PRACTICE REPORT

Outcomes of expanded use of clinical pharmacist practitioners in addition to team-based care in a community health system intensive care unit

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Purpose. Clinical and cost benefits achieved through expanded use of state-licensed clinical pharmacist practitioners (CPPs) with prescribing authority on a critical care team are reported.

Methods. A retrospective pre–post analysis was conducted to evaluate patient care outcomes and cost savings during one-year periods before and after the number of CPPs on a North Carolina community health system's neurotrauma intensive care unit (NTICU) team was increased from one to three. Outcomes assessed included the number and types of medication management encounters, estimated cost savings, and the rate of preventable adverse drug events (ADEs) with expanded use of CPPs.

Results. During the two-year study period, CPPs conducted 13,386 documented medication encounters involving 2,198 patients; associated cost savings totaled an estimated $2,118,426. During the 12 months after CPP involvement on the NTICU team was increased, there was a 182% increase in encounters for therapeutic optimization (p = 0.01), with an associated 29% increase in cost savings and an improved return on investment. The CPP service expansion was also associated with a reduction in preventable ADEs, including a 75% reduction in prescribing-related ADEs (risk ratio [RR], 0.25; 95% confidence interval [CI], 0.05–1.2; p = 0.09) and a 37% reduction in higher-severity ADEs (RR, 0.63; 95% CI, 0.25–1.57; p = 0.36).

Conclusion. With expanded CPP involvement on the NTICU team, there was a substantial increase in therapeutic optimization interventions and a clinically notable reduction in preventable ADEs, as well as an estimated 30% increase in associated cost savings.

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The field of critical care has exemplified interdisciplinary team-based care for well over 25 years.[1] The Society of Critical Care Medicine (SCCM) and the American College of Clinical Pharmacy deem that pharmacists are an essential component of providing quality care to critically ill patients and should be integrated into the intensive care unit (ICU) team for achievement of best-practice models.[2-5]

A dedicated pharmacist in the ICU as a component of team-based care may result in favorable clinical and economic outcomes for patients. In addition to reductions in length of stay[6-9] and mortality,[6-8,10] the presence of a dedicated ICU pharmacist can optimize clinical outcomes,[7,9,11-15] reduce preventable adverse drug events (ADEs),[10,12,13,15-20] and minimize drug–drug interactions[8] and costs.[6,7,10,11,15,16,18,21,22]

Medications are the most common type of therapy in ICUs and are associated with the most frequent types of adverse events. Preventable ADEs are twice as likely to occur and more likely to have life-threatening consequences in ICUs compared with non-ICU settings; vasoactive agents and sedative or analgesic agents are most commonly implicated.[23] Risk factors for ADEs in the ICU versus general care units include renal injury (16-fold higher risk),

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thrombocytopenia (3-fold increase in risk), and urgent ICU admission (2-fold higher risk). Critically ill patients are more vulnerable to ADEs because of changing organ function, complex drug regimens, and alterations in pharmacokinetics.[24,25] On average, a single adverse event in the ICU has been reported to cost nearly $4000 and to be associated with an increased ICU length of stay, with ADE-attributable costs totaling about $1.5 million annually.[26] The higher risk of ADEs, the larger number of i.v. medications, the growth in the use of novel agents in ICUs, the frequent need for rapid decision-making, and the high spending on ICU medications as a percentage of total hospital drug costs have all contributed to the evolution of team-based care in ICUs.

Team-based care has been indentified as an important approach in meeting goals and improving healthcare quality with implementation of the Affordable Care Act. In 2012, an Institute of Medicine discussion paper described team-based care as the provision of health services by providers who work collaboratively to accomplish shared goals and coordinated, high-quality care.[27] SCCM has recognized that a team-based approach is an important factor in the quality of care provided and that a pharmacist is an essential member of the ICU team with regard to achieving best practices.[4] ICUs have modeled team-based care for decades, but advancements in the utilization of pharmacists on ICU teams should continue.

In 2000, revisions of the North Carolina Pharmacy Practice Act included an expanded scope of practice for pharmacists with specialized training or credentialing who meet the requirements for holding the designation clinical pharmacist practitioner (CPP). Licensing for CPPs in North Carolina is overseen jointly by the state boards of medicine and pharmacy.[28,29] With this practice model, a CPP's scope of practice is determined jointly by physicians and pharmacists by mutual written agreement. Aside from evidence demonstrating the benefits of including a pharmacist as a member of the rounding team or using pharmacist-defined protocols to guide medication therapy, data on the benefits of a licensed CPP with prescribing authority in the ICU as a component of team-based care have not been published previously.

The purpose of the analysis described here was to evaluate the benefits of a CPP with prescribing authority as a component of team-based care in a neurotrauma ICU (NTICU) during a one-year period when one CPP served on the NTICU team and during an additional one-year period after a service expansion including increased use of CPPs.

Methods

Setting. The study site was a 730-bed tertiary care community hospital that is the hub of a five-hospital system in a 17-county region and serves as the region's level II trauma center. The 14-bed NTICU has over 1100 patient admissions per year, and a dedicated decentralized CPP participates five days per week in multidisciplinary team rounds. Computerized prescriber order entry (CPOE) was adopted in 2008, and in some cases alerts are used to notify prescribers about serious medication interactions.

Pharmacist activity. During the first year of the two-year study period, one pharmacist from a team of critical care pharmacists was dedicated to NTICU service Monday through Friday and was responsible for clinical services, participation in the multidisciplinary team, electronic verification of medication orders, participation in emergency-code responses, and provision of clinical services for a 34-bed step-down unit. However, among the team of pharmacists, only one was licensed as a CPP during year 1 of the study, and CPP-provided care was not consistent throughout the week. During year 2 of the study, the CPP roster was expanded from one to three in order to achieve consistent Monday–Friday CPP coverage. The weekday multidisciplinary rounding team included the trauma surgeon, a bedside nurse, a care manager, a pharmacist, a respiratory therapist, and a nutrition support professional. During weekday rounds, the CPP assisted with the development of an individualized care plan for each patient and monitored each patient prospectively and daily until discharge from the ICU. Additionally, CPP duties included precepting pharmacy students and residents.

CPPs are supervised by the director of trauma surgery and critical care, and the scope of practice allows the CPP to initiate, modify, or discontinue medications available on the hospital formulary and to order pertinent laboratory tests. The practice agreement allows the CPP to provide comprehensive medication management for medications administered in the ICU, including home medications from admission. With this model, the CPP selects the medication therapy, dosage, duration, and monitoring based on the physician diagnosis and the team's goals for the patient. CPP licensing allowed an expanded scope of practice, different from traditional protocols guiding pharmacists in the ICU. Therapeutic optimization interventions not traditionally provided by ICU pharmacists are accomplished through the CPP agreement. For example, after a surgeon's diagnosis of ventilator-associated pneumonia, the pharmacist may select the antimicrobial regimen and order the appropriate dose, frequency, and duration of therapy; the CPP also may order necessary laboratory tests for monitoring, such as serum creatinine, complete blood count with differential, and follow-up sputum

cultures. Electronic orders entered by the CPP are cosigned by the surgeon within seven days.

Study design. A retrospective pre–post comparison of outcomes associated with CPP practice model expansion was conducted over a 2-year period (2009–11). Institutional review board and other required approvals were obtained. During year 1 of the study (September 1, 2009–August 31, 2010), only one pharmacist was a CPP, but during year 2 (September 1, 2010–August 31, 2011), the agreement was expanded to include three pharmacists. The surgeons and healthcare team had requested CPP staff expansion because the need for CPP services exceeded capacity. The expansion enabled consistency in daily CPP-provided patient care, and two additional critical care pharmacists met eligibility requirements and were approved as CPPs by September 2010. As pharmacists had been participants on the NTICU rounding team for over 10 years prior to the study described here, a controlled nonpharmacist comparison was not possible.

Data collection. Documented medication management encounters and preventable ADEs for all patients admitted to the ICU during the study period were evaluated. Electronic databases used to extract or classify the information included Cerner Explorer Reports (Cerner Corporation, Kansas City, MO) and the institution's trauma registry; the pharmacy's clinical intervention documentation (CID) system and MEDMARX (United States Pharmacopeial Convention, Rockville, MD) were used to collect information about ADEs.

The CID system is an electronic documentation tracking system for pharmacy interventions developed at the institution. Cost savings estimated for each intervention were based on national benchmarking estimates established in 2007 (updated in 2009) using the Action O-I Pharmacy Clinical Service Workload Unit Database and Worksheet (Thompson Healthcare, Stamford, CT). Monetary values for the national cost benchmarks did not change during the course of the study, and inflation was not factored into the cost savings analysis. Estimates of cost savings associated with various interventions were preprogrammed into the CID system (Table 1).

The return on investment (ROI) for both study periods was calculated using a national mean hourly pharmacist wage (plus 25% of that amount for benefits) during each year of the study ($65.73 in the first year and $67.40 in the second year of the study).[30] The hourly wages were multiplied by the time electronically documented as being spent by the decentralized pharmacist in the NTICU providing requested clinical services. The net value of documented patient encounters was derived by subtracting the salary and benefits costs associated with the pharmacist time spent on clinical services from the estimated cost savings. The ROI was calculated by dividing the net value by the combined salary–benefits cost and estimating the return on each dollar invested in pharmacist salary and benefits for the time spent providing clinical services.

The MEDMARX reporting software system is a nationally used standardized ADE data collection system. Events were voluntarily and electronically reported by any member of the care team and reviewed by an unbiased multidisciplinary medication process review committee for severity and classification prior to the study. Standardized taxonomy and definitions established by the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) and a severity index scale for categorizing medication errors based on patient outcomes and the level of threat to the patient were utilized. The index scale is based on event severity from A to I, and higher-severity errors are classified by NCC MERP as follows: category D, error reached the patient and required monitoring to

Table 1.
National Benchmarks for Cost Savings Associated With Pharmacist Interventions[a]

Intervention	Estimated Cost Savings ($)
Anticoagulant dosing	739
Antimicrobial optimization	90
Discontinuation of contraindicated therapy	2200
Discontinuation of duplicate or nonindicated medication	220
General therapeutic optimization	75
Glycemic and electrolyte management	75
I.V.-to-enteral conversion (average)	32
Management of sedation	75
Management of alcohol withdrawal	75
Pain management	600
Pharmacokinetic dosing	90
Renal dosing adjustment	112
Reduction in adverse effects	220
Venous thromboembolism prophylaxis	640
Sedation management	75
Stress ulcer prophylaxis	800

[a]Based on national benchmarking estimates by Thompson Healthcare in 2007 (updated in 2009).

confirm that it resulted in no harm or intervention; category E, error may have resulted in temporary harm and required intervention; category F, error may have resulted in temporary harm and required initial or prolonged hospitalization; category G, error may have resulted in permanent patient harm; category H, error required intervention necessary to sustain life; and category I, error may have contributed to patient death. The errors are also classified by origin (i.e., classified as errors of administration, prescribing, dispensing, procurement, or documentation/transcription, or a combination thereof). Total medication errors, error origin, and the number of category D or higher-severity errors were compared between the study periods. Nonpunitive reporting procedures and the culture of safety were considered to be consistent and stable throughout both study periods, based on Agency for Healthcare Research and Quality surveys at our institution.

Statistical analysis. Statistical analysis was performed by a statistician at the study site's research institute. Descriptive statistics and chi-square analysis were used for nonparametric data; Student's *t* test for parametric continuous data and Wilcoxon rank sum analysis were used when appropriate. Exact methods were used for small counts. Statistical analyses were conducted using SAS statistical software, version 9.3 (SAS Institute, Cary, NC), and the a priori level of significance was 0.05.

Results

Demographic and selected clinical data on the study population for the two-year study overall and for each comparator year are summarized in Table 2. There were no significant differences in baseline patient characteristics between the two one-year periods, with the exception of a higher rate of head, neck, or central nervous system injuries in the year 1 sample and a higher rate of thoracic injuries in the year 2 sample. There were 257 pharmacist-monitored patient-days in year 1 and 256 monitored days in year 2.

Over the two-year period, there were 13,386 documented patient medication encounters by CPPs involving 2,198 patients. These medication management encounters occurred over 513 monitored patient-days (a mean of 26 encounters per monitored day), and the CPPs spent 1,637 hours on the encounters. When changes were made to drug therapy, the most common types of interventions included renal dosing adjustments (n = 4,525), i.v.-to-enteral conversions (n = 1,432), general therapeutic optimization (n = 1,133), discontinuation of duplicate, contraindicated, or nonindicated therapy (n = 993), pharmacokinetic dosing (n = 277), antimicrobial optimization (265), glycemic or electrolyte optimization (n = 209), management of pain, agitation, delirium, or alcohol withdrawal (n = 113), and management of anticoagulant dosing or venous thromboembolism prophylaxis (n = 112). Progress notes written using the SOAP (subjective data, objective data, assessment, plan) format were entered into the electronic medical record for 8,441 of the patient encounters. Although renal dosing, i.v.-to-enteral conversions, and pharmacokinetic dosing were commonly performed (as is typical under traditional ICU pharmacist practice models), the provision of therapeutic optimization services was unique. General therapeutic optimization included interventions to decrease adverse effects; modification of doses, frequencies, or durations; new therapy recommendations; discontinuation or resumption of home medications; and initiation of stress ulcer prophylaxis or antiemetic management. Prevention of duplicate, contraindicated, or nonindicated therapy targeted medications such as erythropoietin, nesiritide, total parenteral nutrition, filgrastim, pegfilgrastim, and agents used for stress

Table 2.
Demographic and Clinical Characteristics of Study Population, Overall and by Study Year[a]

Variable	Overall (n = 2198)	Year 1 (n = 1108)	Year 2 (n = 1090)	p[b]
Mean ± S.D. age, yr	60.5 ± 18.5	60.9 ± 18.3	60.0 ± 18.7	0.41
Male, %	43.6	41.7	45.6	0.07
Race/ethnicity, %				
Caucasian	91.3	92.1	90.6	0.69
Black	4.3	4.0	4.7	
Hispanic	1.0	0.8	0.9	
Other	3.4	3.1	3.8	
Mechanical ventilation, %	46.6	46.9	46.2	0.74
Median (IQR) Injury Severity Score[c]	16 (10–22)	16 (10–22.5)	16 (9–22)	0.21
Type of injury, %[c]				
Head/neck/CNS	66.5	72.8	59.4	<0.01
Thoracic	47.1	43.2	50.7	0.04
Extremity	34.2	31.5	36.7	0.13
Face	19.6	21.5	18.8	0.39
Total pharmacist-monitored days	513	257	256	

[a]IQR = interquartile range, CNS = central nervous system.
[b]Chi-square test, *t* test, or Wilcoxon rank sum analysis used to calculate *p* values associated with frequencies and means; Mann–Whitney *U* test used for comparison of medians.
[c]Trauma patients only.

ulcer prophylaxis. Based on the evaluated national benchmarking data, the estimated cost savings or avoidance associated with these patient encounters was $2,118,426 over the two-year period. The ROI increased after the CPP expansion, from $9 per $1 invested in year 1 to $18 per $1 invested in year 2. This doubling of the ROI reflected daily consistency in CPP involvement in NTICU care and provision of more meaningful therapeutic interventions.

Comparison of the year 1 and year 2 data indicated a significant increase in the frequency of patient encounters for therapeutic optimization ($p < 0.01$) along with a 29% increase in cost savings with the CPP expansion (Table 3). Thus, the addition of two CPPs increased the volume of meaningful interventions. Although not a statistically significant decline, patient deaths decreased by 5.6 per 1000 ICU days during the study.

There was a 24% reduction in overall documented preventable ADEs after CPP expansion. ADEs were documented for 21 of 55,310 medication orders in year 2, compared with 24 of 48,145 medication orders in year 1 (risk ratio [RR], 0.76; 95% confidence interval [CI], 0.42–1.37; $p = 0.37$). The rate of prescribing-related adverse events per total medication orders was reduced by 75% in year 2 versus year 1 (RR, 0.25; 95% CI, 0.05–1.2; $p = 0.09$), from 1.7 to 0.5 per 1,000 patient-days; adverse events classified as category D or higher-severity events were reduced by 37% (RR, 0.63; 95% CI, 0.25–1.57; $p = 0.36$), from 2.7 to 1.9 per 1,000 patient-days. Relative to year 1, in year 2 there were nearly 1,000 additional instances (4.5 per 100 admissions) when a pharmacist discontinued therapy due to a duplication or a contraindication or when a therapy was no longer indicated for the patient; some published studies and institutions define such interventions as prevention of ADEs. The medications most commonly implicated in ADEs were sedative, analgesic, or central nervous system agents in year 1 and insulin in year 2.

Discussion

This study demonstrated a practice model strategy for utilizing a licensed CPP in a community health-system ICU in addition to usual team-based care in a setting where pharmacists had been rounding in the ICU for over 10 years. CPPs are able to prescribe and provide comprehensive medication management and therapeutic optimization beyond the scope of traditional protocol-guided interventions by an ICU pharmacist. With CPP expansion, there was an increase in the frequency of therapeutic optimization ($p < 0.01$), cost savings increased by nearly 30%, and there was a clinically notable reduction in medication errors. We interpret these findings as indicative of an increase in meaningful interventions with the use of three CPPs. The cost savings

Table 3.
Comparative Data on Medication Management Encounters and Hospitalization Outcomes Before (Year 1) and After (Year 2) Expanded Use of CPPs[a]

Intervention/Variable	Year 1 (n = 1108)	Year 2 (n = 1090)	% Change	Risk Ratio[b] (95% CI)	p[c]
Medication Management Encounters					
Therapeutic optimization (no. per 1,000 ICU patient-days)	112.1	316.0	182	2.82 (2.54–3.13)	<0.01
Vancomycin dosing (fraction of total vancomycin doses)[d]	75/1,070	160/1,096	108	2.08 (1.6–2.7)	<0.01
Warfarin dosing (fraction of total warfarin doses)[d]	17/37	75/75	118	2.18 (1.53–3.09)	<0.01[d]
Aminoglycoside dosing (fraction of total aminoglycoside doses)[d]	17/265	25/296	32	1.32 (0.73–2.38)	0.36
I.V.-to-enteral conversion (no.)	1,336	96	–94	0.06 (0.05–0.08)	<0.01
Renal dosing (no.)	2,963	1,562	–54	0.46 (0.43–0.49)	<0.01
Hospitalization Outcomes					
Median (IQR) ICU length of stay, days	2 (1–4)	2 (1–4)	0	. . .[e]	0.11
Total estimated cost savings ($)	925,068	1,193,358	29	. . .	. . .
Deaths per 1,000 ICU days	39.8	34.2	–5.6	. . .	0.19

[a]CPP = clinical pharmacist practitioner, CI = confidence interval, ICU = intensive care unit, IQR = interquartile range, CI = confidence interval.
[b]For likelihood of occurrence in year 2 versus year 1.
[c]Chi-square test, *t* test, or Wilcoxon rank sum analysis used to calculate *p* values associated with frequencies and means; Mann–Whitney *U* test used for comparison of medians.
[d]Exact methods used due to small counts.
[e]Not applicable.

from the medication encounters was well above the salary cost of a CPP in the ICU, and the favorable ROI in year 1 improved with the CPP expansion in year 2. Since inflation was not factored into the cost savings, the savings and ROI are likely underestimated. With the advent of the Affordable Care Act, mitigating avoidable events and reducing costs have become increasingly important as institutions assume higher cost burdens, and we believe our results would have been even more impactful in the setting of an accountable care organization.

The reductions in i.v.-to-enteral conversions and renal dosing interventions ($p < 0.01$ for both) provided by the CPPs were due to implementation of a hospitalwide automatic conversion program that shifted these responsibilities to night-shift pharmacists. This change allowed the CPPs to focus more on therapeutic optimization, and interventions made by the night-shift pharmacists were not included in the CPP volume and cost savings analysis. There were also changes in daily physician-ordered consultations that resulted in fewer renal dosing consultations overall.

At the time of the study, other processes were already in place to improve patient outcomes and safety, including the use of CPOE, computer-based decision support, intensivist staffing, multidisciplinary rounds, and patient-to-nurse ratios of 2:1 (in some cases, 1:1). These processes did not provide a 100% safety net, and additional improvements were possible.

The rate of preventable ADEs during year 1 (5.9 per 1,000 ICU days) was lower than that reported in a previous study (19 per 1,000 ICU days).[24] The rate of preventable ADEs attributed to prescribing was also lower in year 1 (1.7 per 1,000 ICU days) than that reported by Leape et al.[18] (3.5 per 1,000 patient-days), who evaluated the impact of pharmacist inclusion in team rounding on both medical and coronary teaching ICUs for nine months, or by Klopotowska et al.[19] (62.5 per 1,000 monitored days), whose research focused on pharmacist review of patients in a medical–surgical teaching ICU for eight months. Reasons for the relatively low rate of adverse events documented in our study are unclear but may include underreporting, the nonteaching status of the study site, and the established presence of a decentralized pharmacist in the ICU. Although the number of ADEs in year 1 was low, there was even further reduction after expansion of CPPs. We believe that the fact that there had been a decentralized, ICU-experienced rounding pharmacist in the NTICU for over 10 years, as well as the safety-net processes already in place, influenced the low adverse event rate at baseline. The study was not powered to demonstrate a significant difference with such small adverse event rates at baseline, but the goal at the institution is "zero harm" and zero preventable ADEs. When considering the low event rates at baseline and the specified alpha level of 0.05, the study would have required samples of at least 706,000, 106,000, and 235,000 patients per group to demonstrate statistically significant between-group differences in total medication errors, prescribing errors, and category D or higher errors, respectively. However, at our institution the demonstrated improvements were deemed noteworthy and beneficial for optimization of care.

The majority of published studies of ICU pharmacist interventions have focused on medical or general surgical ICU patients, with few conducted in a trauma or neurosurgical ICU. However, two recent studies evaluated the benefits of pharmacist inclusion on the care team in those settings. In our study, the number of medication encounters and the estimated annualized cost savings per patient with the CPP model of practice (6.1 and $964, respectively) were higher than the values previously reported by Hamblin et al.[16] in a trauma ICU (3.1 and $676) or Weant et al.[6] in a neurosurgical ICU (5.2 and $797). However, data are not available to make patient population comparisons regarding age or acuity, and different databases were used for estimating cost savings.

In a 2006 survey, 76.8% of the 1125 hospitals surveyed reported having pharmacists provide drug management as part of established protocols for specific medications.[31] Collaborative practice involves pharmacists playing more active roles in initiation of therapy, dosage adjustments, and monitoring of medication effectiveness and outcomes. In 2002, 38 states permitted pharmacists to engage in collaborative practice within their scope of practice.[28] Our study demonstrated that benefits are achieved when team-based care incorporates CPPs into the ICU team.

Our study had several limitations. First, it was a retrospective analysis, although patient encounters, cost savings, and ADEs were documented prospectively by the CPPs and the ICU care team. An inherent shortcoming of retrospective data analysis is that the demonstration of outcomes can be biased by unidentifiable factors. However, when comparing the two study periods, there were no changes in overall patient characteristics, provision of critical care services, and the institutional culture of safety. In a second study limitation, the data were dependent on documentation and voluntary reports, and underreporting likely occurred. Also, the study was conducted in only one ICU and lacked power to detect a significant between-group difference in ADEs, which could reduce its external validity. Moreover, a controlled nonpharmacist comparison was not possible, since pharmacists had rounded in the ICU for over 10 years prior to the study. An analysis of the impact of increased CPP

presence on physician time would have been meaningful but was not conducted. The CPP model warrants continued evaluation for its impact on patient outcomes, physician time, and key performance indicators in health systems.

Conclusion

With expanded CPP involvement on the NTICU team, there was a substantial increase in therapeutic optimization interventions and a clinically notable reduction in preventable ADEs, as well as an estimated 30% increase in associated cost savings.

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