CLINICAL AND ECONOMIC IMPACT OF DELAYED TRANSFER OF CRITICALLY ILL PATIENTS FROM THE EMERGENCY DEPARTMENT TO THE INTENSIVE CARE UNIT

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ABSTRACT

OBJECTIVE: Numerous factors can cause delays in transfer to an intensive care unit (ICU) for critically ill emergency department (ED) patients. The impact of such delays is unknown. We aimed to determine the clinical and economic impact of ED "boarding" (holding admitted patients in the ED pending transfer to an ICU) for critically ill patients.

DESIGN: This was a retrospective cohort study utilizing the Project IMPACT™ database (a multi-center U.S. database of >150,000 critically ill patients derived from approximately 120 ICUs). Patients admitted from the ED to ICU (2000-2003) were included. Based on the Project IMPACT™ database classification, subjects were divided into two groups: boarding in the ED ≥6 hours ["delayed" (DEL)] versus boarding <6 hours ["non-delayed" (non-DEL)]. Demographics, ICU procedures, ICU and hospital length of stay (LOS), ICU mortality, and in-hospital mortality were analyzed. We compared the two groups using chi-square, Mann-Whitney, and unpaired t-tests. A decision analysis model was developed to estimate the expected costs for each group.

SETTING: Emergency department and intensive care unit

INTERVENTIONS: None

MAIN OUTCOME MEASURES: ICU and hospital survival, ICU and hospital length of stay, total expected hospital cost.

RESULTS: 50,322 patients were admitted from the ED to the ICU during the study period. The two groups [DEL (n=1036) and non-DEL (n=49,286)] were similar in age, gender, DNR status, and APACHE II severity score (p=NS). Among ICU survivors, median ICU LOS was 1.9 days (DEL) versus 1.8 days (non-DEL) ($p<0.01$), and among hospital survivors the median hospital LOS was 7.0 days (DEL) versus 6.0 days (non-DEL) ($p<0.001$). ICU mortality was 10.7% (DEL) versus 8.4% (non-DEL) ($p<0.01$). In-hospital mortality was 17.4% (DEL) versus 12.9% (non-DEL) ($p<0.001$). Expected total hospital costs from the decision analysis model were $17,788 (DEL) and $16,361 (non-DEL).

CONCLUSIONS: Critically ill ED patients with a $\geq$6 hour delay in ICU transfer had increased hospital LOS, ICU mortality, in-hospital mortality, and higher expected costs. These findings suggest a possible clinical and economic benefit from expeditious transfer of critically ill patients from the ED to the ICU, and suggest the need to further evaluate the factors associated with delayed ICU admission as well as the specific determinants of adverse outcomes.

INTRODUCTION

Outcome for critically ill patients often depends upon time-sensitive critical care interventions[1-6] and thus the impact of delays in transfer to an intensive care unit (ICU) on outcome could be substantial. However, the clinical and economic impact of such delays is currently unclear. Emergency department (ED) “boarding” of critically ill patients (holding admitted patients in the ED pending ICU bed availability) is common and increasing in frequency in the United States, resulting in a prolonged ED length of stay.[7, 8] For critically ill ED patients, there are three primary reasons for ED boarding: (1) an increasing volume of critically ill patients presenting to the ED,[9] (2) hospital and ED overcrowding, and (3) a lack of immediately available staffed ICU beds.[8, 10, 11] Between 1990 and 1999, Lambe et al reported a 59% increase in volume of critically ill patients who were evaluated in California EDs.[9] In a 2002 study commissioned by the American Hospital Association, large hospitals with ED overcrowding had a mean waiting time for transfer from the ED to an acute or critical care bed of 5.8 hours, a figure nearly twice as long as the wait time in the minority of large hospitals that did not report overcrowding.[8] In response to these concerns and the public health implications of delayed access to care, the Robert Wood Johnson Foundation recently funded a multimillion dollar initiative called “Urgent Matters” focused on reducing ED overcrowding.[12]

Although ED boarding has been previously utilized as a surrogate for adverse outcome and the link between these contributing factors and ED boarding has been well-established,[10, 11, 13, 14] the specific impact on patient outcome and cost of care remains unclear.[15] The purpose of this study was to determine the clinical and economic impact of ED boarding for critically ill patients.

METHODS

Study Design

This was a retrospective cohort study utilizing the Project IMPACT™ database (Cerner-Project IMPACT, Inc., Bel Air, MD), a large voluntary administrative database originally developed by the Society of Critical Care Medicine in 1996 and specifically designed for the critically ill patient. Approximately 120 adult ICUs from approximately 90 hospitals across the country currently participate in the database, which now contains data for over 200,000 patients. Participating hospitals submit data on a quarterly basis to a central registry which maintains and manages the database.[16] From an investigational standpoint, the Project IMPACT™ database has been used to study many issues in critical care including the assessment of prolonged ICU length-of-stay,[17] the identification of quality outliers,[18] and pulmonary artery catheter use.[19] Each patient entry includes data regarding hospital and organizational characteristics, admission source (e.g. emergency department versus general medical or surgical floor), patient demographics, diagnostic categories, laboratory and physiological data, procedures and complications, severity scores, procedures, complications, ICU and hospital length stay, and discharge status. In our study of delayed ICU admission from the ED, primary outcome measures from Project IMPACT™ that were extracted included ICU mortality, in-hospital mortality, and ICU and hospital length of stay (LOS).

All data that is submitted to Project IMPACT™ by each participating ICU are de-identified in a manner that is HIPAA-compliant.

Study Setting and Population

The ICUs represented in the Project IMPACT™ constitute a wide variety of ICU practice environments including medical, surgical, and multidisciplinary ICUs. The ICUs also have various management and organizational strategies ranging from completely closed units in which the patients are admitted to the service of a critical care specialist (i.e. intensivist) to a completely open unit where patients remain on the service of the primary care physician and an intensivist (and other consultants) may or may not be involved in patient care. Participating hospitals are heterogeneous in terms of hospital size, practice type (community-based, university-based, or teaching hospitals), private versus public, and location (urban, suburban, or rural). Participating hospitals are also not restricted to any particular geographic region in the United States.

Patients were included in the sample if they were admitted to an ICU directly from the ED between January 1, 2000 and December 31, 2003 (e.g. patients admitted from the ED to the floor and then transferred to the ICU along with direct inter-hospital transfers to the ICU were both excluded). Subjects were divided into two main categories: (1) those who were transferred to the ICU in less six hours fromED presentation [“non-delayed” (non-DEL)] and (2) those who were admitted after boarding for 6 hours or more in the ED [“delayed” (DEL)]. We chose a six hour time period as a cut-off point because Project IMPACT™ has a dichotomous variable in which the data collectors record whether or not patients received “ICU level care in an area other than the ICU (boarding) for at least 6 hours immediately prior to ICU admission.” This six-hour period also correlates with the mean waiting time (5.8 hours) in the ED for an acute or critical care bed in overcrowded hospitals reported by the American Hospital Association.[1]

Study Protocol

The Project IMPACT™ database was queried to identify the population described above and the variables below (see "*measurements*") were abstracted. Data were provided in a Microsoft Access (Access, Microsoft Corporation, Redmond, WA) format and were exported into SPSS version 12.0 (SPSS Inc., Chicago, Il) for analysis. The dichotomous variable for ≥6 hour "boarding" was used to split the subjects into two groups for analysis.

Measurements

For each subject, the following baseline patient characteristics from Project IMPACT™ were abstracted: demographic data (including age, gender, presence of a "do not resuscitate" (DNR) order, and presence of any advance directive), Acute Physiology and Chronic Health Assessment (APACHE) II diagnostic category, and APACHE II severity score. In Project IMPACT™, the APACHE II diagnostic category is based on the ICU physician admission note. The APACHE II severity score is based on the worst values for physiologic and laboratory data during the first 24 hours after ICU presentation.[20] The primary outcome measurements included: ICU mortality, in-hospital mortality, and hospital and ICU LOS. Data for procedures performed in the ICU or present at the time of arrival to the ICU were also abstracted including: mechanical ventilation (frequency and duration), central venous catheterization, dialysis catheter insertion, and pulmonary artery catheterization.

To identify whether or not there was heterogeneity in the ten most common diagnostic categories (Project IMPACT™ utilizes APACHE II diagnostic categories) between the DEL and non-DEL cohorts, the number of cases of each diagnostic category (relative to the total number of subjects in each group) were compared. A post-hoc subgroup analysis of outcomes within the sepsis diagnostic category (the most common diagnostic category observed in the DEL group) was also performed.

Logistic regression model:

Because of the potential for interrelationships of several factors upon survival, we developed a logistic regression model to determine the impact of other variables besides delayed admission from the ED upon patient outcome. Continuous independent variables in the model included patient age, gender, and APACHE II score, and dichotomous variables consisted of gender, delayed admission, and the presence of sepsis as a diagnostic category. Overall hospital survival was used as the dependent variable in the model. The model was derived from all patients for whom a complete set of APACHE II scores were recorded (n=30,042).

Cost model

A decision analysis model (**Figure 1**) was developed to estimate the total expected costs for patients in the two groups, in which the two arms of the decision tree were delayed admission to the ICU from the ED (analogous to the DEL cohort) and admission to the ICU within 6 hours from the ED (analogous to the non-DEL cohort). The clinical data derived from Project IMPACT™ was used to populate the model and consisted of the probability of survival to ICU discharge and the overall probability of survival to hospital discharge for both the DEL and non-DEL cohorts. Economic data for the model, which consisted of the average charge for a day in the ICU ($2,991) and on the general medical floor ($1,979), was determined from fiscal year 2004 charge data obtained from Cooper University Hospital in Camden, NJ. The total expected costs were determined for both the DEL and the non-DEL cohort using the baseline values for both costs and probabilities. Multiple sensitivity analyses were performed in which the baseline values were varied throughout a range that was likely to be encountered in all clinical environments. Specifically, for each potential cost parameter the lower bound was set at 25% and the higher bound was set at 400% of the baseline value. In order to account for the variability likely to be observed in all of the model's clinical and cost parameters that are likely to impact both cost and outcome in real world situations, a Monte Carlo sensitivity analysis[21] was also performed with a simulated cohort of 10,000 patients.

Data Analysis and Statistics:

The DEL and non-DEL groups were compared using chi-square and Mann-Whitney test or unpaired t-test for continuous variables. The Mann-Whitney was used for continuous variables that did not have a normal distribution and the unpaired t-test was used for continuous variables that had a normal distribution. The level of statistical significance was tested at $p < 0.05$. All statistical analyses were performed with SPSS version 12.0

(SPSS Inc., Chicago, IL). DATA™ Professional (TreeAge Pro 2005 Suite, release 0.4, TreeAge Software Inc., Williamstown, MA) was used to develop the decision analysis model and perform the sensitivity analyses.

RESULTS

50,322 patients were admitted from ED to ICU from January 1, 2000 through December 31,2003. Of these, 1036 (2.1%) boarded in the ED for 6 or more hours prior to ICU transfer (DEL), and 49,286 (97.9%) were transferred from the ED to the ICU in less than 6 hours (non-DEL). No differences were noted between the two groups with respect to age, gender, DNR status, the presence of any advance directive, and severity score (p=NS). Specifically, the mean age was 57.4 years (DEL) versus 58.4 years (non-DEL) (p=0.10). Gender (% male) was 54.3% male (DEL) versus 54.0% male (non-DEL) (p=0.81). The percentage of patients with a DNR order at the time of ICU admission was 0.1% for both DEL and non-DEL (p=0.60), and the percentage of patients with any kind of advance directive at the time of ICU admission was 17.0% (DEL) versus 15.3% (non-DEL) (p=0.14). The mean Acute Physiology and Chronic Health Evaluation II (APACHE II) score was 16.3 (DEL) versus 15.7 (non-DEL) (p=0.08). Data for baseline patient characteristics at the time of ICU admission are displayed in **Table 1a.**

There was considerable overlap in the APACHE II diagnostic categories between DEL and non-DEL, with eight of the top ten most common diagnostic categories in each group possessing a match within the other group's top ten most common diagnostic categories (**Table 1a**). The sepsis diagnostic category was significantly more common in the DEL group (p <0.001) whereas multiple trauma (p <0.01), coronary artery disease (p <0.001), and respiratory (p <0.01) diagnostic categories were significantly more common in the non-DEL group (**Table 1b**).

There were significant differences in the rates of central venous catheterization [32.5% (DEL) versus 22.0% (non-DEL) ($p<0.001$)], and the use of mechanical ventilation [39.3% (DEL) versus 29.5% (non-DEL) ($p<0.001$)]. However, there was no significant difference in the mean duration of mechanical ventilation [3.5 days (DEL) versus 4.1 days (non-DEL) ($p=0.08$)]. There were no significant differences in the rates of pulmonary artery catheterization [4.1% (DEL) versus 3.2% (non-DEL) ($p=0.11$)] and dialysis catheter insertion [4.0% (DEL) versus 3.1% (non-DEL) ($p=0.11$)]. Data for ICU procedures are shown in **Table 2**.

Among ICU survivors, median ICU LOS was 1.9 days (DEL) versus 1.8 days (non-DEL) ($p<0.01$). Among hospital survivors the median hospital LOS was 7.0 days (DEL) versus 6.0 days (non-DEL) ($p<0.001$). The ICU mortality rate was 10.7% (DEL) versus 8.4% (non-DEL) ($p<0.01$). The in-hospital mortality rate was 17.4% (DEL) versus 12.9% (non-DEL) ($p<0.001$). Data for LOS and mortality are shown in **Table 3**.

In the post-hoc analysis within the most common DEL diagnostic category (sepsis), there were 115 subjects (11.1% of DEL) in the sepsis diagnostic category in the DEL group (DEL_{sepsis}) and 2,689 subjects (6.2% of non-DEL) ($p<0.001$) in the non-DEL group (non-DEL_{sepsis}). The mean age was lower in the DEL_{sepsis} group [63.4 ± 17.3 years (DEL_{sepsis}) versus 67.2 ± 14.7 years (non-DEL_{sepsis}) ($p=0.04$)]. Otherwise, the two sepsis subgroups had similar baseline patient characteristics with respect to genderand severity score (p=NS), with a mean APACHE II score of 24.0 ± 14.7 for DEL_{sepsis}versus 22.4 ± 8.4 for the non-DEL_{sepsis} cohort(p=0.24). The median ICU LOS was 2.5 days (DEL_{sepsis}) versus 1.5 days (non-DEL_{sepsis}) (p=0.55). The median hospital LOS was 9.0 days (DEL_{sepsis}) versus 9.0 days (non-DEL_{sepsis}) (p=0.93). The ICU mortality rate was 27.8% (DEL_{sepsis}) versus 20.4% (non-DEL_{sepsis}) (p=0.06). The in-hospital mortality rate was 35.7% (DEL_{sepsis}) versus 29.0% (non-DEL_{sepsis}) (p=0.13).

The results from the logistic regression are shown in **Table 4**. Advancing age, higher APACHE II score, and male gender were all associated with significantly lower hospital survival, while the presence of a diagnostic category of sepsis did not reach statistical significance.

Expected total hospital costs were $17,788 for the DEL group and $16,361 for the non-DEL group, reflecting a difference in expected costs of $1,427. In a one-way sensitivity analysis in which the average ICU cost per day was varied between $748 and $11,964, the total expected cost was always greater in the DEL group versus the non-DEL group, although the difference narrowed with rising daily ICU cost. Specifically, when the average ICU cost per day was $748, a patient in the DEL cohort consumed $1,635 more than a non-DEL patient. Similarly, at the upper bound of $11,964, a patient in the DEL cohort still consumed more resources, but the difference narrowed to $594.

Figure 2 depicts a two-way sensitivity analysis in which ICU cost per day and floor (non-ICU hospital ward) cost per day were simultaneously varied. As **Figure 2** demonstrates, the non-DEL cohort accrued lower expected total costs in almost all circumstance, as the DEL cohort accrued lower expected total costs only when ICU costs per day were several times the floor costs, and only when floor costs were less than $1,000 per day. In the Monte Carlo simulation of 10,000 patients for each cohort, the mean cost for the DEL cohort was $17,759 (SD $\pm$ $6,532) with a median of $19,416. For the non-DEL cohort, the mean cost was $16,350 (SD $\pm$ $3,705) with a median of $17,138.

DISCUSSION

When the decision is made to admit a critically ill ED patient to the ICU, that patient likely stands the best chance for survival when he or she is transferred as expeditiously as possible..[1-6] As Rivers and colleagues demonstrated in ED patients with septic shock, mortality is significantly reduced when early goal-directed therapy is instituted as soon as the diagnosis is made.[1] Similarly, trauma victims have higher survival when they are expeditiously transferred from the field to properly equipped and staffed trauma centers,[5] and patients with acute myocardial infarction[6] and ischemic cerebrovascular events[22] also do better when reperfusion therapy is expeditiously administered.

Since the critically ill stand to benefit from the highly specialized and skilled environment of the ICU, it stands to reason that delayed transfer to the ICU for those in need is potentially deleterious. Despite this, the “boarding” of critically ill patients in the ED (holding admitted patients in the ED pending inpatient ICU bed availability) and the prolongation of ED length of stay nevertheless remains a common occurrence that is increasing in frequency in the United States.[7, 8, 10, 11] Although ED boarding has been previously utilized as a surrogate for adverse outcome, the impact of ED boarding and delayed transfer to an inpatient bed on patient outcome and cost of care remains unclear.[15] Because of the potential public heath and policy ramifications of delayed transfer to the ICU, we sought to address and examine the clinical and economic impact of ED boarding for critically ill patients.

In this study of over 50,000 patients from the Project IMPACT™ database – a large, clinically-driven database derived from approximately 150 ICUs across the United States – that were admitted directly from the ED to the ICU, DEL subjects had a longer median hospital LOS (7.0 days versus 6.0 days), a higher ICU mortality (10.7% versus 8.4%), and a higher total in-hospital mortality (17.4% versus 12.9%). Among DEL subjects, significantly higher rates of utilization of mechanical ventilation and central venous catheterization in the ICU were observed, although there were no differences in utilization of dialysis and PA catheters between the two cohorts. Expected costs were also higher in the DEL group by $1427 over the non-DEL group, a factor that remained relatively constant in a Monte Carlo sensitivity analysis of a large simulated cohort.

There are many potential sequelae of adverse outcome that may occur as a result of delayed transfer from the ED to the ICU and thus the prolonged ED length of stay. Because of the busy nature of ED practice which entails simultaneous responsibility for numerous patients of varying severities of illness, ED physicians and nurses may not be able to provide the focused one-on-one care that a critically ill patient may require and receive in the ICU, especially in situations of ED overcrowding and high patient acuity relative to the clinical staffing of the ED. While the ICU is a clinical environment that, by definition, enables close attention to the critically ill and allows for recognition of physiologic change and sudden deterioration, the ED is neither designed nor staffed to provide extended longitudinal care for the critically ill patient. It is also possible that there may be a different level of critical care expertise among the physicians and nurses that care for the patients who awaiting ICU transfer, compared to the critical care expertise of the practitioners in the ICU setting. Since many studies have shown that the critically ill have better outcomes when treated in ICUs with close and continuous involvement by critical care physicians[23-25] and other data also shows improved outcome when nurse-to-patient ratios in the ICUs are properly maintained,[26] it stands – by extension – to reason that the critically ill may suffer when treated for prolonged periods in non-ICU settings, a contention further supported by this study.

From an economic standpoint, our decision analysis model estimated that the total expected costs likely to be incurred by critically ill patients admitted to the ICU via the ED the non-DEL cohort accrued fewer expected costs than the DEL cohort. Multiple sensitivity analyses of the variables likely to be encountered in a myriad of real-world settings demonstrated that non-DEL expected costs were lower in almost all circumstances. In addition, a Monte Carlo analysis of a simulated cohort of 10,000 patients further substantiated the results, because it yielded consistent results for higher expected costs for the DEL cohort on the basis of random variation of all the model variations for each of the individual "patient" events.

It is important to note that this economic analysis only estimated the anticipated direct costs, and only those costs that accrued once a patient was admitted to the ICU. In light of this, one could safely surmise that DEL patients will likely accrue more ED-related direct costs along with more indirect costs. Specifically, critically ill (and other) patients who remain in the ED for extended periods of time invariably require additional monitoring and staff attention and will, by definition, shunt valuable resources that could otherwise be allocated to the care and treatment of other ED patients. Therefore, in addition to worse clinical outcomes, higher inpatient LOS (both ICU and total), and higher expected direct costs, the indirect economic consequences of delayed transfer from the ED to the ICU may further compound the potential resource differential between the two cohorts. Clearly, more work is needed to clarify the full scope of the economic ramifications of delayed ICU admission from the ED.

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LIMITATIONS AND SHORTCOMINGS:

There are six main limitations of the study: (1) use of a retrospective methodology and the inherent inability to identify the cause of delay, (2) the lack of institutional data and the inability to control for institutional variation in patient care, (3) the use of a dichotomous variable to define the DEL group, (4) some degree of diagnostic category heterogeneity in the DEL and non-DEL groups, (5) the absence of APACHE II scores for all patients in the database, and (6) reliance on a decision analysis model (because Project IMPACT™ does not record cost) in order to estimate economic impact.

While Project IMPACT™ is a large and robust multicenter database developed by clinicians, it nevertheless possesses inherent shortcomings. Although the number of participating hospitals and ICUs in Project IMPACT™ is large and varied, participation in Project IMPACT™ is nevertheless voluntary and thus, it is possible that the participating ICUs and hospitals may possess characteristics that distinguish them from all other non-participating units and hospitals. Furthermore, since Project IMPACT™ was designed from an ICU perspective, it may fail to capture certain parameters that describe ED workload, acuity, and performance such as ED size and capacity, the volume of critically ill patients presenting to the ED relative to other ED patients, the volume of critically ill inpatients relative to the inpatient ICU capacity at the time of admission, and other indices that may contribute to ED overcrowding and caseload.

Project IMPACT™ also contains also no data regarding other vital ED performance characteristics such as physician and nurse staffing and qualifications (e.g. board certification and eligibility), ED patient case-mix, availability technology, and availability and access to critical care consultation and evaluation. The latter is important, because while critical care services are best delivered in a proper ICU environment, the inability to admit critically ill patients to the ICU does not necessarily imply the absence of critical care assessment, evaluation, and treatment. In the study by Rivers et al of early goal-directed therapy in severe sepsis for example, the key factor under investigation was the rapid institution of the goal-directed therapy by qualified clinical personnel regardless of patient location as opposed to the transfer to a specific location like the ICU to institute the therapy under investigation.[1] Thus in the present investigation, one cannot conclude whether delayed transfer does or does not imply delivery of necessary or even optimal critical care services.

In addition to this, despite the fact that our data show a clear increase in patient mortality in the DEL group, it is possible that this higher mortality rate may reflect triage decisions to some extent, as patients that are viewed as salvageable may be brought expeditiously to an ICU whereas patients with poor prognosis that are thought to be unlikely to benefit from ICU care may be a lower priority for ICU transfer. However, the fact that both groups had similar APACHE II scores and similar rates of DNR and advanced directives upon ICU admission seems to suggest that triage decisions likely only played only a minor role, if any.

From the standpoint of patient-specific variables that may also affect outcome, logistic regression demonstrated the presence of other factors associated with higher mortality besides the presence of a delayed admission, most notably male gender, advancing age, and higher severity of illness. However, it is important to note that APACHE II scores were not available for all patients in the Project IMPACT™ database, since certain participating ICUs elect in advance whether or not to collect APACHE II data. While the potential for a systematic bias is inherently possible, this concern is attenuated by the observation of the expected relationship between mortality and severity of illness.

We also cannot eliminate the possibility that certain institutional factors may have contributed to this difference despite the fact our results showed that DEL patients had higher mortality, LOS, and total expected costs. Specifically, since only 1,036 patients out of a sample of over 50,000 patients were delayed ≥6 hours in the ED prior to ICU transfer, we cannot eliminate the possibility of a center bias (e.g. a large percentage of delayed admissions coming from one or a few hospitals or ICUs) because the institutional variables were stripped from the data as part of the process of de-identification for patient confidentiality. Similarly, we did not assess for the presence of other confounding factors, such as hospital size, ICU management structure, and geographic location. Future work will need to assess whether or not these and other factors are associated with delayed admission and hence, patient outcome and cost.

Since the data for this study was retrospectively derived, we were only able to use a dichotomous variable (≥6 hours boarding) to categorically define the DEL group because of the limits of the Project IMPACT™ database and hence, could not analyze the impact of delayed admission from a continuous standpoint over time. This lack of a continuous variable for total time in the ED limits what can be concluded about time-sensitivity of expeditious transfer to the ICU. However, this figure of 6 hours correlates with the 5.8 hour period that was reported as the mean time to transfer from the ED to an acute or critical care bed in overcrowded U.S. hospitals.[8] In addition to this, one must remain cognizant of the fact that the determination of time in the ED, along the time of initial presentation and the precise time of ICU admission may vary from center to center. Thus further work will need to investigate not only delays from a continuous standpoint versus a dichotomous cutoff but also, will need to ensure that precise definitions are in place to ensure uniformity of time-sensitive data and determinants.

From a diagnostic standpoint, although there are exact matches for eight of the top ten most common APACHE II admission diagnostic categories in the DEL and non-DEL groups, there is some degree of diagnostic heterogeneity, a factor which also could have influenced the observed results. In the non-DEL group, there were significantly more subjects in the multiple trauma, coronary artery disease, and respiratory categories. In the DEL group, there were significantly more subjects in the sepsis category, which was the single most common diagnostic category in the DEL group. Although heterogeneity in the diagnostic categories is a limitation in terms of determining the specific impact of ED boarding, the differences in diagnostic categories represents valuable observational data.

Multiple trauma and coronary artery disease are traditionally thought to be time-sensitive conditions for which the "golden hour" of therapy is critical,[5, 6] and significant delays in the care of either of these conditions could likely be viewed as a breach of the standard of care. Despite the fact that we now have similar data on the time-sensitive nature of hemodynamic optimization in severe sepsis and septic shock from Rivers and coworkers,[1] the fact that sepsis was the most common diagnostic category in the DEL group suggests that sepsis (and the optimal care of the sepsis patient) may not yet be perceived as a highly time-sensitive process. Subgroup analysis within the sepsis diagnostic category revealed a trend toward higher ICU mortality that was nearly statistically significant for the DEL_{sepsis} group despite being significantly younger than the non-DEL_{sepsis} group.

Finally, one must be aware of the limitations inherent in a decision analysis model, in which data, including charge data from one particular institution, is derived from multiple sources and factored into a simulation that depicts the events likely to occur on the basis of probabilistic assumptions. However, multiple sensitivity analyses attenuate this concern, because it determines expected outcomes on the basis of values for costs, LOS, and even clinical outcomes that one will encounter in almost all real-world settings.

The results of this study suggest that delayed admission to the ICU from the ED is associated with increased mortality and higher costs. Further work is needed to identify (1) the factors associated with delayed ICU admission as well as (2) the specific determinants of adverse clinical and economic outcomes for critically ill ED patients and

(3) the precise economic impact and time sensitivity of delayed transfer from the ED to the ICU.

CONCLUSIONS

Critically ill ED patients with a $\geq$6 hour delay in ICU transfer had an increased hospital LOS, ICU mortality, in-hospital mortality, and higher expected costs. These findings show a possible clinical and economic benefit from expeditious transfer of critically ill patients from the ED to the ICU and suggest the need to further evaluate the factors associated with delayed ICU admission as well as the specific determinants of adverse outcomes.

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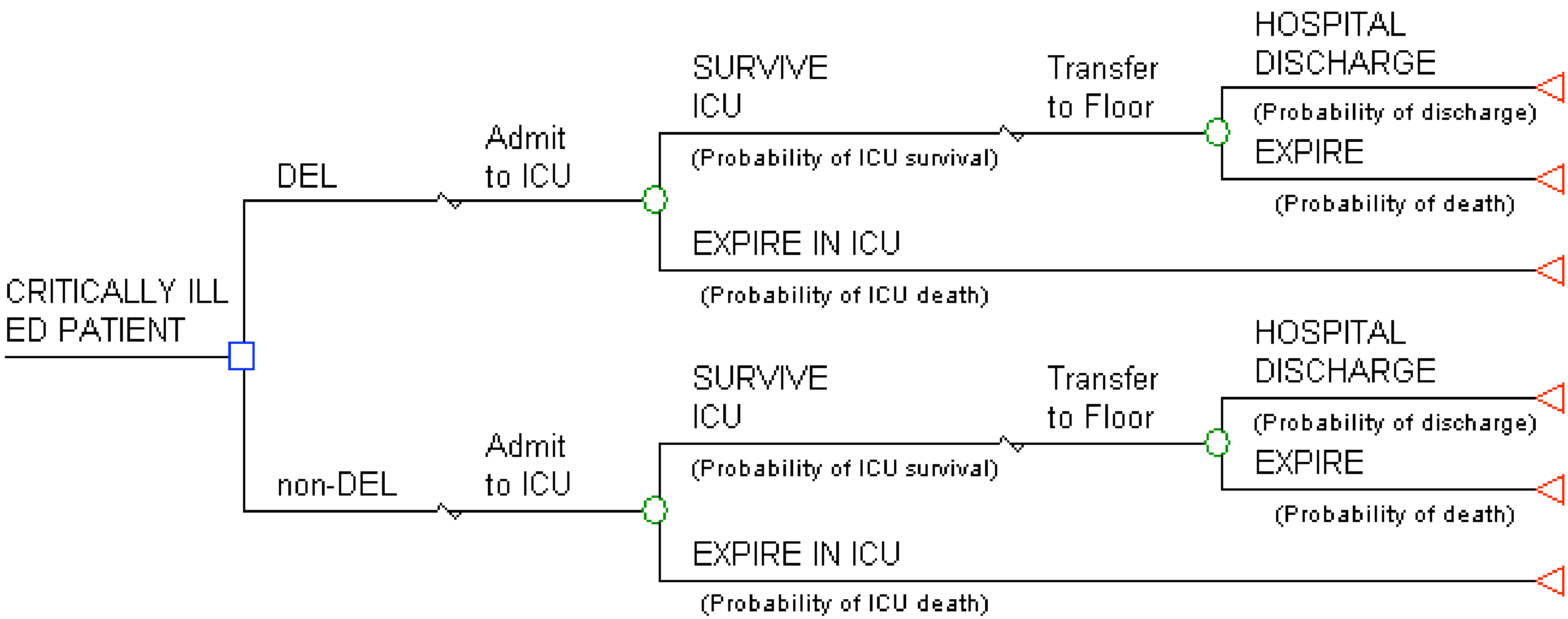
Figure 1: Decision tree used to determine expected costs for critically ill patients (DEL and non-DEL) admitted from the ED to the ICU



[DEL = delayed; non-DEL = non-delayed; ED = emergency department; ICU = intensive care unit; floor = non-ICU ward of the hospital]

Table 1a: Patient characteristics.

	DEL (n= 1036)	non-DEL (n= 49286)	p-Value
Age (years)	57.4 ± 19.7	58.4 ± 19.8	0.10
Gender (% male)	54.3	54.0	0.81
DNR (%) (on admission)	0.1	0.1	0.60
Any advance directive (%)	17.0	15.3	0.14
APACHE II[a]	16.3 ± 8.3	15.7 ± 8.1	0.08
Ten most common APACHE II admission diagnostic categories (%)	Sepsis (11.1)	Gastrointestinal bleeding (8.3)	
	Gastrointestinal bleeding (9.0)	Coronary artery disease (7.7)	
	Intracerebral hemorrhage (7.0)	Drug overdose (7.0)	
	Drug overdose (6.6)	Multiple trauma (6.4)	
	Neurologic (NOS) (6.4)	Intracerebral hemorrhage (6.2)	
	Respiratory infection (5.3)	Sepsis (6.2)	
	Cardiovascular (NOS) (4.7)	Neurologic (NOS) (6.1)	
	COPD (4.6)	Cardiovascular (NOS) (5.4)	
	Coronary artery disease (4.1)	Respiratory (NOS) (5.4)	
	Multiple trauma (4.0)	Congestive heart failure (4.6)	

[DEL = delayed; non-DEL = non-delayed; DNR = do not resuscitate; APACHE = Acute Physiology and Chronic Health Evaluation; NOS = not otherwise specified]

[a] Based on worst values for first 24 hours in ICU

Table 1b: Comparison of the most common APACHE II diagnostic categories (descending order) between DEL and non-DEL cohorts

Diagnostic category	p-Value[a]
Gastrointestinal bleeding	0.32
Coronary artery disease	<0.001
Drug overdose	0.57
Multiple trauma	<0.01
Sepsis	<0.001
Intracerebral hemorrhage	0.57
Neurologic (NOS)	0.77
Cardiovascular (NOS)	0.36
Respiratory (NOS)	<0.01
Congestive heart failure	0.13
Respiratory infection	0.14
COPD	0.17

[NOS = not otherwise specified; COPD = chronic obstructive pulmonary disease; DEL = delayed; non-DEL = non-delayed]

[a] Comparing relative frequencies of these diagnostic categories between the DEL and non-DEL cohorts with chi-square analysis

Table 2: Procedures performed.

	DEL (n = 1036)	non-DEL (n = 49286)	p-Value
Central venous access (%)	32.5	22.0	<0.001
Dialysis catheter (acute) (%)	4.0	3.1	0.11
Pulmonary artery catheter (%)	4.1	3.2	0.11
Mechanical ventilation (%)	39.3	29.5	<0.001
Mean duration (days)	3.5 ± 4.4	4.1 ± 6.0	--
Median duration (days) (range)	1.9 (0-27)	1.7 (0-86)	0.08

[DEL = delayed; non-DEL = non-delayed]

Table 3: Outcomes

	DEL (n = 1036)	non-DEL (n = 49286)	p-Value
ICU LOS [a]			
Mean (days)	3.1 ± 3.6	3.1 ± 4.3	—
Median (range)	1.9 (0.1 – 30.8)	1.8 (0.1 – 82.9)	<0.01
Hospital LOS [b]			
Mean (days)	10.1 ± 11.2	8.7 ± 9.8	—
Median (range)	7.0 (1 – 154)	6.0 (1 - 256)	<0.001
ICU mortality (%)	10.7	8.4	<0.01
In–hospital mortality (%)	17.4	12.9	<0.001
Expected total hospital costs (USD)[c]	17,788	16,361	

[DEL = delayed; non-DEL = non-delayed; LOS = length of stay, USD = United States dollars]

[a] For subjects that survived to ICU discharge and had no "do not resuscitate" (DNR) order at time of admission
[b] For subject that survived to hospital discharge and had no DNR order at time of admission
[c] From decision analysis model

TABLE 4: Logistic regression for hospital survival.

	B	S.E	Wald	df	Sig	Exp(B)
Age	-.01	.001	54.89	1	<.001	.99
Gender (1=male, 0=female)	-.09	.04	5.60	1	.02	.91
DELAYED admission (1=Yes, 0=No)	-.33	.12	8.07	1	<.01	.72
Apache II score	-.17	.001	3857.85	1	<.001	.84
Sepsis (1=Yes, 0=No)	-.09	.06	2.20	1	.14	1.09
Constant	5.70	.10	3711.91	1	<.001	299.27

Figure 2: Two-way sensitivity analysis on expected costs varying the ICU Cost per Day and the Floor Cost per day. The intersection of the graphs reflects the threshold level at which total expected costs would be equivalent. All numbers are in United States dollars. [Floor = non-ICU hospital ward]