

APPENDIX  **Web-Only**

The information presented in this appendix addresses 8 statistical and sampling issues related to our findings. The first is how well the expanded Simplified Acute Physiology Score II (SAPS II) accurately predicts hospital mortality compared with the current SAPS II. The second is the sensitivity of the results to changes in the propensity score. The third determines how results compare when using either random-effects logistic regression (which takes into account the fact that the 101 832 participants are nested within 123 intensive care units [ICUs]) or regular logistic regression (which does not take into account the hierarchical nature of the data). The fourth is a subanalysis of only those patients who received treatment in ICUs that offered a choice in critical care management (CCM). The fifth is a comparison of explicit decomposition of the within and between hospital effects of CCM. The sixth is a conditional logistic regression using matching based on an expanded propensity score. The seventh repeats the analysis presented in the manuscript using the expanded propensity score. The eighth addresses a question about the extent to which hospitals in the Project IMPACT (Cerner, Bel Air, Maryland) database compare with other hospitals in the United States.

Expanded SAPS II

Management practices in hospitals and ICUs today have improved patient outcomes and SAPS II probability of mortality (which was developed >15 years ago) but does not adequately reflect current hospital mortality (1). A newly developed expanded SAPS II uses the original SAPS II score along with the patient's age, sex, length of in-hospital stay before ICU admission, patient's location before the ICU, clinical category, and intoxication to improve the probability of hospital mortality (2). Table 1 was recreated from Table 4 in the manuscript and gives standardized mortality ratios and their 95% CI (based on the exact Poisson methods) over the ICU level variable, indicating the percentage of patients who receive CCM ($\leq 5\%$, $5\%–95\%$, $\geq 95\%$), and over patient-level care CCM (yes or no). The SAPS II overestimates mortality (as can be seen in all 6 standardized mortality ratios that range from 0.63 to 0.78). Table 1 shows that when the expanded SAPS II is used to create the 6 SMR, the values range from 0.91 to 1.19. Thus, the expanded SAPS II was used in all of the analyses run in our study. Note that the standardized mortality ratios for the group who received CCM for the entire stay are consistently higher than the group who did not, independent of which SAPS II score is used.

Propensity Score Sensitivity Analysis

The accuracy of our results depends on how well the propensity score discriminates between those who received CCM and those who did not. Four analyses were done to determine the sensitivity of our results to changes in our propensity score. The first looked at how well the variables in the propensity score were balanced across the quartiles of propensity score. Balance implies that either the means or proportions were

comparable across the risk factor of CCM within a propensity score quartile. Table 2 shows that some of the variables are not balanced, whereas some are. Most are statistically different due, in part, to the large sample size. The variables that were not balanced were added back in the model as covariates to control for the additional imbalance that is not accounted for in the propensity score. Only covariates that were significantly associated ($P < 0.05$) with hospital mortality were kept in the model. Tables 3 and 4 were created from Tables 5 and 6 by using the new model with the additional covariates. Compared with the original tables, there is very little difference between the results, as indicated by similar mortality odds ratios and their associated P values. The second analysis includes the addition of statistically nonsignificant variables to the propensity score that were suggested might be clinically important. We added 3 additional variables to the propensity score: affiliation of the hospital with a medical school (yes or no), ICU type (combined medical or surgical or other; medical only; or surgical or trauma only), and nursing policy (registered professional nurse/ /licensed practical nurse, registered professional nurse only, or registered professional nurse with Critical Care Nurse). We then recreated Table 5 from the manuscript, which is shown below as Table 5. Very little difference is seen in the 16 odds ratios compared with the manuscript Table 5. Thus, addition of these statistically nonsignificant variables does not change the overall results of the study.

The third analysis tested how sensitive the mortality odds ratios were to removing the 4 most influential variables, 1 variable at a time, from the propensity score and then running the logistic regression model. The 4 most influential variables are based on the size of their logistic regression model coefficients in the original propensity score. These are noninvasive ventilation at ICU admission, ventilator in place at ICU admission, tracheostomy in place at ICU admission, and hospital classification (rural, suburban, and urban). In order to compare the effect of removing these variables from the propensity score on the CCM odds ratio, a weighted average of the 16 combinations of SAPS II quartiles and propensity quartiles were calculated for the original propensity score and for each of the propensity scores with the influential variable removed 1 at a time shown in Table 6. When the noninvasive ventilation variable was removed from the propensity score, the weighted average CCM odds ratio was 1.45, which is the same as the original propensity score. When the ventilator in place and tracheostomy in place variables were removed, both of these odds ratios increased to 1.46. When the hospital classification variable was removed the average odds ratio decreased to 1.40. The stability of these 4 mortality odds ratios indicates the robustness of our current propensity score to changes in its makeup.

The fourth sensitivity analysis was designed to estimate the effect of a missing or unknown binary covariate on the propensity score (3, 4). If the true mortality odds ratio for CCM versus no CCM was in fact 1.33, then this missing covariate in the propensity score would have to have a 3.5-fold increase in the odds of mortality and a 3.5-fold increase in the odds of being assigned to the CCM in order to misrepresent the odds ratio as 1.64 (the weighted average of the 16 odds ratios from manuscript Table 5). It was also assumed that half of the patients had this missing covariate. In addition, if the missing covariate had a 6-fold increase in the odds of mortality and a 6-fold increase in the odds

of being assigned to CCM, then a true odds ratio of 0.99 (CCM protective) would be misrepresented as 1.64. We feel that it is highly unlikely that there exists an unknown dichotomous variable in the PI database that we did not include in the propensity score that would have this large of an affect.

Random-Effects Logistic Regression

In the manuscript we ran a random-effects logistic regression, which takes into account that all of 101 832 subjects are nested within the 123 ICUs. Thus, the model uses the between ICU variability and within ICU variability to generate point estimates and standard errors. The model also generates a statistic called “ ρ ” that is equal to the ratio of the between ICU variance to the total variance and ranges from 0 to 1. Zero indicates that all the variability is within the ICU, and 1 indicates that all the variability is between ICUs. Our current model gives an overall ρ of 0.03 for the logistic regression model with CCM, propensity score, SAPS II probability of mortality and their interaction terms. This means that there is not an ICU effect that is confounding the results. Most of the variability is within the ICU and very little exists between ICUs. We also ran regular logistic regression to compare the results with the random-effects logistic regression and recreated Tables 5 and 6 from the manuscript using logistic regression with the results shown below as Tables 7 and 8. The odds ratios in Tables 7 and 8 are similar to values in manuscript Tables 5 and 6, indicating that ICU is not confounding the results. This agrees with the small ρ values generated in the random-effects logistic regression.

Analysis of Patients in ICUs that offer a Choice of CCM

Table 9 shows the 16 mortality odds ratio for ICUs in which there was a choice of CCM or no CCM, defined by quartiles of propensity and quartiles of expanded SAPS II. The choice group is defined by those hospitals that manage between 5% and 95% of their patients with CCM and represents 59.3% of the patients in the database (60 344). Quartile number 1 are those patients with the lowest propensity scores (or lowest SAPS II), whereas quartile 4 has the highest propensity scores (or highest SAPS II). These results indicate that 15 of 16 mortality odds ratios are greater than 1, and of these 15, 8 are statistically significant at the 0.05 level and 1 is very close with a P value = 0.057. When compared with Table 5 in the manuscript, the results are very similar. The P values tend to be a little larger, but this is caused by the smaller sample sizes in the 16 combinations of quartiles of probability and propensity scores.

Comparison of Explicit Decomposition of the Within and Between Hospital Effects

Table 10 shows the mortality odds ratio for CCM versus no CCM for various logistic regression techniques. All of the models contain the risk factor (CCM vs. no CCM) and are adjusted for the current propensity score and expanded SAPS II. There was no CCM interaction terms included in these models because for comparison purposes we only looked at the main effect. The random-effects model controls for potential confounding by the 123 hospital/ICUs. The between hospital error variance was 0.13, whereas the within hospital error variance was 3.29. ρ , which is the ratio of between hospital

variance to total variance, is equal to 0.04, indicating that the mortality odds ratio will be very similar to the logistic regression odds ratio for CCM versus no CCM. The between-effects regression generates an odds ratio based on the average response of the explanatory variables over the 123 hospital/ICUs. The mortality odds ratio is very similar to the logistic regression odds ratio because only about 4% of the variability is between the hospitals. The fixed-effects regression obtains the within hospital/ICU effects by using a conditional logistic regression. Again these results are similar to random-effects logistic regression because most of the variability is within the hospital/ICUs.

Conditional Logistic Regression using Matching, based on an Expanded Propensity Score

An expanded propensity score was developed using only hospitals where there was choice of CCM or no CCM. In this situation *choice* was determined by looking at each of the 123 hospital/ICUs and keeping only those that directed patients to either CCM or no CCM. In order to develop stable models for the individual propensity scores, we only used hospitals that had enough patients to adequately model the number of variables in our propensity score. We started with 101 832 patients and dropped 34 399 due to a lack of choice. This left 67 433 patients in 70 hospitals. Next, we kept only those hospitals that had at least 350 patients assigned to CCM and at least 350 patients assigned to no CCM. This left 33 578 patients in 19 hospitals that we could use to develop a propensity score for each individual hospital. Finally, no 2-way interaction terms were used in the propensity score because there would be greater than 740 additional variables entered into the model that would lead to instability in the standard errors of the estimated coefficients

Table 11 presents all of the variables we considered for the propensity score. Variables 1 to 25 are all patient-level variables, whereas variables 26 to 34 are all hospital-level variables. We calculated the propensity score for each of the 19 hospitals individually using only patient-level variables. We used both patient-level and hospital-level variables when the propensity score was developed for the entire cohort of 101 832 patients.

Because many of the patient-level variables were categorical with more than 2 categories, the propensity score model contained 39 covariates, including the dummy variables. These same 39 covariates were kept in each of the 19 propensity score models regardless of their individual *P* values. Hospital-level variables do not change when creating propensity scores within a specific hospital and were not entered into the model.

Patients were matched on propensity scores by ranking the propensity score within each hospital. Cases were the patients that died within strata, and controls were those that lived. Strata were defined using the first case in the ranked propensity score and ending at the last live patient before the next case. More than 1 case could be included in the strata if the first case was immediately followed by 1 or more cases that did not have any controls in between. Unless the very first patient (the person with the lowest propensity

score) died, all of the patients in this first stratum were dropped because it does not contain a case. Any patient that did not have a propensity score was also dropped from the strata. Missing propensity scores were due to missing observations in the variables used to develop the propensity score. These strata were considered the full data set for these analyses.

Many of the strata were large because there were not many cases (deaths). Because this data set was not designed for a matched case–control analysis, the propensity score could vary over the strata. Thus, all strata were limited to a set number of observations, which was determined from the median of the number of observations in each stratum. The observations associated with propensity scores far from the case were dropped if the number of observations in a particular stratum were above the median observations of all the strata. These strata were considered the reduced data set for these analyses.

Conditional logistic regression analysis was run separately on each of the 19 hospitals. For comparison purposes, we individually ran logistic regression on these same 19 hospitals using our original propensity score and again with our expanded propensity score. These regression models contained the same 3 main effects of CCM, expanded SAPS II, and propensity score. Table 12 compares the odds ratios using logistic regression and the original propensity score, logistic regression and the expanded propensity score, conditional logistic regression on the reduced data set, and conditional logistic regression on the full data set. When the original propensity score was used in a logistic regression model, 15 of 19 have an odds ratio greater than 1.0, and of these, 9 are statistically significant. When the expanded propensity score was used in a logistic regression model, 16 of 19 have an odds ratio greater than 1.0, and of these, 8 are statistically significant. When conditional logistic regression was run that matched on propensity score and when controls that did not have a comparable propensity score were removed (reduced data set), 18 of 19 had an odds ratio greater than 1.0 and of these 9 are statistically significant. When conditional logistic regression was run that matched on propensity score (full data set), 18 of 19 had an odds ratio greater than 1.0, and of these, 9 were statistically significant.

Expanded strata containing cases and controls were developed when the all of the propensity scores from the 19 hospitals were combined using the reduced data set. The conditional logistic regression mortality odds ratio for CCM versus no CCM was 2.16 ($P < 0.001$); however, there was a statistically significant interaction between CCM and SAPS II ($P = 0.006$). Consequently, the same analysis was run over the 4 quartiles of SAPS II by using expanded strata developed of each quartile. Table 13 shows the results. All 4 odds ratios are greater than 1.0; however, only the quartiles 3 and 4 are statistically significant. For comparison purposes, Table 14 shows the same 19 hospitals by using random-effects logistic regression and the original propensity score over the 4 quartiles of SAPS II. The results are almost identical to those in Table 13. When the same conditional logistic regression is run using the full data set, the results (shown in Table 15) are again similar to the reduced data set analysis and the random-effects logistic regression analysis using the original propensity score.

Analysis of the Entire Data Set using the Expanded Propensity Score

We ran the entire data set (101 832 patients) using random-effects logistic regression with a propensity score developed using the expanded list of patient-level variables and hospital-level variables (Table 11) in order to compare this analysis to the manuscript results (Table 5 in the manuscript). Table 16 shows the same random-effects logistic regression mortality odds ratios for CCM versus no CCM, stratified by quartiles of propensity score. There was a statistically significant interaction between CCM and the propensity score, whereas there was not a statistically significant interaction between CCM and expanded SAPS II, unlike the manuscript results. Consequently, the analyses are run over quartiles of propensity score adjusted for expanded SAPS II. The propensity score includes both patient-level variables and hospital-level variables. The odds ratio is the highest for those patients with the lowest propensity to receive CCM. The odds ratio then decreases as propensity quartile increases. The odds ratio for the highest quartile of propensity score is not statistically different from 1.0. These results are similar to the results in the manuscript, with the exception that now there is not a statistically significant interaction between CCM and SAPS II. Thus, only 4 odds ratios compared with 16 in the manuscript exist.

Project IMPACT Hospital Sample

The hospitals in the PI database include academic (university affiliated) as well as for profit and not for profit, community hospitals. We therefore compare our hospital sample with these types of hospitals in the American Hospital Association (AHA) (Table 17). Hospitals in the Project IMPACT database are disproportionately larger and represent more community nonprofit hospitals but have a similar geographic distribution to AHA hospitals.

References

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3. **Rosenbaum PR, Rubin DB.** Assessing sensitivity to an unobserved binary covariate in an observational study with binary outcome. *J R Stat Soc [Ser B]* 1983;45:212-218.
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Table 1. Expected and Actual Hospital Mortality, by ICU and CCM*

Patient Variable†	Intensive Care Unit Type					
	CCM‡			No CCM‡		
	≥95%	5%–95%	≤5%	≥95%	5%–95%	≤5%
Patients, n§	18 601	23 324	261	17	37 020	22 609
Mean SAPS II probability	0.2378	0.2473	0.2301	0.0827	0.1599	0.1951
Mean mortality Rate	0.1800	0.1884	0.1801	0.0588	0.1004	0.1244
SMR (95% CI)	0.76 (0.73–0.78)	0.76 (0.74–0.78)	0.78 (0.57–1.04)	0.71 (0.02–3.96)	0.63 (0.61–0.65)	0.64 (0.61–0.66)

* This table is recreated from Table 4 in the manuscript using the original SAPS II. CCM = critical care management; ICU = intensive care unit; SAPS II = Simplified Acute Physiology Score; SMR = standardized mortality ratio.

† CCM is a patient-level variable that indicates whether or not the patient was managed by a critical care physician for the entire stay.

‡ For the entire stay for patients in the intensive care unit.

§ ICU CCM type is a categorical level ICU variable that represents the percentage of patients managed by critical care physicians.

Table 2. Propensity Score Variables Balanced Across Quartiles of the Propensity Score*

Variable	Quartiles of Propensity Score Across CCM											
	First			Second			Third			Fourth		
	No CCM	CCM	P Value	No CCM	CCM	P Value	No CCM	CCM	P Value	No CCM	CCM	P Value
Mean age	67.6	65.4	<0.001	59.9	61.5	<0.001	59.1	59.9	0.001	57.4	56.1	<0.001
Mean GCS	13.8	13.4	<0.001	13.7	13.3	<0.001	12.9	12.6	<0.001	11.5	11.2	<0.001
Mean licensed hospital beds	323.5	297.4	<0.001	429.2	429.9	0.79	577.1	578.3	0.70	631	687.5	<0.001
Commercial or Medicaid, %	28.5	31.7		43.7	35.8		40.1	39.1		39.6	44.9	
Medicare, %	68.6	64.5	<0.001	49.1	53.8	<0.001	49.7	51.5	0.016	46.7	42.4	<0.001
Self pay, %	2.9	3.8		7.3	10.4		10.3	9.3		13.7	12.7	
Ventilation at admission, %	0.9	0.6	0.055	4.9	4.4	0.198	20.6	22.7	<0.001	65.2	74.0	<0.001
Tracheostomy at admission, %	1.1	0.8	0.076	5.4	5.7	0.49	22.2	24.1	0.002	66.2	74.7	<0.001
Gastrointestinal bleed, %	11.4	8.5	<0.001	4.4	5.6	<0.001	2.7	3.3	0.014	2.1	1.2	<0.001
Noninvasive ventilation at admission, %	0.3	0.3	0.31	0.7	1.0	0.056	2.8	2.8	0.87	4.0	3.5	0.050
Cerebrovascular incident, %	8.0	6.5	0.001	3.6	4.9	<0.001	3.0	3.5	0.076	1.9	1.5	0.102
Chronic immunosuppression, %	1.8	2.5	0.005	4.2	4.4	0.59	5.1	5.1	0.94	6.5	6.2	0.43
Chronic respiratory, %	1.8	2.7	<0.001	4.3	7.8	<0.001	7.7	9.3	<0.001	18.7	14.7	<0.001
Acute renal failure, %	3.3	5.5	<0.001	5.4	6.9	<0.001	7.5	7.9	0.39	10.7	8.5	<0.001
Rural hospital, %	35.9	29.4		6.6	6.7		7.5	6.7		1.7	1.3	
Suburban hospital, %	37.5	33.4	<0.001	48.1	45.8	0.017	27.6	30.1	<0.001	25.4	30.0	<0.001
Urban hospital, %	26.7	37.2		45.3	47.5		64.9	63.2		72.9	68.8	
Continuous sedation, %	1.1	2.3	<0.001	4.4	6.7	<0.001	11.8	14.1	<0.001	32.5	32.4	0.87
Emergency department, %	45.4	52.3		47.9	48.8		41.4	41.3		43.2	38.6	
Another hospital, %	7.1	6.8	<0.001	4.8	5.4	<0.001	4.8	4.3	0.050	4.1	4.2	<0.001
Invasive procedure, %	41.8	30.9		32.2	26.1		27.5	29.0		26.3	35.7	
Other non-ICU, %	5.7	10.1		15.1	19.7		26.4	25.4		26.4	21.5	

* CCM = critical care management; GCS = Glasgow Coma Score; ICU = intensive care unit.

Table 3. Random-Effects Logistic Regression Mortality Odds Ratio, Stratified by SAPS II and Propensity Score

Quartile of SAPS II Probability [†]	Quartile of Propensity Score [‡]	No CCM Count	CCM Count	CCM Odds Ratio (95% CI) [§]	<i>P</i> Value	ρ
1	1	6011	1,200	2.78 (1.29–5.76)	0.0130	0.098
1	2	5974	2013	1.66 (0.89–3.00)	0.1099	0.035
1	3	3664	2586	1.35 (0.78–2.38)	0.2979	0.013
1	4	1224	3005	1.11 (0.48–1.89)	0.7831	0.166
2	1	6335	1428	2.03 (1.41–2.74)	0.0001	0.046
2	2	4749	1989	1.70 (1.25–2.26)	0.0008	0.017
2	3	3189	2576	1.24 (0.93–1.64)	0.1573	0.030
2	4	1580	3671	0.89 (0.65–1.15)	0.4860	0.051
3	1	5135	1457	2.13 (1.51–2.26)	<0.0001	0.059
3	2	4078	1876	1.62 (1.30–1.89)	<0.0001	0.013
3	3	3320	2967	1.52 (1.26–1.75)	<0.0001	0.030
3	4	2147	4342	1.21 (0.90–1.24)	0.0460	0.046
4	1	2874	1201	1.52 (1.15–1.56)	<0.0001	0.054
4	2	2770	1959	1.41 (1.25–1.62)	0.0001	0.043
4	3	3487	3621	1.33 (1.21–1.49)	<0.0001	0.040
4	4	3109	6295	1.29 (1.11–1.34)	0.0001	0.072

* This table is recreated from Table 5 in the manuscript using additional covariates. CCM = critical care management; ICU = intensive care unit; SAPS II = Simplified Acute Physiology Score.

[†] Quartile 1 includes the lowest SAPS II probabilities of death, whereas quartile 4 includes the highest probabilities.

[‡] Quartile 1 is the lowest propensity of being seen by a critical care physician, whereas quartile 4 is the highest propensity.

[§] Random-effects logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality, propensity to see a critical care physician, age, Glasgow Coma Score, gastrointestinal bleed (yes/no), noninvasive ventilation (yes/no), cerebrovascular incident (yes/no), chronic immunosuppression (yes/no), acute renal failure (yes/no), and origin (emergency department, another hospital, invasive procedure, other non-ICU).

^{||} ρ is the ratio of the between ICU variance to the total variance. Zero indicates that all the variability is within the ICU, and 1.0 indicates that all the variability is between ICU.

Table 4. Subgroup Analysis: Random-Effects Logistic Regression Odds Ratio

Group	Quartile of Propensity Score or SAPS II Probability^{†,‡}	No CCM	CCM	CCM Odds Ratio (95% CI)[§]	P Value
Respiratory diagnosis and ventilator in place at ICU admission	–	3075	4822	1.19 (0.99–1.43)	0.061
Respiratory diagnosis and no ventilator in place at ICU admission	–	7363	7074	1.12 (0.98–1.27)	0.088
Ventilator in place at ICU admission	–	9121	14 581	1.29 (1.15–1.44)	<0.001
Circulatory diagnosis	–	17 035	8572	1.48 (1.30–1.69)	<0.001
Infection diagnosis	–	3258	3351	1.13 (0.97–1.33)	0.127
"No choice" group of ICUs	–	22 624	18 862	1.56 (1.29–1.89)	<0.001
Patients not transferred from another hospital¶					
	1	19 146	4779	1.71 (1.46–2.00)	<0.001
	2	16 690	7235	1.50 (1.31–1.71)	<0.001
	3	12 896	11 026	1.32 (1.18–1.47)	<0.001
	4	7643	16 281	1.27 (1.14–1.41)	<0.001
Diagnosis other than respiratory and no ventilator in place at ICU admission**					
	1	11 326	4617	2.11 (1.21–3.68)	0.008
	2	11 365	4552	1.89 (1.40–2.56)	<0.001
	3	11 026	4884	1.90 (1.58–2.27)	<0.001
	4	9444	6478	1.50 (1.35–1.66)	<0.001
≥1 ICU procedures¶¶					
	1	12 180	4131	1.63 (1.38–1.92)	<0.001
	2	9510	6800	1.16 (1.02–1.31)	0.022
	3	7087	9222	1.32 (1.17–1.48)	<0.001
	4	4384	11 926	1.18 (1.03–1.35)	0.015
No ICU procedures**					
	1	6506	2647	2.05 (0.77–5.47)	0.150
	2	6714	2445	1.44 (0.87–2.39)	0.161
	3	6692	2440	1.27 (0.94–1.73)	0.122
	4	6572	2575	1.33 (1.12–1.58)	0.001

* This table is recreated from Table 6 in the manuscript using additional covariates. CCM = critical care management; ICU = intensive care unit; SAPS II = Simplified Acute Physiology Score.

[†] Quartile 1 is the lowest propensity of being seen by a critical care doctor, whereas quartile 4 is the highest propensity.

[‡] Quartile 1 includes the lowest SAPS II probabilities of mortality, whereas quartile 4 includes the highest probabilities.

[§] Random-effects logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality, propensity to see a critical care physician, age, Glasgow Coma Score, gastrointestinal bleed (yes/no), noninvasive ventilation (yes/no), cerebrovascular

Table 5. Random-Effects Logistic Regression Odds Ratio for Mortality, Stratified by SAPS II and Propensity Score*

Quartile of SAPS II Probability†	Quartile of Propensity Score‡	No CCM Count	CCM Count	CCM Odds Ratio (95% CI)§	P Value	ρ
1	1	6011	1200	2.41 (0.94–6.20)	0.068	0.05
1	2	5974	2013	1.80 (0.92–3.52)	0.086	0.03
1	3	3664	2586	1.35 (0.73–2.49)	0.34	<0.01
1	4	1224	3005	1.36 (0.64–2.90)	0.43	0.13
2	1	6335	1428	2.28 (1.55–3.35)	<0.001	0.04
2	2	4749	1989	1.76 (1.27–2.44)	0.001	0.01
2	3	3189	2576	1.21 (0.87–1.67)	0.25	0.03
2	4	1580	3671	0.88 (0.64–1.21)	0.43	0.05
3	1	5135	1457	2.32 (1.81–2.97)	<0.001	0.05
3	2	4078	1876	1.77 (1.41–2.22)	<0.001	0.04
3	3	3320	2967	1.46 (1.20–1.77)	<0.001	0.03
3	4	2147	4342	1.17 (0.97–1.41)	0.098	0.05
4	1	2874	1201	1.47 (1.21–1.77)	<0.001	0.04
4	2	2770	1959	1.36 (1.15–1.59)	<0.001	0.04
4	3	3487	3621	1.32 (1.17–1.51)	<0.001	0.03
4	4	3109	6295	1.17 (1.04–1.31)	0.008	0.03

* This table is recreated from Table 5 in the manuscript using additional variables: primary medical school, ICU type, and nursing policy in the propensity score. CCM = critical care management; ICU = intensive care unit; SAPS II = Simplified Acute Physiology Score.

† Quartile 1 includes the lowest SAPS II probabilities of death, whereas quartile 4 includes the highest probabilities.

‡ Quartile 1 is the lowest propensity of being seen by a critical care physician, whereas quartile 4 is the highest propensity.

§ Random-effects logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality and propensity to see a critical care physician.

|| ρ is the ratio of the between ICU variance to the total variance. Zero indicates that all the variability is within the ICU, and 1.0 indicates that all the variability is between ICU.

Table 6. Sensitivity of the Mortality Odds Ratio when the 4 Most Influential Covariates are Removed from the Propensity Score*

Quartile of SAPS II Probability†	Quartile of Propensity Score‡	Mortality Odds Ratio for CCM Versus No CCM§				
		Manuscript Table	No Noninvasive Ventilation	No Ventilator in Place	No Tracheostomy in Place	No Hospital Classification
1	1	2.83	2.68	2.90	3.04	2.31
1	2	1.98	1.80	1.81	1.70	1.54
1	3	1.45	1.02	0.89	0.93	1.27
1	4	1.11	0.84	0.84	0.97	0.8
2	1	2.12	1.65	1.67	1.69	1.56
2	2	1.88	1.84	1.88	1.80	1.76
2	3	1.25	1.15	1.11	1.06	1.22
2	4	0.86	1.04	1.03	1.06	1.00
3	1	2.26	2.37	2.41	2.28	2.25
3	2	1.76	1.82	1.81	1.89	1.89
3	3	1.50	1.52	1.47	1.47	1.42
3	4	1.19	1.17	1.15	1.14	1.15
4	1	1.53	1.46	1.43	1.51	1.48
4	2	1.36	1.36	1.35	1.33	1.29
4	3	1.36	1.21	1.26	1.19	1.18
4	4	1.18	1.17	1.13	1.17	1.17
Weighted average		1.64	1.55	1.55	1.55	1.49

* CCM = critical care management; SAPS II = Simplified Acute Physiology Score.

† Quartile 1 includes the lowest SAPS II probabilities of death, whereas quartile 4 includes the highest probabilities.

‡ Quartile 1 is the lowest propensity of being seen by a critical care physician, whereas quartile 4 is the highest propensity.

§ Random-effects logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality and propensity to see a critical care physician.

Table 7. Regular Logistic Regression Odds Ratio, Stratified by SAPS II and Propensity Score*

Quartile of SAPS II Probability†	Quartile of Propensity Score‡	No CCM Count	CCM Count	CCM Odds Ratio (95% CI)§	P Value
1	1	6011	1200	2.77 (1.32–5.80)	0.007
1	2	5974	2013	2.02 (1.13–3.63)	0.018
1	3	3664	2586	1.48 (0.86–2.54)	0.158
1	4	1224	3005	0.84 (0.43–1.64)	0.62
2	1	6335	1428	2.05 (1.48–2.85)	<0.001
2	2	4749	1989	1.87 (1.40–2.50)	<0.001
2	3	3189	2576	1.24 (0.94–1.63)	0.133
2	4	1580	3671	0.79 (0.60–1.05)	0.104
3	1	5135	1457	1.92 (1.58–2.33)	<0.001
3	2	4078	1876	1.64 (1.37–1.97)	<0.001
3	3	3320	2967	1.38 (1.18–1.62)	<0.001
3	4	2147	4342	1.04 (0.89–1.21)	0.63
4	1	2874	1201	1.37 (1.19–1.57)	<0.001
4	2	2770	1959	1.39 (1.24–1.57)	<0.001
4	3	3487	3621	1.25 (1.14–1.38)	<0.001
4	4	3109	6295	1.13 (1.03–1.23)	0.007

* This table is recreated from Table 5 in the manuscript using logistic regression. CCM = critical care management; SAPS II = Simplified Acute Physiology Score.

† Quartile 1 includes the lowest SAPS II probabilities of death, whereas quartile 4 includes the highest probabilities.

‡ Quartile 1 is the lowest propensity of being seen by a critical care physician, whereas quartile 4 is the highest propensity.

§ Random-effects logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality and propensity to see a critical care physician.

Table 6. Subgroup Analysis: Random-Effects Logistic Regression Odds Ratios*

Group	Quartile of Propensity score or SAPS II Probability†, ‡	No CCM	CCM	CCM Odds Ratio (95% CI)§	P Value
Respiratory diagnosis and ventilation at ICU admission	–	3075	4822	1.26 (1.10–1.44)	0.001
Respiratory diagnosis and no ventilation at ICU admission	–	7363	7074	1.05 (0.95–1.16)	0.39
Ventilation at ICU admission	–	9121	14 581	1.35 (1.25–1.45)	<0.001
Circulatory diagnosis	–	17 035	8572	1.47 (1.32–1.63)	<0.001
Infection diagnosis	–	3258	3351	1.15 (1.02–1.31)	0.029
"No-choice" group of ICUs	–	22 624	18 862	1.37 (1.28–1.46)	<0.001
Patients not transferred from another hospital¶					
	1	19 146	4779	1.48 (1.32–1.67)	<0.001
	2	16 690	7235	1.47 (1.32–1.67)	<0.001
	3	12 896	11 026	1.24 (1.14–1.35)	<0.001
	4	7643	16 281	1.14 (1.05–1.24)	0.001
Diagnosis other than respiratory and no ventilation at ICU admission**					
	1	11 326	4617	2.10 (1.29–3.43)	0.003
	2	11 365	4552	1.90 (1.45–2.49)	<0.001
	3	11 026	4884	1.89 (1.62–2.20)	<0.001
	4	9444	6478	1.43 (1.33–1.54)	<0.001
≥1 ICU procedures¶					
	1	12 180	4131	1.48 (1.32–1.66)	<0.001
	2	9510	6800	1.18 (1.08–1.30)	<0.001
	3	7087	9222	1.26 (1.16–1.38)	<0.001
	4	4384	11 926	1.13 (1.02–1.24)	0.017
No ICU procedures**					
	1	6506	2647	2.11 (0.80–5.551)	0.129
	2	6714	2445	1.47 (0.90–2.40)	0.121
	3	6692	2440	1.26 (0.95–1.66)	0.103
	4	6572	2575	1.15 (1.01–1.31)	0.040

* This table is recreated from Table 6 in the manuscript using logistic regression. CCM = critical care management; ICU = intensive care unit; SAPS II = Simplified Acute Physiology Score.

† Quartile 1 is the lowest propensity of being seen by a critical care doctor, whereas quartile 4 is the highest propensity.

‡ Quartile 1 includes the lowest SAPS II probabilities of mortality, whereas quartile 4 includes the highest probabilities.

§ Logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality and propensity to see a critical care physician.

|| No choice is defined an ICU that manages ≥95% of its patients by a critical care physician or an ICU that manages ≤5% of its patients by a critical care physician.

¶ Statistically significant interactions between propensity score and CCM variable; thus, analysis is run individually over the propensity score quartiles.

** Statistically significant interactions between SAPS II probability of mortality and CCM variable; thus, analysis is run individually over the SAPS II probability quartiles.

Table 9. Intensive Care Units that Treat 5% to 95% of their patients with Critical Care Management*

Probability†	Propensity‡	No CCM	CCM	Odds Ratio (95% CI)§	P Value	ρ
1	1	3106	817	3.18 (0.97–10.45)	0.057	0.000
1	2	3771	1364	1.55 (0.71–3.41)	0.270	0.030
1	3	3035	1326	1.71 (0.81–3.60)	0.160	0.041
1	4	1081	1152	1.24 (0.54–2.84)	0.607	0.145
2	1	3346	967	2.34 (1.52–3.59)	0.000	0.025
2	2	3064	1326	1.87 (1.27–2.75)	0.002	0.021
2	3	2449	1283	1.31 (0.89–1.93)	0.173	0.068
2	4	1265	1717	0.86 (0.59–1.23)	0.404	0.102
3	1	2709	990	2.51 (1.92–3.28)	0.000	0.046
3	2	2480	1232	1.74 (1.36–2.23)	0.000	0.038
3	3	2318	1629	1.62 (1.30–2.03)	0.000	0.042
3	4	1625	2110	1.19 (0.97–1.46)	0.088	0.051
4	1	1242	814	1.54 (1.26–1.89)	0.000	0.042
4	2	1298	1208	1.35 (1.13–1.61)	0.001	0.041
4	3	2022	2195	1.40 (1.21–1.61)	0.000	0.041
4	4	2209	3194	1.11 (0.98–1.26)	0.113	0.045

* We used our original propensity score as a covariate in the model for only those who have a choice. CCM = critical care management; SAPS II = Simplified Acute Physiology Score.

† Quartile 1 includes the lowest SAPS II probabilities of death, whereas quartile 4 includes the highest probabilities.

‡ Quartile 1 is the lowest propensity of being seen by a critical care physician, whereas quartile 4 is the highest propensity.

§ Random-effects logistic regression results, in which outcome is hospital mortality, adjusted for SAPS II probability of mortality and propensity to see a critical care physician.

|| ρ is the ratio of the between ICU variance to the total variance. Zero indicates that all the variability is within the ICU, and 1.0 indicates that all the variability is between ICU.

Table 10. Comparison of Mortality Odds Ratio for Critical Care Management Versus No Critical Care Management, by Different Regression Techniques*

Model (<i>n</i> = 101 832)	Mortality Odds Ratio (95% CI)†	<i>P</i> Value
Logistic regression	1.34 (1.28–1.40)	<0.001
Random-effects Logistic Regression‡, §	1.42 (1.34–1.51)	<0.001
Between-effects logistic regression§	1.32 (1.25–1.39)	<0.001
Fixed-effects logistic regression§, 	1.44 (1.29–1.62)	<0.001

* CCM = critical care management; ICU = intensive care unit; OR = odds ratio; SAPS II = Simplified Acute Physiology Score.

† Mortality OR is for CCM vs. no CCM and is adjusted for current propensity score and expanded SAPS II. No interaction terms with CCM in these models exist.

‡ Between hospital error variance is 0.13, and the within hospital error variance is 3.29. This produces a ρ equal to 0.04, which is equal to the between hospital variance to the total variance.

§ The stratification variable is the 123 hospitals to ICUs.

|| The fixed-effects logistic regression would not converge due to an overflow error in the maximum likelihood estimation by using the entire sample of 101 832; thus, we took a random sample of 1 to 3 of the observations by hospital to ICU and used 33 582 participants.

Table 11. Variables in the Expanded Propensity Score*

Number	Variables
1	Age
2	Chronic gastrointestinal Chronic cardiovascular Chronic respiratory Chronic renal
3	Chronic use of Immunosuppressive Drugs Chronic HIV
4	Active cancer within 5 y
5	Gender
6	Race White Black Other/unknown
7	Insurance Commercial/managed care Medicaid Medicare Self pay
8	Invasive monitoring in place at ICU admission
9	Acute renal failure
10	Continuous sedation
11	Coma or deep stupor
12	Gastrointestinal bleed
13	Noninvasive respiratory support (BiPAP/CPAP) in place at ICU admission
14	Full code
15	Glasgow Coma Score 3–5 6–9 10–12 13–15
16	Nutritional support in place at ICU admission
17	Surgery before ICU admission
18	Mechanical ventilator in place at ICU admission + previous positive pressure ventilation
19	Thoracostomy in place at ICU admission
20	Tracheal airway in place at ICU admission
21	Arterial lines in place at ICU admission
22	Central venous line in place at ICU admission
23	Pulmonary artery catheter in place at ICU admission
24	Heart rate >150 at ICU admission
25	Systolic blood pressure <90 at ICU admission
26	Number of licensed hospital beds
27	Primary medical school
28	Hospital region Central Mid and South Atlantic New England West & Mountain
29	Hospital classification Urban Suburban Rural
30	Hospital organization Academic Community, not for profit, nonacademic Community, for profit, nonacademic
31	Location before ICU Emergency department Another hospital Invasive procedure Other non-ICU unit
32	ICU type Combined medical – surgical or other ICU Medical ICU only Surgical trauma ICU
33	Nurse policy RN or LPN RN only RN with CCRN
34	Nurse to ratio 1:1 1:2 1:3 Other

* BiPAP = Bilevel positive airway pressure; CCRN = Critical Care Nurse; CPAP = continuous positive airway pressure; ICU = intensive care unit; LPN = licensed practical nurse; RN = registered professional nurse.

Table 12. Mortality Odds Ratio for Critical Care Management Versus No Critical Care Management Comparing the Expanded Propensity Score Versus the Old Propensity Score for the Largest 19 Hospitals*

Hospital	Original Propensity Score†		Expanded Propensity Score‡		Reduced Data Set§		Full Data Set	
	OR	P Value	OR	P Value	OR	P Value	OR	P Value
1	3.04	<0.001	2.64	<0.001	2.33	0.001	2.35	0.001
2	1.62	0.143	1.45	0.261	1.40	0.391	1.26	0.522
3	0.96	0.879	0.95	0.872	1.04	0.921	1.04	0.921
4	0.95	0.812	0.90	0.597	1.06	0.810	1.06	0.803
5	1.45	0.001	1.49	0.002	1.61	0.003	1.60	0.003
6	1.08	0.535	1.03	0.796	1.15	0.340	1.17	0.292
7	1.64	0.089	1.73	0.067	1.87	0.057	1.92	0.046
8	2.28	<0.001	1.93	0.004	2.00	0.008	1.92	0.011
9	1.35	0.203	1.37	0.208	1.35	0.289	1.35	0.294
10	1.27	0.216	1.13	0.537	1.01	0.968	1.00	0.999
11	1.64	0.015	1.52	0.043	1.71	0.020	1.76	0.016
12	1.48	0.047	1.19	0.383	1.21	0.405	1.16	0.524
13	2.27	0.001	2.07	0.004	2.44	0.002	2.49	0.002
14	3.74	<0.001	3.15	<0.001	3.39	<0.001	2.96	0.001
15	2.42	0.001	3.28	0.001	3.89	0.002	3.89	0.002
16	2.26	<0.001	1.94	<0.001	1.71	0.006	1.71	0.006
17	0.84	0.195	0.94	0.672	0.96	0.782	0.95	0.722
18	0.99	0.939	1.03	0.874	1.25	0.280	1.25	0.280
19	1.40	0.124	1.26	0.310	1.32	0.256	1.31	0.271

* SAPS II = Simplified Acute Physiology Score.

† Logistic regression with CCM, expanded SAPS II, and the old propensity score as main effects.

‡ Logistic regression with CCM, expanded SAPS II, and the expanded propensity score as main effects.

§ Conditional logistic regression matching cases (hospital death) and controls (hospital survival) on the expanded propensity score and eliminating controls that do not have a comparable expanded propensity score with that of the case (reduced data set).

|| Conditional logistic regression matching cases (hospital death) and controls (hospital survival) on the expanded propensity score (full data set).

Table 13. Reduced Data Set Conditional Logistic Regression by using the Original Propensity Score and Combining all 19 Hospitals over Quartiles of Expanded SAPS II*

Quartile of SAPS II	Dropped Due to Unmatched Propensity Score	Observations in Model	Odds Ratio	P Value
1	4099	2690	1.38	0.345
2	4007	3948	1.24	0.159
3	3970	4194	1.62	<0.001
4	2859	4222	1.28	0.005
Total	14 935	15 054†	–	–

* SAPS II = Simplified Acute Physiology Score.

† Reduced data set used in the analysis.

Table 14. Random-Effects Logistic Regression using the Current Propensity Score and Combining all 19 Hospitals over Quartiles of Expanded SAPS II*

Quartile of SAPS II	Observations in model	Odds Ratio	P Value
1	8244	1.63	0.096
2	8251	1.23	0.128
3	8288	1.70	<0.001
4	8293	1.33	<0.001
Total	33 076	–	–

* SAPS II = Simplified Acute Physiology Score.

Table 15. Full Data Set Conditional Logistic Regression using the Original Propensity Score and Combining all 19 Hospitals over Quartiles of Expanded SAPS II*

Quartile of SAPS II	Observations in Model	Odds Ratio	P Value
1	4465	1.32	0.417
2	7247	1.15	0.370
3	7893	1.54	<0.001
4	8203	1.23	0.002
Total	27 808†	–	–

* SAPS II = Simplified Acute Physiology Score.

† Full data set used in the analysis.

Table 16. Random-Effects Logistic Regression Mortality Odds Ratio Stratified By Propensity Score*

Propensity Quartile†	No CCM Count	CCM Count	Mortality Odds Ratio (95% CI)‡	P Value	ρ§
1	21 416	4044	1.92 (1.63–2.26)	<0.001	0.12
2	19 152	6304	1.56 (1.39–1.75)	<0.001	0.15
3	14 132	11 326	1.39 (1.28–1.52)	<0.001	0.17
4	4946	20 152	1.09 (0.98–1.21)	0.123	0.092

* CCM = critical care management; ICU = intensive care unit.

† Quartile 1 is the lowest propensity of being seen by a critical care physician, whereas quartile 4 is the highest propensity.

‡ Random-effects logistic regression results, in which outcome is hospital mortality and adjusted for SAPS II probability of mortality.

§ ρ = is the ratio of the between ICU variance to the total variance. Zero indicates that all the variability is within the ICU, and 1.0 indicates that all the variability is between ICU.

Table 17. Comparison of Project Impact and AHA Hospitals*

Variable	Project Impact Hospitals	AHA Hospitals 2002
<i>n, %</i>	100 (100)	5949 (100)
Hospital beds, %		
50–99	1	1372 (23)
100–199	6	1396 (23)
200–299	17	717 (12)
300–399	23	409 (7)
400–499	15	201 (3)
≥500	38	324 (5)
Urban, %	47	3571 (60)
Academic hospital, %	13	364 (6)
Community not for profit, %	81	2730 (46)
Community for profit, %	6	838 (14)
Geographic region		
Central	52	3034 (51)
Mid and South Atlantic	24	1540 (26)
New England	12	269 (5)
West and Mountain	12	1106 (19)

* AHA = American Hospital Association. The source of the AHA data is the FY2002 AHA Annual Survey Database. (Chicago: Health Forum, an American Hospital Association affiliate, 2003. Compiled by AHA Resource Center on 12 December 2007). The PI database does not include any City or County, State, Veterans Administration, Military, or other Federal Government hospitals.