at a fully staffed, mature, and operational trauma center with appropriate resource allocation, outcomes (specifically mortality) would not be impacted by time of day.

METHODS

Identification of Patients. Following approval from the institutional review board at the University of Tennessee Health Science Center, consecutive patients admitted to the Presley Regional Trauma Center (the level 1 trauma center in Memphis, TN) with penetrating abdominal trauma requiring exploratory laparotomy over a 12-month period (ending December 2016) were evaluated. Medical records were reviewed for data regarding patient demographics, severity of injury and shock, associated injuries, time and type of operative intervention, and outcomes. These data were then merged with patient data from the trauma registry (NTRACS version 4.1, Digital Innovations) to compile the database for this study. There were no exclusion criteria. All data were collected prospectively and analyzed retrospectively.

Comparison. The patients were stratified by age, sex, severity of shock (as measured by admission base excess, systolic blood pressure [SBP], and lactate) and injury (as measured by injury severity score [ISS] and abdominal abbreviated injury severity [AIS]), operative complexity (as measured by operative time and intraoperative transfusions), and time of day at initial presentation. Patients were then divided into 2 groups based on the time of day at initial presentation. Those patients who presented between 0700 and 1900 comprised the DAY group, and those patients presenting after 1900 but before 0700 comprised the NIGHT group.

Outcomes. Outcomes including use of damage control laparotomy (DCL), ventilator days, intensive care unit (ICU) length of stay (LOS), hospital LOS, morbidity (surgical site infection, abscess, suture line failure, dehiscence, venous thromboembolism, ventilator-associated pneumonia, sepsis, and multiple organ failure), and mortality were recorded and compared between the 2 groups.

Statistical Analysis. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC). Comparisons between the NIGHT and DAY groups were performed using a Student *t* test and χ^2 analysis or Wilcoxon rank sum test where appropriate. The Kolmogorov–Smirnov test for normality was performed on all continuous variables; those that were normally distributed are presented with means and standard deviations, and those that were not normally distributed are presented as medians and interquartile ranges. Multivariable logistic regression analysis was performed to determine significant predictors of DCL in the study population. Only those variables on univariable analysis exhibiting a significance less than .2 were considered for inclusion in the full multiple regression model. The final multivariable model was constructed in a backwards stepwise fashion to identify independent predictors of DCL following penetrating abdominal trauma.

RESULTS

Patient Characteristics. Over the 12-month period, 210 patients that underwent exploratory laparotomy following penetrating abdominal trauma were identified. All patients suffered penetrating injuries with the majority secondary to gunshots (79%) followed by stabs (20%). These patients ranged in age from 18 to 84 years (mean = 32 years) and included 181 men (86%) and 29 (14%) women. Mean ISS and abdominal AIS were 13 and 3, respectively. One hundred twenty-seven (61%) patients had bowel injuries, 48 (23%) patients had liver injuries, 30 (14%) patients had gastric injuries, 25 (12%) had splenic injuries, and 10 (5%) had pancreatic injuries identified at exploration. The

Table 1
Patient characteristics—all patients

Characteristics	All patients
<i>n</i>	210
Age	32 (13)
Male	86%
GCS	15 (15, 15)
ISS	13 (9, 20)
ABD AIS	3 (2, 4)
BE	−4.0 (5.3)
Lactate	4.1 (3.6)
SBP	130 (23)
OR transfusions	2 (0, 6)
OR time	134 (90, 191)
Night	69%
DCL	20%
Morbidity	38%
Mortality	2.9%

Patient characteristics of study population.

ABD AIS, abdominal abbreviated injury severity scale; BE, base excess; GCS, Glasgow Coma Scale; OR, operating room.

majority (69%) of all patients were admitted at night, with 20% of all patients undergoing DCL. The overall morbidity and in-hospital mortality were 38% and 2.9%, respectively. Table 1 shows the demographic and clinical characteristics for all patients included in the study.

Comparison: DAY Versus NIGHT. Of the 210 patients, 65 (31%) presented during the day (DAY) and 145 (69%) patients presented at night (NIGHT). Table 2 demonstrates a comparison of the clinical characteristics and selected outcomes between these 2 groups. Both groups were similar with respect to age and severity of initial shock (as measured by admission SBP, base excess, and lactate). However, there was a significantly greater proportion of men in the NIGHT group compared to the DAY group. In addition, despite significantly increased injury severity (as measured by ISS: 17 vs 8, $P = .04$ and abdominal AIS: 3 vs 2, $P < .0001$), operative complexity (as measured by intraoperative transfusions: 3 vs 0, $P = .004$), and use of DCL (24% vs 11%, $P = .028$) in the NIGHT group, there was no difference in either overall morbidity

Table 2
Characteristic comparison between DAY and NIGHT

Characteristics	DAY	NIGHT	P
<i>n</i>	65	145	
Age	33 (14)	32 (12)	.489
Male	78%	90%	.030
GCS	15 (15, 15)	15 (15, 15)	.449
ISS	8 (10, 19)	17 (10, 23)	.042
ABD AIS	2 (1, 3)	3 (2, 4)	<.0001
BE	−3.8 (5.1)	−4.6 (5.7)	.351
Lactate	4.0 (2.0)	4.0 (3.4)	.633
SBP	127 (26)	131 (22)	.254
OR transfusions	0 (0, 3)	3 (0, 6)	.0004
OR crystalloid (L)	2 (1.5, 3.1)	2.5 (1.8, 3.4)	.450
OR time	135 (94, 195)	132 (90, 190)	.833
DCL	11%	24%	.028
Morbidity	40%	37%	.633
Vent days	0 (0, 2)	0 (0, 1)	.933
ICU LOS	0 (0, 3)	0 (0, 3)	.536
Hospital LOS	7 (5, 12)	8 (6, 16)	.195
Mortality	4.6%	2.1%	.306

Patient characteristics divided into DAY and NIGHT. Using a logistic regression model to predict DCL, multivariable logistic regression failed to identify time of day as a predictor of DCL (OR 1.54; 95% CI 0.59–4.04) but found both abdominal AIS (OR 1.41; 95% CI 1.03–1.94) and operative transfusions (OR 1.18; 95% CI 1.09–1.28) to be significantly associated with DCL. Furthermore, stepwise multivariable logistic regression identified abdominal AIS (OR 1.46; 95% CI 1.07–1.99, $P = .019$) and operative transfusions (OR 1.18; 95% CI 1.09–1.28, $P < 0.0001$) as independent predictors of DCL.

Vent days, days on ventilator.

(37% vs 40%, $P = .63$) or mortality (2.1% vs 4.6%, $P = .31$) between the groups. Not surprisingly, there was also no difference in ventilator days, ICU LOS, or hospital LOS between the 2 groups.

Outcomes. A logistic regression model was then developed using the database to predict DCL following penetrating abdominal trauma. After adjusting for sex, severity of injury (abdominal AIS), operative complexity (intraoperative transfusions), and time of day, multivariable logistic regression analysis failed to identify time of day as a predictor of DCL (odds ratio [OR] 1.54; 95% confidence interval [CI] 0.59–4.04) but found both abdominal AIS (OR 1.41; 95% CI 1.03–1.94) and operative transfusions (OR 1.17; 95% CI 1.08–1.28, $P < .0001$) to be significantly associated with DCL. Furthermore, stepwise multivariable logistic regression identified abdominal AIS (OR 1.46; 95% CI 1.07–1.99, $P = .019$) and operative transfusions (OR 1.18; 95% CI 1.09–1.28, $P < .0001$) as independent predictors of DCL in patients requiring exploratory laparotomy following penetrating abdominal trauma (area under the curve 0.96, 95% CI = 0.89–0.99).

DISCUSSION

In our analysis of 210 consecutive patients over a 12-month period undergoing laparotomy after penetrating abdominal trauma, we found that the majority of patients with penetrating abdominal trauma present at night and with a higher injury burden as measured by both ISS and abdominal AIS. Not surprisingly, these patients required more intraoperative transfusions coupled with a more liberal use of DCL. Despite these findings, there was no difference in outcome (either morbidity or mortality) based on time of presentation. Regression analysis confirmed that use of DCL was associated with severity of injury rather than time of presentation. These results underscore the importance of maintaining appropriate resource allocation at a mature, well-established trauma center to provide care founded on the patient's injury burden and physiologic status rather than the time of day.

Resources available to trauma centers vary wildly between nations and even regions. As a result, spanning the gap between published recommendations for resources and the availability of said resources remains a challenge. Examples of requirements for level I and II trauma centers, as outlined by the American College of Surgeons, include 24-hour in-house anesthesia coverage and operating room availability within 15 minutes [7]. The cost of achieving this necessary level of readiness can quickly escalate [8]. Ashley et al reported that the mean annual readiness costs for level I and II centers conforming to American College of Surgeons guidelines were 10.1 and 4.9 million dollars, respectively [9].

When materials and personnel are limited, the optimal deployment of these assets remains critical. This, in part, explains the continued interest in better defining the seasonal, regional, diurnal, and nocturnal variations in trauma patient volume and severity [10–14]. Although understanding variations in trauma volume is critical, it should be remembered that what holds true for one region does not necessarily apply to another.

Barbosa et al, for example, identified that operative trauma was more likely to occur at night, over the weekends, and was associated with greater mortality in their Brazilian trauma population. More specifically, they identified admission at night as an independent risk factor for surgical mortality in trauma patients [1]. Studies in the United Kingdom and Canada conversely found no difference in mortality between patients presenting on nights and/or weekends compared to those arriving at “normal” hours, which may reflect their highly developed multihospital acute care and trauma system [2,3]. In contrast, Hirose et al found in their Japanese population that nighttime, but not weekend admission, was associated with increased mortality [4]. Pape-Koehler et al in their review of a largely German registry found that injuries most commonly occurred between 12:00 and 5:00 PM, on

Saturdays, and between the months of May and September [5]. Lastly, Egol et al [6], in their evaluation of American trauma patients using the National Trauma Data Bank, found that hospital admission between midnight and 6:00 AM was associated with increased risk of in-hospital mortality. In fact, the authors identified an increased adjusted relative risk for those patients arriving during the designated night time. This pattern was found to hold strongest at level III/IV trauma centers but was weakest at level 1 trauma centers. Based on these findings, the authors suggested physician fatigue as a potential contributing factor coupled with decreased hospital resources at night for this observed increased mortality [6]. This, in turn, raises the question of whether there is a need to adjust hospital resources to combat this discrepancy based on time of day.

Our institution remains fortunate in this regard. In addition to in-house trauma surgeons, there are 3 operating rooms—with the accompanying anesthesia, nursing, and surgical staff—dedicated to trauma cases. These rooms are available 24 hours a day and 7 days a week. As a result, emergent operative trauma cases can proceed with the same speed, regardless of whether it is 2 o'clock in the afternoon or morning. This benefit likely contributes to our institution's ability to produce similar outcomes at night when compared to the day despite the greater frequency and severity of penetrating injuries at night when compared to those during the day. By grasping a center's unique temporal variation in trauma volume and committing resources appropriately, acceptably low mortality can be maintained regardless of season, day, or hour.

LIMITATIONS

This study has several inherent limitations. The primary limitation of this study is that it is retrospective. Although the data were collected prospectively, it was analyzed retrospectively. As a result, this precludes the exclusion of selection bias and unevaluated differences as potential confounding variables. In addition, this allows only for associations to be made and cannot account for potential confounding differences. For example, we do not know the exact reason why a surgeon chose to perform DCL at any particular time. Secondly, we did not record weapon type—the use of higher-velocity, larger-caliber guns with higher-capacity magazines could differ by time of day, accounting for the increased injury burden at night. Third, simply altering the choice for what constitutes DAY and NIGHT by just 1 hour (either earlier or later) may impact our conclusions, especially if a patient presented close to the original cutoff times. Finally, because this study examined trauma patients exclusively from a single trauma center (The Presley Regional Trauma Center, the level 1 trauma center in Memphis, TN), application of the results to other populations should be done cautiously.

In conclusion, consistent with popular belief, the majority of penetrating abdominal trauma requiring operative intervention occurs after the sun goes down. However, despite these patients (NIGHT) having a greater injury burden, more operative transfusions, and an increased use of DCL, morbidity and mortality were not different. Thus, outcomes at a fully staffed and operational trauma center with appropriate resource allocation should not be impacted by time of day.

Conflict of Interest

There are no conflicts of interest to declare.

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CRediT authorship contribution statement

Emily K. Lenart: Conceptualization, Investigation, Investigation. **Richard H. Lewis, Jr:** Writing - review & editing. **John P. Sharpe:** Writing - review & editing. **Peter E. Fischer:** Writing - review & editing.

Martin A. Croce: Writing - review & editing, **Louis J. Magnotti:** Conceptualization, Validation, Formal analysis, Writing - review & editing.

References

- [1] Barbosa Lde S, dos Reis Junior GS, Chaves RZ, et al. Night admission is an independent risk factor for mortality in trauma patients—a systemic error approach. *Rev Col Bras Cir.* 2015;42:209–14.
- [2] Metcalfe D, Perry DC, Bouamra O, et al. Is there a 'weekend effect' in major trauma? *Emerg Med J.* 2016;33:836–42.
- [3] Laupland KB, Ball CG, Kirkpatrick AW. Hospital mortality among major trauma victims admitted on weekends and evenings: a cohort study. *J Trauma Manag Outcomes.* 2009;3:8.
- [4] Hirose T, Kitamura T, Katayama Y, Sado J, Kiguchi T, Matsuyama T, et al. Impact of nighttime and weekends on outcomes of emergency trauma patients: a nationwide observational study in Japan. *Medicine.* 2020;99(1):e18687.
- [5] Pape-Köhler, Simanski Christian, Nienaber Ulrike, Lefering Rolf. External factors and the incidence of severe trauma: time, date, season and moon. *Injury.* 2014;45:S93–9.
- [6] Egol KA, Tolisano AM, Spratt KF, et al. Mortality rates following trauma: the difference is night and day. *J Emerg Trauma Shock.* 2011;4:178–83.
- [7] American College of Surgeons Committee on Trauma. Resources for optimal care of the injured patient. , 17–21Chicago, Ill: American College of Surgeons; 2014; 76–86.
- [8] Brasel KJ, Akason J, Weigelt J. Dedicated operating room for trauma: a costly recommendation. *J Trauma Acute Care Surg.* 1998;44:832–8.
- [9] Ashley DW, Mullins RF, Dente CJ, Johns TJ, Garlow LE, Medeiros RS, et al. How much green does it take to be orange? Determining the cost associated with trauma center readiness. *J Trauma Acute Care Surg.* 2019;86:765–73.
- [10] Brinck Tuomas, Heinänen Mikko, Söderlund Tim, Lefering Rolf, Handolin Lauri. Does arrival time affect outcomes among severely injured blunt trauma patients at a tertiary trauma centre? *Injury.* 2019;50:1929–33.
- [11] Stonko DP, Dennis BM, Calcut RA, Betzold RD, Smith MC, Medvecz AJ, et al. Identifying temporal patterns in trauma admissions: informing resource allocation. *PLoS One.* 2018;13:1–11.
- [12] Groh EM, Feingold PL, Hashimoto B, McDuffie LA, Markel TA. Temporal variations in pediatric trauma: rationale for altered resource utilization. *Am Surg.* 2018;84:813–9.
- [13] Yaghoubian A, De Virgilio C, Destro L, Kaji AH, Putnam B, Neville AL. Optimal deployment of trauma personnel in the 80-hour work week era based on peak times of trauma patient arrival. *Am Surg.* 2010;76:1039–42.
- [14] Kieffer WK, Michalik DV, Gallagher K, McFadyen I, Bernard J, Rogers BA. Temporal variation in major trauma admissions. *Ann R Coll Surg Engl.* 2016;98:128–37.