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Impact of Pharmacists to Improve Patient Care in the Critically Ill: A Large Multicenter Analysis Using Meaningful Metrics With the Medication Regimen Complexity-ICU (MRC-ICU) Score*

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Members of the MRC-ICU Investigator Team are listed in Appendix 1 (http://links.lww.com/CCM/H140).

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Abstract

OBJECTIVES: Despite the established role of the critical care pharmacist on the ICU multiprofessional team, critical care pharmacist workloads are likely not optimized in the ICU. Medication regimen complexity (as measured by the Medication Regimen Complexity-ICU [MRC-ICU] scoring tool) has been proposed as a potential metric to optimize critical care pharmacist workload but has lacked robust external validation. The purpose of this study was to test the hypothesis that MRC-ICU is related to both patient outcomes and pharmacist interventions in a diverse ICU population.

DESIGN: This was a multicenter, observational cohort study.

SETTING: Twenty-eight ICUs in the United States.

PATIENTS: Adult ICU patients.

INTERVENTIONS: Critical care pharmacist interventions (quantity and type) on the medication regimens of critically ill patients over a 4-week period were prospectively captured. MRC-ICU and patient outcomes (i.e., mortality and length of stay [LOS]) were recorded retrospectively.

MEASUREMENTS AND MAIN RESULTS: A total of 3,908 patients at 28 centers were included. Following analysis of variance, MRC-ICU was significantly associated with mortality (odds ratio, 1.09; 95% CI, 1.08–1.11; $p < 0.01$), ICU LOS (β coefficient, 0.41; 95% CI, 00.37–0.45; $p < 0.01$), total pharmacist interventions (β coefficient, 0.07; 95% CI, 0.04–0.09; $p < 0.01$), and a composite intensity score of pharmacist interventions (β coefficient, 0.19; 95% CI, 0.11–0.28; $p < 0.01$). In multivariable regression analysis, increased patient: pharmacist ratio (indicating more patients per clinician) was significantly associated with increased ICU LOS (β coefficient, 0.02; 0.00–0.04; $p = 0.02$) and reduced quantity (β coefficient, −0.03; 95% CI, −0.04 to −0.02; $p < 0.01$) and intensity of interventions (β coefficient, −0.05; 95% CI, −0.09 to −0.01).

CONCLUSIONS: Increased medication regimen complexity, defined by the MRC-ICU, is associated with increased mortality, LOS, intervention quantity, and intervention intensity. Further, these results suggest that increased pharmacist workload is associated with decreased care provided and worsened patient outcomes, which warrants further exploration into staffing models and patient outcomes.

Keywords

burnout; metrics; patient safety; pharmacy; quality; workload

Icu workforce optimization is a widespread challenge affecting the multiprofessional team, including critical care pharmacists (1, 2). Despite concerns of high patient care workloads resulting in both adverse patient outcomes and clinician burnout, strategies to best allocate existing resources and justify new pharmacist positions are scarce. Indeed, while the jointly published position article from Society of Critical Care Medicine (SCCM) and American College of Clinical Pharmacy provides a veritable list of activities critical care pharmacists perform to improve patient-centered care, discussion of metrics for value tracking and workload prediction as well as the optimal patient: pharmacist ratio are notably lacking due to vital knowledge gaps (3, 4).

Resource allocation is a core challenge facing the profession. As census does not necessarily correlate with critical care pharmacists' needs and activities, it is difficult to reliably predict, in real-time, the critical care pharmacist needs by a patient or ICU. Further, the relationships of the optimal patient: pharmacist ratio, the quality of critical care pharmacist care, and the resulting ICU patient-related outcomes are poorly characterized (5). It has been previously proposed that the first step toward filling these vital knowledge gaps is the development and validation of an objective, readily quantifiable, and externally applicable metric to connect the components of the optimal pharmacy practice model (which is ultimately a component of the optimal ICU team-based model), including patient-centered outcomes, healthcare costs, pharmacist welfare, and pharmacist resources (5). While other metrics have been studied, all have significant limitations to applicability in the unique discipline of critical care including lack of correlation to patient-centered outcomes, lack of external validity, and lack of studies relevant to the ICU (5).

The Medication Regimen Complexity-ICU (MRC-ICU) scoring tool is the first metric proposed with the specific intention of describing relevant relationships in the optimal critical care pharmacy practice model and has shown early promise at overcoming

historical limitations in pilot studies (6–13). This 37-line item score has been provided in Supplemental Digital Content – Table 1 (http://links.lww.com/CCM/H141). To calculate an individual patient's MRC-ICU score at a given time point, each medication prescribed is assigned a weighted value ranging from 1 to 3. These values are summed to provide a total score. For example, a patient receiving cefepime (2 points), vancomycin (3 points), norepinephrine (1 point), and vasopressin (1 point) on ICU day 2 would have a day 2 MRC-ICU score of 7. To date, this metric has been successfully correlated to patient acuity (as measured by the Acute Physiology and Chronic Health Evaluation [APACHE III]), patient-centered outcomes including mortality and length of stay (LOS), ICU-related complications including fluid overload and drug-drug interactions, and pharmacist workload, as measured by documented pharmacist interventions (6–15). Furthermore, it has been successfully built into the electronic health record in one academic medical center (12). It has even shown superior correlation to pharmacist workload compared with the traditional patient acuity score Sequential Organ Failure Assessment (11). The studies that chronicle the development and evaluation of the MRC-ICU are summarized in Supplemental Digital Content – Table 2 (http://links.lww.com/CCM/H141). The primary limitation of all MRC-ICU evaluations to date has been the small sample and one (or two) center designs that inherently lack the robust external validity necessary for widespread use (6–15).

The purpose of this study was to provide initial characterization of the MRC-ICU metric in a large, diverse population of critically ill patients and to explore its predictive ability for patient-centered outcomes (i.e., mortality, ICU LOS) and critical care pharmacist workload (i.e., critical care pharmacist intervention quantity and intensity). The central hypothesis of this study was that medication regimen complexity is a metric that reliably predicts patient outcomes and pharmacist activity.

METHODS

This study was a multicenter, observational study that captured critical care pharmacist interventions at academic medical centers and community hospitals in the United States between August 2018 and January 2019. Methodology has been previously described (16). Briefly, critical care pharmacists were asked to prospectively collect interventions for 20 shifts. Interventions were categorized according to an evidence-based framework (16). Retrospective chart review was used to capture patient outcomes and MRC-ICU. Inclusion criteria were adult patients (≥ 18 yr old) admitted to an ICU setting for at least 24 hours who were cared for by participating critical care pharmacists during the study period.

The rationale for this study was to relate medication regimen complexity as measured by MRC-ICU with patient-centered outcomes and pharmacist activity. The study had two primary aims: 1) to evaluate the MRC-ICU's relationship to patient outcomes (e.g., mortality, LOS) and 2) to evaluate the MRC-ICU's relationship to pharmacist workload (e.g., quantity and intensity of pharmacist interventions) in diverse critically ill populations. The relationship between patient: pharmacist and both patient outcomes and pharmacist workload was also explored. The hypotheses were that increasing MRC-ICU is associated with the increased odds of hospital mortality and increased ICU LOS. Further, we

hypothesized that increasing MRC-ICU is associated with increased quantity and complexity of pharmacist interventions.

Data including institution characteristics, patient outcomes, components of the MRC-ICU score, patient: pharmacist ratio, and pharmacist interventions were collected. Institution characteristics included institution type, ICU type, and geographic region. Patient outcomes included mortality and ICU LOS. Quantity of interventions was defined as the total number of interventions recorded per patient for their ICU stay. Interventions and categories were assigned using previously published methods (16, 17). Medications were individually cataloged (e.g., cefepime, vasopressin) during data collection, and the scores were calculated centrally by the core investigator team.

Pharmacist interventions were categorized as low-, medium-, and high-intensity interventions. These designations were made by three pharmacist investigators (A.S., Brian Murray, Susan E. Smith) through independent categorization based on expert opinion followed by discussion. Final categorization was based on number of votes. The composite score was equal to: (the number of low-intensity interventions) plus 5 (the number of moderate-intensity interventions) plus 25 (the number of high-intensity interventions). The weights assigned for the three intensities of intervention are based on the fact that there are at most four interventions of each intensity category. Thus, a factor of 5 and 25 would prevent an overlap of scores for different compositions of number of interventions. Intervention types and intensity categories are provided in Supplemental Digital Content – Table 3 (http://links.lww.com/CCM/H141).

Descriptive statistics were performed including summary statistics for all outcomes, predictor, and covariate variables. This sample was a convenience sample with sample size determined by number of pharmacist participants and their census during the data collection period. Two exposure variables were evaluated: MRC-ICU and patient: pharmacist ratio. Four outcome variables were evaluated: mortality, LOS, quantity of pharmacist interventions, and intensity of pharmacist interventions. A histogram of MRC-ICU distribution was plotted, and four quartiles were developed. Univariate analysis of variance was evaluated for MRC-ICU quartiles and their relationship to mortality, ICU LOS, quantity of interventions, and intensity of interventions. Multivariable regression models were developed to evaluate the relationship of MRC-ICU and patient: pharmacist ratio in relation to mortality, ICU LOS, quantity of interventions, and intensity of interventions. Multivariable linear regression models were used to describe increasing LOS, critical care pharmacist intervention quantity, and critical care pharmacist intervention complexity given medication regimen complexity. Each model included covariates a priori considered to potentially confound the relationship between independent and dependent variables: institution type, ICU type, and geographic region. Multicollinearity of the variables was checked prior to model fitting to avoid any potential correlations between the predictor variables. The variance inflation factors of all predictor variables were within acceptable thresholds (< 2.5), indicating no collinearity between the variables. Linear regression model results are reported as coefficient estimates (e.g., change in LOS) with 95% CIs and logistic regression model results are reported as odds ratios (ORs) with 95% CIs. Statistical significance was set at p value of less than 0.05 for two-tailed tests. All analysis was

completed in R (Version 3.6.1; R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/). Results are presented as mean (SD) or total (percent) unless otherwise noted. The Rush University Medical Center Institutional Review Board (IRB) served as the central and coordinating IRB (IRB number 18021508-IRB01). This study was endorsed by the SCCM Discovery Network and was a work product of the SCCM Clinical Pharmacy and Pharmacology Section.

RESULTS

This study included a total of 65 critical care pharmacists from 28 institutions on 3,908 patients. Most patients were cared for at academic medical centers (2,441, 80.8%) with the largest number admitted to a medical ICU (1,768, 45.7%). The mean (SD) MRC-ICU score was 10.4 (6.3). The patient: pharmacist ratio was 26.8 (22.1), and critical care pharmacists completed 9.4 (5.9) interventions per patient. Demographic characteristics and a summary of patient outcomes are summarized in Table 1.

Patients managed in the cardiovascular surgery ICU had the highest mean MRC-ICU of 12.7 (7.0), and medical ICU, which had the largest number of patients, had a mean score of 9.5 (6.0). MRC-ICU percentiles were 5 (25th percentile), 9 (50th percentile), and 15 (75th percentile). Significant differences among quartiles were present for patient characteristics including presence of continuous renal replacement therapy and mechanical ventilation, institution type, and region of the United States (Table 2).

Increasing MRC-ICU quartile was significantly associated with increased mortality. The rate of mortality tripled from the lowest to highest quartile (7.8% vs 24.8%; $p < 0.01$) (Table 2). After adjusting covariates in the multivariable regression model, each 1 point increase in MRC-ICU score was associated with 7% increased odds of hospital mortality (OR, 1.07; 95%, 1.05–1.10; $p < 0.01$). Table 3 summarizes factors associated with mortality.

LOS was significantly associated with MRC-ICU quartile, with ICU LOS doubling from the lowest to highest quartile (5.7 vs 11.3 d; $p < 0.01$) (Table 2). After adjusting for potential confounding factors in the multivariable linear regression model, each point increase in the MRC-ICU was associated with a 0.25 day longer ICU LOS (95% CI, 0.19–0.31; $p < 0.01$). Table 4 summarizes factors associated with LOS. While patient: pharmacist ratio was not statistically significantly associated with mortality, increasing pharmacist workload (as evidenced by a higher patient: pharmacist ratio) was associated with increased LOS (β coefficient, 0.02; 0.00–0.04; $p = 0.02$).

The quantity of pharmacist interventions was significantly associated with MRC-ICU quartile and increased with each higher quartile (lowest to highest quartile comparison: 6.1 vs 7.1 interventions; $p < 0.01$) (Table 2). After adjusting for potentially confounding factors in the multivariable linear regression model, each point increase in the MRC-ICU was associated with a 0.08 greater total number of interventions per patient (95% CI, 0.05–0.11; $p < 0.01$). Interestingly, the regression model also identified a relationship between patient: pharmacist ratio and the number of interventions per patient with each increase additional patient per pharmacist decreasing the quantity of interventions per

patient by 0.03 (95% CI, −0.04 to −0.02; $p < 0.01$). Supplemental Digital Content – Table 4 (http://links.lww.com/CCM/H141) summarizes other factors associated with the quantity of interventions.

Intensity of interventions was assessed through the development of a composite score, which weighted both the quantity and intensity of interventions. Intensity of interventions increased by MRC-ICU quartile (lowest to highest quartile comparison: 12.5 vs 15.5; $p < 0.01$) (Table 2). Further, for each 1-point increase in MRC-ICU score, the intensity of interventions increased by 0.20 (95% CI, 0.08–0.31; $p < 0.01$). Increased patient: pharmacist ratio was significantly associated with reduced intensity of interventions (β coefficient, −0.05; 95% CI, −0.09 to −0.01) (Supplemental Digital Content – Table 5, http://links.lww.com/CCM/H141). Additional characterization of the MRC-ICU score is provided in Supplemental Digital Content – Table 6 (http://links.lww.com/CCM/H141).

DISCUSSION

In the first large-scale, multicenter analysis of medication regimen complexity, MRC-ICU demonstrated a relationship to both patient outcomes and pharmacist activity. These results support MRC-ICU as an objectively calculated, validated means to calculate the metric of medication regimen complexity across a diverse patient population of critically ill patients. Further, this study demonstrates for the first time that increased patient: pharmacist ratio, indicating clinicians have increased patient care workload, is associated with increased LOS and both lower intervention quantity and intensity.

The relationship between medication regimen complexity and mortality observed here builds upon several smaller studies (8, 9, 18). Although a notable relationship was observed between adding just one medication (or 1 point to the MRC-ICU) and increased mortality, this study was unable to adjust for the potential interacting relationship between medication regimen complexity and patient acuity, which in fact together may be a more useful mortality predictor when machine learning methodology is applied (9). Indeed, when APACHE III data were added to the MRC-ICU using machine learning, a superior prediction model was developed in a small pilot study (17). However, the original theory behind the score appears to be well supported in that features reasonably associated with higher acuity (e.g., mechanical ventilation) are also associated with more complex medications that are associated with such an intervention (e.g., continuous infusion sedatives, analgesics, neuromuscular blockade), all culminating in both higher mortality risk and the requirement for more clinician intervention. LOS remained significantly associated with medication regimen complexity through both univariate and multivariable analysis, in line with previous studies (6, 18). Increased quantity of interventions was also related to shortened in LOS, but although an important signal, these interpretations are limited by lack of acuity data.

Critically ill patients are a highly heterogeneous and dynamic population at high risk for ADEs (19). While it is well known that the number of medications increases risks of ADEs and that many medications used in the ICU setting pose a high risk for ADEs, formally linking medication regimen complexity to both patient-centered outcomes and

critical care pharmacist activity presents a unique finding (20–22). This is particularly salient for dictating the workload of critical care pharmacists given their unique skillsets and pharmacologic knowledge that facilitate timely interventions and who have previously demonstrated a reduction in ADEs by almost 70% (23, 24). Clinician staffing is an established factor in providing safe care to critically ill patients, but the optimal patient: pharmacist ratio in various ICU settings is largely uncharacterized (25, 26). Limited investigation regarding workload optimization has been completed, and little is known about how the workload of a critical care pharmacist affects patient outcomes or the intensity of their clinical interventions (5, 27). Regardless, it is notable that despite critical care pharmacists being considered essential members of the ICU team per the position statement on critical care pharmacist services and that pharmacists confer significant benefits through presence on multiprofessional ICU team rounds (including reduction of adverse drug events by nearly three-quarters), only 70% of ICUs report a rounding pharmacist on weekdays and just 15% of ICUs have a rounding pharmacist on weekends (27). As such, the observation that as patient: pharmacist ratio increased, the number and intensity of interventions decreased is a novel finding that warrants further investigation in appropriately designed, prospective studies as it may suggest that high critical care pharmacist workload adversely affects patient care provided. Because staffing decisions are based on historical concepts like physical location or medical service and not driven by precision metrics, observed patient: pharmacist ratios are not based on MRC-ICU scores.

While intervention counting captures many direct patient care activities (e.g., renal dose adjustments), it does not capture the myriad of indirect activities critical care pharmacists perform (e.g., developing treatment protocols) (4, 28). Further, tying “value” to these interventions is prone to significant limitations and debate among experts (29–33). Thus, intervention counting not only does not entirely capture what a pharmacist does but also does so relatively poorly, and for these reasons, pure intervention counting is colloquially termed “widget counting,“ to denote its some-what ineffective nature (5). As such, this study fails to account for the contribution of “indirect interventions” such as treatment protocols that are known to improve outcomes (and likely reduce the quantity of “tracked” interventions through proactive design). Furthermore, “carry-over education” that contributes to an ICU culture of evidence-based pharmacotherapeutic care that is provided by pharmacists to the medical team and is then reapplied in other settings (regardless of the presence or absence of the pharmacist) likely has widespread impact that is difficult to quantify. Finally, the nature of intervention tracking itself has well documented limitations including how interventions may be more likely to occur during certain shifts, certain points in a patient’s ICU stay (e.g., more intervention on day 1), etc (6). Notably, a particularly acute patient (or series of acute patients) may yield numerous high-intensity interventions by the pharmacist that are never captured due to lack of time. Future studies must incorporate evaluations reflective of the holistic nature of critical care pharmacist activity (e.g., quality improvement, education, etc.) and be designed to account for such limitations. However, it remains notable that even despite institutional variations that likely include protocols and guidelines that influence intervention numbers, critical care pharmacists still have an active role in the care of critically ill patients.

To date, robust analysis of critical care pharmacist practice has been limited by the "before-after" design of studies (34–38). Indeed, most every study evaluating the value a pharmacist brings compares one pharmacist to zero pharmacists and observes improvement in outcomes. No studies have evaluated the comparative effectiveness of one versus two (one vs three, etc.). As such, an exploratory analysis was conducted to evaluate "incremental improvements" and observed that increases in the number of patients assigned to a given critical care pharmacist actually reduced number of interventions per patient. Although hypothesis generating, this evaluation is the first attempt to show an important relationship among workload and productivity.

Not all critically ill patients receive the care of a critical care pharmacist. Core questions remain to be determined and pose risk to patients so long as they remain unanswered: notably, how to employ metrics to connect patient status to critical care pharmacist intervention predictions and the relationship of the patient: pharmacist ratio and patient outcomes. Globally, this construct may be conceived of as the Patient-Medication-Pharmacist Intervention-Outcome Pathway, with each component here considered to be involved in a causal relationship. As such, the MRC-ICU metric may act as a first step in describing these relationships and poses a potential improvement over simple intervention counting in that it may represent data "aligned" with the best practices for critical care pharmacists. Although beyond the scope of this study, theoretical applications of a validated metric are numerous, and the possibility exists that individual institutions can adapt the score to individual needs. Potential uses include: 1) bedside use as a priority scoring tool in resource-limited environments where a critical care pharmacist cannot review all ICU patients in a given shift to identify patients most likely to require intervention, 2) generated prediction summaries that may be used by leadership to justify resource allocation (e.g., the number of interventions predicted by the MRC-ICU and census is beyond the ability of a single pharmacist in a single shift and requires an additional pharmacist), and 3) use in predictive modeling that incorporates the metric and other ICU patient data to predict ICU complications and identify where a critical care pharmacist could intervene to prevent these complications (which notably has applications in both resource-rich and poor environments).

Several limitations are present. Although this was a large, multicenter, prospectively identified study population, investigators were critical care pharmacist members of SCCM largely at academic medical centers that chose to participate in a relatively extensive research project. Further, there was relative under-representation of certain ICU types (e.g., surgical, burn). Taken together, these may limit external validity. Second, all critical care pharmacist interventions were based on voluntary self-reporting; although reporting was performed in real-time, this may introduce bias that includes both under-reporting and over-reporting. As such, this study used convenience-based sampling with reporting occurring when pharmacists were on-service/available during the study period, which potentially limits the ability to make determinations regarding associations between ratios and outcomes (and potentially resulted in a reduced correlation between MRC-ICU and quantity of interventions observed). Further, the role of "extenders" such as pharmacy residents was not evaluated. Third, objective illness severity indicators were not collected, allowing for the possibility that the critical patients had the highest number of interventions but were also still most likely to have worse outcomes regardless of clinician intervention.

Fourth, while clinical acumen would suggest that some interventions require more time, expertise, and effort than others, a rigorously validated system for this type of ranking has never been developed. The intensity score is a potential solution to this gap but requires further investigation. Finally, given the inherent team-oriented nature of ICU care, delineating the unique contribution of the pharmacist (or any profession) as a separate entity to patient outcomes is not possible without potential residual confounding secondary to influences from the entire care team. Although these limitations preclude definitive conclusions about the relationship of patient: pharmacist ratio and outcomes, the results provide important insights. These insights may inform further investigations including more granular information regarding patient acuity and specified staffing information for pharmacists as well as other members of the multiprofessional team. In summary, these results are hypothesis generating that warrant future exploration.

Seth Godin says, “A useful metric is both accurate (in that it measures what it says it measures) and aligned with your goals. Don’t measure anything unless the data helps you make a better decision or change your actions.” The ultimate goal of the MRC-ICU is to be a clinically meaningful metric that is aligned with the goals of providing high-quality pharmacotherapeutic care to critically ill patients. The implementation of the MRC-ICU (or a similar metric) as a real-time metric embedded in the electronic health record to serve as either a triage tool at the bedside for critical care pharmacists or as a tool to make resource allocation decisions at the executive level will require several key steps and has been previously outlined (6). Robust studies creating high-quality prediction models incorporating patient-specific data such as age, admission diagnosis, and relevant laboratory values (in addition to the MRC-ICU) will be needed. Artificial intelligence may play a key role in harnessing the vast amounts of data generated by ICU patients, and a pilot study showed promise with the MRC-ICU (17). Second, more granular characterization of MRC-ICU as it relates to pharmacist activity (e.g., time-in-motion studies) will aid resource allocation. Furthermore, additional studies specifically designed to relate pharmacist workload to patient-centered outcomes are warranted. Finally, appropriate implementation of the MRC-ICU into an electronic health record requires thoughtful user-designed systems that incorporate the key stakeholders (e.g., bedside clinicians, administrators, information technology specialists, etc.).

CONCLUSIONS

These results suggest that increased pharmacist workload is associated with worsened patient outcomes and decreased care provided. Future research should evaluate use of objective metrics like medication regimen complexity to inform critical care pharmacist staffing models and how they affect patient outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1.

Demographic Characteristics

Characteristic	ICU Patients (*n* = 3,908)
Region of the United States	
Midwest	1,374 (45.5)
Northeast	259 (8.6)
South	1,126 (37.3)
West	260 (8.6)
Type of institution	
Academic	2,441 (80.8)
Community teaching	474 (15.7)
Community nonteaching	58 (1.9)
Region of the United States, *n* (%)	
Midwest	1,374 (45.5)
Northeast	259 (8.6)
South	1,126 (37.3)
West	260 (8.6)
ICU type, *n* (%)	
Medical	1,786 (45.7)
Burn	60 (1.5)
Cardiac	209 (5.3)
Cardiovascular surgery	206 (5.2)
Decentralized/mixed	765 (19.6)
Neurosciences	406 (10.3)
Surgical	347 (8.8)
Trauma	129 (3.3)
Population outcomes	
ICU length of stay, d, mean ± SD	10.6 ± 4.5
Hospital mortality (%)	574 (14.6)
Staffing information (per shift)	
Patients per pharmacist	26.8 (22.1)
Number of rounding services covered	1.7 (1.3)
Interventions per patient for ICU stay	9.4 (5.9)
Medication Regimen Complexity-ICU score at 24 hr, mean ± SD	10.4 (6.3)

Data are presented as *n* (%) unless otherwise stated.

TABLE 2.

Demographic Features and Outcomes by Medication Regimen Complexity-ICU Quartile

Factor	MRC-ICU 0–5 (*n* = 1,154)	MRC-ICU 6–9 (*n* = 1,020)	MRC-ICU 10–14 (*n* = 909)	MRC-ICU ≥ 15 (*n* = 783)	*p*
Region					
Midwest	572 (62.9)	389 (49.1)	248 (36.2)	147 (24.3)	< 0.01
Northeast	74 (8.1)	58 (73)	49 (7.1)	74 (12.3)	
South	210 (23.1)	278 (35.1)	307 (44.8)	325 (53.8)	
West	53 (5.8)	67 (8.5)	82 (12)	58 (9.6)	
Institution type					
Academic	747 (82.2)	624 (78.8)	530 (773)	518 (85.8)	< 0.01
Community teaching	143 (15.7)	145 (18.3)	124 (18.1)	58 (9.6)	
Community nonteaching	12 (1.3)	15 (1.9)	14 (2)	16 (2.6)	
ICU type					
Medical	528 (45.8)	455 (44.6)	410 (45.1)	369 (47.1)	< 0.01
Burn	19 (1.6)	22 (2.2)	13 (1.4)	6 (0.8)	
Cardiac	119 (10.3)	46 (4.5)	24 (2.6)	17 (2.2)	
Cardiovascular surgery	36 (3.1)	44 (4.3)	41 (4.5)	85 (10.9)	
Decentralized/mixed	202 (175)	214 (21)	204 (22.4)	141 (18)	
Neurosciences	166 (14.4)	119 (11.7)	72 (79)	41 (5.2)	
Surgical	66 (5.7)	96 (9.4)	92 (10.1)	91 (11.6)	
Trauma	18 (1.6)	24 (2.4)	53 (5.8)	33 (4.2)	
Patient characteristic					
Continuous renal replacement therapy	12 (1)	27 (2.6)	41 (4.5)	110 (14)	< 0.01
Mechanical ventilation	17 (1.5)	183 (17.9)	526 (57.9)	652 (83.3)	< 0.01
Mechanical circulatory support	3 (0.3)	7 (0.7)	10 (1.1)	28 (3.6)	< 0.01
Pharmacist interventions, mean (SD)					
Total interventions per patient	6.1 (4.3)	6.6 (5)	6.6 (5.2)	7.1 (5.7)	< 0.01
Composite quality score of interventions	12.5 (15.2)	13.9 (15.5)	14 (16.1)	15.5 (16.5)	< 0.01
Patient outcomes					
ICU length of stay (d), mean (SD)	4.5 (5.7)	6.4 (6.8)	8.4 (7.8)	11.3 (8.7)	< 0.01
Hospital mortality	88 (78)	116 (11.5)	162 (18.1)	192 (24.8)	< 0.01

MRC-ICU = Medication Regimen Complexity-ICU.

Values are reported as *n* (%) unless otherwise stated.

TABLE 3.

Univariate and Multivariate Regression of Variables Related to Mortality

	Univariate Analysis		Multivariate Analysis	
Factor	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***
Medication Regimen Complexity-ICU score	1.09 (1.08–1.11)	< 0.01	1.07 (1.05–1.1)	< 0.01
Patient:pharmacist ratio	1 (0.99–1.00)	0.35	1 (0.99–1.01)	0.76
Region		< 0.01		< 0.01
Midwest	Reference	–	Reference	–
Northeast	0.90 (0.50–1.57)	0.72	0.71 (0.35–1.63)	0.48
South	2.77 (1.97–3.96)	< 0.01	2.60 (1.60–4.65)	< 0.01
West	0.48 (0.11–1.38)	0.23	0.79 (0.17–2.62)	0.73
Institution type		< 0.01		< 0.01
Academic	Reference	–	Reference	–
Community teaching	0.87 (0.65–1.15)	0.33	1.02 (0.71–1.43)	0.93
Community nonteaching	1.64 (0.84–2.99)	0.12	1.85 (0.86–3.8)	0.1
ICU type		< 0.01		< 0.01
Medical	Reference	–	Reference	–
Burn	0.42 (0.15–0.96)	0.07	0.59 (0.17–1.54)	0.34
Cardiac	0.52 (0.32–0.81)	0.01	0.71 (0.41–1.16)	0.19
Cardiovascular surgery	0.85 (0.57–1.25)	0.44	0.61 (0.35–1.02)	0.07
Mixed	0.69 (0.54–0.87)	< 0.01	0.79 (0.47–1.3)	0.35
Neurosciences	0.6 (0.42–0.82)	< 0.01	0.75 (0.51–1.09)	0.14
Surgery	0.3 (0.18–0.46)	< 0.01	0.24 (0.13–0.42)	< 0.01
Trauma	0.7 (0.4–1.15)	0.19	0.24 (0.09–0.54)	< 0.01
Patient characteristic				
Continuous renal replacement	3.82 (2.78–5.20)	< 0.01	2.14 (1.44–3.15)	< 0.01
Mechanical ventilation	2.47 (2.06–2.96)	< 0.01	1.33 (1–1.76)	0.05
Mechanical circulatory support	1.52 (0.68–3.04)	0.27	1.95 (0.76–4.53)	0.14

OR = odds ratio.

TABLE 4.

Univariate and Multivariate Regression of Factors Associated With ICU Length of Stay (d)

	Univariate Analysis		Multivariate Analysis	
Factor	**Change in LOS (95% CI)**	***p***	**Change in LOS (95% CI)**	***p***
Medication Regimen Complexity-ICU score	0.41 (0.37–0.45)	< 0.01	0.25 (0.19–0.31)	< 0.01
Patient:pharmacist ratio	0.01 (0–0.02)	0.15	0.02 (0–0.04)	0.02
Region		0.02		0.30
Midwest	Reference	–	Reference	–
Northeast	2.12 (1.1–3.15)	< 0.01	1.23 (0.16–2.31)	0.02
South	0.76 (0.15–1.37)	0.01	−0.44 (−1.17 to 0.29)	0.23
West	1.94 (0.91–2.96)	< 0.01	1.32 (0.22–2.43)	0.02
Institution type		< 0.01		< 0.01
Academic	Reference	–	Reference	–
Community teaching	−2.1 (−2.86 to −1.35)	< 0.01	−1.22 (−2.04 to −0.41)	< 0.01
Community nonteaching	1.66 (−0.36 to 3.68)	0.11	2.34 (0.38–4.29)	0.02
ICU type		< 0.01		< 0.01
Medical	Reference	–	Reference	–
Burn	7.39 (5.48–9.3)	< 0.01	8.26 (6.23–10.3)	< 0.01
Cardiac	−0.31 (−1.38 to 0.76)	0.57	0.62 (−0.46 to 1.71)	0.26
Cardiovascular surgery	4.14 (3.07–5.22)	< 0.01	1.07 (−0.17 to 2.3)	0.09
Mixed	−0.86 (−1.49 to −0.23)	0.01	−0.79 (−1.95 to 0.36)	0.18
Neurosciences	0.18 (−0.62 to 0.99)	0.65	0.14 (−0.75 to 1.03)	0.76
Surgery	0.79 (−0.07 to 1.64)	0.07	1.56 (0.50–2.62)	< 0.01
Trauma	3.14 (1.8–4.47)	< 0.01	0.59 (−0.95 to 2.13)	0.45
Patient characteristic				
Continuous renal replacement	5.63 (4.54–6.72)	< 0.01	3.23 (2.04–4.43)	< 0.01
Mechanical ventilation	4.99 (4.52–5.46)	< 0.01	2.96 (2.24–3.68)	< 0.01
Mechanical circulatory support	738 (5.19–9.56)	< 0.01	3.93 (1.39–6.47)	< 0.01

LOS = length of stay.