Evaluating reduction in medical costs associated with pharmacists' presence in the emergency department using a novel cost avoidance framework

Matthew Poremba, PharmD, Department of Pharmacy, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Kelsey Champa, PharmD, Department of Pharmacy, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Erin Reichert, PharmD, BCPS, Department of Pharmacy, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Purpose: The purpose of this study was to evaluate the cost avoidance associated with emergency medicine pharmacist (EMP) presence in the emergency department (ED) using a novel cost avoidance framework.

Summary: This single-center, retrospective, observational study examined EMP interventions from November 1, 2021, through March 31, 2022. EMPs prospectively selected up to 10 shifts in which to log interventions during the study period. Interventions were categorized into 25 cost avoidance categories, 10 of which incorporated recently proposed probability variables. All categories were organized into 4 broad cost avoidance domains, including resource utilization, individualization of patient care, adverse drug event prevention, and hands-on care. During the study period, 894 interventions were logged, which accounted for $143,132 in cost avoidance (lower probability value of $124,186, upper probability value of $168,858), with a median cost avoidance per shift of $1,671 (interquartile range, $1,025 to $2,451). On the basis of 240 shifts, the estimated annual total cost avoidance per pharmacist was extrapolated to be $401,040.

Conclusion: While the mean cost avoidance of $161.10 per intervention observed in our study was less than that in prior cost avoidance studies due to the conservative and potentially more realistic estimates used, implementation of this cost avoidance framework still showed substantial cost avoidance associated with EMP presence in the ED.

Keywords: costs and costs analysis, emergency medicine, hospital administration, interventions, medication, pharmacists

Am J Health-Syst Pharm. 2023;80(suppl 3):S111-S118

The role of emergency medicine pharmacists (EMPs) has transitioned from focusing on medication preparation and dispensing to involvement in direct patient care as part of an EM multidisciplinary team in the emergency department (ED), including, but not limited to, assisting with emergency response and providing transitions-of-care services.[1,2] As the role of the EMP has evolved, multiple professional organizations have stated that they consider EMPs to be essential providers and have advocated for 24-hour pharmacist coverage.[1,3,4] Despite EMPs being recognized as essential providers, a financial rationale is often necessary on an institutional level to create clinical pharmacist positions and expand services. Cost avoidance studies have previously been used to provide a financial rationale.[5,6]

Previous cost avoidance studies have shown significant reductions in cost associated with the presence of an EMP.[7-9] Recently published guidance on cost avoidance in pharmacy practice sought to improve the quality and validity of future studies by proposing a cost avoidance calculation that factors in the probability of a trajectory change without pharmacist intervention (pTC), the probability of a consequence occurring (pCON), and the attributed

Address correspondence to Dr. Reichert (erin.reichert@osumc.edu).
Twitter: @ereichertem

https://doi.org/10.1093/ajhp/zxac376

cost value of a given consequence (cCON).[10] The purpose of this study was to evaluate savings associated with EMP presence in the ED using a novel cost avoidance framework. This study adds to the literature by utilizing cost avoidance categories unique to EMPs that have not previously been assessed in this field of study.

Methods

Study setting. The study was conducted at an urban academic medical center with over 80,000 ED visits annually. The 109-bed ED is staffed by EM faculty, resident physicians, and advanced practice providers. At the time of this study, 7 EMPs, accounting for 6.5 full-time equivalents, and 2 postgraduate year 2 (PGY2) EM pharmacy residents provided clinical coverage to the ED from 7:00 AM to 2:00 AM Monday through Friday and 10:30 AM to 8:30 PM on weekends and holidays. From 10:00 AM until 11:00 PM on weekdays, 2 EMPs are present to provide clinical services, with 1 pharmacist present at all other times. Daily clinical activities include, but are not limited to, bedside emergency response, pharmacotherapy consultation, antimicrobial stewardship, patient and provider education, discharge prescription review, culture review and follow-up for discharged patients, medication reconciliation, and patient profile review.

Study design. This was a single-center, retrospective, observational study encompassing the period from November 1, 2021, to March 31, 2022. During the study period, EMPs prospectively selected up to 10 shifts and PGY2 EM pharmacy residents prospectively selected 6 shifts on weekdays and nonholidays for inclusion in the study. EMPs signed up with the study investigators to prospectively select shifts, ranging in duration from 6 to 10 hours, in which to log interventions, to decrease the likelihood that shifts would contain a large volume of administrative and educational duties. Cost avoidance activities documented via iVents, a tool created by Epic Systems (Verona, WI), and progress notes were retrieved from the electronic medical record (EMR) for the selected shifts.

Matthew Poremba, PharmD, is currently an emergency medicine clinical pharmacy specialist at University of Maryland Medical Center in Baltimore, MD. He graduated from the University at Buffalo School of Pharmacy and Pharmaceutical Sciences in Buffalo in 2020. After graduation, he completed a postgraduate year 1 pharmacy practice residency at Sharp Memorial Hospital in San Diego, CA. He completed this project during his postgraduate year 2 emergency medicine pharmacy residency at The Ohio State University Wexner Medical Center in Columbus, OH.

Progress notes are included in the permanent medical record and are part of the current EMP workflow at the study site. Progress notes are written for a variety of reasons, including, but not limited to, documentation of bedside emergency response, medication dose adjustments, culture follow-up, discharge prescription review, patient education, and medication reconciliation. iVents are not part of the permanent medical record but can easily be retrieved from the EMR and can only be logged and viewed by pharmacists. iVents were logged using a standard documentation template created by the study team, which allowed categorization of interventions into specific cost avoidance categories. Logging iVents is not part of the standard EMP workflow, and education was provided to EMPs before the study period. The iVents documentation template was available for 1 month before the start of the study to give pharmacists a chance to use the tool and provide feedback.

Data collection. Data collected consisted of each patient's age, discharge disposition, length of stay (LOS), boarding in the ED, and emergency severity index (ESI) score. Progress notes and iVents for preselected shifts were queried from the EMR. EMPs recorded a broad cost avoidance domain and cost avoidance category with every iVent. All interventions were reviewed by a member of the study team during data collection and adjusted as necessary to ensure that the correct cost avoidance category was selected for the intervention performed or the intervention was excluded if it did not align with any predefined cost avoidance category.

Cost avoidance framework. The research team utilized a novel framework to calculate the cost avoidance associated with various EMP activities after review of existing literature and incorporation of probability variables from the 2021 guidance published by Patanwala and colleagues.[10-24] EMP activities were categorized into 4 broad domains: adverse drug event (ADE) prevention, resource utilization, hands-on care, and individualization of patient care. These domains were further divided into 25 categories of cost avoidance, each with unique cost avoidance values. Values were adjusted to estimated values in 2022 US dollars.[25] Fixed values obtained from the literature were used for certain cost avoidance categories, while calculations and probability values were used for categories that involved ADE prevention. The cost avoidance categories, associated values, and calculations used are available in Table 1.

For cost avoidance categories using calculations, direct cost savings was defined as the direct measurable savings that occurred as a result of pharmacist intervention, ie, the difference in medication cost if switching from an intravenous to an oral medication. pTC was assumed to be 1 for any intervention that occurred after

Table 1. Cost Avoidance Domains and Categories

Cost avoidance category	Cost avoidance value[a]
Broad domain: individualization of patient care	
Antimicrobial therapy initiation and streamline	pTC × ($386.80[18] × pCON) + DCS
Culture follow-up	$631.34[11,19]
Drug info consultation	$101[11,20]
DVT prophylaxis	$60[21]
Initiation of nonantimicrobial therapy	pTC × ($153 × pCON) + DCS[11,13]
Reversal program cost avoidance	pTC × ($8,312[10,22] × pCON) + DCS
Broad domain: ADE prevention	
ADE prevention	pTC × ($2,013[10-12] × pCON) + DCS
Anticoagulant therapy monitoring	$420[23]
Antimicrobial pharmacokinetics evaluation—aminoglycosides	$200[13]
Antimicrobial pharmacokinetics evaluation—vancomycin	$153[13]
Dosage adjustment: nonrenal	$153[11-13]
Medication reconciliation leading to possible ADE prevention	pTC × ($2,013[10-12] × pCON) + DCS
Renal adjustment (non-CRRT)	pTC × ($2,013[10-12] × pCON) + DCS[15]
Broad domain: bedside response	
Bedside monitoring	pTC × ($2,013[10-12] × pCON) + DCS
Code blue response	0.274 × ($2,013[10-12,14] × pCON) + DCS
Code blue response + therapy initiation	[0.274 × ($2,013[10-12,14] × pCON) + DCS] + pTC × $153[11,13]
Medication teaching/discharge education	$631.34[11,19]
Rapid response participation	$153[11]
Rapid sequence intubation	$153[11]
Stroke code participation	Fibrinolytic given: $627.90[11,24] No fibrinolytic given: pTC × $153 × pCON + DCS[11,13]
Toxicology consult	$385.62[11,16]
Broad domain: resource utilization	
Direct savings	DCS – cost of medication or laboratory value discontinued
Isolation orders removed	pTC × $35[17]
Medication conversion: intravenous to oral	DCS
Rejection of restricted medication	DCS – cost of drug denied

Abbreviations: ADE, adverse drug event; CRRT, continuous renal replacement therapy; DCS, direct cost savings; DVT, deep vein thrombosis; pCON, probability of consequence; pTC, probability of trajectory change.
[a]Costs have been adjusted to 2022 US dollars using the Consumer Price Index for Medical Care.[25]

a treatment decision had been made, and a range of 0.5 to 0.75 was used for interventions where it was unclear whether the change would have occurred without pharmacist presence. The pCON value used was a conservative estimate of 0.01 to 0.05. Calculated cost avoidance values included an average anticipated cost avoidance value, along with a lower probability value (LPV) and an upper probability value (UPV) obtained by using permutations of the cost avoidance calculation with the worst and best possible values for each probability variable, respectively.

Outcomes and data analysis. The primary outcome of this study was the total cost avoidance associated with EMP activities documented during intermittent shifts throughout the study period. Secondary outcomes included total cost avoidance extrapolated to an annual estimate using 240 shifts, median cost avoidance per EMP shift, and number of interventions performed with associated cost avoidance based

on patients' ESI score, disposition, age, ED LOS, and boarding in the ED. Descriptive statistics were used for all data. Normally distributed data are presented as mean (SD), and nonnormally distributed data are presented as median (25th- to 75th-percentile interquartile range [IQR]). Cost avoidance values are described as ranges, using the LPV and UPV.

Ethics. The Office of Responsible Research Practices determined that the study did not involve regulated research involving human subjects and could be conducted without further institutional review board review or exemption. A quality release form was approved by the health system's chief quality officer.

Results

A total of 894 interventions were logged during 76 prospectively selected shifts, comprising 643 clinical hours in the ED. Of the 76 shifts, 64 were recorded by EMPs and 12 were recorded by PGY2 EM pharmacy residents. EMPs logged 805 (90%) interventions, and the pharmacy residents logged 89 (10%). The majority of interventions, 486 (54.4%), were logged as iVents in the EMR, while 408 (45.6%) were documented in progress notes.

The total estimated cost avoidance over the entire study period was $143,132 (LPV to UPV, $124,186 to $168,858). Looking at broad domains of cost avoidance classification, 284 (31.7%) interventions represented individualization of patient care, accounting for $36,507 of cost avoidance. This was the most commonly logged broad domain for interventions. Of the remaining interventions, 280 (31.3%) were categorized as ADE prevention accounting for $33,429 of cost avoidance, 207 (23.1%) were categorized under bedside response accounting for $59,773 of cost avoidance, and 89 (10.0%) were categorized under resource utilization accounting for $13,423 of cost avoidance. Bedside response was the domain associated with the largest cost avoidance, which was largely informed by the medication teaching/discharge education and stroke response categories. Thirty-four (3.9%) interventions were logged that did not fit into any prespecified cost avoidance domain and were assigned a conservative cost avoidance value of $0. After excluding these 34 interventions, the mean cost avoidance was $161.10 (SD, $260.92) per intervention logged. Of all the interventions, 452 (50.6%) were logged into categories using a calculation with probability variables that have not been incorporated in prior cost avoidance studies, while 408 (45.6%) were logged in categories with no probability values incorporated. The number of interventions logged and cost avoidance associated with each individual category of cost avoidance are available in Table 2.

When examining secondary outcomes, the total cost avoidance was extrapolated to an annual estimate per pharmacist of $401,040 using 240 shifts as the amount of time a full-time employee would be expected to work. The median number of interventions logged per shift was 11 (IQR, 7-14). Median cost avoidance per shift was $1,671 (IQR, $1,025-$2,451). When excluding PGY2 EM pharmacy residents, the median number of interventions per shift was 11 (IQR, 8-16) and the median cost avoidance per shift was $1,835 (IQR, $1,072-$2,649). Looking at the PGY2 EM pharmacy residents exclusively, the median number of interventions per shift was 6 (IQR, 5-11) and the median cost avoidance per shift was $1,156 (IQR, $845-$1,470). The number of interventions and cost avoidance based on various patient-specific factors are summarized in Table 3.

Discussion

At our urban academic medical center, there was substantial cost avoidance associated with EMP presence when using a novel cost avoidance framework. Cost avoidance estimates incorporating probability variables accounted for only $24,948, or 17.3%, of all cost avoidance despite representing 50.6% of all interventions recorded, while fixed-value cost avoidance estimates accounted for $118,339 (82.1%) of all cost avoidance. Part of this disparity may be due to our use of a very conservative pTC range of 0.01 to 0.05 for our calculations. Another reason for this difference is how we incorporated direct costs in interventions that utilized calculations. For example, if laboratory monitoring was ordered with the intent of preventing an ADE, the cost of ordering that laboratory test was included as a negative direct cost savings value. Similarly, if there was a change in medications, the difference in costs between those medications was used as the direct cost savings value, whether that value was a net positive or negative. This led to some interventions having lower bounds of negative values, which may have resulted in cost occurrence as opposed to cost avoidance. These interventions may still represent clinically appropriate interventions made by EMPs, even in cases of cost occurrence.

Our study also contained new cost avoidance categories unique to EMPs that have not previously been described in the literature. This included documentation of medications administered that had not been charted to ensure accurate billing, which was included as part of the direct savings category. This intervention type was recorded 5 times and associated with a cost avoidance of $709. Another unique intervention was removal of isolation orders for patients testing negative for coronavirus disease 2019 (COVID-19). Because of the number of boarding patients with COVID-19 in the ED, EMPs found themselves in a unique position to initiate removal of isolation orders on these patients in situations where patients tested negative. This was logged 31 times and was associated with a cost avoidance of $682 (LPV to UPV, $558 to $806).[17] EMPs were also able to log their intervention category as "other," which the study team assessed, reassigning interventions to a cost avoidance category if applicable. There were 163 interventions logged as "other," of which 34 were ultimately excluded. While logging interventions as "other" may in part have been due to EMPs'

Table 2. Interventions Logged and Associated Cost Avoidance

Cost avoidance category	Interventions, No. (%)	Cost avoidance, estimated (LPV to UPV)
Broad domain: individualization of patient care		
Antimicrobial therapy initiation and streamline	55 (6.2)	$1,155 ($495 to $2,365)
Culture follow-up[a]	78 (8.7)	$21,299
Drug info consultation	60 (6.7)	$10,440
DVT prophylaxis	11 (1.2)	$1,914
Initiation of nonantimicrobial therapy	70 (7.8)	$61 (–$175 to $294)
Reversal program cost avoidance	10 (1.1)	$1,638 ($449 to $3,206)
Broad domain: ADE prevention		
ADE prevention	98 (11.0)	$6,767 ($741 to $14,606)
Anticoagulant therapy monitoring	6 (0.7)	$5,592
Antimicrobial pharmacokinetics evaluation—aminoglycosides	1 (0.1)	$259
Antimicrobial pharmacokinetics evaluation—vancomycin	6 (0.7)	$1,188
Dosage adjustment: nonrenal	57 (6.4)	$11,241
Medication reconciliation leading to possible ADE prevention	80 (8.9)	$6,562 ($1,658 to $13,436)
Renal adjustment (non-CRRT)	32 (3.5)	$1,820 ($520 to $3,516)
Broad domain: bedside response		
Bedside monitoring	27 (3.0)	$2,227 ($573 to $4,593)
Code blue response	5 (0.6)	$185 ($60 to $305)
Code blue response + therapy initiation	0 (0)	$0
Medication teaching/discharge education	28 (3.1)	$22,088
Rapid response participation	64 (7.2)	$12,672
Rapid sequence intubation	18 (2.0)	$3,564
Stroke code participation[b]	61 (6.8)	$17,041 ($14,313 to $20,737)
Toxicology consult	4 (0.4)	$1,996
Broad domain: resource utilization		
Direct savings	45 (5.0)	$11,243
Isolation orders removed	31 (3.5)	$682 ($558 to $806)
Medication conversion: intravenous to oral	11 (1.2)	$696
Rejection of restricted medication	2 (0.2)	$802

Abbreviations: ADE, adverse drug event; CRRT, continuous renal replacement therapy; DVT, deep vein thrombosis; LPV, lower probability value; UPV, upper probability value.
[a]Culture follow-up values only used the estimated cost avoidance value if the documented intervention involved a change in the emergency department discharge plan of care for the patient.
[b]Seventeen cases involved fibrinolytic administration while 44 cases did not have a fibrinolytic agent administered.

awareness that the study team would go back and review interventions to assign them to an appropriate category, the volume of interventions logged this way was a substantial finding. Overall, 129 interventions that were logged in the "other" category were found to belong to a cost avoidance category, representing 15% of all interventions with cost avoidance values associated. This may indicate that, even with education on how to log interventions, EMPs may be unsure of how to categorize all interventions. Previous studies required EMPs to select a category for

Table 3. Interventions and Associated Cost Avoidance Based on Patient-Specific Factors

	Interventions, No. (%)	Cost avoidance, estimated (LPV to UPV)
Interventions by ESI score		
1	141 (15.7)	$24,590 ($21,021 to $29,515)
2	419 (46.9)	$61,231 ($50,906 to $75,183)
3	250 (28.0)	$41,949 ($37,816 to $47,546)
4	49 (5.5)	$10,695 ($10,578 to $10,898)
5	17 (1.9)	$1,471 ($1,130 to $1,882)
None recorded	18 (2.0)	$3,196 ($2,735 to $3,834)
Interventions by disposition		
Admission	607 (67.8)	$85,861 ($70,538 to $106,700)
Discharge	249 (27.9)	$52,348 ($49,507 to $56,228)
Death	17 (1.9)	$1,522 ($1,001 to $2,179)
Other	21 (2.4)	$3,401 ($3,140 to $3,751)
Interventions by age range, years		
<30	101 (11.3)	$22,530 ($21,528 to $23,882)
30-39	105 (11.8)	$20,076 ($18,640 to $22,053)
40-49	102 (11.4)	$12,749 ($11,238 to $14,817)
50-59	172 (19.2)	$30,110 ($25,418 to $36,470)
60-69	174 (19.5)	$27,133 ($22,571 to $33,402)
70-79	138 (15.4)	$18,823 ($15,375 to $23,438)
80-89	85 (9.5)	$10,260 ($8,455 to $12,711)
>89	17 (1.9)	$1,451 ($961 to $2,085)
Interventions by patient's ED LOS, hours		
0 to <12	403 (45.1)	$80,907 ($73,209 to $91,582)
12 to <24	228 (25.5)	$33,086 ($28,017 to $39,901)
24 to <36	145 (16.2)	$14,643 ($10,935 to $19,709)
36 to <48	66 (7.4)	$7,966 ($6,463 to $9,842)
>48	48 (5.4)	$4,373 ($3,467 to $5,583)
Unknown	4 (0.4)	$2,157 ($2,095 to $2,241)
Interventions by boarding status		
Boarded	411 (46.0)	$47,055 ($37,078 to $60,467)
Not boarded	481 (53.8)	$95,909 ($87,064 to $108,055)
Unknown	2 (0.2)	$168 ($44 to $336)

Abbreviations: ED LOS, emergency department length of stay; ESI, emergency severity index; LPV, lower probability value; UPV, upper probability value.

every intervention logged, and, in situations where EMPs were unsure about intervention categorization, they may have chosen not to include certain interventions or have potentially categorized them under an incorrect category. Giving EMPs the option to log an intervention in the "other" category with adjudication by our study team on the back end may have led to more accurate results.

When looking at the volume of interventions based on patient-specific factors, interventions were most commonly made on patients with ESI scores of 1 through 3 and admitted patients. All these variables indicate that EMPs at the study site were most likely to make interventions on high-acuity patients. This may be reflective of the study site's 45% admission rate for

patients presenting to the ED, which is much higher than the 12.4% admission rate for ED visits across the US.[26] There were 411 interventions made on patients boarding in the ED, accounting for 46% of all interventions. We also assessed the number of interventions based on patient age and found no significant trends.

Our study found a lower cost avoidance per intervention than reported in previous literature looking at the cost avoidance associated with EMPs. The PHARM-EM study found an annual cost avoidance with an EMP to be $1,971,262 over 240 shifts when using the framework of Hammond et al,[11] originally developed for application to pharmacist practice in the intensive care unit. During the study, 13,984 interventions were accepted, accounting for $7,531,862 of cost avoidance, with a mean cost avoidance of $538.61 per intervention.[9,11,27] The EMPIRE-C study estimated $5,350,755 in cost avoidance associated with 9,181 interventions made by pharmacists at community hospitals, with a mean cost avoidance of $582.80 per intervention.[28] The lower cost avoidance values seen in our study are likely due to the incorporation of new probability variables, which led to more conservative estimates of cost avoidance, and the reporting of our results as ranges of estimates. For example, cost avoidance in the ADE prevention category was calculated very differently than in previous studies. Combining major and minor ADE prevention as logged in the PHARM-EM study, there were 766 total interventions resulting in a total cost avoidance of $1,387,192 and a mean cost avoidance of $1,810.96 per intervention.[9] In our study, ADE prevention accounted for 98 interventions totaling $6,767 in cost avoidance, for a mean cost avoidance of $69.05 per intervention. In addition, compared to PHARM-EM, we only applied a fixed value to stroke response where a fibrinolytic agent was administered based on the fixed value from reduction in time to fibrinolytic administration. For other stroke alerts, we used the major ADE prevention cost avoidance value as EMPs are highly active at our site, assisting with bedside administration of various medications, ensuring appropriate adherence to blood pressure goals, and performing targeted medication reconciliation for anticoagulants. Ultimately, our hope is that the values reported in this study more accurately reflect the imprecise nature of cost avoidance studies.

This study had several limitations. First, it was performed at a single site where EMPs are responsible for more than just order verification during patient care hours. We did not assess interventions made by our pharmacists responsible for ED order verification during the study period, so certain interventions commonly made on order verification may have been missed by this study. Second, this study relied on EMPs to self-report interventions, which may have led to underreporting due to the ED environment as well as intervention documentation fatigue.[29,30] Self-reporting of interventions may have also led to more interventions being made due to the Hawthorne effect, as pharmacists were aware which shifts were being included in the study and may have modified their behavior.[31] Third, building the optimal cost avoidance study would require a team of researchers reviewing and assigning values for each individual intervention; however, with the size of our study team, this approach was not feasible. Fourth, our annualized cost avoidance estimate of $490,560 per pharmacist used 240 shifts to allow for more direct comparisons with previous studies in this field, which may be an overestimate, as EMPs were able to select shifts to log interventions with minimal administrative and educational duties, and may not completely reflect real EMP practice. Fifth, our results may not be generalizable to other sites where there are lower volumes of high-acuity patients, less focus on EMP involvement in high-acuity patient management, and lower numbers of patients who board in the ED. Finally, one major limitation of attempting to estimate the cost avoidance associated with all EMP activity is that certain aspects of the workflow (administrative tasks, education) are not quantifiable within a financial framework.

Conclusion

When assessing a sample of the interventions performed at a single site, a cost avoidance framework incorporating new variables and categories of cost avoidance unique to EMPs and not previously assessed found significant cost avoidance associated with EMP presence in the ED. Future studies involving multiple sites that incorporate these new cost avoidance calculations should be performed for a more generalizable cost avoidance value.

Disclosures

The authors have declared no potential conflicts of interest.

References

1. Ortmann MJ, Johnson EG, Jarrell DH, et al. ASHP Guidelines on Emergency Medicine Pharmacist Services. *Am J Health-Syst Pharm*. 2021;78(3):261-275. doi:10.1093/ajhp/zxaa378
2. Randolph TC. Expansion of pharmacists' responsibilities in an emergency department. *Am J Health-Syst Pharm*. 2009;66(16):1484-1487. doi:10.2146/ajhp080698
3. Farmer BM, Hayes BD, Rao R, Farrell N, Nelson L. The role of clinical pharmacists in the emergency department. *J Med Toxicol*. 2018;14(1):114-116. doi:10.1007/s13181-017-0634-4
4. American College of Emergency Physicians. Clinical policy statement: clinical pharmacist services in the emergency department. Accessed December 13, 2021. https://www.acep.org/patient-care/policy-statements/clinical-pharmacist-services-in-the-emergency-department/
5. Tripicchio K, Urick B, Easter J, Ozawa S. Making the economic value proposition for pharmacist comprehensive medication management (CMM) in primary care: a conceptual framework. *Res Social Admin Pharm*. 2020;16(10):1416-1421. doi:10.1016/j.sapharm.2020.01.001
6. Chuang LC, Sutton JD, Henderson GT. Impact of a clinical pharmacist on cost saving and cost avoidance in drug therapy in an intensive care unit. *Hosp Pharm*. 1994;29(3):215-218.

7. Sin B, Ciaramella C, Stein G, et al. Implementation of an advanced pharmacy practice model in the emergency department. *J Pharm Pract*. 2020;33(4):481-490. doi:10.1177/0897190018819412
8. Lada P, Delgado G. Documentation of pharmacists' interventions in an emergency department and associated cost avoidance. *Am J Health-Syst Pharm*. 2007;64(1):63-68. doi:10.2146/ajhp050213
9. Rech MA, Adams W, Smetana KS, et al. PHarmacist Avoidance or Reductions in Medical Costs in Patients Presenting the EMergency Department: PHARM-EM study. *Crit Care Explor*. 2021;3(4):e0406. doi:10.1097/cce.0000000000000406
10. Patanwala AE, Narayan SW, Haas CE, Abraham I, Sanders A, Erstad BL. Proposed guidance on cost-avoidance studies in pharmacy practice. *Am J Health-Syst Pharm*. 2021;78(17):1559-1567. doi:10.1093/ajhp/zxab211
11. Hammond DA, Gurnani PK, Flannery AH, et al. Scoping review of interventions associated with cost avoidance able to be performed in the intensive care unit and emergency department. *Pharmacotherapy*. 2019;39(3):215-231. doi:10.1002/phar.2224
12. Classen DC, Pestotnik SL, Evans RF, Lloyd JF, Burke JP. Adverse drug events in hospitalized patients. Excess length of stay, extra costs, and attributable mortality reprints. *JAMA*. 1997;277(4):301-306.
13. Hamblin S, Rumbaugh K, Miller R. Prevention of adverse drug events and cost savings associated with PharmD interventions in an academic level I trauma center: an evidence-based approach. *J Trauma Acute Care Surg*. 2012;73(6):1484-1490. doi:10.1097/TA.0b013e318267cd80
14. Draper HM, Eppert JA. Association of pharmacist presence on compliance with advanced cardiac life support guidelines during in-hospital cardiac arrest. *Ann Pharmacother*. 2008;42(4):464-479. doi:10.1345/aph.1K475
15. Cheung D, Go A, Cooper M, Schwarz K. Evaluation of a pharmacist-driven renal dosing protocol at an academic medical center. *J Am Coll Clin Pharm*. 2020;3(4):736-742. doi:10.1002/jac5.1230
16. Wiegand TJ, Crane PW, Kamali M, et al. Billing and reimbursement for a bedside toxicology service at a tertiary care academic center during its first fiscal year. *J Med Toxicol*. 2015;11(1):48-58. doi:10.1007/s13181-014-0423-2
17. Edmond MB, Masroor N, Stevens MP, Ober J, Bearman G. The impact of discontinuing contact precautions for VRE and MRSA on device-associated infections. *Infect Control Hosp Epidemiol*. 2015;36(8):978-980. doi:10.1017/ice.2015.99
18. Fraser GL. Antibiotic optimization. An evaluation of patient safety and economic outcomes. *Arch Intern Med*. 1997;157(15):1689-1694. doi:10.1001/archinte.157.15.1689
19. Sebaaly J, Parsons LB, Pilch NA, Bullington W, Hayes GL, Easterling H. Clinical and financial impact of pharmacist involvement in discharge medication reconciliation at an academic medical center: a prospective pilot study. *Hosp Pharm*. 2015;50(6):505-513. doi:10.1310/hpj5006-505
20. Brown JN. Cost savings associated with a dedicated drug information service in an academic medical center. *Hosp Pharm*. 2011;46(9):680-684. doi:10.1310/hpj4609-680
21. Schädlich PK, Kentsch M, Weber M, et al. Cost effectiveness of enoxaparin as prophylaxis against venous thromboembolic complications in acutely ill medical inpatients: modelling study from the hospital perspective in Germany. *Pharmacoeconomics*. 2006;24(6):571-591. doi:10.2165/00019053-200624060-00005
22. Procopio GL, Jain RP, Tompkins DM, Perez JM, Bicking K. Impact of a pharmacist driven anticoagulation reversal program at a large academic medical center. *J Thromb Thrombolysis*. 2022;53(1):158-166. doi:10.1007/s11239-021-02491-7
23. Mamdani MM, Racine E, McCreadie S, et al. Clinical and economic effectiveness of an inpatient anticoagulation service. *Pharmacotherapy*. 1999;19(9):1064-1074. doi:10.1592/phco.19.13.1064.31591
24. Boudreau DM, Guzauskas GF, Chen E, et al. Cost-effectiveness of recombinant tissue-type plasminogen activator within 3 hours of acute ischemic stroke: current evidence. *Stroke*. 2014;45(10):3032-3039. doi:10.1161/STROKEAHA.114.005852
25. FRED Economic Data. Consumer Price Index for All Urban Consumers: Medical Care. Accessed February 17, 2022. https://fred.stlouisfed.org/series/CPIMEDSL
26. Centers for Disease Control and Prevention. National Hospital Ambulatory Medical Care Survey: 2018 emergency department summary tables. Accessed June 26, 2022. https://www.cdc.gov/nchs/fastats/emergency-department.htm
27. Hammond DA, Flowers HJC, Meena N, Painter JT, Rech MA. Cost avoidance associated with clinical pharmacist presence in a medical intensive care unit. *J Am Coll Clin Pharm*. 2019;2(6):610-615. doi:10.1002/jac5.1111
28. Dietrich SK, Bushong BT, Schneider-Smith EA, Mixon MA. Emergency medicine pharmacist interventions reducing exposure to costs (EMPIRE-C). *Am J Emerg Med*. 2022;54:178-183. doi:10.1016/j.ajem.2022.01.054
29. Alwadie AF, Naeem A, Almazmomi MA, Baswaid MA, Alzahrani YA, Alzahrani AM. A methodological assessment of pharmacist therapeutic intervention documentation (TID) in a single tertiary care hospital in Jeddah, Kingdom of Saudi Arabia. *Pharmacy*. 2021;9(2):97. doi:10.3390/pharmacy9020097
30. Pouliot J, Hahn M, Sharpe B. Impact of initiating clinical pharmacy services in a non-academic community medical center emergency department setting. *J Contemp Pharm Pract*. 2019;66(2):29-34. doi:10.37901/jcphp17-00029
31. McCarney R, Warner J, Iliffe S, van Haselen R, Griffin M, Fisher P. The Hawthorne effect: a randomised, controlled trial. *BMC Med Res Methodol*. 2007;7(1):3. doi:10.1186/1471-2288-7-3