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Hospital nurse staffing and sepsis protocol compliance and outcomes among patients with sepsis in the USA: a multistate cross-sectional analysis

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ABSTRACT

Objectives Sepsis is a serious inflammatory response to infection with a high death rate. Timely and effective treatment may improve sepsis outcomes resulting in mandatory sepsis care protocol adherence reporting. How the impact of patient-to-nurse staffing compares to sepsis protocol compliance and patient outcomes is not well understood. This study aimed to determine the association between hospital sepsis protocol compliance, patient-to-nurse staffing ratios and patient outcomes.

Design A cross-sectional study examining hospital nurse staffing, sepsis protocol compliance and sepsis patient outcomes, using linked data from nurse (2015–2016, 2020) and hospital (2017) surveys, and Centers for Medicare and Medicaid Services Hospital Compare (2017) and corresponding MedPAR patient claims.

Setting 537 hospitals across six US states (California, Florida, Pennsylvania, New York, Illinois and New Jersey).

Participants 252 699 Medicare inpatients with sepsis present on admission.

Measures The explanatory variables are nurse staffing and SEP-1 compliance. Outcomes are mortality (within 30 and 60 days of index admission), readmissions (within 7, 30, and 60 days of discharge), admission to the intensive care unit (ICU) and lengths of stay (LOS).

Results Sepsis protocol compliance and nurse staffing vary widely across hospitals. Each additional patient per nurse was associated with increased odds of 30-day and 60-day mortality (9% (OR 1.09, 95% CI 1.05 to 1.13) and 10% (1.10, 95% CI 1.07 to 1.14)), 7-day, 30-day and 60-day readmission (8% (OR 1.08, 95% CI 1.05 to 1.11, p<0.001), 7% (OR 1.07, 95% CI 1.05 to 1.10, p<0.001), 7% (OR 1.07, 95% CI 1.05 to 1.10, p<0.001)), ICU admission (12% (OR 1.12, 95% CI 1.03 to 1.22, p=0.007)) and increased relative risk of longer LOS (10% (OR 1.10, 95% CI 1.08 to 1.12, p<0.001)). Each 10% increase in sepsis protocol compliance was associated with shorter LOS (2% ([OR 0.98, 95% CI 0.97 to 0.99, p<0.001)) only.

Conclusions Outcomes are more strongly associated with improved nurse staffing than with increased compliance with sepsis protocols.

INTRODUCTION

Sepsis is the leading cause of death in US hospitals and costs the healthcare system an

Strengths and limitations of this study

► This is a large-scale quantitative analysis of hospital nurse staffing, sepsis protocol compliance and sepsis patient outcomes.
► Hospitals in the six study states account for one-third of hospital admissions nationally, making this one of the largest studies to consider care protocol compliance and nurse work environments and staffing.
► Data available through the RN4CAST Survey leverage nurses as frontline informants of hospital nurse staffing.
► The cross-sectional design of this study limits interpretation of results to associations.

estimated US$20 billion in hospital spending annually.[1] Early recognition and treatment of sepsis reduce mortality, yet many patients do not receive this essential care.[2–5] In October 2015, the Centers for Medicare and Medicaid Services (CMS) implemented a national sepsis quality measurement programme based on the Surviving Sepsis Campaign guidelines.[6] The severe sepsis and septic shock early management bundle, known as SEP-1, requires hospitals to collect and report data on adherence to a multicomponent bundle for eligible patients with sepsis.[6]

SEP-1 represents the percentage of certain sepsis patients who received care consistent with the Surviving Sepsis Campaign guidelines in a timely manner. Interventions for patients with severe sepsis include phlebotomy (serum lactate and blood cultures), and timely administration of appropriate medications (broad-spectrum antibiotics within 3 hours of sepsis recognition). Additional time-sensitive interventions are required within specified times from sepsis onset among patients with septic shock, including administration of intravenous fluids and vasopressors (within 3

and 5 hours, respectively), and repeat volume assessments (within 6 hours). While providers must place orders for care protocols, these interventions often reach the patient through the bedside nurse.

Protocols are a common strategy for improving healthcare outcomes. For example, in 2013 the New York state legislature responded to the death of a 12-year-old sepsis patient with Rory's Regulations, mandating sepsis protocol compliance in hospitals.[7] Policymakers in Illinois and New Jersey have since followed suit in 2016 and 2018, respectively.[8] These protocols outline essential, consensus-driven clinical interventions targeted towards sepsis patients. While the science underlying sepsis and other clinical protocols to improve care outcomes suggest that outcomes would improve if compliance were high, compliance is quite variable across hospitals and the organisational context of these care processes is more broadly influential, impacting a range of patients and outcomes. The nursing aspects of a hospital's context of care delivery, such as nurse staffing, may be as or even more important than protocols. There is substantial evidence for the association between hospital patient-to-nurse ratios and patient outcomes, including mortality,[9 10] readmissions,[11] and lengths of stay.[10 11]

Both SEP-1 bundle compliance rates and patient-to-nurse staffing ratios vary widely across hospitals, potentially signifying preventable deaths.[11–15] There is room for improvement on both fronts. A narrow preoccupation with clinical processes at the expense of attention to improving care environments including nurse staffing may hinder progress towards improving sepsis care and outcomes. This is especially salient as SEP-1 may in the future be tied to financial incentives under the Value-Based Purchasing Programme, and state legislators may follow the examples of California and New York in passing mandatory patient-to-nurse ratios and/or sepsis protocol legislation. Studies accounting for both the processes and context of care are needed to inform clinical and organisational interventions to improve sepsis outcomes. We examine, both separately and simultaneously, the associations of patient-to-nurse staffing ratios and adherence to the SEP-1 severe sepsis and septic shock management bundle on the outcomes of patients with sepsis in 537 hospitals in 6 states.

METHODS

Study design and data sources
This cross-sectional analysis linked data from four sources: (1) the American Hospital Association Annual Survey (2017), (2) Hospital Compare data publicly available from CMS (2017), (3) CMS MedPAR data and (4) a survey of registered nurses (RNs) in six states (California, Florida, Pennsylvania, New Jersey, Illinois and New York).

Study sample of hospitals and patients
This was a study of 252 699 patients in 537 hospitals. Hospitals included in the study were adult non-federal acute care facilities located in one of the six nurse survey states. Patients were Medicare beneficiaries ages 65 years or older and admitted to a study hospital in 2017 with a diagnosis of sepsis present on admission. To safeguard the reliability of our estimates of staffing and patient outcomes, we excluded hospitals with fewer than 5 nurse respondents and/or fewer than 25 sepsis patients.

Study sample of nurse informants
Nurses practising in the study hospitals served as front-line clinician informants on features of the care environment, reporting on staffing levels in their respective facilities. These data were collected by surveying RNs in six states: a 30% random sample of all RNs in California, Florida, Pennsylvania and New Jersey surveyed by mail in 2015–2016, and 100% (not a sample) of RNs in New York and Illinois surveyed by email between December 2019 and February 2020. The six states were selected to represent different parts of the country as well as funding opportunities. The survey was state-based to mirror RN licensure lists, which are the only complete sampling frame for RNs. The response rate was 26% (52,510 nurses) across California, Florida, Pennsylvania, New JerseyJ,[16] and 17% (13,000) across New York and Illinois.[11] A follow-up survey of non-responders ruled out concerns for response bias on the staffing variable of interest.[16] In aggregate, nurse survey responses produce reliable estimates of hospital characteristics, including staffing and help avoid the potential for bias found in methods that rely on a single administrator reporting on behalf of the hospital.[16] Because hospital characteristics are the goal of this survey, more important than the response rate of nurses is the representation of hospitals. The survey provided information on most adult non-federal acute care facilities across the six states and, as larger hospitals are more readily captured because they employ more nurses, patient representation reasonably exceeds that of hospitals.

While the time between the end of the first survey period and the start of the second is close to 4 years, the true time lag is considerably less. The study is concerned with producing reliable estimates of staffing in the study hospitals in 2017—roughly equidistant from each survey period. The time between collection of the last first-period survey response and the first hospitalisation in the patient data is less than the time between the first and last hospitalisations in the study, which span an acceptable time for a cross sectional analysis. Furthermore, the pace of organisational change, such as modifying nurse staffing levels in hospitals, is slow. Having already ruled out the impact of COVID-19 in the survey period, staffing is otherwise unlikely to change substantially in the time between periods of nurse surveys and 2017, the year of the patient and other hospital data. The timescale of organisational change reinforces that nurse-reports of staffing on the survey dates in their respective states are reliable estimates for our analysis of 2017 patient data.

Measures

Outcome variables

The dependent variables were patient-level measures derived from 2017 MedPAR data. An indicator for death in or out of the hospital within 30 or 60 days of the index hospital admission served as our mortality variables. The intensive care unit (ICU) admission variable flagged hospitalisations that involved intensive care utilisation. Readmissions, whether to the index or other hospital in the study sample, were recorded at 7, 30 and 60 days of discharge from the index hospital. Length of stay represented the duration in days of a patient's index hospitalisation.

Explanatory variables

The independent variables were medical-surgical nurse staffing and SEP-1 sepsis bundle adherence. The staffing measure was derived from individual nurse survey responses of the number of patients each cared for on their last shift. Nurse survey respondents also reported their hospital of employment and unit type. Medical-surgical nurse responses were aggregated by hospital to produce staffing estimates of the average number of patients nurses in each hospital cared for at one time.

SEP-1 sepsis bundle adherence is a measure of timely and effective care provided to sepsis patients obtained from publicly available data on the CMS Hospital Compare website. The CMS measure is determined via chart abstraction of a sample of the target patients. At the patient level, it is an all-or-nothing variable; hospitals only get credit in cases where all the interventions were delivered within the specified time frame. The results, aggregated to the hospital level, represent the percent of sepsis patients who received timely and effective care.

Potentially confounding variables

Our confounding variables included additional characteristics of both hospitals and patients. Hospital characteristics were derived from the 2017 American Hospital Association Annual Survey. These included ordered, categorical variables for hospital size and teaching status as defined by the number of licensed beds (small=less than 100 beds; medium=101–250 beds; and large=more than 250 beds), and the ratio of residents to beds—nonteaching (no medical trainees); minor teaching (0–0.25 medical trainees per bed), and major teaching (≥0.25 medical trainees per bed), respectively. An indicator variable distinguished hospitals with the capacity to perform major organ transplantation and/or open-heart surgery (high-technology hospitals) from those that offered neither service (low-technology hospitals). Patient characteristics were derived from the 2017 MedPAR data and included age, sex, and dummy variables for 29 Elixhauser comorbidities, transfer status (an indicator for transfer in from another hospital), and diagnostic-related groups representing the severity of illness. Finally, a measure of ICU staffing—identical to the medical-surgical staffing measure presented as an explanatory variable, except

produced using ICU nurse survey responses—was also included.

Analysis

We computed descriptive statistics for the study hospitals and patients (numbers and percentages) as well as for the outcome variables, medical/surgical staffing, and SEP-1 adherence (mean, SD, median, minimum, maximum). Our analyses of outcomes employed multilevel models with clustered robust standard errors. Logistic regression models produced ORs for mortality, readmissions and ICU admission. Zero-truncated negative binomial models produced incident rate ratios (IRRs) for length of stay. For both statistical methods and each outcome, we first modelled the unadjusted associations of the two independent variables with each outcome separately (one model for each independent-dependent variable pair), then introduced patient and hospital confounding characteristics as controls, and finally included both medical/surgical staffing and SEP-1 adherence jointly in final models, one for each outcome. The fit and predictive power of these final models was assessed using concordance statistics, or c-statistics, which represent the areas under the receiver operating characteristic curve for the different models.

The independent variable for staffing represented average patients per nurse on medical-surgical units. A 1-unit increase in our models represented an additional patient per medical-surgical nurse assignment. For regression analyses, we scaled the SEP-1 variable such that a 1-unit increase represented 10% higher adherence to the sepsis care bundle. Analyses of mortality (within 30 and 60 days, separately) and ICU admission used the full study sample of 252 699 patients. We modelled hospital readmissions using 191 919 patients, which excluded patients who died during the index hospitalisation or were discharged to acute care hospitals. Analyses of lengths of stay excluded additional patients for lengths of stay >60 days for a final subgroup of 191 614 patients. Limited data were missing for hospital teaching and technology status (13 and 40 hospitals, respectively). These hospitals were retained in the analyses through the addition of a 'missing' category for each variable.

Patient and public involvement

Patients were not involved in the design of the study and the use of secondary data precluded the need to recruit subjects.

RESULTS

Table 1 presents the distribution of study hospitals and patients and summary statistics for the independent variables (medical-surgical staffing and SEP-1 adherence) for the full sample and by hospital organisational characteristics (size, teaching and technology status). As the first row of table 1 indicates, this was a study of 252 699 sepsis patients in 537 hospitals. Most (63.5%) hospitals were

Table 1 Medical-surgical nurse staffing and SEP-1 scores in the 537 study hospitals by across selected characteristics

	N (%) hospitals	N (%) patients	Medical-surgical staffing			SEP-1		
			Mean (SD)	Median	Min-Max	Mean (SD)	Median	Min-Max
Total	537 (100)	252 699 (100)	5.5 (1.0)	5.4	2.3–10.5	51.6 (16.9)	52.0	1–100
Hospital size								
≤100 beds	25 (4.7)	3692 (1.5)	5.7 (0.7)	5.8	4.3–7.0	53.4 (17.0)	53.0	21–88
101–250 beds	171 (31.8)	55 606 (22.0)	5.5 (1.1)	5.4	2.3–10.5	53.3 (17.5)	53.0	11–100
≥250 beds	341 (63.5)	193 401 (76.5)	5.4 (1.0)	5.3	3.4–8.7	50.7 (16.5)	51.0	1–93
Teaching								
Non-teaching	207 (38.6)	88 728 (35.1)	5.3 (0.9)	5.3	2.3–7.6	51.7 (16.4)	51.0	15–91
Minor	223 (41.5)	105 395 (41.7)	5.5 (1.0)	5.5	3.4–10.5	54.2 (16.6)	55.0	11–100
Major	94 (17.5)	52 896 (20.9)	5.6 (1.2)	5.4	3.6–8.6	46.2 (17.2)	44.5	1–87
Technology								
High-tech	305 (56.8)	170 552 (67.5)	5.7 (1.0)	5.8	3.4–8.5	53.3 (16.8)	54.5	15–100
Low-tech	192 (35.8)	66 819 (26.4)	5.2 (0.8)	5.1	2.3–9.0	50.8 (16.4)	51.0	1–93

Values may not add up to 100% due to missing data, which in all cases affects ≤6% of all patients.

large (≥250 beds) and as a result cared for an even larger proportion of the study patients (76.5%). At least 59% of hospitals were teaching hospitals and a similar proportion of patients (63% or more) received care in those hospitals. More than two-thirds (68%) of patients received care in high-tech hospitals, which accounted for more than half (57%) of all study hospitals. The average medical-surgical staffing ratio for all hospitals was 5.5 patients per nurse (median, 5.4), but these conditions varied widely across hospitals (minimum, 2.3; maximum, 10.5). The staffing range was most narrow among small hospitals (4.3–7.0), but these hospitals also tied high-tech hospitals for having the highest average staffing ratio (5.7). Average staffing was best among low-tech hospitals (mean 5.2), but the range (2.3–9.0) indicates substantial variation within this category. SEP-1 compliance varied widely across all hospitals (mean, 52; range, 99). Within hospital categories, the mean varied least (<3%) across categories of hospital size and technology status and greatest by teaching status (46% vs 54% for major vs minor teaching hospitals). The range within categories was substantial in all cases, but least among hospitals with ≤100 beds (67%).

Table 2 presents summary statistics (numbers and percentages) of patients by outcome variables and the patient characteristics used for risk adjustment.

Patient characteristics

The average patient was 79 years old (SD, 9 years). Patients were evenly represented by sex (51% male). The large majority (85%) of patients were diagnosed with severe sepsis without mechanical ventilation lasting >96 hours (65.5% without, 19.3% with a major complication or comorbidity). Ninety-nine percent of patients are accounted for with the addition of diagnoses involving infectious disease with (8.8%) and without (2.0%) major complication or comorbidity, and severe sepsis requiring

mechanical ventilation >96 hours (3.3%). The 16 comorbidities listed in table 2 involved 10% or more of patients. Hypertension and fluid and electrolyte disorders were most common and present in a large majority of all sepsis cases (78% and 62%, respectively).

Patient outcomes

Twenty-three per cent of sepsis patients died within the first 30 days of their index admission. An additional 5% died in the subsequent 30-day period, resulting in a 28% 60-day mortality rate. One-quarter of the 191 919 patients in our analysis of readmissions were readmitted to a study hospital. Most (71%) of these readmissions occurred within 30 days of discharge, at which point nearly 18% of all patients had been readmitted. The percentage of patients readmitted in the first 7 days (6%) was comparable to the percentage readmitted in days 31–60 (7%). One-quarter (25%) of patients were admitted to the ICU during their index hospitalisation. On average, the patients in our analysis of length of stay were hospitalised for 1 week (mean length of stay, 7.0 days), but lengths of stay varied across patients (SD, 5.9 days).

Table 3 presents estimates of the unadjusted and adjusted associations of nurse staffing and SEP-1 adherence with patient outcomes, from models that estimate them separately and jointly. Both staffing and SEP-1 are significant in the unadjusted models for all outcomes. In all cases, the estimates suggest that each additional patient per nurse was associated with increased odds of mortality, readmissions, ICU admission and longer lengths of stay. Similarly, higher rates of sepsis bundle compliance were associated with lower odds of these negative outcomes. The direction and magnitude of the associations were fairly stable across all models and for all outcomes. The difference across models within each patient outcome most often represented 1%, but never exceeded 2%,

Table 2 Sepsis patient outcomes and characteristics

	Patients	
	No	%
Patient outcomes		
Mortality (252 699 cases)		
30-day mortality	56 742	22.5
60-day mortality	70 047	27.7
Readmissions (191 919 cases)		
7 day readmissions	10 787	5.6
30-day readmissions	33 664	17.5
60-day readmissions	47 469	24.7
ICU Admissions (252 699 cases)	62 610	24.8
Length of stay | mean (SD)	191 614	7.0 (5.9)
Patient characteristics		
Age | mean (SD)	252 697	79.2 (9.0)
Male	129 869	51.4
Sepsis Diagnosis Related Group		
Severe sepsis without MV >96 hour with MCC (871)	165 553	65.5
Severe sepsis without MV >96 hour without MCC (872)	48 835	19.3
Infectious disease with MCC (853)	22 350	8.8
Severe sepsis with MV >96 hours (870)	8379	3.3
Infectious disease with CC (854)	4921	2.0
Other	2661	1.1
Common comorbidities		
Hypertension	197 334	78.1
Fluid and electrolyte disorders	156 209	61.8
Congestive heart failure	80 089	31.7
Chronic pulmonary disease	78 372	31.0
Deficiency anaemias	77 446	30.6
Renal failure	77 105	30.5
Diabetes with chronic complications	64 425	25.5
Hypothyroidism	48 996	19.4
Other neurological disorders	46 097	18.2
Weight loss	41 079	16.3
Coagulopathy	35 573	14.1
Diabetes without chronic complications	34 365	13.6
Obesity	33 531	13.3
Depression	31 540	12.5
Peripheral vascular disease	29 606	11.7
Valvular disease	29 550	11.7

There are two patient observations with data missing for 'age'.
Comorbidities shown are those that involved at least 10% of the patients, ordered according to their prevalence.
CC, complication or comorbidity; MCC, major complication or comorbidity; MV, mechanical ventilation.

change in odds. As hospital and patient characteristics were introduced in the adjusted model and the independent variables were included together in final joint/adjusted model, our confidence in the significance of the

SEP-1 findings was reduced to a narrower set of outcomes: first to 60-day mortality, 7-day readmissions, length of stay and ICU admission; and finally, to length of stay only.

In the joint/adjusted model, 10% higher adherence to SEP-1 bundles was associated with a 2% decrease in odds of longer lengths of stay (IRR, 0.98; 95% CI 0.97 to 0.99; p<0.001). While the association of SEP-1 with ICU admissions was slightly larger (representing a 3% decrease in odds of ICU admission for each 10% increase in SEP-1 adherence), the p value did not cross our p<0.05 threshold for significance (OR, 0.97; 95% CI 0.93 to 1.01; p=0.087). For each additional patient per nurse assignment, the odds of each negative outcome increased by 7% for 30-day and 60-day readmissions; 8% for 7 day readmissions; 9% for 30-day mortality; 10% for 60-day mortality and longer lengths of stay; and 12% for ICU admission (ORs 1.07–1.12; p<0.01). These associations are above and beyond (or net of) the associations involving the SEP-1 bundle and after taking into account hospital and patient confounding variables. The c-statistics associated with these final models were in all cases greater than 0.6, and in most cases greater than 0.7, which indicates that their fit to the observed data and predictive ability ranged from reasonable to good.[17]

DISCUSSION
We provide new evidence that allows for a better understanding of how important adequate nurse staffing is to sepsis patient outcomes above and beyond SEP-1 bundle adherence in acute care hospitals. In this study, each additional patient added to a nurse's workload was associated with a substantial increase in the odds of 30-day and 60-day mortality (9% and 10%); 7-day, 30-day and 60-day readmission (8%, 7%, 7%), longer length of stay (10%) and ICU admission (12%). We conclude that adequate nurse staffing, which is not addressed in current sepsis care guidelines, is essential to achieving the expected improved outcomes that motivated the development and implementation of sepsis care guidelines.

Several investigators have questioned the use of the SEP-1 bundle and its association with patient outcomes, noting the need for additional evidence.[18 19] Yet, all have failed to estimate the value of nurses—the clinicians who most often implement components of the SEP-1 bundle and actively monitor the status of these critically ill patients. While the implementation of state-mandated sepsis protocols in New York improved sepsis bundle compliance and reduced mortality, sepsis-related mortality remains higher in New York when compared with other states.[20] Hospital nurse staffing remains highly variable in New York hospitals with over half of hospitals having patient-to-nurse ratios above the pending safe staffing legislation ratios.[21] This study examines both the processes (SEP-1) and context (nurse staffing) of care. Better staffing reasonably improves a hospital's ability to meet SEP-1 criteria, but this study documents the association of nurse staffing with a broad range of outcomes

Table 3 Unadjusted and adjusted associations of nurse staffing and SEP-1 compliance with patient outcomes

Patient outcome		Separate				Joint	
		Unadjusted		Adjusted		Adjusted	
		Staffing	SEP-1	Staffing	SEP-1	Staffing	SEP-1
30-day mortality	OR	1.08	0.98	1.09	0.98	1.09	0.99
	(95% CI)	(1.05 to 1.11)	(0.97 to 1.00)	(1.06 to 1.13)	(0.97 to 1.00)	(1.05 to 1.13)	(0.97 to 1.01)
	P value	<0.001	0.042	<0.001	0.069	<0.001	0.193
60-day mortality	OR	1.09	0.98	1.11	0.98	1.10	0.99
	(95% CI)	(1.06 to 1.11)	(0.97 to 1.00)	(1.07 to 1.14)	(0.96 to 1.00)	(1.07 to 1.14)	(0.97 to 1.00)
	P value	<0.001	0.021	<0.001	0.038	<0.001	0.138
7-day readmissions	OR	1.07	0.98	1.08	0.98	1.08	0.99
	(95% CI)	(1.04 to 1.10)	(0.96 to 0.99)	(1.05 to 1.12)	(0.97 to 1.00)	(1.05 to 1.11)	(0.97 to 1.00)
	P value	<0.001	0.002	<0.001	0.037	<0.001	0.144
30-day readmissions	OR	1.06	0.99	1.07	1.00	1.07	1.00
	(95% CI)	(1.03 to 1.08)	(0.98 to 1.00)	(1.05 to 1.10)	(0.98 to 1.01)	(1.05 to 1.10)	(0.99 to 1.01)
	P value	<0.001	0.028	<0.001	0.383	<0.001	0.864
60-day readmissions	OR	1.06	0.99	1.07	1.00	1.07	1.00
	(95% CI)	(1.04 to 1.08)	(0.98 to 1.00)	(1.05 to 1.10)	(0.98 to 1.01)	(1.05 to 1.10)	(0.99 to 1.01)
	P value	<0.001	0.028	<0.001	0.385	<0.001	0.876
Length of stay	IRR	1.11	0.96	1.10	0.97	1.10	0.98
	(95% CI)	(1.09 to 1.14)	(0.95 to 0.98)	(1.08 to 1.12)	(0.97 to 0.98)	(1.08 to 1.12)	(0.97 to 0.99)
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ICU admission	OR	1.13	0.95	1.13	0.96	1.12	0.97
	(95% CI)	(1.06 to 1.21)	(0.92 to 0.99)	(1.04 to 1.23)	(0.92 to 1.00)	(1.03 to 1.22)	(0.93 to 1.01)
	P value	<0.001	0.008	0.004	0.044	0.007	0.087

The patient N changes across models. Analyses of mortality and ICU admission (n=252 699) use the full study sample. Analyses of readmissions (n=191 919) exclude 60 780 patients: 30 437 for in-hospital mortality and 30 343 patients who were discharged to acute care hospitals. Analyses of lengths of stay (n=191 614) exclude an additional 305 patient for lengths of stay >60 days.
'Staffing' is average patient-to-nurse ratio on medical-surgical units; a 1-unit change represents one patient per nurse.
'SEP-1' reflects the percentage of certain sepsis patients who received recommended care in a timely manner; a 1-unit increase represents a 10% increase hospital compliance.
Adjusted models included as controls characteristics of the hospital (size, teaching status, technology status, ICU nurse staffing levels) and patient (age, sex, 29 comorbidities, transfer status, severity of illness).
ICU, intensive care unit; IRR, incidence rate ratio.

among patients with sepsis above and beyond SEP-1 bundle compliance.

It has been suggested that situational awareness and improved communication could be the answer to improved sepsis outcomes.[22] Nurses play a critical role here, too. In addition to implementing SEP-1 bundle components, nurses also provide patient surveillance to detect subtle changes in the physiologic status of critically ill patients.[23 24] Numerous aspects of the care environment can support adequate communication among nurses and other clinicians. For example, there is substantial evidence to suggest that hospitals that provide an environment where nurses have the opportunity to participate in hospital affairs, nurse managers have the ability to lead and support nurses, and there are good nurse-physician relationships have a decrease in poor patient outcomes such as mortality, failure-to-rescue, and non-mortality adverse events.[25 26] Hospitals that invest in nursing, such

as Magnet hospitals, have both better nurse staffing ratios and better work environments.[27–29]

This study had a few limitations. This study was cross-sectional and by design it limits our ability to identify causal relationships. Additionally, we may not control for all confounders of these associations. For example, we do not have information on the presence of sepsis response teams or other sepsis-specific initiatives within our study hospitals. Nor do we control for socioeconomic status of the patients or deprivation of the hospitals' service area. Caution is advised, therefore, when interpreting results. Data on nurses were from those who responded to our survey and response bias is a potential unknown. However, our survey methods have been validated extensively and we have conducted substudies of samples of non-respondents showing no evidence of response bias on variables of interest.[16] While data were limited to sepsis patients in hospitals in six states, the hospitals in these

states account for one third of hospital admissions nationally. This is one of the largest studies to date to consider not only compliance with care protocols but also detailed information on nurse staffing. The Hospital Compare measure of SEP-1 bundle compliance scores is limited.[30] SEP-1 is a time-sensitive, all or nothing metric. There is no partial credit. A single missed or delayed intervention codes the hospital as uncompliant for that patient. This does not allow for clinician judgement and the time involved with many invasive procedures.

CONCLUSIONS

Many have questioned how to manage sepsis and improve SEP-1 bundle compliance. We provide evidence that an investment in nurse staffing provides value to sepsis patients above and beyond the use of protocols to guide care. Sepsis patients cared for in hospitals with better nurse staffing experience better outcomes that extend beyond their hospitalisation, an association that remained even after controlling for SEP-1 bundle compliance. Patients in better staffed hospitals not only have shorter lengths of stay, but they are also more likely to avoid the ICU. The decreased likelihood of mortality for these patients extends beyond discharge (to at least 60 days) and they are less likely to experience a readmission. At a time when many are calling for a change to the SEP-1 bundle protocol, equal consideration to adequate nurse staffing is warranted to substantially improve outcomes for sepsis patients.

of Pennsylvania IRB), the investigators cannot provide hospital identifiers. Nor can they share individual nurse survey data, identified or not, as a condition of research participant consent.

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