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POISON CENTRE

The association between U.S. Poison Center assistance and length of stay and hospital charges

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Context. Poison centers (PCs) play an important role in poison prevention and treatment. Studies show that PCs reduce system-wide cost by reducing the number of unnecessary visits to emergency departments and by providing improved patient management. However, there remains a debate regarding the impact of PCs on patient outcomes at the hospital level. *Objective.* To evaluate the impact of PC involvement on length of hospitalization and total hospital charges. *Materials and methods.* We conducted a retrospective analysis of inpatient cases treated in Illinois hospitals in 2010. We linked the Illinois Poison Center database with an Illinois hospital billing dataset and controlled for important patient-level and facility-level covariates. *Results.* In the multivariable model, length of hospitalization among PC-assisted patients was 0.58 days shorter than that of patients without PC assistance ($p < 0.001$). Hospital charges for PC-assisted patients in the lower quintiles were significantly higher than patients without PC assistance (+\$953; $p < 0.001$), but were substantially lower in the most costly quintile of patients (−\$4852; $p < 0.001$). Balancing the higher charges for treating patients with PC assistance in the lower quintiles with the savings in the highest quintile, among inpatients there is a potential cumulative decrease of \$2,078 in hospital charges per 10 patients. *Discussion.* Among the inpatient cases, PC assistance was associated with lower total charges only among the most expensive to treat. However, this outlier group is very important when discussing medical costs. It has been repeatedly shown that the majority of treatment costs are attributable to a small fraction of patients as seen in this study.

Keywords Poisoning; Poison control center; Hospital charges; Length of stay

Introduction

Toxic exposures or poisonings are a continuing public health issue. With more than 70 million naturally occurring and artificially processed chemical substances registered worldwide,[1] more than 3.7 billion prescriptions filled in the United States each year,[2] and the near endless number of substances made toxic by dose alone, it is not surprising that there are more than 2.3 million cases of human poisonings reported to poison control centers in the US annually.[3] In addition, Centers for Disease Control and Prevention data reported that there were over 1 million total non-fatal poisonings treated in hospitals and 42,917 fatal poisonings in the US for 2010.[4,5] Poisonings continue to be the leading cause of fatal injuries in the US since 2009, supplanting transportation related fatal injuries.[5]

Poison centers (PCs) play an important role in poison prevention and treatment. The role of PCs has been evolving since their inception in the 1950s. Currently, they provide services 24 hours a day year round. In terms of cost savings, PCs primarily reduce system-wide cost by reducing the number of unnecessary visits to emergency departments.[6–13] In addition, expert consultation with PC toxicologists appears to lead to more effective care and shorter hospital stays.[14–16] Currently, there are 56 PCs nationwide, answering nearly 4 million calls each year from both the general public and medical professionals. Ecological studies estimate that for each dollar spent to fund PCs, four to nine dollars are saved, primarily from a reduction in exposures and unnecessary hospital visits.[9]

However, there remains a debate regarding the impact of PCs on patient outcomes at the hospital level. Although previous studies have shown that patients receiving PC assistance during the course of their treatment have shorter hospital stays and lower hospital charges, the limitations of these past studies makes the findings difficult to generalize.[14–16] None of the studies have controlled for type and severity of exposure, despite studies showing that the intensiveness of treatment varies by both the dose and spectrum of exposures. Furthermore, past studies have used strict exclusion criteria, in particular the omission of suspected attempted suicides and patients with comorbidities, which limits the generalizability of the findings to the

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broader patient population. Both subgroups represent a large proportion of the patients treated in hospitals for exposures to substances. The past studies have also restricted their analyses to patients with documentation of ICD-9 external cause of injury codes (ECODES) or primary diagnoses indicating poisoning. However, this procedure omits patients with secondary diagnoses for poisoning whose records emphasize the resulting condition (e.g., organ failure) rather than the cause. Most importantly, previous studies did not control for important covariates known to be directly related to length of hospitalization and hospital charges.[17]

There remains a need for studies that evaluate the impact of PCs on hospital length of stay and cost in a broad patient population with a wide array of exposures, while controlling for important factors associated with longer hospitalizations and higher hospitalization costs. In this study, we conducted a retrospective analysis of inpatient cases treated in Illinois hospitals in 2010 to evaluate the impact of PC assistance on length of hospitalization and total hospital charges.

Methods

Data sources

For this project, year 2010 PC data were obtained from the Illinois Poison Center. The PC database is a compilation of all the calls received by center staff during the year. The Illinois PC is not exclusively a pharmacy- or nursing-based system, but includes a multidisciplinary team of trained physicians, pharmacists, and nurses who receive calls and provide callers with poison prevention and exposure management information. The core staff is comprised primarily of approximately equal numbers of pharmacists and nurses. In addition to receiving calls from the general public, the Illinois Poison Center provides telephonic consults to 190 facilities with emergency room services through a hospital membership network. Each hospital in the network pays a variable fee which is based on the number of emergency room visits for all reasons (not restricted to poisoning visits) during the previous year. On average, the Illinois PC receives 56 calls per year from each health care facility relating to inpatient cases (interquartile range 18–99 calls per year). PC involvement is generally restricted to phone consultations, although bedside consults ($n = 250$ per year) and real-time consults ($n = 1200$ per year) do occur. Treatment guidelines are sent to the health care facility for most patients, but electronic medical records are not shared with the PC. The staff collects standardized data including demographic information, number and type of exposures, medical treatments and medical outcomes.

In addition, we obtained year 2010 medical record data from the Illinois Hospital Association for inpatient cases treated in Illinois hospitals. The inpatient database includes all patients treated for more than 23 hours (i.e., inpatients only) for any medical reason. Based on an annual statewide audit, the hospitals included in this dataset during the year 2010 treated 96.5% of all patient admissions statewide.[18] The dataset includes data on patient demographics (age and gender), exposure information, health outcomes (diagnoses, hospital procedures, and discharge status), and economics (hospital charges and payer source). The IRB at UIC has approved this work (#2012-0116).

Case ascertainment

In order to evaluate the impact of PC involvement among patients treated in hospitals, we linked the PC data with the medical record data. From the PC data, we only included calls relating to exposures treated at a health care facility with an emergency department ($N = 20{,}027$ out of 79,777 calls relating to exposures; of which 10,272 were documented to have been admitted). Calls made to the PC regarding patients treated in health care facilities without emergency departments (e.g., private physician offices and school nurses) or at the caller's home were not included in the analysis. The medical record database does not include urgent care facilities, institutional medical offices (e.g., schools, jails), or private physician offices.

We used a probabilistic data linkage procedure to link the datasets, which was accomplished in multiple steps, or passes. The initial pass identified records in the PC and medical record datasets that matched exactly on hospital identification number, patient age, patient sex, date of admission/call, and exposure type ($N = 1{,}802$). In order to match by exposure, we developed a crosswalk to convert ICD-9 ECODES (up to 3 listed per patient) or diagnosis codes (NCODES; up to 28 per patient) into American Association of Poison Control Centers Generic Codes. In subsequent passes, we allowed for variation on date of admission/call (+/− 1 day; $N = 456$). In the final linkage round, we linked exactly on hospital identification number, patient age, patient sex, date of admission/call, but allowed for exposure type to not match between the records ($N = 2{,}710$).

PC cases that linked with the medical records in the first two rounds on exposure type differed from those that did not link on exposure type on the following variables (matched on exposure type vs. did not match on exposure type): more likely to involve self-harm cases, 76.9% versus 54.7%; and more likely to have 3 or more exposures listed, 78.3% versus 50.3%. The two groups did not differ substantially by distribution by race/ethnicity, age, source of admission, place of exposure, payor type and comorbidities.

Selection of the comparison group (No PC Involvement)

For the comparison group, we selected from a list of all inpatient cases with an ICD-9 code for a poisoning (diagnosis N-codes and cause of injury E-codes). We randomly frequency matched the PC-involved patients with comparison cases on the following variables: (1) intentional self-harm and (2) combinations of three major categories of exposures (nondrug substances only, ethanol only, drug/medication only, nondrug substance and drug/medication concomitantly, ethanol and drug/medication concomitantly, ethanol and nondrug substance concomitantly, and all three major exposure groups concomitantly). Within each of the matching strata, an equivalent number of comparison patients to index patients were identified. Patients with ICD-9 ECODES 950-959 (attempted suicide) were categorized as intentional self-harm cases.

Primary outcome variables

The two main outcome variables of interest were length of stay and total hospitalization charges (in USD). Length of stay is measured in days from date of admission to date of discharge. Total hospital charges is the sum of all procedure, service, and facility charges accumulated from the point of admission to discharge. Total hospital charges are in 2010 U.S. dollars. Hospital charges are a proxy measure for cost, but may not directly reflect reimbursement, resource consumption, or comprehensive economic costs. Both dependent variables (length of stay and total monetary compensation) were not normally distributed.

Statistical analysis

We used SAS software for all statistical analyses (v.9.4; Cary, NC). Appropriate parametric and nonparametric tests (Wilcoxon's Rank Sum) were used to evaluate bivariate relationships. Cumulative proportions and prevalence of demographic characteristics, place, and severity of exposures are described for index patients and the comparison group. For descriptive purposes, we identified patients whose exposures were the primary reason for treatment, defined as patients with an exposure listed as the primary diagnosis, reason for visit, reason for admission, or with a cause of injury code (ICD-9 E-CODE) relating to an exposure.

Several key aspects of the data shaped our decision for the multivariable statistical modeling. Because we used frequency matching rather than paired matching, unconditional statistical tests were used to assess associations and the matching variables were included as potential confounders.[19] Second, in scenarios with nonparametric data, ordinary least squares (OLS) regression produces biased parameter estimates. This is because in OLS the parameter estimates will be weighted toward the outliers, which also inflates the variance. Therefore, for the multivariable regression analysis, we used robust MM-estimation as implemented in SAS (PROC ROBUSTREG). Akaike (AIC) criterion and Schwarz information criteria (BIC) were also used for model selection and to identify the best weighting function.

Previous studies have shown that the majority of hospital costs are attributable to a minority of patients.[20–22] In addition, we hypothesized that PC involvement of toxicologists would limit medical complications and improve treatment primarily among the most severely exposed patients. Although MM-estimation addresses heteroschedasticity, we were interested in describing the potential outliers of total cost. Therefore, we evaluated the impact of PC involvement among the highest quintile of hospital charges separately in the multivariable regression models.

Statistical evaluation of covariates, as well as a priori knowledge, was used to determine inclusion of covariates in the final models. We evaluated the following patient-level variables: age, gender, race/ethnicity, Medicaid coverage as a proxy measure for low income, no insurance coverage as indicated by self-pay, total number of exposures, types of exposures (frequency matching categories), length of stay, intentional self-harm (i.e., suicide attempt), comorbidities measured by the Elixhauser index,[23] required mechanical ventilation, and required surgical intervention. We also evaluated the following facility level variables which have been identified as strong predictors of hospital costs (Street et al., 2010): type of hospital ownership (private vs. public), volume of patients at treating hospital, geographic variability (11 emergency medical services [EMS] regions which was strongly correlated with population density), teaching status, and range of services at hospital (general hospital vs. specialized facilities). Parameter estimates for PC involvement are presented, including the 95 percent confidence intervals. No evidence of multicollinearity among the independent variables in the final adjusted models was indicated.

Finally, because the patients with PC assistance that matched on exposures in the first linkage rounds differed from those that did not match on exposure, we conducted a sensitivity analysis of only the cases that matched on exposure ($N = 2{,}258$). A random subset of frequency-matched comparison cases without PC involvement were used in the sensitivity models to keep a 1:1 proportion of patient with and without PC involvement.

Results

In total, there were 9,936 patients included in this study, of which 4,968 received PC assistance during the course of their treatment. Patients receiving PC assistance were treated in 180 hospitals out of 186 facilities statewide with emergency rooms in combination with inpatient services. Demographic characteristics for both PC-assisted patients and those patients who did not receive PC assistance are shown in Table 1. PC-assisted patients were significantly younger than non-PC-assisted patients ($p < 0.01$). Overall, the distribution by gender and race/ethnicity did not differ substantially between the subgroups. Patients with PC involvement had fewer comorbidities ($p < 0.01$). Although the proportion of cases involving intentional self-harm was identical in both PC involvement groups, PC-assisted patients were substantially more likely to be discharged to a psychiatric facility.

Exposures

There was a substantially greater proportion of PC assisted patients that had their main diagnosis documented as a poisoning exposure compared to non-PC assisted patients ($p < 0.01$; Table 2). In addition, PC assisted patients had a greater number of exposures listed in their medical records compared to patients without PC involvement (mean number of exposures: 3.5 vs. 2.8 respectively; $p < 0.01$; Table 2). However, the overall distribution of substances was quite similar between the two groups. Analgesics, ethanol, stimulants and

Table 1. Demographic characteristics and hospitalization data regarding patients receiving and not receiving Illinois Poison Center assistance in 2010, Illinois.

	Poison center-assisted cases (*N* = 4968)	No poison center assistance (*N* = 4968)
Mean age in years (SD)	35.5 (15.7)	41.4 (18.8)
0 to 12 years	114 (2.3%)	20 (0.4%)
13 to 17 years	410 (8.3%)	434 (8.7%)
18 to 29 years	1496 (30.1%)	1127 (22.7%)
30 to 39 years	971 (19.6%)	797 (16.0%)
40 to 49 years	1033 (20.8%)	1018 (20.5%)
50 to 59 years	644 (13.0%)	1011 (20.4%)
60 years and older	300 (6.0%)	561 (11.3%)
Sex		
Female	2868 (57.7%)	2771 (55.8%)
Male	2100 (42.3%)	2197 (44.2%)
Unknown	0 (0.0%)	0 (0.0%)
Race, Ethnicity		
White, Non-Hispanic	3333 (67.1%)	3405 (68.5%)
Black or African American	835 (16.8%)	882 (17.8%)
Hispanic Latino	520 (10.5%)	364 (7.3%)
Asian	69 (1.4%)	48 (1.0%)
American Indian or Alaska Native	6 (0.1%)	9 (0.2%)
Native Hawaiian or Pacific Islander	1 (0.0%)	0 (0.0%)
Other	204 (4.1%)	260 (5.2%)
Medical information		
Main Diagnosis Involved Poisoning	4563 (91.9%)	4077 (82.1%)
Intentional Self-Harm (i.e. suicide attempt)	3218 (64.8%)	3218 (64.8%)
Mean Elixhauser Comorbidity Index (SD)	2.5 (1.6)	2.9 (1.8)
Mean Days in Hospital (SD)	2.98 (3.6)	4.46 (5.2)
Required Mechanical Ventilation	485 (9.8%)	378 (7.6%)
Required Surgical Intervention	301 (6.1%)	504 (10.1%)
Discharged to a Psychiatric Facility	1829 (36.8%)	1044 (21.0%)
Discharged Home	2489 (50.1%)	3057 (61.5%)
In-Hospital Fatalities	50 (1.0%)	54 (1.1%)
Payor		
Medicaid	1334 (26.9%)	1220 (24.6%)
Medicare	685 (13.8%)	1091 (22.0%)
Private Insurance	1637 (33.0%)	1758 (35.4%)
Self-pay	1001 (20.2%)	700 (14.1%)
Other*	311 (6.3%)	199 (4.0%)
Mean Charges, in dollars (SD)	19564 (36347)	21778 (37407)

*Other Payors include CHAMPUS, CHAMPVA, Hill Burton Free Care, Workers' Compensation, Charity, and Unspecified/Miscellaneous.

street drugs, and sedatives/hypnotics/antipsychotics were the most common types of exposures (Table 2).

Among those with exposures to analgesics, the most common exposures were to opioids (with PC assistance, 8.4% vs. no PC assistance, 8.6%) and over the counter salicylates, aromatic analgesics, and propionic acid derivatives (with PC assistance, 31.8% vs. no PC assistance, 21.3%). Among those with exposures to sedative/hypnotics/antipsychotics, the most common exposures were to barbiturates and benzodiazepines (with PC assistance, 24.7% vs. no PC assistance, 25.8%), phenothiazine-based, butyrophenone-based and atypical antipsychotics (with PC assistance, 33.3% vs. no PC assistance, 28.4%), and other sedatives/hypnotics (with PC assistance, 6.8% vs. no PC assistance, 6.0%).

Primary outcome: length of stay

PC-assisted inpatients on average had 1.5 days shorter length of stay (LOS) than non-PC-assisted inpatients (3.0 days vs. 4.5 days; $p < 0.01$). Median LOS was one day shorter among PC-assisted inpatients. After adjusting for covariates, the LOS among PC-assisted patients was 0.58 days shorter compared to that of patients without PC assistance (CI95%: −0.66, −0.51; $p < 0.001$). In the sensitivity model which included only the cases that matched on exposure in the first linkage rounds, the adjusted parameter estimate was −0.64 (CI95%: −0.74, −0.53; $p < 0.001$). The final adjusted models controlled for the following covariates: Age, comorbidities, EMS region, attempted suicide, and total exposures.

Primary outcome: total hospital charges

The median total hospital charge for PC-assisted patients was $12,196 compared to $11,918 among non-PC-assisted patients ($p = 0.247$). However, mean charges were lower for PC-assisted patients (Table 1). In the descriptive analysis, the unadjusted quantile regression model showed that the distribution of charges deviated substantially in the highest quintile (80th percentile and higher) between the patients

Table 2. Specific type of poisoning by exposure for patients receiving and not receiving Illinois Poison Center assistance in 2010, Illinois.

	Poison center-assisted cases ($N = 4968$)	No poison center assistance ($N = 4968$)
Number of Exposures Listed per Patient		
Only 1 substance	599 (12.1%)	1435 (28.9%)
2 substances	1237 (24.9%)	1087 (21.9%)
3 substances	1009 (20.3%)	1036 (20.9%)
4 substances	813 (16.4%)	618 (12.4%)
5 or more substances	1310 (26.4%)	792 (15.9%)
Drugs and Diagnostic Agents		
Analgesics	2592 (52.2%)	2459 (49.5%)
Anesthetics	300 (6.0%)	279 (5.6%)
Anticholinergic Drugs	9 (0.2%)	0 (0.0%)
Anticoagulants	30 (0.6%)	97 (2.0%)
Anticonvulsants	338 (6.8%)	186 (3.7%)
Antidepressants	112 (2.3%)	47 (0.9%)
Antihistamines	270 (5.4%)	168 (3.4%)
Antimicrobials	54 (1.1%)	98 (2.0%)
Antineoplastics	22 (0.4%)	79 (1.6%)
Asthma Therapies	3 (0.1%)	6 (0.1%)
Cardiovascular Drugs	270 (5.4%)	162 (3.3%)
Cold and Cough Preps	71 (1.4%)	18 (0.4%)
Diagnostic Agents	191 (3.8%)	378 (7.6%)
Dietary Supplements/Herbals/Homeopathic	26 (0.5%)	3 (0.1%)
Diuretics	19 (0.4%)	45 (0.9%)
Electrolytes and Minerals	24 (0.5%)	20 (0.4%)
Ethanol	1330 (26.8%)	1330 (26.8%)
Eye, Ear, Nose, Throat Preparations	7 (0.1%)	4 (0.1%)
Gastrointestinal Preparations	37 (0.7%)	17 (0.3%)
Hormones/Hormone Antagonists	156 (3.1%)	288 (5.8%)
Muscle Relaxants	310 (6.2%)	124 (2.5%)
Narcotic Antagonists	0 (0.0%)	3 (0.1%)
Sedative/Hypnotics/Antipsychotics	2231 (44.9%)	1987 (40.0%)
Serums/Toxoids/Vaccines	8 (0.2%)	5 (0.1%)
Stimulants and Street Drugs	1632 (32.9%)	1780 (35.8%)
Vitamins	12 (0.2%)	6 (0.1%)
Miscellaneous Drugs	1364 (27.5%)	1176 (23.7%)
Unknown Drug	707 (14.2%)	848 (17.1%)
Non-Drug Agents		
Adhesives and Glues	11 (0.2%)	11 (0.2%)
Alcohols (not inc. ethanol)	267 (5.4%)	261 (5.3%)
Bite and Envenomations	2 (0.0%)	0 (0.0%)
Chemicals	54 (1.1%)	9 (0.2%)
Cleaning Substances (Household)	8 (0.2%)	2 (0.0%)
Cosmetics and Personal Care	10 (0.2%)	6 (0.1%)
Products		
Fertilizers	1 (0.0%)	0 (0.0%)
Fumes, Gases and Vapors	41 (0.8%)	25 (0.5%)
Heavy Metals	20 (0.4%)	2 (0.0%)
Hydrocarbons	40 (0.8%)	19 (0.4%)
Paints and Stripping Agents	1 (0.0%)	0 (0.0%)
Pesticides	20 (0.4%)	1 (0.0%)
Polishes and Waxes	2 (0.0%)	0 (0.0%)
Waterproofers Sealants	27 (0.5%)	26 (0.5%)

with and without PC involvement (Fig. 1). Table 3 presents the cumulative charges by quintile for patients with and without PC assistance. The magnitude in cumulative differences of total charges between the patients with and without PC assistance is most pronounced in the upper quintile. Among the 20% of patients with the highest hospital charges, the net cumulative charges were substantially lower in the group with PC assistance, despite the observation that the sum of the five most extreme outliers did not differ substantially ($3.6M with PC assistance vs. $3.2M without assistance). Table 4 presents the charges by billing category. Charges relating to laboratory procedures were higher among the PC-assisted group, and charges relating to surgery and length of stay were higher in patients without PC assistance.

Table 5 presents the results from the multivariable regression models. Total charges for PC-assisted patients in the lower quintiles were significantly higher than patients without PC assistance (+$953.15), but were substantially lower in the most costly quintile of patients (−$4851.69). The sensitivity models showed similar results for the inpatient cases

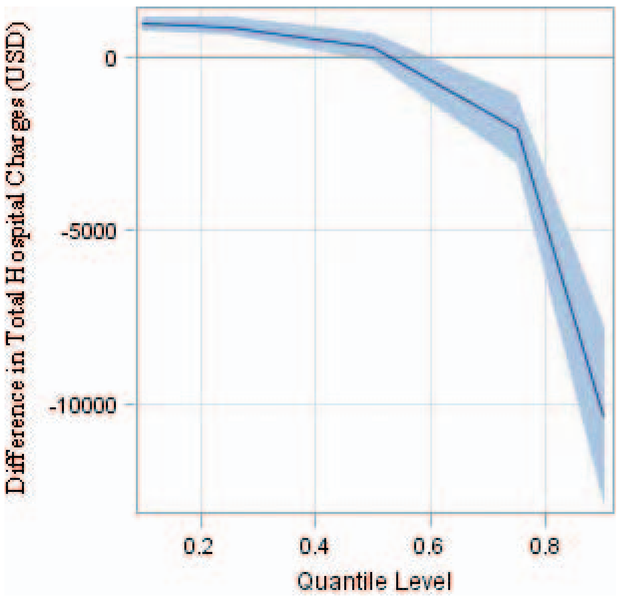

Fig. 1. Difference in total hospital charges across quintiles. Comparison of patients with poison center assistance to patients without poison center assistance, Illinois, 2010 (colour version of this figure can be found in the online version at www.informahealthcare.com/ctx).

(lower quintiles: $1,234.56 higher in PC-assisted patients, $p < 0.001$; upper quintiles, −$4,821.49 lower in PC-assisted patients, $p < 0.001$). The final adjusted models controlled for the following covariates: gender, age, comorbidities, required mechanical ventilation, required surgical intervention, attempted suicide, and total admissions (hospital level).

Estimated reduction in cost annually

Balancing the higher hospital charges for treating patients with PC assistance in the lower quintiles with the savings in the highest quintile, there is a potential cumulative decrease of $2,078 in hospital charges per 10 patients. This assumes that the general patient population will have similar profiles to those reported in this study. The estimated savings among the 10,272 inpatient cases assisted by Illinois Poison Center during 2010 was $2.1 million. Furthermore, in 2010 in Illinois alone, there were $N = 337{,}164$ patients admitted to hospitals with any diagnosis or cause of injury relating to an adverse event from an exposure to a substance based on our global inclusion criteria, of which $N = 166{,}949$ patients had a principal diagnosis, reason for admission or cause of injury directly relating to a poisoning. In just the latter group alone, the crude estimate of potential savings in this patient population in Illinois in 2010 had PC assistance been provided to all of them would have been $34.6 million USD.

Discussion

Among poisoning patients treated in hospitals, PC assistance was associated with shorter hospitalizations. The shorter length of hospitalization could be the result of improved coordination and management of exposure cases which results in faster clearance of patients. The external assistance by PC personnel may also translate to greater coordination among personnel within the hospital—such as pharmacologists, lab specialists, and clinical toxicologists. This also explains the observation that patients with PC assistance had higher cumulative laboratory costs, but lower charges relating to surgery and length of stay.

The observed difference in length of hospitalization in this study was not as pronounced as reported in previous studies that did not control for important predictors of duration of stay.[14–16,24] In our study, length of hospitalization was on average 1.5 days shorter among PC-assisted patients when using an unadjusted OLS model, which is nearly identical to some previous reports.[14–16,24] However, past studies do not adjust for the impact of the outliers or the role of potential confounders, in particular comorbidities and regional differences.

In addition, the present study found net savings in cumulative total charges among inpatient cases, despite the observation that a greater proportion of PC-assisted patients required mechanical ventilation and involved multiple exposures. PC assistance was associated with lower total charges only among the most expensive to treat. However, this outlier group is very important when discussing medical costs. It has been repeatedly shown that the majority of treatment costs are attributable to a small fraction of patients.[20–22] Instead of simply reducing the influence of the outliers in a single unified statistical model, we chose to analyze the upper quintile separately in order to better characterize the change in cost per patient across the quintiles (Fig. 1).

This study indicates that at the hospital point-of-contact, the most severe cases are the primary beneficiaries of PC involvement in the treatment process in terms of hospital charges. In Illinois, the most complex cases referred through the State PC are managed by a group of practicing toxicologists and pharmacologists, and frequently involve multiple consultations over the course of hospitalization. At a con-

Table 3. Distribution of cumulative medical charges by quintiles in US dollars for patients receiving and not receiving poison center assistance in 2010, Illinois.

Inpatient cases	Poison center-assisted cases	No poison center assistance	Difference in cumulative charges
Less than 20 percentile	$5,518,761.08	$4,685,817.38	$832,943.70
20 to 40 percentile	$8,860,478.78	$8,170,425.10	$690,053.68
40 to 60 percentile	$12,199,525.23	$12,016,008.77	$183,516.46
60 to 80 percentile	$17,788,199.63	$19,384,792.26	$(1,596,592.63)
80 percentile and higher	$52,827,705.84	$63,938,373.74	$ (11,110,667.90)

Table 4. Distribution of cumulative medical charges by revenue type in US dollars for patients receiving and not receiving poison center assistance in 2010.

	Poison center-assisted cases ($N = 4968$)		No Poison Center Assistance ($N = 4968$)	
Charge category	Sum of charges	Proportion of total charges (%)	Sum of charges	Proportion of total charges (%)
Anesthesiology	$291,996.21	0.3	$728,223.37	0.7
Laboratory	$20,639,857.97	21.2	$17,002,413.41	15.7
Oncology	$ 89,533.24	0.1	$85,112.31	0.1
Operating Room	$1,598,219.96	1.6	$4,325,872.41	4.0
Pharmacy	$15,130,656.94	15.6	$15,338,521.61	14.2
Radiology	$6,483,578.55	6.7	$7,732,277.70	7.1
Room	$28,942,623.16	29.8	$36,491,974.68	33.7
Other	$24,018,204.53	24.7	$26,491,021.74	24.5
Total	$97,194,670.56		$108,195,417.23	

ceptual level, engaging these specialists would potentially result in more medical interventions across the patient population—thereby raising cost in some patients, while simultaneously reducing medical complications resulting from inadequate, delayed or inappropriate care, particularly among the more complicated and severe cases.

The precautionary principle informs triage protocols. It is known that we frequently overtriage patients, in part because of the difficulty to pinpoint who really will benefit from intensive services.[25] PC assistance can be viewed in this manner as well, especially in facilities without an attending toxicologist. The net cost benefit appears to be substantial among inpatient cases, especially in large hospital systems treating many patients suffering from various exposures. However, costs could be further reduced by developing a system to better identify patients who would benefit the most from assistance from a toxicologist. In this study, the upper quintile comprised a disproportionate number of elderly patients, persons suffering from multiple comorbidities, exposures to nonpharmaceutical agents, individuals suffering from adverse effects from pharmaceuticals and patients requiring mechanical ventilation. A triage-like protocol for poisoning that includes criteria that are not specific to a substance or dose may be very beneficial, in particular at facilities without attending toxicologists, to help medical staff decide whether to engage their local PC center.[26,27] In addition, to maximize the benefits of PC services in the hospital setting, it would be necessary to triage patients simply because there is a maximum capacity that any State PC can manage. The number of poisoning cases treated in emergency rooms and subsequently admitted is substantial. In 2010, 337,164 patients were admitted to Illinois hospitals with any diagnosis or cause of injury relating to an adverse event from an exposure to a substance based on our global inclusion criteria. This represents an admission rate of 41.2%, which is comparable to national estimates by the CDC and a recent study from Kentucky (37% and 41.3%, respectively).[4,28]

Our study indicates that restricting data analyses relating to toxic exposures to patients with ECODES or a primary diagnosis for poisoning is limiting. Datasets that are designed for billing systems emphasize diagnosis codes that relate to the billable diagnosis-related group code or those that have higher reimbursement rates. Therefore, exposures may be listed secondary to codes emphasized for billing purposes. In addition, many coding software only require cause of injury codes for specific primary diagnoses. For poisoning research and surveillance, it is self-limiting to not take into account secondary diagnoses that are present on admission. As an illustration, the total number of "poisoning" cases we observed in both the outpatient and inpatient datasets in Illinois nearly equaled national estimates provided by the CDC.[4] Furthermore, most of the past studies have excluded self-harm/psychiatric patients and patients with comorbidities. Both of these groups comprise a large proportion of the general patient population suffering from adverse effects from exposures

Table 5. Multivariable regression models of association between total hospital charges and patients receiving poison center assistance in 2010, Illinois.

	Unadjusted parameter estimate (in 2010 USD)	*P* value	Adjusted parameter estimate (in 2010 USD)	CI95%	*P* value
Main model					
Below upper quintile (< 80%)	$652.01	< 0.001	$953.15	714.52, 1191.78	<.001
Upper quintile	$ (7,585.11)	< 0.001	$ (4,851.69)	− 6463.09, − 3240.29	<.001
Sensitivity model*					
Below upper quintile (< 80%)	$1,055.76	< 0.001	$1,234.56	914.76, 1554.37	<.001
Upper quintile	$ (6,598.28)	< 0.002	$ (4,821.49)	− 6733.09, − 2909.89	<.001

*Sensitivity model only includes patients that linked on exposures during the initial linkage rounds in addition to the main matching variables which are hospital name, age, gender, and date of treatment.

to substances, as well as patients assisted by PCs. This limits the generalizability of these studies.

Limitations

There are inherent uncertainties that are unavoidable when using probabilistic data linkage methodology. The primary concern is the false match rate. Some diagnoses and exposures could be misclassified due to coding and billing errors. The main matching variables in isolation are not specific – hospital, age, gender, date of treatment, but in combination provide a greater level of precision, which is enhanced further by matching on exposure. However, the model estimates from the sensitivity analysis were very similar to the main model indicating that linkage criteria that do not include exposure type may be suitable for these types of analyses.

Another concern was whether patients that did not match to the inpatient records within the PC dataset (of the $N = 10{,}272$ identified as admitted to a hospital in the PC database) differed from those that matched making the findings less generalizable. In a comparison of those that matched to those that did not, we found that cases that matched to inpatient records were slightly older (mean age 35 y.o. vs. 29 y.o.) and a greater proportion had a moderate to severe poison severity measure (38% vs. 25.2%). They did not differ by gender, proportion of self-harm cases, acuity of exposure, number of exposures, or location of exposure. The differential inclusion of more severe cases in the PC-assisted group would diminish the observed difference in LOS and total charges when compared to a general patient population made up of less severe cases.

Analyses evaluating length of stay as an outcome can potentially be biased by its method of calculation as well as differential inclusion of psychiatric cases or patients with comborbidities. The inpatient dataset only includes patients hospitalized for a minimum of a 24 hours, therefore using the date instead of the hour of admission would not inadvertently include cases hospitalized for less than 1 day. The problem with using the date is that it artificially inflates length of stay up to one day. However, there was no evidence to indicate that the admission and discharge times would substantially differ between the groups with and without PC assistance. Both groups had the same number intentional self-harm cases, very few cases of children ($<$ 12 y.o.), and similar proportions of non-drug exposures which may be related to occupational tasks. Although suicide risk patients may remain longer in the hospital for observation as well as at the request of psychiatric facilities to ensure the patient is no longer physically at risk, the two groups had the same number of self-harm cases through matching. In addition, we controlled for comorbidities and age to control for potential confounding in the multivariable model.

An additional potential limitation is that the Illinois Poison Center is unique and the findings are not generalizable to other PCs in the U.S. or internationally because of the robust collaborative practice model in Illinois that supplements the general staff answering calls. However, in the U.S. 19 States have similar toxicology resources as Illinois which includes bedside and real-time consults by toxicologists.[29] In Illinois these augmented consultations represent only a fraction of the cases analyzed in this analysis. The majority of cases were restricted to the general telephonic consult staff which in Illinois is a mix of pharmacists and nurses, while in most States in the U.S. The centers are exclusively pharmacy-based or nursing-based. However, both groups of specialists in Illinois undergo the same standardized education program to work in the PC. Furthermore, all PCs in the U.S. use Micromedex, the evidence-based clinical reference system used for telephonic consults. Therefore, the information provided to callers will be similar across PCs and the decision trees for treatment recommendations would be very similar regardless of the State PC for any similarly exposed patient.

Conclusions

Previous studies show that PCs reduce cost system-wide, largely attributable to a reduction in unnecessary emergency room visits,[6–13] but may also be the result of poison prevention activities.[6] In this study, the hospital charges were significantly lower in the most expensive quintile of patients. PC services provide an efficient use of resources with an apparent benefit at the inpatient level in terms of lower charges and fewer hospital days, which translates into more resources available to treat other patients. However, to maximize the value of PC assistance system-wide, a formalized triage scheme should be developed to help medical practitioners identify patients early in the course of treatment that benefit most from the inclusion of toxicologists in their treatment process.[26,27]

Authorship

Dr. Lee Friedman had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Lee Friedman was involved in the conception and design, acquisition of data, analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content and statistical expertise. Alison Krajewski was involved in the conception and design of the data linkage methods, analysis and interpretation of the data, drafting of the article, and statistical expertise. Ember Vannoy was involved in the conception and design, and development of the data linkage methodology. Amy Allegretti was involved in the conception and design, analysis and interpretation of the data. Mike Wahl was involved in the acquisition of data and critical revision of the article for important intellectual content.

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Declaration of interest

LSF provides consulting services to the Illinois Poison Center related to real-time surveillance and education outreach. MW is Director of the Illinois Poison Center. None of the other authors have any conflicts of interest that may be relevant to the submitted work.

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