Prompting Physicians to Address a Daily Checklist and Process of Care and Clinical Outcomes

A Single-Site Study

Curtis H. Weiss[1], Farzad Moazed[2], Colleen A. McEvoy[2], Benjamin D. Singer[2], Igal Szleifer[3,4], Luís A. N. Amaral[5,6], Mary Kwasny[7], Charles M. Watts[1,8], Stephen D. Persell[9,10], David W. Baker[9,10], Jacob I. Sznajder[1], and Richard G. Wunderink[1]

[1]Division of Pulmonary and Critical Care Medicine and [2]Department of Internal Medicine, Northwestern University Feinberg School of Medicine, Chicago; [3]Department of Biomedical Engineering, [4]Chemistry of Life Processes Institute, [5]Department of Chemical and Biological Engineering, and [6]Howard Hughes Medical Institute, Northwestern University, Evanston; [7]Department of Preventive Medicine, Biostatistics Collaboration Center, Northwestern University Feinberg School of Medicine, Chicago; [8]Northwestern Memorial Hospital, Chicago; and [9]Division of General Internal Medicine and [10]Institute for Healthcare Studies, Northwestern University Feinberg School of Medicine, Chicago, Illinois

***Rationale*: Checklists may reduce errors of omission for critically ill patients.**

***Objectives*: To determine whether prompting to use a checklist improves process of care and clinical outcomes.**

***Methods*: We conducted a cohort study in the medical intensive care unit (MICU) of a tertiary care university hospital. Patients admitted to either of two independent MICU teams were included. Intervention team physicians were prompted to address six parameters from a daily rounding checklist if overlooked during morning work rounds. The second team (control) used the identical checklist without prompting.**

***Measurements and Main Results*: One hundred and forty prompted group patients were compared with 125 control and 1,283 preintervention patients. Compared with control, prompting increased median ventilator-free duration, decreased empirical antibiotic and central venous catheter duration, and increased rates of deep vein thrombosis and stress ulcer prophylaxis. Prompted group patients had lower risk-adjusted ICU mortality compared with the control group (odds ratio, 0.36; 95% confidence interval, 0.13–0.96; $P = 0.041$) and lower hospital mortality compared with the control group (10.0 vs. 20.8%; $P = 0.014$), which remained significant after risk adjustment (odds ratio, 0.34; 95% confidence interval, 0.15–0.76; $P = 0.008$). Observed-to-predicted ICU length of stay was lower in the prompted group compared with control (0.59 vs. 0.87; $P = 0.02$). Checklist availability alone did not improve mortality or length of stay compared with preintervention patients.**

***Conclusions*: In this single-site, preliminary study, checklist-based prompting improved multiple processes of care, and may have improved mortality and length of stay, compared with a stand-alone checklist. The manner in which checklists are implemented is of great consequence in the care of critically ill patients.**

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Checklists prevent medical errors and improve outcomes for critically ill patients.

What This Study Adds to the Field

In this study, prompting to use a checklist improved process of care measures and may have reduced severity-adjusted mortality and length of stay. Prompting may provide a novel and more effective approach to checklist implementation.

Keywords: outcome and process assessment; quality improvement; critical care

The complexity of the ICU environment places critically ill patients at increased risk of medical error, particularly errors of omission (1–3). Checklists have become synonymous with attempts to simplify care and reduce errors of omission (4). ICU checklists increase compliance with clinical practice guidelines (5) and lead to earlier extubation (6) and transfer from ICU to telemetry units (7), and decreased rates of catheter-related bloodstream infection (8, 9).

Despite these encouraging results, the benefit of widespread checklist use remains unclear. Prior checklist research has generally addressed a single topic (e.g., catheter-related bloodstream infections). No rigorously controlled studies of the benefits of checklists exist: published studies have used mostly the before/after model (7, 9, 10), which can be compromised by coincident interventions (8).

Implementation issues raise the greatest concern regarding effective use of checklists. Successful quality improvement interventions often provide a mechanism to encourage or enforce the intervention's adoption (11). However, administrative mandates for checklists often do not consider the importance of implementation strategy in achieving the culture change essential for their success (12).

Despite general appreciation of the benefits of checklists by clinicians, results of checklist introduction to many critical care services have been disappointing. We therefore sought to determine whether regular verbal prompting to address multiple quality parameters on a checklist leads to superior process of care and improved clinical outcomes than the unprompted use of an identical checklist.

Some of the results of this study have been previously reported in the form of an abstract (13).

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Correspondence and requests for reprints should be addressed to Curtis Weiss, M.D., M.S., Division of Pulmonary and Critical Care Medicine, Northwestern University Feinberg School of Medicine, 240 East Huron Street, McGaw M-300, Chicago, IL 60611. E-mail: curtisweiss@fsm.northwestern.edu

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METHODS

Setting

The study was conducted in the medical intensive care unit (MICU) at Northwestern Memorial Hospital (NMH, Chicago, IL), a tertiary care urban university-affiliated hospital. The MICU is a closed-unit staffed by two separate teams, each with an independent patient census. The two teams admit patients on alternating days. Each team consists of one pulmonary/critical care attending physician, one fellow, one pharmacist, and several residents and interns. Attendings and fellows have weekday rotations of 1–4 weeks, often with different weekend coverage (*see* the online supplement).

Study Design

Before the study we designed and instituted an MICU daily rounding checklist as a quality improvement tool (Figure 1). Faculty, fellows, pharmacists, and nurses were trained to complete the checklist daily (*see* the online supplement).

We conducted a prospective concurrently controlled cohort study. The study was approved by the Institutional Review Board with a waiver of consent. All patients admitted to the MICU service on or after June 25, 2009 and discharged on or before September 15, 2009 were eligible for inclusion. This time period was chosen to minimize the crossover of attendings and fellows between MICU teams. Exclusion criteria included the following: (*1*) patients physically located in a different ICU for more than the first 72 hours of their ICU stay, (*2*) patients transferred from a different ICU service, and (*3*) patients transferred to another ICU service within 12 hours of MICU admission. Only the first MICU admission was included for patients admitted more than once without intervening hospital discharge (14, 15). All included patients were monitored through hospital discharge. We also performed a retrospective analysis of the 1,283 MICU patients admitted from July 1, 2008 to June 25, 2009 (preintervention group) who otherwise met the above inclusion criteria.

Intervention

A non–care-providing resident physician (the prompter) initiated discussion with one of the MICU teams (prompted team), using scripted questions if any of the following six parameters under investigation were overlooked on daily work rounds: mechanical ventilation weaning, empirical antibiotics, central venous catheters (CVCs), Foley urinary catheters, and deep vein thrombosis (DVT) and stress ulcer prophylaxis. A verbal prompting script addressing the selected checklist topics was developed before study initiation (*see* Figure E1 in the online supplement). For example, if the rounding team failed to discuss the presence or management of a CVC, the prompter would ask, "The CVC has been in place for [X] days. Do you want to continue it"? The prompters had no patient care responsibilities; there was no contact between the prompters and any patient. Verbal prompting was directed at the attending and fellow.

Nursing:	***MICU ROUNDING CHECKLIST - PG 1***														
Patient: **Date:**															
Date of Admission: **ROOM NO:**															
ICU DAY→	**A**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Lines and Tubes bundle	**Give initial date and day number**														
Central Line 1; Site/type/insertion date:_____															
Central Line 2; Site/type/insertion date:_____															
Arterial Line; Site/insertion date: _____															
Rectal tube															
Other:_____															
Patient care bundle	**Check = yes**														
Appropriate stool within past 24 hrs															
Any glucose > 140															
Restraints															
Foley															
Weight															
Nutrition:															
Nutrition goal rate: % of goal _____															
Pressure Ulcer--LOCATION: **STAGE:**															
Pressure Ulcer--LOCATION: **STAGE:**															
Pressure Ulcer--LOCATION: **STAGE:**															
Pharmacy:															
Antibiotics (Name and Reason, eg. Vancomycin, E)															
(Empiric, **P**neumonia, **L**ine, **A**bdominal, **U**rine, **O**ther)	**Give initial date and day number**														
Antibiotic 1:_____															
Antibiotic 2:_____															
Antibiotic 3:_____															
Antibiotic 4:_____															
Antibiotic 5:_____															
DVT prophylaxis (Heparin, Lovenox, SCD, Contraindicated, Other:___															
GI prophylaxis															
Physician:															
Ventilator bundle	**Give day number**														
Intubated; initial date:_____															
	Check = yes														
Can patient have daily waking?															
Can patient have weaning trial?															
HOB > 30															
	Fellow, **A**ttending, **P**lanned, **N**o														
Family updated within 24 hrs															
Goals/disposition discussed															
Other?															
Clinical Trial enrollment candidate (Give name: ARDS, sepsis, VAP)															
Attending/Fellow Certification															

Figure 1. Daily rounding checklist. The medical intensive care unit (MICU) checklist was introduced in March 2009. Faculty, fellows, pharmacists, and nurses were trained in its use. Multiple parameters are included along the *left side*. Nurses are responsible for filling out the *yellow section*, pharmacists the *orange section*, and physicians the *green section*. The checklist was designed to be able to follow parameters over time, with each *column of boxes* representing each ICU day. The attending or fellow is required to initial the checklist on each day. ARDS = acute respiratory distress syndrome; DVT = deep vein thrombosis; GI = gastrointestinal; HOB = head of bed; SCD = sequential compression device; VAP = ventilator-associated pneumonia.

Any patient admitted to the prompted team was included regardless of whether the prompter was present during their ICU stay (e.g., patients admitted and discharged over the weekend). Prompting began during the first rounds after a patient's MICU admission, occurred after a care-providing resident's presentation but before the MICU team entered the patient's room, and continued daily (whenever the prompter was present) until MICU discharge.

The unprompted MICU team, with availability of the identical checklist, served as a control (*see* the online supplement). Both teams were unaware of the goals of the study.

Data Collection

For each patient, the prompter recorded the number of days he/she was present, and for each checklist parameter the number of days on which prompting occurred and whether prompting led to a change in medical management. We retrieved checklists from both groups at ICU discharge. Primary outcomes included differences between the prompted and control groups related to the process of care parameters under investigation: ventilator-free days (16); duration of empirical antibiotics (defined as antibiotics administered without culture-documented infection), total antibiotics, and CVCs (excluding hemodialysis catheters and peripherally inserted central catheters); Foley urinary catheter duration in eligible patients; pharmacological deep vein thrombosis (DVT) prophylaxis per eligible days; and stress ulcer prophylaxis per eligible days. We collected primary outcomes from the electronic medical record, except for Foley catheter duration, which was obtained from patients' checklists.

Secondary outcomes included ICU and hospital mortality, ICU length of stay (LOS), and ventilator-associated pneumonia (*see* the online supplement). Data necessary to calculate Acute Physiology and Chronic Health Evaluation (APACHE) IV–predicted mortality and ICU LOS were collected retrospectively (14, 15). We also collected hospital mortality and ICU LOS for preintervention group patients. We obtained the results of bronchoalveolar lavage fluid cultures for mechanically ventilated patients.

Statistical Analysis

Descriptive data are summarized as mean (standard deviation, SD), median (interquartile range, IQR), or number (%). We used a χ^2 test to compare categorical variables, and Student's *t* test and Wilcoxon or Kruskal-Wallis rank-sum tests to compare continuous variables, as appropriate. Patients were excluded from a specific outcome analysis if they were not exposed to the parameter in question (e.g., patients who did not receive antibiotics were excluded from the antibiotic analyses).

We constructed logistic regression models to adjust ICU and hospital mortality for APACHE IV–predicted hospital mortality, age, sex, and night or weekend ICU admission status. Differences are expressed as the odds ratio (OR) for death with 95% confidence intervals (CIs). We calculated standardized mortality ratios (SMRs, observed/APACHE IV–predicted mortality), reported with 95% CIs. We analyzed mean ICU LOS by Monte Carlo hypothesis testing (100,000 synthetic samples), to remove the effects of random variation in nonnormally distributed variables. Observed/APACHE IV–predicted LOS ratios were calculated. We constructed Kaplan-Meier curves and Cox proportional hazards models of the proportion remaining in the ICU. All tests are two-tailed, and a *P* value less than 0.05 was considered significant. Analyses were performed with SAS (version 9.2; SAS Institute, Cary, NC), except for the Monte Carlo simulations (17).

RESULTS

One hundred and forty prompted, 125 control, and 1,283 preintervention group patients were enrolled. We found no significant differences in baseline characteristics between the prompted and control groups (Table 1).

Process of Care

A prompter was present on 67.9% of prompted group daily rounds during the 82-day intervention period. Prompting was required on 64.7% of patient-days. The amount of prompting for each care practice is provided in Table 2.

TABLE 1. BASELINE CHARACTERISTICS OF STUDY PATIENTS

Characteristic	Prompted (*n* = 140)	Control (*n* = 125)	*P* Value
Age (yr), mean (SD)	58.5 (17.8)	57.3 (17.8)	0.60
Sex (male), no. (%)	69 (49.3)	51 (40.8)	0.17
Race, no. (%)			
White	71 (50.7)	69 (55.2)	
African American	47 (33.6)	42 (33.6)	0.54
Hispanic/other	22 (15.7)	14 (11.2)	
Location before MICU, no. (%)			
Emergency department	79 (56.4)	76 (60.8)	
General medical ward	54 (38.6)	44 (35.2)	0.75
Outside hospital transfer	7 (5.0)	5 (4.0)	
Diagnosis, no. (%)*			
Sepsis	32 (22.9)	32 (25.6)	
Pneumonia	20 (14.3)	11 (8.8)	
Obstructive airway disease	8 (5.7)	15 (12.0)	
Other respiratory†	13 (9.3)	14 (11.2)	
GI hemorrhage	17 (12.1)	12 (9.6)	0.39
Metabolic	7 (5.0)	11 (8.8)	
Neurological	10 (7.1)	6 (4.8)	
Drug intoxication/withdrawal	6 (4.3)	6 (4.8)	
Other	27 (19.3)	18 (14.4)	
Sepsis subdiagnosis, no. (%)*			
Pulmonary	6 (18.8)	7 (21.9)	
GI	7 (21.9)	8 (25.0)	
Urinary	9 (28.1)	5 (15.6)	0.82
Soft tissue	2 (6.3)	3 (9.4)	
Unknown	8 (25.0)	9 (28.1)	
Mechanical ventilation, no. (%)	36 (28.8)	41 (29.3)	0.93
Hospital discharge disposition, no. (%)			0.45
Home	96 (76.2)	71 (71.7)	
Long-term acute care or skilled nursing facility	30 (23.8)	28 (28.3)	

Definition of abbreviations: GI = gastrointestinal; MICU = medical intensive care unit.

* Diagnoses, including sepsis subdiagnoses, are adapted from the Acute Physiology and Chronic Health Evaluation (APACHE) IV prediction models (14, 15).

† Includes acute respiratory distress syndrome, pulmonary hemorrhage/hemoptysis, pleural effusion, respiratory arrest, lung cancer, sleep apnea, and nonspecified respiratory diagnoses.

Compared with the control group, the prompted group had increased median (IQR) ventilator-free days (22 [14–26] vs. 16 [0–21.5] d; $P = 0.028$), shorter empirical antibiotic (2 [1–3] vs. 3 [2–7] d; $P = 0.012$) and central venous catheter (3 [2–5] vs. 5 [2–8] d; $P = 0.007$) duration, and increased mean (SD) proportion of pharmacological DVT (0.96 [0.18] vs. 0.76 [0.35]; $P < 0.001$) and stress ulcer prophylaxis (0.93 [0.22] vs. 0.83 [0.31]; $P < 0.001$). The mean (SD) proportion of days of antibiotic use that were empirical also decreased with prompting (0.77 [0.32] vs. 0.91 [0.29]; $P < 0.001$). Foley catheter duration was not significantly reduced with prompting (3 [2–7] vs. 4 [2–11] d; $P = 0.29$) (Table 3).

We conducted post-hoc analyses of two intermediate outcomes. In the prompted group, 14 of 51 (27.5%) bronchoalveolar lavage cultures were positive (bacterial colony-forming units $\geq 10^4$/ml) (18–21), compared with 17 of 40 (42.5%) in the control group ($P = 0.13$). No catheter-related bloodstream infections were documented during the study period in any patient.

Mortality

There was no difference in hospital mortality between the control and preintervention groups. Both ICU and hospital mortality were lower in the prompted group compared with the control group, whereas APACHE IV–predicted mortality was similar (Table 4 and Figure 2A).

In multivariate analyses, severity-adjusted ICU mortality as well as severity-adjusted hospital mortality were reduced in

TABLE 2. AMOUNT OF PROMPTING NEEDED IN INTERVENTION GROUP

Variable	Prompting Patient-days/ Rounding Patient-days (%)*
Overall†	334/516 (64.7)
Foley catheter‡	98/238 (41.2)
Empirical antibiotics	103/284 (36.3)
Central venous catheter	53/206 (25.7)
Mechanical ventilation	35/249 (14.1)
DVT prophylaxis§	5/336 (1.5)
Stress ulcer prophylaxis§	5/497 (1.0)

Definition of abbreviation: DVT = deep vein thrombosis.

Note: Intervention group, n = 140.

* Represents interventions in the 140 prompted group patients during the 82 days of the study. Shown is the total number of patient-days on which a prompting intervention occurred divided by total number of patient-days on which rounding occurred. For each variable (except overall), only rounding patient-days during which the variable was present were included (e.g., only days on which patients were mechanically ventilated were included as rounding patient-days for this variable).

† Number of patient-days on which prompting occurred at least once.

‡ Mechanically ventilated patients were ineligible for Foley catheter prompting.

§ Rounding days are the total patient-days eligible for DVT or stress ulcer prophylaxis, respectively.

the prompted group (ICU mortality: OR, 0.36; 95% CI, 0.13–0.96; $P = 0.041$; hospital mortality: OR, 0.34; 95% CI, 0.15–0.76; $P = 0.008$). The prompted group SMR was 0.45 (95% CI, 0.25–0.76); the SMR for the control group was 0.96 (95% CI, 0.63–1.40). The hospital mortality difference was observed in the second through fourth quartiles of predicted mortality (Figure 2B). Age, sex, night or weekend ICU admission status, and attending experience (Table E1) were not predictors of death.

We found significant differences in hospital mortality between the prompted group and both a seasonal preintervention subgroup (1 yr before the intervention and before checklist institution, 24.0%), and the remainder of the preintervention group (20.2%) ($P = 0.008$); there was no difference between the checklist-only control group and either preintervention group.

Post-hoc review revealed lower ICU and hospital mortality rates in the prompted group for patients with sepsis (especially gastrointestinal sepsis), pneumonia, and the category Other Respiratory, with a similar distribution of diagnoses (Table 5). Patients who died in the hospital in the prompted group had higher APACHE IV–predicted mortality (53.7%; SD, 26.5%) than those who died in the control group (40.5%; SD, 24.8%); this was not statistically significant ($P = 0.16$).

Length of Stay

APACHE IV–predicted ICU length of stay was similar in the prompted and control groups. Mean ICU LOS in the prompted group was shorter compared with control (Table 4). There was no difference in ICU LOS between the checklist-only control and preintervention (4.3 d) groups. Observed/predicted LOS ratios (95% CI) for the prompted and control groups were 0.59 (0.48–0.69) and 0.87 (0.68–1.06), respectively ($P = 0.02$). The difference between prompted and control group ICU LOS was pronounced after 4 ICU days (Figure 3).

DISCUSSION

In this single-site, preliminary study, we demonstrate that prompting physicians on one MICU team to discuss care practice parameters on a checklist improves multiple processes of care compared with a similar team that received checklists but no prompting. Prompting was associated with shortened duration of mechanical ventilation, empirical antibiotic use and central venous catheter use, and increased use of DVT and stress ulcer prophylaxis. Using the checklist without ongoing prompting did not result in improvement compared with baseline measurement of outcomes. The prompted group, however, had lower severity-adjusted mortality and length of stay.

Our study contrasts active checklist use versus passive implementation, the latter representing a quality improvement paradigm in which a tool or process is initiated through regulatory or administrative mandate (22). Indeed, a comparison of checklist-only control group outcomes with the preintervention cohort suggests that the checklist itself had little effect. Instead, our study suggests that effective quality improvement requires a robust implementation and adherence strategy. Constant attentiveness to the care practices under investigation, driven by prompting, achieved improvements in processes of care. We do not believe the checklist is superfluous: prompting by memory would be prone to similar errors of omission that it attempts to prevent.

Overlooked in the enthusiasm for checklists is the fact that the most prominent examples enforced changes in behavior. Bedside nurses were empowered to stop CVC insertion with overt support from hospital administrators in the Keystone Project (9). Surgeons were not allowed to begin an operation or transfer a patient to the recovery room without checklist completion in the World Health Organization Surgical Safety Checklist Study (10). Even in the oft-cited airplane pilot illustration (23), participation by a copilot is compulsory. We describe our intervention as prompting rather than enforcing,

TABLE 3. PROCESS OF CARE OUTCOMES

Variable	Prompted (*n = 140*)	Control (*n = 125*)	*P* Value
Ventilator-free days	22 (14–26)	16 (0–21.5)	0.028
Antibiotics			
Empirical antibiotics, d	2 (1–3)	3 (2–7)	0.012
Total antibiotics, d	3 (2–5)	3 (2–7)	0.41
Proportion empirical antibiotics*	0.77 (0.32)	0.91 (0.29)	<0.001
Central venous catheter, d	3 (2–5)	5 (2–8)	0.007
Foley catheter, d	3 (2–7)	4 (2–11)	0.29
DVT prophylaxis/eligible	1 (1, 1)	1 (0.6–1)	<0.001
Proportion DVT prophylaxis*	0.96 (0.18)	0.76 (0.35)	
Stress ulcer prophylaxis/eligible	1 (1, 1)	1 (0.75–1)	<0.001
Proportion stress ulcer prophylaxis*	0.93 (0.22)	0.83 (0.31)	

Definition of abbreviation: DVT = deep vein thrombosis.

Values shown are medians (interquartile range) unless otherwise noted. Only patients who were exposed to each variable were included in its analysis (e.g., only patients who received mechanical ventilation during their intensive care unit stay were included in the ventilator-free analysis).

* Mean (SD).

TABLE 4. CLINICAL OUTCOMES

Variable	Prompted (*n* = 140)	Control (*n* = 125)	*P* Value
Mortality			
APACHE IV–predicted hospital mortality, no. (%)	31.1 (22.2)	27.2 (21.7)	0.86
ICU mortality, no. (%)	9 (6.4)	17 (13.6)	0.050
Adjusted odds ratio (95% CI)	0.36 (0.13–0.96)	Reference	0.041
Hospital mortality, no. (%)	14 (10.0)	26 (20.8)	0.014
Adjusted odds ratio (95% CI)	0.34 (0.15–0.76)	Reference	0.008
SMR (95% CI)*	0.45 (0.25–0.76)	0.96 (0.63–1.4)	
Length of Stay			
APACHE IV–predicted LOS, d†	5.8 (2.0)	5.5 (2.0)	0.17
ICU LOS, d			
Mean (SD)	3.5 (4.3)	4.9 (7.0)	0.07‡
Median (IQR)	1.9 (1.0–3.7)	1.9 (1.2–4.9)	0.45
Observed/predicted LOS ratio (95% CI)*	0.59 (0.48–0.69)	0.87 (0.68–1.06)	0.02‡

Definition of abbreviations: APACHE = Acute Physiology and Chronic Health Evaluation; CI = confidence interval; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay; SMR = standardized mortality ratio.

* Standardized mortality ratio (SMR) or standardized length of stay ratio was calculated as observed/predicted mortality or length of stay, respectively.

† Mean (SD).

‡ Determined by Monte Carlo simulation.

to reflect that the checklist addressed more nuanced decisions (e.g., when to discontinue empirical antibiotics or wean mechanical ventilation) for which a prompted discussion is more appropriate than a mandatory decision. Our study suggests that checklists require an accountability strategy to change behavior and ultimately progress to culture change. This finding is critical to quality improvement strategies based on checklists.

Our study has several strengths that build on other successful quality improvement interventions (5, 7–11). First, prompting was face-to-face and repetitive, which strongly encouraged physicians to change their management behavior, similar to prior studies that employed local quality champions and close monitoring (9, 10). In contrast, checklist implementation without repetitive prompting in the control group had no mechanism of accountability, and did not yield improvement in outcomes.

Second, our intervention targeted multiple care practices. This may have led to more clinical benefit than any single practice alone (10, 11). Previous strategies that individually targeted our prompting topics—including empirical antibiotics (18, 24, 25), mechanical ventilation weaning (26, 27), and CVCs (8, 9)—are each associated with improved outcomes. Also, duration of mechanical ventilation, prior antibiotic use, and prior broad-spectrum antibiotic use are all independent predictors of ventilator-associated pneumonia due to potentially drug-

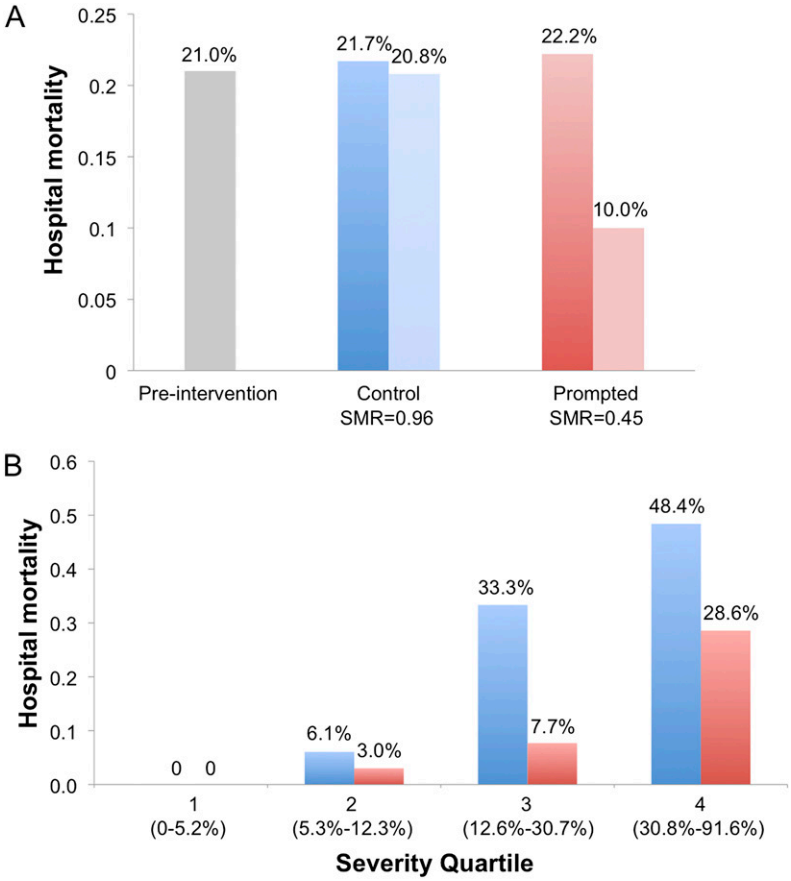

Figure 2. Hospital mortality. (*A*) Observed (*light blue* and *red columns*) and Acute Physiology and Chronic Health Evaluation (APACHE) IV–predicted (*dark blue* and *red columns*) hospital mortality in the prompted and control groups, and observed preintervention hospital mortality (*gray column*). Mortality rates (%) and standardized mortality ratios (SMRs) are shown. (*B*) Observed hospital mortality in the control group (*blue columns*) and prompted group (*red columns*) according to patient quartile of predicted risk. Prompted and control patients were pooled and divided into equal quartiles of predicted risk. The range of predicted mortality for patients in each quartile is shown underneath each quartile number.

TABLE 5. MORTALITY ACCORDING TO INTENSIVE CARE UNIT ADMISSION DIAGNOSIS

	Prompting Group		Control Group	
	Deaths/ Total	Mortality Rate	Deaths/ Total	Mortality Rate
Hospital Mortality				
Sepsis	6/32	0.19	11/32	0.34
GI	1/7	0.14	6/8	0.75
Pulmonary	2/6	0.33	2/7	0.29
Urinary	0/9	0	1/5	0.20
Soft tissue	0/2	0	0/3	0
Unknown	3/8	0.38	2/9	0.22
Pneumonia	4/20	0.20	5/11	0.46
Obstructive lung disease	1/8	0.13	0/15	0
Other respiratory*	0/13	0	6/14	0.43
All other diagnoses	3/67	0.045	4/53	0.075
ICU Mortality				
Sepsis	3/32	0.094	7/32	0.22
GI	1/7	0.14	4/8	0.50
Pulmonary	1/6	0.17	1/7	0.14
Urinary	0/9	0	0/5	0
Soft tissue	0/2	0	0/3	0
Unknown	1/8	0.13	2/9	0.22
Pneumonia	4/20	0.20	4/11	0.36
Obstructive lung disease	0/8	0	0/15	0
Other respiratory*	0/13	0	5/14	0.36
All other diagnoses	2/67	0.030	1/53	0.019

Note: Diagnoses, including sepsis subdiagnoses, are adapted from the Acute Physiology and Chronic Health Evaluation (APACHE) IV prediction models (14, 15).

*Includes acute respiratory distress syndrome, pulmonary hemorrhage/hemoptysis, pleural effusion, respiratory arrest, lung cancer, sleep apnea, and nonspecified respiratory diagnoses.

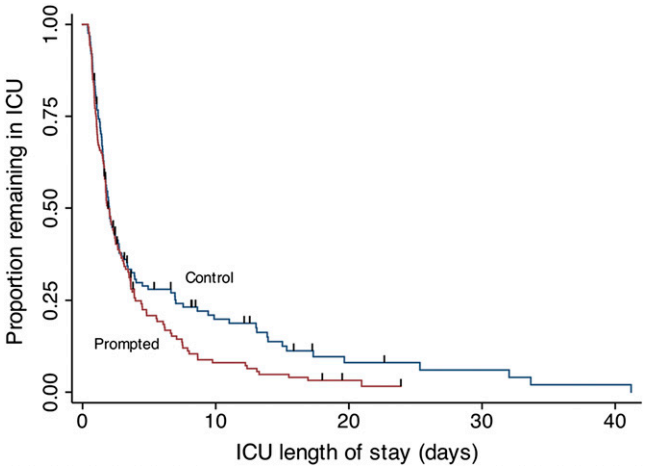

Figure 3. Kaplan-Meier analysis of intensive care unit (ICU) length of stay. Among ICU survivors, the proportion of patients remaining in the ICU is shown according to their ICU length of stay; *tick marks* represent ICU deaths. The Acute Physiology and Chronic Health Evaluation (APACHE) IV–adjusted hazard ratio (95% confidence interval) determined by Cox proportional hazards model was 0.67 (0.52–0.88; $P = 0.003$).

resistant bacteria (28), which itself increases mortality (29). The improvement of several factors in combination may have plausibly led to the improvement of outcomes observed in our study.

Third, an individual prompt may impact patient care or alter provider behavior beyond that single instance of prompting. In the example of mechanical ventilation, prompting for a weaning trial occurred on only 15% of patient-days, yet a substantial 6-day increase in ventilator-free days was observed. A single prompt for mechanical ventilation weaning could have prevented multiple future days of ventilation if weaning was successful on that prompted day. Prompting at one time also may have led the prompted physician to order spontaneous breathing trials on other patients or the same patient on subsequent days, even when no prompter was present. In addition, the prompt may have elicited a discussion of the rationale for the prompt, resulting in an enhanced educational effect that would carry over to other patients on other days.

Although we hypothesized that prompting would improve quality of care, mortality and LOS benefits were unanticipated. The association of prompting with reduced mortality was observed for both severity-adjusted ICU and hospital mortality, suggesting that the effects of prompting in the ICU had a direct impact on ICU outcome and that this effect increased by hospital discharge. However, this was a small study, with a 95% confidence interval for the adjusted odds ratio of mortality that was wide (0.15–0.76), which precludes a definitive analysis of the factors that may have contributed to the mortality reduction.

Some of the mortality difference may have been due to chance, as small studies may be prone to variation. Nevertheless, even a conservative estimate based on the upper 95% confidence interval limit for adjusted mortality suggests that the intervention may have led to a reduction in deaths. Several findings may support this. There was no difference in severity of illness, baseline characteristics, or discharge disposition. The results suggest lower mortality in the prompted group for patients with sepsis, pneumonia, and other respiratory conditions, diagnoses directly related to the processes of care targeted for prompting. We found no difference in mortality in the lowest patient quartile or highest range of predicted mortality (Figure E2), as expected because ICU interventions would not be expected to affect mortality when risk of death is very high or very low. We observed no early difference in LOS; an early difference would suggest that repetitive prompting was unlikely to be responsible. Last, neither seasonal nor overall variation in hospital mortality or ICU LOS between the preintervention and control groups was demonstrated, and control group SMR matched that of a prior 1-year prospective quality project in the same ICU (1,619 patients admitted in 2006–2007; SMR; 0.96; our unpublished data). Despite these findings, our intervention deserves further exploratory analyses and study in a large, multicenter study.

Our study has several potential limitations. First, It was a single-site preliminary study, potentially limiting the generalizability of the results, particularly the mortality effect, of prompting based on our specific checklist to other settings. However, the benefit of a prompter or other similar accountability strategy is likely generalizable to improvements in different processes of care addressed by a different unit-specific checklist. Reproduction of the clinical outcome benefits in larger studies will depend on the linkage between the process of care issues addressed by the checklist and disease-specific outcomes, as well as baseline compliance.

Second, the study cohorts were relatively small. We purposefully limited the length of the study to minimize crossover of attending physicians and fellows from one team to the other, which could have reduced the apparent influence of prompting. Frequent physician rotation within teams could have impacted patients with longer ICU lengths of stay. Third, no research personnel were attached to the control team. As a result, the degree of checklist use by the control team was not directly observed, which also limited our ability to ascertain other differences in team characteristics. Last, although baseline characteristics, severity of illness, discharge disposition, and night or weekend ICU admission were not confounders, other residual confounders could exist.

Using a resident physician as a prompter is clearly an artificial construct of this study. To test effectiveness and widespread implementation, future studies should focus on determining the optimal

approach to prompting, such as an electronic decision-support tool (30, 31) or virtual prompting (11). Alternative forms of prompting may increase the feasibility of future multicenter studies; however, the benefit of face-to-face prompting in our study may not be reproduced electronically.

In summary, this single-site study suggests that simply having a checklist available for reference without consideration of a robust implementation and adherence strategy is unlikely to maximize desired patient outcomes. The complexity of critical care medicine may benefit from, and provide an opportunity to investigate, novel approaches to reduce errors of omission.

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