Power and limitations of daily prognostications of death in the medical intensive care unit

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Objective: **We tested the accuracy of predictions of impending death for medical intensive care unit patients, offered daily by their professional medical caretakers.**

Design: **For 560 medical intensive care unit patients, on each medical intensive care unit day, we asked their attending physicians, fellows, residents, and registered nurses one question: "Do you think this patient will die in the hospital or survive to be discharged?"**

Results: **We obtained >6,000 predictions on 2018 medical intensive care unit patient days. Seventy-five percent of MICU patients who stayed ≥4 days had discordant predictions; that is, at least one caretaker predicted survival, whereas others predicted death before discharge. Only 107 of 206 (52%) patients with a prediction of "death before discharge" actually died in hospital. This number rose to 66% (96 of 145) for patients with 1 day of corroborated (i.e., >1) prediction of "death," and to 84% (79 of 94) with at least 1 unanimous day of predictions of death. However, although positive predictive value rose with increasingly stringent prediction criteria, sensitivity fell so that the area under the receiver-operator characteristic curve did not differ for single, corroborated, or unanimous predictions of death. Subsets of older (>65 yrs) and ventilated medical intensive care unit patients revealed parallel findings.**

Conclusions: **1) Roughly half of all medical intensive care unit patients predicted to die in hospital survived to discharge nonetheless. 2) More highly corroborated predictions had better predictive value; although, approximately 15% of patients survived unexpectedly, even when predicted to die by all medical caretakers. (Crit Care Med 2011; 39:000–000)**

KEY WORDS: prognostication; medical intensive care unit; clinical predictions; medical intensive care unit survival

Sick adults may require expensive and scarce resources, and at least some patients have a poor prognosis for survival if they require intensive care. Thus, proposals for rationing often target these patients (1–4). However, although sick adult patients clearly require costly medical care, it is well recognized that population-based tools (Acute Physiology and Chronic Health Evaluation or one of its iterations) (5–10) have proven imperfect at conveying the prognostic subtlety that personalized one-to-one patient care would ideally reflect.

Consequently, other studies have attempted to assess individualized clinical predictions of survival for MICU patients (11–14). Most prognostic efforts have obtained assessments at a single point, admission to the MICU. Consequently, many of these assessments have omitted one crucial dimension of ICU care: Time. Most patients are admitted to an MICU for a trial of therapy, tacitly or explicitly agreed to by both the physician caretakers and patients or their surrogates. After a relatively brief period of intensive care, it is expected that patients will "declare themselves"—a metaphor for the purported increase in accuracy of prognostic estimates as a function of length of MICU stay. On this view, the ethical appropriateness of continuing MICU support would be revisited periodically, illuminated ever more brightly by ongoing revision of increasingly accurate prognostications.

Unfortunately, few studies have looked longitudinally at individual MICU patients, assessing prospectively their subsequent likelihood of dying and the power of various purported prognostic indices over time (15–17). We hypothesized that the subset of adult MICU patients who were most likely to die would declare themselves, separating prognostically from their surviving confreres with every passing day. Specifically we hypothesized that serial predictions, obtained daily from clinical caretakers (attending physicians, fellows, residents, and registered nurses) would be highly effective in distinguishing patients who would survive to discharge from those who would die in hospital.

METHODS

Patient Population. We identified 603 adult patients consecutively admitted to the medical intensive care unit (MICU) at a large urban teaching hospital (the University of Chicago Hospitals) for 7 months. No postoperative surgical patients were admitted to this unit. For each patient, we determined the following items: Age, gender, diagnosis, date and time of hospital admission, date and time of MICU admission, date of MICU and hospital discharge (for survivors), and date and time of death in hospital (for nonsurvivors). In addition, we attempted to extend the interpretation of our analyses by repeating them on two subsets of MICU patients: 1) Patients with respiratory failure severe enough to require mechanical ventilation (n = 193) and 2) patients >65 yrs old (n = 186).

Predictions Protocol. For 560 of 603 patients, on each day that each patient was in the MICU, we asked one question of the patient's nurse, resident, fellow, and attending physician: "Do you think this patient is going to die in the hospital or survive to hospital dis-

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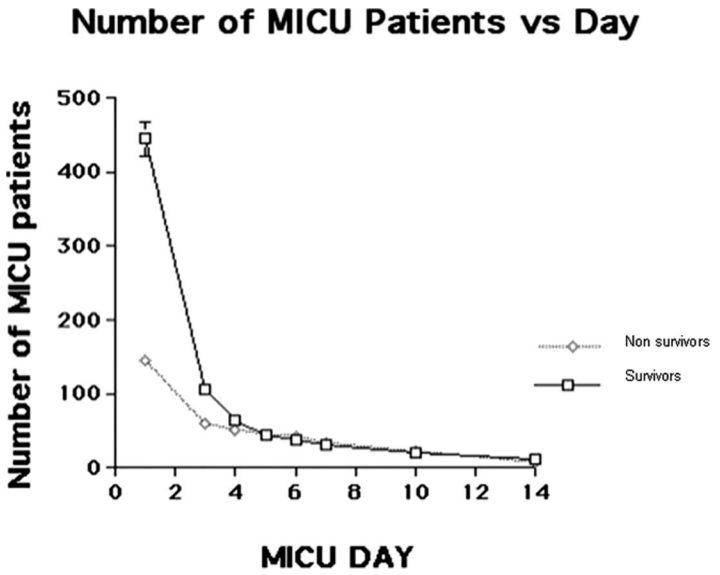

Figure 1. Medical intensive care unit (*MICU*) population as a function of length of MICU stay. Only 20% (116 of 590) of patients remained in the MICU by day 4, and proportionally more survivors than nonsurvivors were discharged in the first 72 hrs.

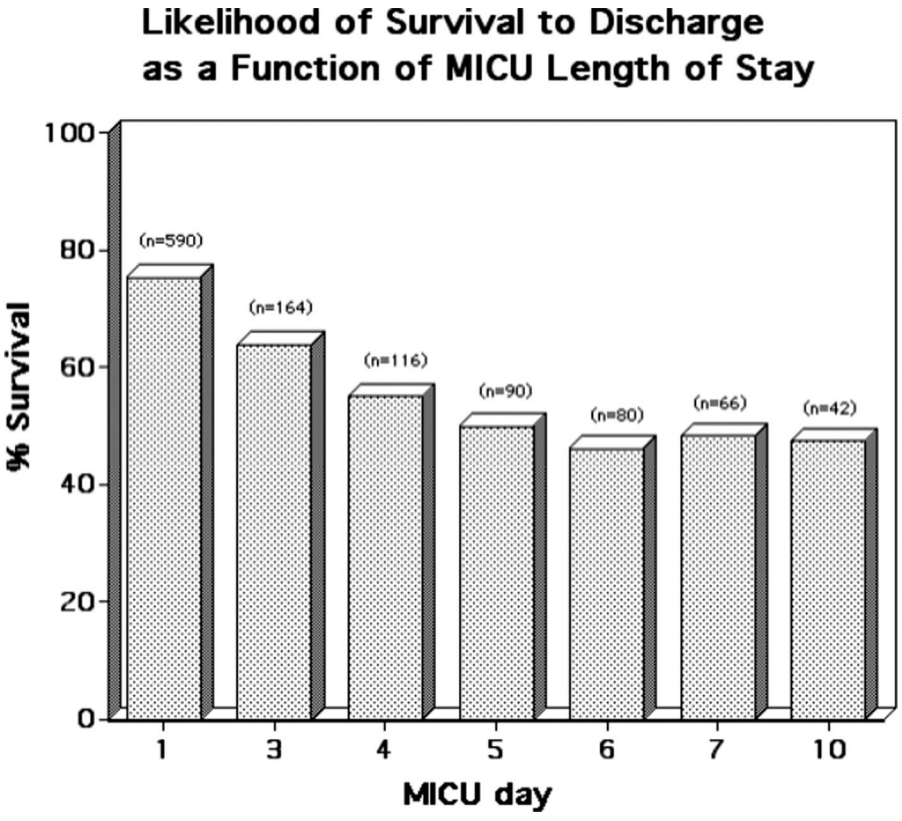

Figure 2. Likelihood of survival as a function of the length of medical intensive care unit (*MICU*) stay. The percentage of MICU patients who would ultimately survive to discharge fell steadily and significantly from the day of MICU admission.

charge?" Forty-three patients died or were discharged before any predictions could be obtained. Respondents were polled individually and privately, in an attempt to minimize the influence of other respondents on the opinions offered. The investigators spent several hours each day in the MICU, attempting to obtain the predictions of the primary nurse, primary medical resident, MICU fellow, and MICU attending for each eligible patient. Respondents were allowed to demur if they could not offer an opinion with moderate or high confidence.

Statistical Analysis. Student's *t* test, linear regression, and analysis of variance were used for parametric analyses of patient populations. The chi-square test was used for nonparametric analyses of categorical variables for patient populations. Positive predictive value (PPV), negative predictive value, sensitivity, specificity, and receiver-operator characteristic curves were derived in the usual fashion. Statistical significance was accepted at a value of $p < .05$ for primary analyses and $p < .01$ whenever repeated analyses of the same data were performed (e.g., analyses of subpopulations >65 yrs or patients requiring mechanical ventilation).

This study was approved by the institutional review board at the University of Chicago.

RESULTS

MICU Patient Demographics and Mortality

Our original study population was made up of 603 MICU patients. Seventy-five percent of patients survived to hospital discharge. The median age for the entire MICU population was 55 yrs. MICU survivors were slightly but significantly younger than nonsurvivors (53 ± 19 yrs vs. 58 ± 15 yrs; $p = .003$). The average MICU length of stay for survivors was 3.5 ± 4.3 days, significantly shorter than average MICU length of stay for nonsurvivors, 5.5 ± 5.6 days ($p < .001$).

Figure 1 displays the number of remaining MICU patients as a function of length of MICU stay. Two points emerge. First, the MICU population was transformed within 72 hrs of MICU admission. Only 20% (116 of 590) of the original population remained in the MICU by day 4. Second, proportionally more survivors than nonsurvivors were discharged in the first 72 hrs. Consequently, the likelihood of survival to hospital discharge was lower for patients who remained on MICU day 4 than on MICU day 1. By day 10, only 24 of 433 (6%) survivors remained in the MICU.

Figure 2 displays the likelihood of survival as a function of the length of MICU stay. On day 1, 75% of MICU patients survived to discharge. The percentage of MICU patients who would ultimately survive to discharge fell steadily and significantly from the day of MICU admission ($r = .83$; $p = .015$). By day 10, only 48% of the patients who remained in the MICU would survive to hospital discharge.

Table 1. Distribution of caretaker predictions of "death before hospital discharge" vs. "survival to discharge" obtained daily for 560 patients

Group	Total Days with Prediction	Days With: Any Prediction of Death	>1 Prediction of Death	100% Prediction of Death	100% Prediction of Death Excluding Last Day	100% Prediction to Live	Any Disagreement Live/Die
All patients (n = 560)							
Ave	3.60	1.49	0.96	0.44	0.31	1.69	1.47
SD	4.44	3.35	2.48	1.36	1.15	2.24	3.02
Median	2	0	0	0	0	1	0
Count	560	206	145	94	64	422	241
Sum	2018	837	535	249	172	939	821
All nonsurvivors (n = 127)							
Ave	5.09	3.97	3.12	1.74	1.17	0.54	2.80
SD	4.90	4.55	3.79	2.34	2.09	1.07	3.51
Median	3	2	2	1	0	0	1
Count	127	107	95	79	51	35	92
Sum	647	504	396	221	148	68	355
All survivors (n = 433)							
Ave	3.17	0.77	0.32	0.06	0.06	2.02	1.08
SD	4.20	2.49	1.41	0.40	0.38	2.38	2.75
Median	2	0	0	0	0	2	0
Count	433	99	50	15	13	387	149
Sum	1371	333	139	28	24	871	466

Ave, average.

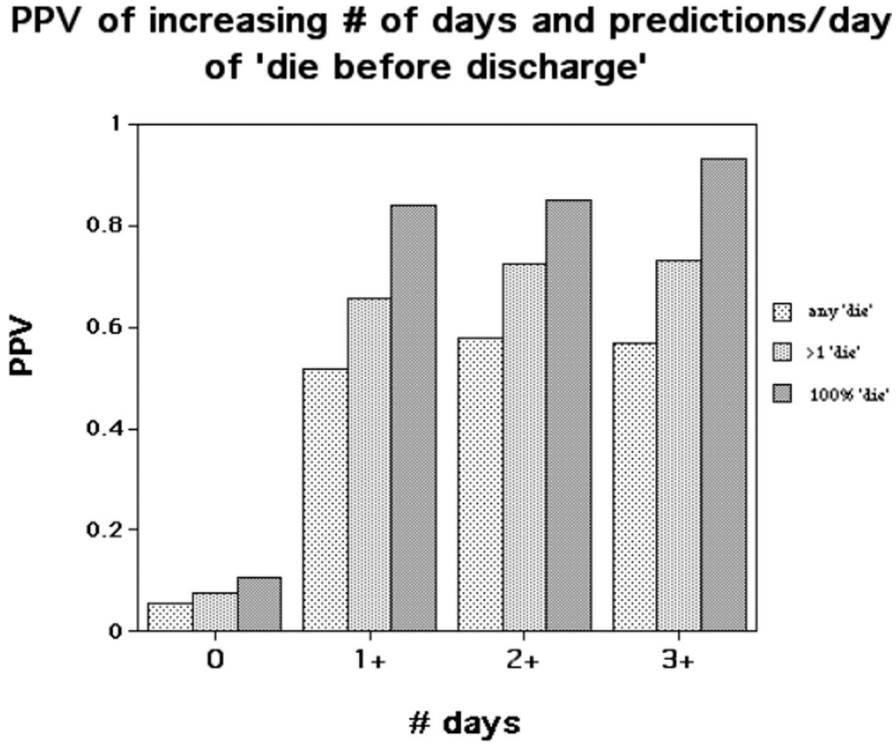

Figure 3. Predictive power of increasing number of predictions of "death before discharge." Fifty-two percent of patients with any prediction of death before discharge actually died in hospital. Increasingly stringent caretaker predictions of "death" had higher positive predictive value (*PPV*), although 16% of patients with a unanimous prediction of death, survived to discharge nonetheless.

Serial Predictions as Predictors of Mortality

Prediction Profiles for Survivors. Table 1 displays the distribution of >6,000 caretaker predictions obtained for 560 patients on 2018 days of MICU hospitalization. Of these 560 patients, 433 (77%) survived to hospital discharge, and their prediction profiles reflected two distinct hospital courses. Of 433 survivor profiles, 334 (77%) were characterized by 100% accurate prediction of survival by every medical caretaker on every MICU day; that is, every day, every caretaker predicted survive to hospital discharge, and the patient was eventually discharged alive. Alternatively, 99 (23%) MICU survivors had at least 1 MICU day characterized by a prediction of death before discharge. Indeed, 15 patients (3% of survivors) survived despite having at least 1 hospital day in which all respondents predicted death.

Prediction Profiles for Nonsurvivors. Table 1 also reveals that prediction profiles for 127 MICU nonsurvivors reflected two distinct hospital courses. Of the 127 nonsurvivors, 72 (57%) had every day of their MICU stay characterized by unanimous caretaker predictions of death before discharge. In contrast, 55 (43%) nonsurvivors had at least 1 MICU day where at least one caretaker predicted that the patient would survive, and 35 (27%) nonsurvivors had at least 1 day of unanimous prediction of survival; that is, every caretaker was confident the patient would survive to discharge.

Discordant Predictions of Death Before Discharge. Forty-three percent (241 of 560) MICU patients, and 41% (821 of 2018) MICU patient days were characterized by disagreement among predictors; that is, some respondents predicted death

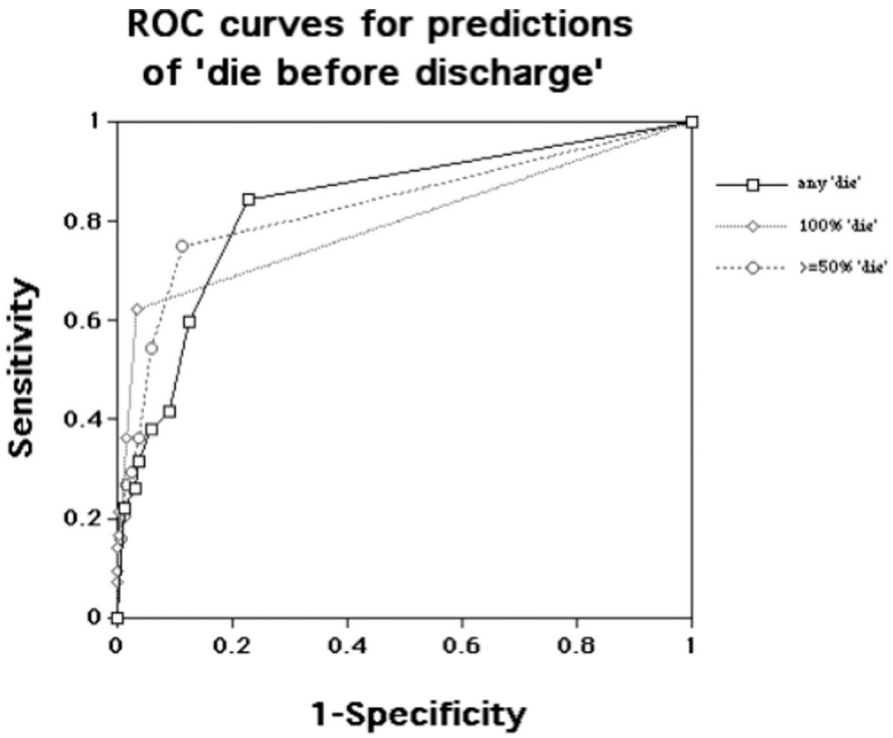

Figure 4. Receiver-operator characteristic (*ROC*) curves for predictions of "death before discharge." The area under the ROC curve did not differ significantly comparing one prediction, multiple predictions, and unanimous predictions of death before hospital discharge.

but others disagreed. Ninety-two (38%) of these 241 patients eventually died. The likelihood of predictive discord increased significantly as a function of MICU stay; only 27% (104 of 378) of patients who were discharged in the first 3 days had a discordant MICU day compared with 75% (137 of 182) of patients who remained after 72 hrs ($p < .001$). This trend was confirmed in patients >65 yrs of age and ventilated MICU patients, where discordant predictions were found in 49% (92 of 186) and 42% (81 of 193) patients, respectively, but rose to 76% (50 of 66) and 78% (90 of 116) for patients remaining after the third MICU day.

Predictive Power of Multiple Predictions of Death Before Discharge for Death in the Hospital

Figure 3 displays the predictive power of increasing number of predictions of death before discharge per day and the increasing number of days with predictions of death. Several points are apparent. Of the 560 profiled MICU patients, 354 (67%) never had any prediction of death; only 21 of 354 (6%) died, and 206 patients had at least one prediction of death before discharge. The predictive power of a caretaker prediction of death before hospital discharge was not much better than chance; only 107 of 206 (52%) of patients with any prediction of death before discharge actually died in hospital. Increasingly stringent caretaker predictions of death were significantly better predictors of death. Of 145 patients with at least 1 day where multiple (two or more) respondents predicted death, 96 (66%) did not survive to discharge, and 79 (84%) of 94 patients with at least 1 unanimous day (100% of caretakers predicted death before discharge) died in hospital (both $p < .001$ vs. single prediction of death). If the day of MICU death was excluded from the prediction profiles, the PPV of 1 day of unanimous prediction of death did not change significantly (51 of 64 = 80%; $p = .49$).

The predictive power of 1 day of 100% predictions of death before discharge was comparable for MICU subpopulations. Eighty-one percent (52 of 64) of ventilated patients and 84% (26 of 31) of patients >65 yrs of age with a unanimous day of predictions of death before discharge died in hospital.

Figure 3 also reveals that there was no significant gain in the predictive power of a prediction of death, a corroborated prediction of death, or a unanimous prediction of death, comparing patients with 1 day vs. 2 days vs. 3 or more days of these categories.

Figure 4 presents receiver-operator characteristic curves for increasingly stringent predictions of death before discharge. The greater PPV associated with increasingly stringent predictions of death was offset by the loss of sensitivity so that the AUC did not differ significantly comparing one prediction of death, multiple predictions of death, and unanimous predictions of death (AUC = 0.82, 0.82, 0.79; p = not significant). The area under receiver-operator characteristic curves generated for ventilated patients and patients >65 yrs of age did not differ from those of the population as a whole.

Withdrawing and Withholding Intensive Care Interventions, and "Negotiated" MICU Death. For 562 of 603 (93%) patients, the medical record was sufficiently detailed to allow insight into the occurrence of discussions of withdrawing/withholding intensive medical interventions. Of 562 patients, 138 (25%) had a withdrawal/withholding agreement; 98 (71%) of these patients died before hospital discharge, representing 77% of all MICU deaths. The average MICU stay for negotiated deaths lasted 6.0 ± 5.9 days. Conversely, 424 (75%) patients had no agreement to withdraw/withhold intensive intervention; only 29 (7%) of these patients died. The average MICU stay for non-negotiated deaths was 5.0 ± 8.5 days.

Of the 424 patients with no agreement to withdraw/withhold MICU intervention, 84 (20%) had at least one prediction of death before hospital discharge. PPV of predictions of death before discharge in this group was dismal; only 16 (19%) of these patients died. As expected, increasingly stringent predictions of death before discharge improved PPV to 25% (10 of 40) for patients with 1 day of corroborated prediction of death, and 53% (7 of 13) for patients with 1 day of unanimous prediction of death (all $p < .01$ vs. patients with decisions to withdraw/withhold). Furthermore, this improved PPV came at the cost of a loss of sensitivity, which fell from 55% for any prediction of death to 34% and 24% for corroborated and unanimous predictions, respectively (all $p < .01$ vs. patients with decisions to withdraw/withhold).

DISCUSSION

It is often claimed that admission to an MICU acts as a "trial of therapy" for a sick patient, whose prognosis will "declare" itself over time. At one level this is obviously true—for patients who have died, the outcome is certain and will not change over time. The question we addressed here is: What are the limits of our prognostic ability for individual patients who remain alive on each day in the MICU? Specifically, we hypothesized that medical caretaker predictions would become increasingly powerful predictors of nonsurvival over time, allowing us to identify more and more accurately patients for whom ethically relevant alternatives to continued MICU intervention (i.e., palliative care) might be envisioned.

We emphasize five major findings.

1) The passing of time radically altered the composition and prognosis of MICU patients. Only one-fifth of the initial population remained in the MICU 72 hrs after admission. The likelihood of survival to eventual hospital discharge fell with every passing day that a patient did not leave the MICU.
2) The eventual outcomes for MICU patients became progressively less clear, not more clear, over time. Only 27% of patients who left the MICU in the first 3 days had any caretaker disagreement about their prognosis—this number grew to 75% for MICU patients who remained >72 hrs.
3) A single prediction of death before discharge was no better than chance in distinguishing patients who would die in the MICU as opposed to those who would survive to discharge. Increasingly stringent prediction criteria (i.e., corroborated or unanimous predictions of death before discharge) gained predictive power, but remained imperfect; 15% of patients with 1 day of unanimous predictions of death survived to hospital discharge nonetheless. Nearly 12% of patients with ≥3 days of unanimous prediction of death before discharge survived.
4) More than 75% of MICU deaths were negotiated, taking place after a discussion of withdrawing/withholding intervention had occurred. For patients who died without an agreement to withdraw/withhold MICU intervention, the accuracy of predictions of death before discharge was even worse than for those whose death was negotiated.
5) Finally, subpopulations appeared not to matter. Daily caretaker predictions were equally powerful (or imperfect) at predicting outcomes for older, younger, ventilated, or nonventilated MICU patients.

Why analyze clinical predictions? Objective measures of illness severity, such as Acute Physiology and Chronic Health Evaluation scores, have well-known inaccuracies when used for individual prognostication. In our experience, physicians who work in MICUs, and who must make decisions or recommendations for individual patients, always consider physiologic data when they assess patients and make clinical judgments about prognosis, but they consider other nonquantifiable things, too. Their unique expertise lies in their ability to consider both objective measures and subjective ones. In the end, they are left with a prediction or a professional judgment about the patient's prognosis. This judgment is difficult to quantify, but we think it is important. Other physicians, in other contexts, agree (18). We tried to quantify professional judgment by asking MICU caretakers to commit to a prediction of outcome for each patient on each day. This is, admittedly, an unusual sort of variable to include in a measure of illness severity or prognosis. It is, however, the one that clinicians use in their actual practice day in and day out. We wanted to test the predictive power of these inevitable impressions.

Several methodological concerns of our study and its implications can be addressed directly. In-hospital mortality is a traditional outcome, although long-term follow-up of discharged patients who had been predicted to die would be very important. We have studied only one MICU, which may raise concerns of generalizability. However, we believe that the analyses of subgroups of ventilated patients and patients >65 yrs of age presented here may help extend our observations to comparable analyses of patient populations in other MICUs.

Were the clinical predictions gathered from various MICU caretakers independent, or did they reflect a "herd phenomenon" influenced from comments expressed on clinical rounds? We spent hours each day attempting to poll each caretaker individually and in isolation (cf. 11, 12). Nevertheless, we cannot exclude the possibility that predictions were at times tilted by comments on joint rounds. However, the observation that nearly 40% of all MICU patient days, and 75% of patient days remaining after MICU day 3, were characterized by caretaker disagreement over their future outcome would seem to mitigate this concern.

Did predictions about likely impending demise lead to decisions that made death more likely, as has been reported previously for adults with do-not-resuscitate status (19)? If so, this phenomenon would tend to inflate the accuracy of caretaker predictions, precisely because caretakers would convince families to withdraw ICU care once patients are thought doomed. The demographics of our MICU population make this question more accessible than has been previously reported. Rocker et al (20), in a study of caretaker predictions in Canadian MICUs, reported that the percentage of negotiated deaths, that is, deaths following agreement to withhold/withdraw MICU intervention, was 96%. Consequently, only 4% of their patients died while receiving maximal intensive intervention. In contrast, in our MICU, 25% of our patient deaths did not follow from an agreement to withdraw/withhold intensive intervention. This desire for continued ICU intervention even in the face of impending death likely reflects the expressed preferences of our MICU patients and their families, a majority of whom are poor and African-American—a phenomenon that has been described previously by Dula and Williams (21). Analysis of the subset of MICU deaths that were not accompanied by decisions to withdraw/withhold intervention revealed that the prognostic power of predictions of death before discharge in this group was particularly poor (reaching only 50 of 50 for patients who had unanimous predictions of death before discharge). These observations suggest that the "self-fulfilling prophesy" concern is not particularly relevant, at least in our MICU.

In sum, a 72-hr trial of therapy transforms the MICU. Nearly four-fifths of MICU patients will either be discharged or dead by MICU day 4. The likelihood of survival for patients in the MICU falls from 75% on admission to barely 50% after day 4. The eventual outcome for MICU patients remaining after 72 hrs becomes progressively less clear, as caretakers disagree on the outcomes for 75% of this population. Serial clinical predictions are imperfect predictors of eventual outcome, as nearly half of all patients

who were predicted to die survived to discharge. Even more remarkably, 12% of patients with ≥3 days of unanimous predictions of death before discharge, survived nonetheless. Predictive power for subpopulations of ventilated MICU patients and patients older than 65 yrs did not differ from the group as a whole.

We make two final points. First, these data should inform the ongoing discussions we have with the families of our patients, while patients are in the MICU. Second, if we are to serve our patients and their families, we must continue to search for better prognostic tools.

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