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The Cost of Medication Errors in the Emergency Department: Implications for Clinical Pharmacy Practice

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Executive summary

Introduction

The main purpose of this capstone project is to provide an objective analysis of the cost of a medication error in the emergency department. The secondary objective of this analysis is to estimate the cost avoidance impact of providing clinical pharmacy services in the emergency department (ED).

Literature review

Previous literature has described the scope of clinical pharmacy services in the ED and has, to some extent, presented economic outcomes analyses of the impact of these services (Cohen et al., 2009; Lada and Delgado, 2007). According to Cohen et al., the current literature is still lacking a formal pharmacoeconomic model for estimating cost avoidance associated with pharmacist-initiated interventions in the ED.

Methods

Two data sets, one national and one local, were used to answer our basic research questions. The Nationwide Emergency Department Sample (NEDS) was used to estimate the national median cost of a medication error in the ED, and intervention data from the ED at the University of Kentucky Chandler Medical Center (UKCMC) was used to estimate cost avoidance via the prevention of medication errors.

Results

Based on analysis of the NEDS data, a medication error in the ED was estimated to result in a $268 increase in total ED costs. The difference in the medication error group and the control group reached a high level of significance [$p = 0.0000$]. By applying this result to the data on interventions recorded in the ED at UKCMC, cost

avoidance attributable to the presence of a clinical pharmacist in the ED was estimated to be $189,208 per year.

Discussion/Conclusion

The results of this analysis differ from those found in previous literature due in part to differences in methodology and population/facility size. The results of this analysis suggest that the cost avoidance associated with the prevention of medication errors by a clinical pharmacist in the ED would cover a large portion of the expected salary and compensation associated with hiring a clinical pharmacist to work in the ED.

Introduction

The main purpose of this capstone project is to provide an objective analysis of the cost of a medication error in the ED. The secondary objective of this analysis is to estimate the cost avoidance associated with the provision of clinical pharmacy services in the ED. This capstone project begins with an examination of the past and current available literature relating to the provision of clinical pharmacy services in the ED, with emphasis placed on literature that addresses either the cost of medication errors or the economic impact of interventions made by pharmacists in the ED. Where applicable, the literature review will expand to include more general research on economic outcomes as they relate to both the practice of pharmacy and medication errors.

After the pertinent literature has been reviewed and specific gaps in the current knowledge are identified, data and methods will be set up in a way to fill those gaps and answer the following basic research questions:

(1) How much does a medication error increase total emergency department costs?

(2) How much cost avoidance is associated with the prevention of medication errors by a clinical pharmacist in the emergency department?

Provided is a description of how two separate data sets, one containing national data and one containing local data, were employed to produce a cost avoidance estimate for clinical pharmacy services in the ED at UKCMC. This section will also include a discussion of any potential ethical issues or possible sources of bias in collection and analysis of the data.

Immediately following the methods section, the analysis of the cost of a medication error in the ED will be presented. That result will then be applied to the data obtained in the ED at UKCMC to estimate a cost avoidance value for the prevention of

medication errors by a clinical pharmacist in the ED. In this section the inpatient costs for the medication error group and the control group will also be compared, and the effect of a medication error on the likelihood of being admitted to the hospital will be addressed.

Following the results section, a brief exploration of how these findings compare with the results of other researchers is offered. The possible implications of these findings for hospital administrators as well as what other factors could enter into their decision-making process are discussed. Finally, the conclusions reached through this analysis and possible arguments for ED policy changes will be presented. This project concludes with the limitations of this research and author recommendations for further research in this field.

Literature Review

Past literature has described the scope of clinical pharmacy services in the ED. A recent review by Cohen, et al. listed more than fifty different services provided by clinical pharmacists in emergency departments. Examples of these services included: conducting chart reviews, anticoagulation services, obtaining allergy histories, participating on medical rounds, prospective medication order review, and recommending dosage adjustments (Cohen et al., 2009). In 2007, Lada and Delgado described additional pharmacy services in the ED such as answering nursing queries, obtaining order clarifications, and suggesting initiation/discontinuation of drug therapy. Many of these services could either directly or indirectly prevent or reduce the occurrence of medication errors and in effect reduce the number of preventable adverse drug events.

In light of the many available opportunities for provision of clinical pharmacy services in the ED, a survey of 135 physician residency programs in Emergency Medicine across the country was conducted in 2007 to assess the prevalence of these services in academic emergency departments (Szczesiul et al., 2009). The investigators found that only 8% of institutions had 24-hour pharmacist coverage in the ED and 70% reported no pharmacy presence in the ED. The authors also indicated that although approximately one third of academic EDs did have some form of clinical pharmacy presence, they did not appear to make full use of these clinical assets. The variety of clinical pharmacy service opportunities that exist in the ED directly reflects the complexity of care provided in the department. This high stress, fast paced clinical environment coupled with the aforementioned complex level of care can lead to inadvertent mistakes in the medication use system. Along with intensive care units and operating rooms, the ED is one of three places in the hospital with the highest frequency and severity of errors (Kohn et al., 1999)

In December 2008, the American Society of Health-System Pharmacists (ASHP) released a statement regarding the provision of clinical pharmacy services in the hospital emergency department. The conclusion of ASHP was that “Every pharmacy department should provide the ED with the pharmacy services required to ensure safe and effective patient care” (ASHP, 2008). This statement reflects the values found in a 1999 Institute of Medicine report on improving patient safety and applies those values to the practice of pharmacy in the ED (Kohn et al., 1999). The ASHP proposed the need for further research in the field, including a focus on economic outcomes as they relate to pharmacy services in the ED. The current literature contains an assortment of

information on economic outcomes related to clinical pharmacists in other practice settings (Kaboli et al., 2006), but it is difficult to find information on economic outcomes research specific to prevention of medication error by a clinical pharmacist in the emergency department (Kroner et al., 2008; Lee et al., 2002; McMullin et al., 1999). Economic outcomes research in general allows policy makers to compare the cost of a proposed solution with the benefit offered by that solution. Gaining the approval of hospital administration has been cited as the most common challenge to the implementation of ED pharmacy services (Witsil et al, 2010).

In 2007, Lada and Delgado used pharmacists interventions at an urban, level I trauma center and applied them to an economic outcomes model based on pharmacists' recommendations at a Veteran's Affairs medical center to estimate cost avoidance associated with pharmacist interventions in the ED (Lee et al., 2002). According to the Centers for Disease Control and Prevention, "a trauma center is a type of hospital that has resources and equipment needed to help care for severely injured patients. The American College of Surgeons Committee on Trauma classifies trauma centers as Level I to Level IV. A Level I trauma center provides the highest level of trauma care" (CDC, 2009). The analysis conducted by Lada and Delgado showed an estimated cost avoidance of approximately $3 million per year attributable to pharmacist interventions in the ED (Lada P, Delgado G, 2007). In 1997, Bates et al. used billing data from two large tertiary care hospitals in Boston, Massachusetts to estimate the cost of a preventable adverse drug event (ADE). They found that a preventable ADE in the hospital was associated with a post-event cost of about $4,685 and an increased length of stay of 4.6 days. A recent review article examining the effect of clinical pharmacists

in the ED, however, stated “the cost avoidance data reported in the articles reviewed lack formal structured pharmacoeconomic analysis” (Cohen et al., 2009). In the discussion of their results, Lada and Delgado also identified development and validation of an economic model for evaluating ED pharmacy services as an area for future research (Lada P, Delgado G, 2007). Thus, existing literature provides a fair foundation for estimating the cost of medication errors in the ED and the potential for cost avoidance associated with clinical pharmacy services in the ED, but further research is needed to develop an economic model to accurately describe the true value of clinical pharmacy services in the ED. The knowledge gained by the following research may be considered as an essential piece of the economic architecture, which addresses the cost of medication errors in the ED and the potential for a clinical pharmacist to reduce these costs.

Research Design

Data Description

The 2006 Nationwide Emergency Department Sample (NEDS) is, as the name implies, a national database that contains data from 958 hospital-based EDs in 24 states. In total the NEDS contains data for approximately 26 million records of ED visits, each of which are described by more than 100 possible data elements. One of the elements included in this data set is a detailed list of any diagnosis codes from the International Classification of Diseases 9 - Clinical Modification (ICD 9-CM) that were recorded for each ED visit. One important caveat of the NEDS data set is that is contains information on external causes of injury and poisoning. This is represented by the variable “ECODES” in the NEDS. The presence of this variable in the data set is

critical for performing the analyses required to answer the first research question above, because it allows the selection of a "medication error group" from the main data set. A medication error group was selected by isolating ED visits that contained the ICD 9-CM error codes E850.0-E858.9. These codes were chosen to identify the group with documented medication errors because they denote accidental poisoning by drugs, medicinal substances, and biologicals, but do not include poisonings secondary to suicide attempts or appropriate therapeutic administration of these compounds (ICD 9-CM, E850.0-E858.9). A more exhaustive description of the data elements contained in the NEDS is publicly available on the HCUP website (HCUP, 2006).

Medication Error Cost Analysis

Microsoft ® Structured Query Language (SQL) database management software was used to isolate emergency department events containing the ICD 9-CM medication error codes of interest from the general NEDS dataset. With SQL, a file containing error code information, observation weighting values, and ED cost information along with unique identifiers for each observation in the data set was formatted for analysis using the statistics software STATA (StataCorp, 2007, College Station, TX, USA), where all further data analysis was carried out. Again, using SQL, a control group was randomly selected from those observations not containing the medication error codes E850.0-E858.9 at a control: case ratio of more than 2:1. There were two reasons for doing this. First, because of the size of the existing data set, no additional costs were incurred by increasing the number of controls. Second and more importantly, as the ratio of controls to cases increases, the power of the study also increases up to a control-to-case ratio of about 4:1 (Hennekens and Buring, 1987).

Because it is known that medical cost data is skewed to the right and non-normally distributed, STATA was used to generate transformed cost data histograms for total ED costs in both the medication error group and the control group. Some scholars in the past have argued against transformation analysis for non-normal data, but in this case it is being used as an empirical check for skewed data rather than to represent quantitative findings (Nixon and Thompson, 2004).

Determining the cost of medication errors was conducted using median costs because of the non-normal distribution of data. The Wilcoxon rank sum test was used to detect any significant differences in median costs between the medication error group and the control group.

In the NEDS, inpatient cost information for ED events that resulted in admission to the hospital was provided in a separate database known as the inpatient file. Observations in the inpatient file were linked back to the core emergency department file by a unique identification variable. This unique identification variable allowed for the generation of two additional data sets, one containing cost information on patients from the original medication error group who were also admitted to the hospital, and the other containing cost information on patients from the original control group who were also admitted to the hospital. Median inpatient cost data was computed and Wilcoxon rank sum tests were performed on the inpatient cost data using the same methods described for the ED cost data. Analyses were also conducted to determine what impact a medication error in the ED had on the likelihood of being admitted to the hospital from the ED.

Cost Savings/Avoidance Analysis

To determine cost savings, data compiled between September 2008 and February 2009 in the ED at the University of Kentucky Chandler Medical Center (UKCMC) was used. Reportable events (medication errors) that occurred in the ED were recorded using an online form. This form allowed the user to input several variables to describe each event. These descriptive variables contained information on date and time of each event, what medication was involved, what type of practitioner reported the event, and what intervention was made. A potential severity score was also assigned to each event, ranging from A to E, with A being the least serious and E being a potentially severe or life-threatening error. To estimate cost savings generated via the avoidance of preventable medication errors by a clinically trained ED pharmacist, this data was used to determine the number and percentage of medication errors prevented by interventions attributable to the presence of a pharmacist in the ED. The cost data generated from the NEDS database was then used to calculate a cost avoidance estimate for the prevention of medication errors by a pharmacist in a hospital based ED.

Potential Ethical Problems

As in any analysis, there is a possibility of researcher bias in the collection and collation of data. To minimize this possibility, a non-practicing health services researcher was consulted to assist in the compilation and analysis of available data. Medication error reporting is an interesting subject as it relates to bias, because many individual factors can lead to either over reporting or under reporting of errors. Due to the nature of the data collected in the ED at UKCMC, attention bias could have led to a

relative over reporting of medication errors. For example, a pharmacist who is specially trained to recognize and respond to medication therapy issues may be more attuned to the recognition of medication errors than another member of the healthcare team whose training and focus is not as heavily oriented toward drug therapy. For this reason, given the same set of patient encounters, a pharmacist would be likely to report a higher number of medication errors even though the true number of errors would be the same for both situations. A publicly available national database was used to ensure that no differential reclassification occurred favoring pharmacy services. Although the NEDS is a national data set, over or under reporting of the error codes of interest could have occurred. Bias leading to under reporting of errors in the NEDS could stem from an overarching culture in which medication error reporting leads to punishment for individuals rather than being used as a learning tool to improve the local healthcare process. One author suggested moving away from this culture of blame and punishment toward a "culture of safety", where reporting errors and learning from them are emphasized as a method of achieving safe health care (Leape, 2009). Until this type of culture is in place, however, one might expect the status quo of medication error under reporting to persist.

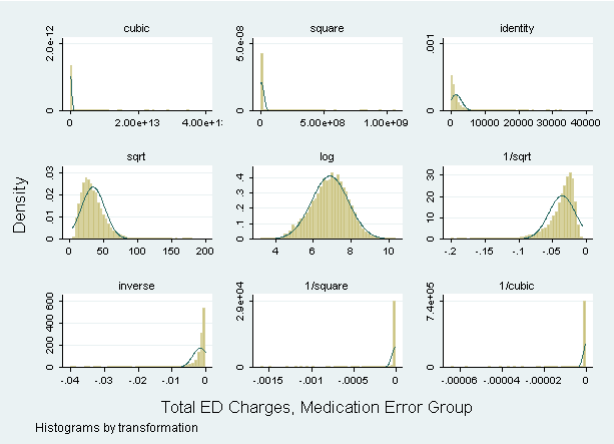
Results

From the NEDS database the medication error group was found to contain a total of 59,633 observations. Again using SQL, a control group of size n=150,000 was selected from those observations not containing an ICD 9- CM error code between E850.0-E858.9. This selection yielded a control: case ratio of roughly 2.5:1.

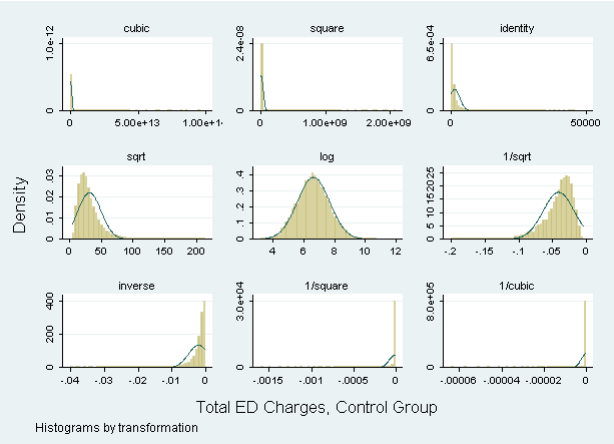
As shown in Figure 1, transformation modeling conducted in STATA confirmed that total ED costs for both the medication error group and the control group fit well into a logarithmic model.

Figure 1. Transformation analysis performed to determine appropriate method of normalization of cost data.

Case costs



Control costs



Emergency Department Cost Analysis

Of the 59,633 observations in which a medication error of E850.0-E858.9 was documented, 44,439 also contained a value for total ED costs for the visit. Table 1 below contains the breakdown of ED cost data for both the medication error group and the control group. A Wilcoxon rank sum test showed that the difference in total emergency department costs between these two groups reached a high level of significance [p = 0.0000].

Table 1: ED cost data for medication error group and control group			
	Medication Error Group	**Control Group**	**Difference (95% CI)**
Median ($)	1027	759	268
Interquartile Range ($)	513-1922	376-1518	
Range ($)	25-32,753	25-45752	

Inpatient Cost Analysis

From the original medication error group of 59,633 observations, 19,834 were present in the inpatient database showing that they had been admitted. Only 260 of these observations were missing total cost information. Of the other 19,574 observations, the median total cost for emergency department and inpatient services was $11,836. Of the 150,000 observations in the control group, 23,002 were present in the inpatient database. The median for the 22,694 observations in the control group that contained total cost information for emergency department and inpatient services was $16,102. A Wilcoxon rank sum test showed that the difference in total hospital costs (ED plus inpatient) between these two groups also reached a high level of significance [p = 0.0000].

Table 2: Inpatient Admissions stratified by group		
	Medication Error Group	Control Group
Admitted	19,834	23,002
Not Admitted	39,799	126,998
Odds ratio	**2.75**	

Patients who experienced a medication error were more likely to be admitted to the hospital than those who did not. OR = 2.75 (95% confidence interval = 2.69-2.81).

UKCMC ED Data Analysis

Table 3: UKCMC ED Reportables September 08-February 09		
Person Reporting Error/Intervention	**Number of Errors/Interventions Reported**	**Percentage of total**
PharmD	277	74.5%
PharmD Resident	50	13.4%
PharmD Student	25	6.7%
Nurse	15	4.0%
PharmD/Nurse	1	0.3%
Pharmacy Technician	4	1.1%
Total	372	100.0%
Attributable to ED Pharmacist Presence	353	94.9%

The data from the ED at the UKCMC showed that during the six-month period of September 2008 to February 2009, 353(94.9%) reported interventions were attributable to the presence of a clinical pharmacist in the ED (Table 3). By applying this number of interventions to the calculated estimate of the cost of a medication error in the ED, a cost avoidance figure was determined by the following:

(Number of Interventions) x (Median Cost of Medication Error) = Cost Avoidance

(353) x ($268) = $94,604

This cost avoidance figure is based on interventions made over a six month period. By extrapolating this figure out to a one-year period, one could expect the cost avoidance total to double to roughly $189,208.

Discussion

The primary goal of this project was to determine the cost of a preventable medication error in a hospital emergency department using an unbiased national data set. Our analysis of the data showed that a preventable medication error results in a median increase in ED costs of $268.

The secondary goal was to estimate the economic impact of interventions made by a clinical pharmacist in the ED by looking specifically at cost avoidance secondary to the prevention of medication errors in the ED. At UKCMC, in a six-month period, the data shows that 353 medication errors were prevented by interventions initiated by a clinical pharmacist in the ED. This number included not only interventions made by the clinical ED pharmacist, but also those made by the PharmD candidates and pharmacy practice residents they were responsible for precepting. The presence of PharmD candidates and pharmacy practice residents in the ED was determined to be directly dependent on the fact that there was a clinical ED specialist there to supervise and mentor them, and therefore any interventions they made could be causally linked back to the ED pharmacist. Based on the number of interventions recorded in this six-month window and the previously estimated ED cost of a preventable medication error, the associated cost avoidance for these interventions is $94,604 over six months or about $189,208 per year. This estimated cost avoidance may be sufficient to cover a large portion of the expense associated with financing two clinical ED pharmacist positions at UKCMC.

Characteristics of an ideal ED clinical pharmacist would be one that has (A) graduated from a college of pharmacy accredited by the Accreditation Council for Pharmacy Education (ACPE) and (B) completed two years of post-graduate residency

training, with the second year focusing on Emergency Department pharmacy practice. Because of the scarcity of post-graduate year two (PGY2) ED pharmacy practice residency programs, a pharmacist with at least three to five years of clinical practice should also be able to take on this role.

According to the Bureau of Labor Statistics (BLS), the mean national salary for pharmacists working in general medical and surgical hospitals was $103,480 (BLS, 2008). Based on the expected level of experience and training required for becoming a clinical ED pharmacist, hospital administrators can expect to pay this amount ±10%. This salary will vary with level of pharmacist experience and regional differences in variables such as demand for pharmacists and cost of living. Assuming a generous benefits package valued at roughly 40% of base salary, the true cost of hiring a full time clinical pharmacist for the ED would be roughly $145,000 per year.

The ED at UKCMC has a patient volume of roughly 50,000 visits per year. During the time this medication error intervention data was collected, two clinical ED pharmacists were employed at UKCMC, providing services to the ED ten hours per day, seven days per week. The pharmacists were scheduled to work between 1pm and 11pm. This time frame overlaps significantly with the hours of 3pm to 2am, which are reported to be the busiest hours of the day in the ED at UKCMC. It is expected that the true cost avoidance figure would vary by facility depending on the level of pharmacist presence in the ED (hours/week) and the annual number of patients treated at a given ED.

Lada and Delgado reported a cost avoidance from prevention of med errors of $436,150 over four months (Lada P, Delgado G, 2007). There are a few reasons for the

difference between their reported cost avoidance and ours. First, the setting of their study was the Emergency Department at Detroit Receiving Hospital in Detroit, Michigan, whose annual patient volume (84,000/year) is nearly twice that of the ED at UKCMC. Other differences may stem from the provision of 24-hour pharmacist coverage in the ED and the fact that they based cost estimates on expert's projections of the costs of treating the potential medication errors that their pharmacists prevented.

Compared to research on preventable adverse drug events in the hospital, which estimated hospital costs at $4,685 (Bates, 1997), our findings for a preventable medication error in the ED suggest a much smaller increase in costs. This may be related to the dramatic increase in the acuity of care for inpatients when compared to ED patients. One might expect that a medication error occurring in a patient who is already in need of admission to the hospital would require more money and resources to remedy.

Though the total inpatient costs were higher for patients who were admitted to the hospital without experiencing a medication error in the ED, our analysis showed that patients who experienced a medication error were almost three times as likely [OR = 2.75 (2.69-2.81)] to require hospital admission. This finding implies that medication error prevention by a clinical ED pharmacist could further contribute to cost avoidance by preventing this increase in the patient's likelihood of being admitted to the hospital and incurring inpatient medical costs.

One could argue that patients who are more seriously ill and require a more complex level of care would logically be more likely to experience a medication error and subsequently be admitted to the hospital. This analysis was not set up to assess

severity of illness or required level of care. By using total hospital costs (inpatient plus ED) as a surrogate for severity of illness, however, it appears that the patients who were admitted from the ED without experiencing a medication error were actually more expensive to care for and, by extension, more severely ill.

Litigation costs represent an immense area of potential cost avoidance not addressed in this research. A 2002 report on medical malpractice claims in *The Archives of Internal Medicine* stated that preventable inpatient ADEs (medication errors) had a mean cost per case of $376,500 for defense and indemnity (Rothschild, 2002). In September of 2008, Medicare stopped paying for certain types of medical errors known as "never events" that had been identified previously by the National Quality Forum (Milstein, 2009). While medication errors were not included as one of these never events, the National Quality Forum (NQF) did include "patient death or serious disability associated with a medication error" as a serious reportable event in an updated consensus report (NQF, 2006). As healthcare costs and public demand for higher quality healthcare continue to increase, it is logical to believe that Medicare could in the near future add some medication errors to the list of never events that will no longer be covered.

Limitations of Analysis

All studies have limitations in their analyses; some limitations have also been identified in this study. One limitation of this analysis is that the total cost avoidance estimates are only valid for the ED at UKCMC, because the intervention data collected there was essential in the cost avoidance calculation. On the other hand, since the estimated cost of a medication error in the ED is based on national median data from NEDS, this figure should be applicable to the wider population of other hospital-based

emergency departments. Hospital administrators at other facilities could possibly use this information and apply it to their own data on medication errors, thus giving them some guidance on local policy implementation pertaining to clinical ED pharmacy practice.

As stated earlier in the research design, the events in the ED at UKCMC were assigned a subjective potential severity rating by the person reporting the event. While subjective in nature, this variable suggests the common sense notion that medication errors that differ in severity will require different treatments that will vary in cost. Our analysis is based on the assumption that regardless of the potential severity of an individual event, in aggregate the associated cost should approach the same value. This assumption allows the possibility of either over or under estimating the true cost avoidance figure.

Further Research

Ongoing research in this field should expand the assessment of cost avoidance to include other areas of pharmacy practice in the ED. Examples could include: therapeutic drug substitution, drug selection and dosing, patient and family medication counseling, and home medication reconciliation. Other ancillary services provided by a clinical pharmacist in the ED including answering medication questions posed by other healthcare practitioners and precepting pharmacy students and residents should also be studied.

The current analysis could be expanded to include a subgroup analysis designed to detect significant differences in costs of medication errors associated with specific drugs or drug classes (i.e. vancomycin or antimicrobial agents). Such an analysis could

help guide ED practitioners and administrators in the development of policies and procedures directing at reducing medication errors in these areas.

Conclusion

Based on the analysis of the data from NEDS 2006, a medication error in the ED results in an increase of $268 in total ED costs alone. When this figure is coupled with data from UKCMC dealing with pharmacist-led interventions to prevent medication errors, six-month cost avoidance totals come to $94,604. Based on national averages, this amount is enough to pay for a fair portion of the salary for the two clinical ED pharmacists employed by UKCMC during that time period. Given that this cost avoidance figure takes into account neither the avoidance of litigation and indemnity costs or the cost savings created by other functions of a clinical ED pharmacist, we conclude that a clinical pharmacist in the ED may generate enough cost avoidance to justify a significant portion of the monetary cost of his or her salary and other compensation.

References

1. ASHP:American Society of Health-System Pharmacists Council on Pharmacy Practice.
ASHP statement on pharmacy services to the emergency department. *Am J Health-Syst Pharm.* 2008; 65:2380-3.

2. Bates DW, Spell N, Cullen DJ, et al. The Costs of Adverse Drug Events in Hospitalized Patients. *JAMA*. 1997; 277:307-11.

3. BLS: United States Department of Labor. Bureau of Labor Statistics: Occupational Employment and Wages; Pharmacists, May 2008. *Available online at:* http://www.bls.gov/oes/current/oes291051.htm *accessed March 27, 2010.*

4. CDC: Centers for Disease Control and Prevention. Injury Prevention and Control: Trauma Care (2009). *Available online at:* http://www.cdc.gov/traumacare/ *accessed March 7, 2010.*

5. Cohen V, Jellinek SP, Hatch A, Motov S. Effect of clinical pharmacists on care in the emergency department: A systematic review. *Am J Health-Syst Pharm.* 2009; 66:1353-61.

6. Fairbanks RJ, Hays DP, Webster DF et al. Clinical pharmacy services in an emergency department. *Am J Health-Syst Pharm.* 2004; 61:934-7.

7. HCUP Nationwide Emergency Department Sample (NEDS). Healthcare Cost and Utilization Project (HCUP). 2006. Agency for Healthcare Research and Quality, Rockville, MD. *Available online at:* www.hcup-us.ahrq.gov/nedsoverview.jsp *accessed August 15, 2009.*

8. Hennekens CH, Buring JE. 1987. *Epidemiology in Medicine.* Lippincott Williams & Wilkins. Boston, MA.

9. Kaboli PJ, Hoth AB, McClimon BJ, Schnipper JL. Clinical Pharmacists and Inpatient Medical Care: A Systematic Review. *Arch Intern Med*. 2006; 166:955-964.

10. Kohn LT, Corrigan JM, Donaldson MS, eds. To err is human: building a safer health system. Washington, DC: National Academy Press; 1999.

11. Kroner BA, Billups SJ, Garrison KM, et al. Actual Versus Projected Cost Avoidance for Clinical Pharmacy Specialist-Initiated Medication Conversions in a Primary Care Setting in an Integrated Health System. *J Manag Care Pharm.* 2008; 14(2):155-63.

12. Lada P, Delgado G Jr. Documentation of pharmacists' interventions in an emergency department and associated cost avoidance. *Am J Health-Syst Pharm.* 2007; 64:63-8.

13. Leape LL. Errors in medicine. *Clinica Chemica Acta.* 404(2009) 2–5.

14. Lee AJ, Boro MS, Knapp KK et al. Clinical and economic outcomes of pharmacist recommendations in a Veterans Affairs medical center. *Am J Health-Syst Pharm.* 2002; 59:2070-7.

15. McMullin ST, Hennenfent JA, Ritchie DJ et al. A prospective, randomized trial to assess the cost impact of pharmacist initiated interventions. *Arch Intern Med*. 1999; 159:2306-9.

16. Milstein, A. Ending Extra Payment for "Never Events" — Stronger Incentives for Patients' Safety. *N Engl J Med* 360;23. June 4, 2009.

17. Mutnick AH, Sterba KJ, Peroutka JA, et al. Cost savings and avoidance from clinical pharmacist interventions. *Am J Health-Syst Pharm.*1997; 54:392-6

18. NQF: National Quality Forum. Serious Reportable Events in Healthcare 2006 Update. *Available online at:* http://www.qualityforum.org/Topics/Safety.aspx *accessed April 10, 2010.*

19. Rothschild JM, Federico FA, Gandhi TK et al. Analysis of Medication-Related Malpractice Claims. Causes, Preventability, and Costs. *Arch Intern Med*. 2002;162: 2414-2420.

20. Santell JP, Hicks RW, McMeekin J, Cousins DD. Medication Errors: Experience of the United States Pharmacopeia (USP) MEDMARx Reporting System. *J Clin Pharmacol.* 2003; 43:760-767.

21. Szczesiul JM, Fairbanks RJ, Hildebrand JM, et al. Survey of physicians regarding clinical pharmacy services in academic emergency departments. *Am J Health-Syst Pharm*. 2009; 66:576-9

22. Witsil JC, Aazami R, Murtaza UI, Hays DP, Fairbanks RJ. Strategies for implementing emergency department pharmacy services: Results from the 2007 ASHP Patient Care Impact Program. *Am J Health-Syst Pharm.* 2010;67:375-9.