Analyses approach: exploring the effect of emergency department interventions on outcomes of hospitalisation

Karen Clark and Loretta Normile describe the approach of analysis of variables for outcomes research. The purpose of the study was to explore the effects of interventions in the emergency department on outcomes of hospitalisation for cases admitted to intensive care directly from an emergency department.

Introduction

This article describes an exploratory analysis approach to studying processes in an emergency department (ED) for time-based interventions implemented on outcomes of a hospitalisation for critical care admissions originating from the ED. Processes and interventions not only affect the length of stay in the ED before disposition, but also help with admissions to an inpatient bed. These factors also have an impact on outcomes of a given hospital stay.
The study used a retrospective convenience sample of 1,536 cases with admissions to five intensive care units (ICUs) originating from the study hospital’s ED. The methodology was an exploratory, descriptive, correlational, and comparative analysis of secondary data. The data were collected from an existing database presently in use in the study hospital. The statistical software program used was SPSS. Statistics included descriptive, frequencies, correlations, cross tabulations, box plots and scatter plots, as well as linear and logistic regression for final analyses. Several regression models were used to explore predictors for outcomes of length of stay and hospital mortality. Both the ICU and hospitalisation were separately analysed for length of stay and mortality. Length of time spent in the ED after receiving the order for admission to an ICU bed was also explored related to predictors.

Conditions in the ED affect all aspects of care delivery, whether provided for patients discharged home or admitted to the hospital. Hospital patients with admissions originating from the ED in many instances are kept for long periods while awaiting a bed. This affects all activities in an ED, not just admissions. A Government Accounting Office (GAO) report (2003) on hospital ED conditions found that one key factor contributing to overcrowding in the ED involved the inability to move patients out of the ED and into inpatient beds when they must be admitted rather than released. Further, the report identified difficulties in getting critical care or telemetry beds for admitted patients, which contributed to the ‘boarding’ of those admitted patients in the ED. Between 1997 and 2000, use of the ED was up by 14 per cent. However, available EDs decreased by 2 per cent, resulting in a total average increase in visits of 16 per cent.

A study by McCaig and Burt (2004) found that for the year 2002, ED use was 110.2 million visits. On average, patients spent 3.2 hours in the ED. Data from the National Hospital Ambulatory Medical Care Survey for 2003 (McCaig and Burt 2005) estimated ED visits at 3.9 million. Approximately 14.2 per cent of these arrived by ambulance. Of all visits in 2003, approximately 14 per cent resulted in hospital admission. According to this report, the average time spent in the ED remained 3.2 hours.

Derlet and Richards (2000) addressed prolonged waiting times in the ED as a public safety risk leading to poor outcomes. The waiting times for critical
care patients affect cost, access to services and clinical management, influencing the potential for poor outcomes related to mortality and morbidity, according to Derlet et al (2001). Svenson et al (1997) found a ‘substantial number of patients boarded in the ED because of a lack of available ICU beds. Thirty percent waited for an average of 10 hours in the ED and even after the bed was available, it took an average of two hours to transfer the patient to the ICU.

Svenson et al (1997) found critically ill patients comprised a substantial percentage of ED patients and they remained in the ED for prolonged periods. Yet little is known of the outcomes of this acutely ill population. Additionally, staffing was recognised as problematic: ‘EDs must be staffed adequately with appropriately trained personnel to care for these patients.’

Clark and Normile (2002), in a study covering six US states, found that 59 per cent of respondents ‘indicated difficulties in getting critical care patients out of the emergency department to critical care beds’. The GAO (2003) cited limitations, reporting the extent of time patients waited or how long they were boarded in the ED. Hospitals do not collect this specific time-sensitive information and thus estimate how long and how often patients board.

Outcomes research

In an effort to establish outcomes research, the American Academy of Nursing recognised the importance of outcomes in the delivery of care and established ‘an Expert Panel of Health Care Quality to examine policy issues related to outcomes research and outcomes management’ (Jones et al 1997). This panel proposed research on healthcare interventions. The specific indicators identified included mortality, morbidity and cost. A need for the inclusion of nurses in decisions concerning outcomes of the delivery of health care was also identified, as was a need for nurses to adopt an integrated practice framework and participate in research. The panel also identified the importance of nursing involvement in research and that ‘outcomes analyses can influence health policy and patient decisions’ (Jones et al 1997). Involving nurses in research encourages different views of approaches to research methodologies.

In a quality improvement measure, Lieberman (2003) suggested implementing information technology throughout a healthcare system to measure
outcomes to increase access to appropriate services. He added: ‘Many experts believe the way to fix this problem is to encourage doctors and hospitals to invest in systems to help them track what they are doing and give them information to improve the quality of care they provide.’

An analysis of outcomes could provide services and healthcare coverage providers with information on the most cost-efficient methods to deliver quality care to ED patients who are admitted to ICUs, accurate information to consumers on what to expect and pertinent data to regulatory agencies.

**Systems for data collection for outcomes research**

One mechanism in outcomes research is the use of integrated data systems able to track outcomes of measurable interventions throughout a hospital stay. Studies such as Dean et al (2001) proposed using outcomes-research methodology with data-driven systems to link predictor variables of interventions across departments, such as pre-hospital settings, to outcomes of hospital stays. Dean et al specifically studied outcomes of ED stays based on an integrated computer system that captured measurable interventions pre-hospital and specific results of an ED stay.

Sophisticated computer tracking systems employed in EDs generally exist independently of other hospital computer systems. Information gathered in ED computer tracking systems is important for analysis related to services provided within the ED. Typically these systems capture information such as the patient’s name, complaint, age, assigned doctor, assigned nurse and location on ‘tracking boards’ (Boger 2003). Some systems are manual, others computerised, and information captured in an ED is not always available for permanent storage to analyse trends later that can affect outcomes of care. Some hospital EDs have elected to develop internal tracking systems unique to their needs instead of buying commercially available computer systems. This is due in part to varying limitations, benefits, costs and difficulties in meeting specific hospital requirements. Even ‘home grown’ systems do not routinely interface or communicate easily with hospital-wide computerised systems, easily analyse outcomes or provide results from data, tests or information. Therefore, once the patient is admitted to the hospital and leaves the ED there has been no consistent methodology for associating ED events
to the outcomes of hospitalisation. In many instances, however, data is collected to determine outcomes of interventions such as time to thrombolytics for patients with myocardial infarctions (American College of Cardiology and American Heart Association 1999). Yet for outcomes research, integrated computer systems between the ED and the hospital system can provide the mechanisms to measure outcomes of services provided in the ED before admission and throughout the hospital stay.

**Purpose of this study**

The importance of timeliness of interventions is crucial to outcomes of any ED visit. Therefore, the purpose of this study was to employ and describe exploratory methods of analysis to determine the impact of timeliness of interventions in the ED for patients admitted to ICU on outcomes of mortality and length of hospital stay.

**Methodology**

This study used exploratory analysis procedures. The primary base population observed included all patients admitted through the ED at the participating hospital. From that population, the ICU patients admitted through the ED formed the group of study. ED visits were roughly 65,000 per year during the study years, with approximately 30 per cent of those visits resulting in admission to the hospital from the ED. Identifying only those patients admitted directly to the ICU resulted in a sample size of 1,536.

**Ethical considerations**

Approval for this study was obtained from the participating hospital and the Human Subjects Review Board of George Mason University in Fairfax, Virginia.

**Data source and systems**

Operational processes pose difficulties such as tracking patient flow through EDs and communication for patients, families, staff and other departments interacting with the ED (McKay 1999). The participating facility, a member of a multi-hospital healthcare system, uses a computer-tracking system data-
base in the ED. At the time of this study, all member hospitals used this data system. However, the flagship hospital alone had developed the database tracking system sufficiently to provide the variables for this study. The system was developed under the direction of physician informatics specialists and is the infrastructure to capture data elements specific to the needs of the hospital system. Information entered into the database includes, but is not limited to, patient demographics, test results, vital signs and insurance status. Additionally, several thousand data points are collected and entered, and can be tracked for analysis. The database provides the ability to view real-time pictures in the ED department while the patient is having tests such as a CT scan in the radiology department. Once the patient is admitted and moved into the hospital, the timeliness of interventions and events can be tracked and analysed throughout the hospital stay beginning with entry into the ED.

At the time of this study the programme was built in part on a Microsoft SQL Server which allowed for the handling of hundreds of terabytes of patient data, both live and historical, in a Windows framework. It included many Windows-based computers that interfaced with other systems. This platform provides data viewers that have the capability to read imported and exported data in text files that are reconfigured to view in a variety of formats and across systems. This allows sharing of information not only between hospital computer programmes but across the hospitals that are in the system. At the time of this study, no literature was found that identified analyses of collected data using this type of system to compare the effect of events occurring in the ED on outcomes of the hospital stay.

**Process of accessing data, sample identification and access**

The database was accessed remotely using the internet. Two specific software programs were necessary to access and collect the data for this study. Secure Remote provided the platform necessary to connect to the host program, which contained the specific database information. Both programs required log-on names and individual passwords to protect patients’ private medical information.

The database was used to determine the number of admissions originating from the ED to the five individual ICUs identified at the participating hospital.
The anticipated admissions from the ED to the five ICU units ranged from approximately 300 to 500 per year. Therefore, the two-year sample size was estimated to range from 600 to 1,000 cases.

Initially, the database query for admissions specific to the ICUs did not result in the expected number of admissions. A second query submitted to the programme was performed for all admissions and visits to the five individual ICUs. To accomplish this query, the request submitted was for all ‘visits’ as a specified identifier or filter. This step listed admissions as visits to the ICUs. All admitted patients occupying ICU beds, whether for hours or days, were identified. The results of this query found approximately 400 to 500 admissions or visits to each of the ICUs per month. Individually scanned charts were reviewed for each admission or visit to all five ICUs to determine the origin of the ICU visit. Once the admissions originating from the ED that met the inclusion and exclusion criteria were identified, separate monthly files were created.

**Building the database for analysis**

To collect the study variables, monthly files were created and saved in separate views to be imported later into SPSS. Account numbers and dates were used initially to match cases identified as John or Jane Doe. The International Classification of Diseases – Ninth Version (ICD-9) (National Center for Health Statistics 2002) was the element recorded in the hospital database identifying ED complaint, admission diagnosis, discharge diagnosis and co-morbidities. Each data file was reviewed to make sure there was no mismatching of data as the data was time and case sensitive. Upon final review and verification of each month of data, the data was exported to Excel and then into SPSS. Each file was again cleaned by checking and re-checking to make sure data were accurate for each individual case and re-checked for accuracy across the continuum of time from arrival in the ED to hospitalisation disposition. After carefully matching cases across time from admission to discharge, each monthly file was prepared to merge it into one database file. The original data and the list of the 2002 version of ICD-9s were verified. During final cleaning and review of accuracy of the data, ICD-9s collected were listed by the 19 disease categories (ICD-9 CM 2004). Based on the frequency of ICD-
9s reported, this study’s cases categories were collapsed from 19 to 14 for the three data elements of ED complaint, admission diagnosis and discharge diagnosis. The final sample size was 1,536. Each of the time elements included in the study was in a different format in the reference facilities systems. To allow for analysis of the time elements, the date and time variables were converted into a format that SPSS could understand. Once those dates and times were verified as accurate, all of the time elements were converted to minutes for consistency of analyses.

**Analysis procedures**

Exploratory analysis procedures provide mechanisms to investigate complex inter-relationships among variables (Polit and Beck 2004). Using this approach clarified a large set of variables by identifying factors for further analysis. Steps were taken manually by investigating descriptive data, frequencies, box plots, scatter plots, cross tabulations and correlational analysis of the variables. Several of the variables were categorised and dummy coding used, along with steps to identify relationships, including inter-relationships with extraneous variables or confounding variables in this study. Further steps led to several models that employed logistic and linear regression. Based on the outcomes of the stages of analysis and the reduced number of variables, logistic regression was used for the dichotomous outcome variable of mortality. Linear regression was used for the outcome variable of study: length of stay. In the regression models, backward stepwise method was used to explore the independent variables’ relationships to the dependent variables, with exp(B) (or e^B) for both odds ratios and confidence intervals included in the analysis.

**Time-sensitive variables**

To allow for conformity and consistency in analysis of time variables, each of the time sensitive variables was converted to minutes. It was noted that there was a significant skew to the right (Figure 1). Log transformation was performed to convert the distribution of the raw data to a roughly normal distribution (Figure 2). By converting the time-sensitive variables into log normal values, the data was more evenly distributed and the statistical output of the data measurable.
Figure 1. Pre Log Transformation

Total time in ED in minutes: Up to 1,622 minutes with a mean of 298 minutes

Figure 2. Post Log Transformation
In addressing the possibility of a Type I error, a significance value of 0.05 was used. To reduce the possibility of a Type II error, the sample size included all cases that met the inclusion or exclusion criteria from the secondary dataset during the time period of the study. The data was reviewed, cleaned and explored for accuracy related to the time and case-sensitive nature of the study.

**Results**

In using exploratory analysis, the purpose of this study was to investigate the relationship between waiting times while in the ED on subsequent outcomes of ICU admissions originating from the ED. The study design was a non-experimental, exploratory, retrospective, comparative analysis on a secondary data set from an existing database in a full service tertiary care trauma centre hospital. Total sample size was 1,536 cases admitted from the ED to an ICU. The variables were analysed using SPSS 11.5. Some of the data elements were missing when the data was collected on the sample of ED admissions to ICU. To maximise the validity and reliability of the findings, the missing elements were controlled using SPSS to define the best sample size related to the most complete data entries. The final sample size used for the regression models was 1,200. The level of significance was selected as 0.05 for all analyses two-tailed.

Exploratory analysis included independent variables with models using logistic regression analysis of dichotomous dependent variables and linear regression analysis of time-sensitive dependent variables. Several regression models were used to explore possible predictors related to the outcomes of length of stay and mortality of the hospitalisation. Using this methodology for analysis allowed the exploration of the many variables and factors that are interrelated in the ED environment. These interrelated factors affected the timelyness of interventions in the ED environment.

The logistic regression model in this study investigated mortality as the outcome. Time-sensitive variables included: time from arrival to order for ICU bed; time from order for ICU bed to leaving ED; time to first medication; time to first radiological examination; time to first lab work result; whether admitted from the ED on the weekend or on a weekday; ED complaint and discharge diagnosis based on the ICD-9; patient’s age; as well as the level of
the service provided by the ED physician based on case need in the course of the ED visit.

Using the logistic regression model the predictor variable of major interest on the outcome of hospital mortality was the amount of time after receiving an order for an ICU bed to leaving the ED. The significance was 0.032 with mortality odds of 1.169 times more likely to occur based on the variables that were found to be significant to hospital mortality (Clark and Normile 2007a). With increasing age, the odds of mortality increased per year of age by 1.047 at a significance of .000. If admitted to the ICU from the ED at the weekend, odds of mortality increased by 1.578, B coefficient of +.456, confidence interval of 1.076 to 2.315 and significance of .021 (Table 1). The factors of time to first medication, to first radiological examination and first blood work result were not significant. In logistic regression analysis, the Nagelkerke R Square measures the strength of associations. The result of .401 indicated a moderate association between the dependent variable of hospital mortality and the independent variables included in the model, thus supporting the validity of the findings.

<table>
<thead>
<tr>
<th>Predictive independent variables</th>
<th>B</th>
<th>Sig.</th>
<th>exp(B)</th>
<th>Lower</th>
<th>Upper</th>
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<tbody>
<tr>
<td>Log Times: Admission order to out of ED</td>
<td>.156</td>
<td>.032</td>
<td>1.169</td>
<td>1.012</td>
<td>1.350</td>
</tr>
<tr>
<td>Age</td>
<td>.045</td>
<td>.000</td>
<td>1.047</td>
<td>1.034</td>
<td>1.059</td>
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<tr>
<td>ED Walkins</td>
<td>-.449</td>
<td>.018</td>
<td>.638</td>
<td>.439</td>
<td>.928</td>
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<tr>
<td>Weekend admissions</td>
<td>.456</td>
<td>.021</td>
<td>1.578</td>
<td>1.076</td>
<td>2.315</td>
</tr>
<tr>
<td>Intensity of ED Physician Service 4</td>
<td>.532</td>
<td>.000</td>
<td>1.703</td>
<td>1.321</td>
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<tr>
<td>ED Complaint: Respiratory</td>
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<tr>
<td>Constant</td>
<td>-4.680</td>
<td>.000</td>
<td>.009</td>
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</table>
The linear regression model examined the time-sensitive dependent variable of length of hospital stay. Interventions analysed and found significant were time to first medication, age, weekend versus weekday admissions from the ED, discharge diagnosis of infectious diseases and intensity of service. The ANOVA was significant at .000 with an R square of .153. Even though the R square was not large, the linear regression model was significant for time to medication at .003, with a B coefficient of .055, odds of 1.06, and 95 per cent confidence interval at .019-.092. Weekend admission was noted to have a negative B coefficient of -.138, significance of .017, odds of .87 with confidence interval of -.252 to -.025. This indicated that when compared to the other variables in this regression model, cases admitted on weekends were less likely to have a longer length of hospital stay (Clark and Normile 2007b).

Mortality in the ICU was also explored exclusive of hospital mortality. It was noted that time to first radiological examination had a significance of .060. Significance between 0.05 and 0.10 with exploratory research may warrant further study. Patients admitted on the weekend had a significance of .020, and odds of 1.640, and positive B of .495, indicating those cases were more likely to die in the ICU. Patients were less likely to die in the ICU, with a significance of .010, if they walked into the ED to be seen rather than arriving via ambulance. The Nagelkerke R Square for this model was .432.

**Strengths and limitations**
The strengths of this study included the computer database system, which helped with the collection of ED variables and hospital stay variables from one system. SPSS was used to explore the relationships, controlling for the extraneous confounding variables as much as possible. Regression analysis assisted with identifying predictive variables in an exploratory model. These included interventions in the ED on hospital mortality, hospital length of stay, ICU mortality, and ICU length of stay. The length of stay in the ED was divided into two parts of the whole, or time from arrival to receiving the admission order, and from receiving the order to leaving. By separating the total time in the ED into the two parts, means to explore the variables was provided and differences in outcomes were identified.
A limitation of this study was the use of only one large teaching hospital with a convenience sample. This limits the generalisation of the findings. Additionally, many factors exist simultaneously in the ED, which can affect analysis. These factors include staffing variation, staffing ratios, staffing in other departments that interact with the ED, timeliness of receiving results of tests, bed capacity of the hospital, time of year, shift, weekend or weekday, acuity of the patient upon arrival and presence of chronic illnesses.

Conclusions
The importance of accessibility to health care becomes more apparent as the healthcare delivery system crisis continues to search for better ways to deliver quality, accessible and cost-effective care. Using a database system containing patient data from request for care to disposition helped with this research: one of the findings suggested the longer a patient waits in the ED for an ICU bed after the admission order, the more likely the mortality. These findings were consistent with a study completed by Bell and Redelmeier (2001) who found that patients admitted to the hospital at the weekends had a higher mortality rate than those admitted on weekdays. Overall hospital system issues are reflected rather than an individual hospital or department process issue. The Joint Commission on Accreditation of Healthcare Organizations (2004) and the GOA report (2003) support the premise of system problems affecting the flow of patients and outcomes of care.

The economic condition of the healthcare system, with many hospital and ED closures, has reduced accessibility to care in some areas. This increases the burden on and visits to those EDs that remain open. A lack of skilled nursing staff is a factor in the decision to close beds, according to Derlet and Richards (2002). With the nursing shortage increasing, further demands are placed on the existing system that is already in crisis. According to a GAO (2004) report, health care was the USA’s top tax expenditure for the fiscal year 2004, estimated at $115.6 billion. The nursing shortage, reduced availability of inpatient beds with hospital closures, fewer available specialty physicians, varying degrees of insurance coverage and the ageing of the workforce all have an impact on a patient’s transition from the ED to an inpatient bed.

Continued research using a system-wide database interfaced with an
in-hospital system assists with the ability to do outcomes research related to process interventions. Using this approach with exploratory methods of analysis promotes the discovery of inferences to improve quality outcomes. These outcomes establish mechanisms to pursue structural changes, such as policy and procedures, which in turn can increase accessibility to quality care, and reduce duplication and cost.

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Acknowledgements
Thanks to Craig Feied MD, informatics specialist, for use of his database system and to Sigma Theta Tau Epsilon Zeta Chapter for partial funding of this research.

This article has been subject to double-blind review


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