A Population-Based Observational Study of Intensive Care Unit–Related Outcomes

With Emphasis on Post-Hospital Outcomes

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Abstract

Rationale: Many studies of critical illness outcomes have been restricted to short-term outcomes, selected diagnoses, and patients in one or a few intensive care units (ICUs).

Objectives: Evaluate a range of relevant outcomes in a population-based cohort of patients admitted to ICUs.

Methods: Among all adult residents of the Canadian province of Manitoba admitted to ICUs over a 9-year period, we assessed ICU, hospital, 30-day, and 180-day mortality rates; ICU and hospital lengths-of-stay; post-hospital use of hospital care, ICU care, outpatient physician care, medications, and home care; and post-hospital residence location. We explored data stratified by age, sex, and separate categories of geocoded income for urban and rural residents. For post-hospital use variables we compared ICU patients with those admitted to hospitals without the need for ICU care.

Measurements and Main Results: After ICU admission there was a high initial death rate, which declined between 30 and 180 days and thereafter remained at the lower value. Hospital mortality was 19.0%, with 21.7% dying within 6 months of ICU admission. Women had higher hospital mortality than men (20.8 vs. 17.8%; $P = 0.0008$). Among urban residents there was a steady gradient of declining hospital mortality with rising income ($P < 0.0001$). Mean ICU length of stay was 3.96 days, increasing 0.11 d/yr over the study period ($P = 0.001$); median ICU length of stay was 2.33 days and did not change over time. In the year after ICU care, 41% were rehospitalized, 10% were readmitted to an ICU, 98% had outpatient physician visits, 96% used prescription medications, and 27% used home care services. Although most of these parameters were statistically higher than for hospitalizations not requiring ICU care, differences were generally small. Among hospital survivors, 2.7% were discharged to chronic care facilities, with 2.5% living in such facilities 3 months later.

Conclusions: Post-hospital medical resource use among ICU survivors is substantial, although similar to that after non-ICU hospitalization. Although the fraction of survivors unable to live independently was small, a larger fraction required home care services. Identifying post-hospital supports needed by ICU survivors can be useful for policy makers and others responsible for healthcare planning.

Keywords: outcomes research; outcomes assessment; intensive care units; long-term care; health resources

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Assessing the value and quality of care for critically ill patients in intensive care units (ICUs) should include long-term, patient-centered outcomes (1). Because they are easy to acquire, most ICU outcome studies still focus on the outcomes of short-term mortality and length of stay (LOS). Although some studies have reported longer-term mortality endpoints, and outcomes other than mortality, these have generally assessed small cohorts and/or been limited to patients with select diagnoses (2, 3). Most population-based studies have been limited to specific patient or diagnostic subsets (4–6). A knowledge gap therefore exists regarding a larger range of long-term outcomes after ICU care. We sought to overcome these limitations by assessing a range of outcomes related to ICU care among all adults admitted to ICUs in an entire Canadian province.

For comparison with prior studies we assessed short-term mortality and LOS. Because most individuals place more value on long-term than short-term survival (7), we also assessed long-term mortality. Furthermore, people generally place great emphasis on quality of life, of which being independent is a vital component (8, 9). Accordingly, we evaluated independence after illness, as indicated by the need for home care services and the ability to live independently. Finally, recognizing the relevance of societal interests, we evaluated how critical illness affects subsequent use of healthcare services.

Methods

Overview of Methods

Using an existing database, which has been shown to accurately identify ICU care, this population-based study assessed short-term and long-term mortality, ICU and hospital LOS, post-hospital resource use and post-hospital independence. Analysis included evaluating trends over time and stratification by sex, age, and income. For some outcomes we performed more detailed analysis using multivariable regression models to adjust for a larger range of potential confounding variables.

General Methods

We assessed all adult residents of the Canadian province of Manitoba admitted to any of its 12 high-intensity ICUs over 9 fiscal years 1999/2000 to 2007/2008 (April 1, 1999 to March 31, 2008). All are closed-model ICUs staffed by intensivists or cardiologists and include all provincial Level 1 and Level 2 adult ICUs (10). The ICU types are: six medical-surgical, two coronary care, one medical, one surgical/trauma/neurosurgical, one cardiac surgical, and one respiratory. In 2007 Manitoba had a population of 1.19 million (11), covered by single-payer, governmental health insurance. Virtually every Manitoban who required ICU care received it in Manitoba; there are no Canadian population centers exceeding 15,000 people, or Canadian medical centers with certified intensivists within 150 miles of its borders, ensuring a population-based sample.

This analysis used a previously described database, covering all provincial residents, linking administrative hospital abstracts, patient demographic and clinical information, vital statistics, the national census, and data on use of prescription drugs, outpatient physician services, and home care (12, 13). We have demonstrated that this database accurately identifies the existence and timing of ICU care (14).

Correctly quantifying ICU care requires accounting for inter-ICU and/or interhospital transfers. Transfers generate multiple database records, which must be identified and merged to construct full episodes of ICU care and ICU-containing hospital care. Done as previously described (15), these episodes are the units of measure for this study.

We evaluated all ICU care for Manitoba residents aged 17 years or older, with final hospital discharge during the study period. We assessed outcomes stratified by age, sex, and socioeconomic status (SES). Income, as proxy of SES (16), was assessed as average household income within geographic dissemination areas, based on the 2001 Canadian census (17), divided into separate quintiles for urban and rural residents, plus an 11th category (referred to as "not calculated") for those living in postal codes for which average household income is not available, mainly chronic care facilities but also other institutions.

This work was approved by the Health Research Ethics Board of the University of Manitoba and the Manitoba Health Information Privacy Committee. It was supported by a grant from the Manitoba Department of Health. All analyses were conducted using the data repository housed at the Manitoba Centre for Health Policy. Fisher exact test was used to compare proportions. Statistical analysis was done using SAS 9.2 (SAS Institute, Inc., Cary, NC). *P* values less than 0.05 were considered significant.

Mortality Outcomes

For each study year, we calculated mortality in ICU, in hospital, at 30 and 180 days after initial ICU admission for individuals admitted to an ICU in that year. To avoid biased mortality evaluation for patients with multiple ICU admissions, in any given time interval we limited consideration to each individual's initial ICU episode. We created Kaplan-Meier survival curves, counting from each person's initial ICU episode over the entire study period. Temporal trends were assessed using linear regression applied to the 9 yearly values.

As hospital mortality is the most common outcome used in ICU studies, we chose it to compare mortality rates between subgroups, combining all study years together. We performed age-adjusted subgroup comparisons by logistic regression modeling of hospital mortality, including categorized age in the model.

LOS Outcomes

LOS of ICU episodes and ICU-containing hospital episodes were calculated as the time elapsed from initial ICU/hospital entry until final ICU/hospital exit. Individuals with multiple admissions were included multiple times in these results. However, we excluded time spent in the six-bed chronic ventilator unit at one of the Winnipeg hospitals, reasoning that their extremely long LOS would skew the results and because in many other jurisdictions such patients would be transferred to a chronic ventilator facility separate from an acute care hospital.

We report LOS values unadjusted for age. Trends over time were assessed using linear regression applied to the 9 yearly values. We performed age-adjusted subgroup comparisons of LOS by median regression modeling, including categorized age in the model.

Post-Hospital Resource Use Outcomes

We evaluated post-hospital health services use among those discharged alive from

ICU-containing hospital episodes, combining all study years together. Individuals could be included multiple times in this evaluation.

Resource use was assessed over 365 days beginning from hospital discharge. To account for death or moving away from Manitoba during this period, we report annualized resource use, using the proportion of the post-hospital year during which the person was alive and resident in Manitoba. We excluded people who died on the day they left the hospital and hospital episodes for childbirth; the rationale for the latter is that they very rarely lead to ICU admission but comprise a large proportion of hospitalizations and have substantial post-hospital resource use.

We assessed five types of post-hospital health resource use: (*1*) proportion having at least one outpatient physician care visit, and the annualized number of visits; (*2*) proportion receiving at least one prescription drug dispensed from a nonhospital pharmacy, and annualized total cost of medications dispensed; (*3*) proportion having any hospital care, and average annualized number of hospital days; (*4*) proportion having any ICU admissions; and (*5*) proportion having any home care use. Medication costs, including pharmacy fees, were obtained from Manitoba's Drug Prescription Information Network database (18) and are reported in 2013 Canadian dollars, using the prescribed medicines portion of the Manitoba consumer price index (19). As home care data were only available through fiscal year 2006/2007, evaluation of that parameter was restricted to the hospitalizations during the first 7 years of the study period.

We calculated unadjusted post-hospital resource use, including those who had no use, and compared use among survivors of ICU-containing hospitalizations to those who survived hospitalization without ICU care, and to the general population.

Adjusted comparisons were made using multivariable regression modeling, accounting for clustered data due to individuals with multiple hospitalizations via General Estimating Equations (GEE), with an exchangeable correlation matrix (20). Covariates were: index hospital LOS, age, sex, SES, comorbid conditions, prorated portion of the year that the patient was alive and resident in Manitoba, main hospital diagnosis, and hospital discharge location (community living vs. a chronic care facility). Comorbidity was assessed as the presence of 31 preexisting conditions (21). Hospital diagnosis was identified as the Most Responsible Hospital Diagnosis, defined as that responsible for the majority of the hospital stay (22), and categorized into International Classification of Diseases, 9th revision, Clinical Modification chapters. Because the prorated portion of the post-hospital year was included as an independent variable in the model, dependent variables were actual resource use, rather than the annualized versions. We assessed for multicollinearity using variance inflation factors (23); none exceeded a value of 2.3, indicating no problematic multicollinearity.

Modeling of post-hospital outpatient physician visits and pharmacy costs used GEE linear regression, including both within-person and between-person effects of age (24). Because prescription medications for institutionalized people derive from sources distinct from outpatient pharmacies, which are not included in the provincial prescription drug database, such persons were excluded in assessing outpatient pharmacy costs. Because more than half of hospital survivors had no hospitalizations in the year after discharge from the index hospitalization, we modeled hospital days with zero-inflated, negative binomial regression. Because of lack of software to perform zero-inflated GEE modeling, we restricted consideration to each individual's first hospital episode; also, computational limitations required us to omit hospital diagnosis and post-hospital location from this model and to group the comorbidities into a smaller number of categories. Zero-inflated models have two linked parts (25); for our purpose the one of interest is the negative binomial model of the number of hospital days, after taking account of the excessive number of zero values present.

Post-Hospital Location Outcome

We assessed residency locations prehospital, immediately post-hospital, and at 3 months postdischarge. Living situations were categorized as living in chronic care institutions versus community living. These were determined using data from hospital abstracts and the provincial Long Term Care database.

Results

Mortality and LOS Outcomes

Characteristics of the 38,862 patients admitted to ICUs are shown in Table E1 in the online supplement. Survival for this cohort after initial ICU admission (Figure E1) shows high initial rates of death, which then declined between 30 and 180 days and subsequently remained at the lower rates. Hospital mortality was 19.0%, with another 2.7% dying during the next 6 months (Table 1). There were no significant temporal linear trends (1999–2008) in any of the mortality endpoints. Hospital mortality was higher for women than men (unadjusted 20.8 vs. 17.8%; age-adjusted

Table 1. Unadjusted mortality rates (%) for Manitoban residents admitted to intensive care units, by fiscal year

Fiscal Year	No. People	Mortality Endpoint			
		ICU	Hospital	30 d	180 d
1999/2000	4,454	10.46	18.81	16.50	21.73
2000/2001	4,753	10.86	18.54	16.28	21.57
2001/2002	4,504	9.92	18.14	15.90	21.05
2002/2003	4,220	9.50	18.34	15.52	21.45
2003/2004	4,162	11.46	20.01	17.52	22.44
2004/2005	4,125	12.19	20.63	17.75	23.49
2005/2006	4,079	11.35	18.90	16.30	21.72
2006/2007	4,180	10.72	19.14	15.72	21.05
2007/2008	4,355	11.02	18.28	15.98	20.37
Unweighted average	—	10.83	18.98	16.39	21.65

Definition of abbreviation: ICU = intensive care unit.
For each individual, only their first episode of ICU care in each fiscal year was assessed.

comparison, $P = 0.0008$) and differed by SES (*see* RESULTS in online supplement; Figures E2 and E3).

Mean LOS for ICU and ICU-containing hospital episodes were, respectively, 3.96 ± 5.8 and 22.7 ± 42.5 days (Table E2). Linear trending showed that mean ICU LOS increased by 2.7 h/yr ($P = 0.001$); as this was not accompanied by an increase in the median value ($P = 0.52$), the rising average resulted from more episodes with relatively long LOS. ICU LOS varied little across age groups; most notable was that it declined for those 85 years of age and older (Figure E4). There were also consistent gradients of declining ICU LOS with rising SES (Figure E5, age-adjusted comparison, $P < 0.0001$).

Post-Hospital Resource Use Outcomes

Over the 9 years, adult Manitobans experienced 736,249 nonobstetrical episodes of acute hospital care from which they left the hospital alive. Excluding 1,264 episodes as indicated above, we analyzed 734,985 hospital episodes, of which 31,486 (4.3%) contained ICU care.

In the year after ICU care, 41% were rehospitalized, 10% were readmitted to an ICU, 98% had outpatient physician visits, 96% used prescription medications, and 27% used home care services (Figure 1, Table E3). Although most of these parameters were statistically higher than for those hospitalized but not admitted to ICU, differences were small, except for 25% higher medication costs ($2,355 vs. $1,883, $P < 0.001$), higher incidence of ICU admission (10.4 vs. 2.8%, $P < 0.001$), and higher rate of home care use (26.5 vs. 20.9%, $P < 0.001$). Compared with the general population, all five of the resource use parameters are substantially higher for those who were hospitalized (Table E3).

Analysis of home care use included 483,902 hospitalizations. Among the 24,564 requiring ICU care, there was a substantial post-hospital increase in home care use. Although 13.4% of these ICU survivors were enrolled in home care before hospitalization, 26.5% used such services during the post-hospital year; this 13% increase was more than triple the 4% increase for hospitalized people not admitted to ICUs. In addition, 23.6% of ICU survivors who were not using home care at the time of hospitalization used it in the post-hospital year; the comparable value for those hospitalizations that did not experience ICU care was significantly lower, at 15.7% ($P < 0.001$).

After multivariable modeling adjustment, the mean number of outpatient physician visits in the year after hospitalization was 0.91 higher for those who received ICU care compared with those who did not ($P < 0.0001$, Table E4); this was less than half the unadjusted difference (Table E3). After adjustment, post-hospital outpatient pharmacy costs were similar between patients who did versus did not receive ICU care (mean difference, $14; $P = 0.41$; Table E5). Thus, almost all of the $472 difference in the unadjusted mean difference (Table E3) is attributable to differences between the two patient subsets.

After adjustment, there were 0.81-fold fewer subsequent hospital days for index hospitalizations that included ICU care ($P < 0.0001$, Table E6).

Post-Hospital Residence Location

Among 31,486 hospital survivors of ICU care, 1.2% resided in chronic care facilities before hospitalization and 2.7% were discharged to one (Table E7, $P < 0.001$ for difference in proportions). Of ICU patients who were community-dwelling before

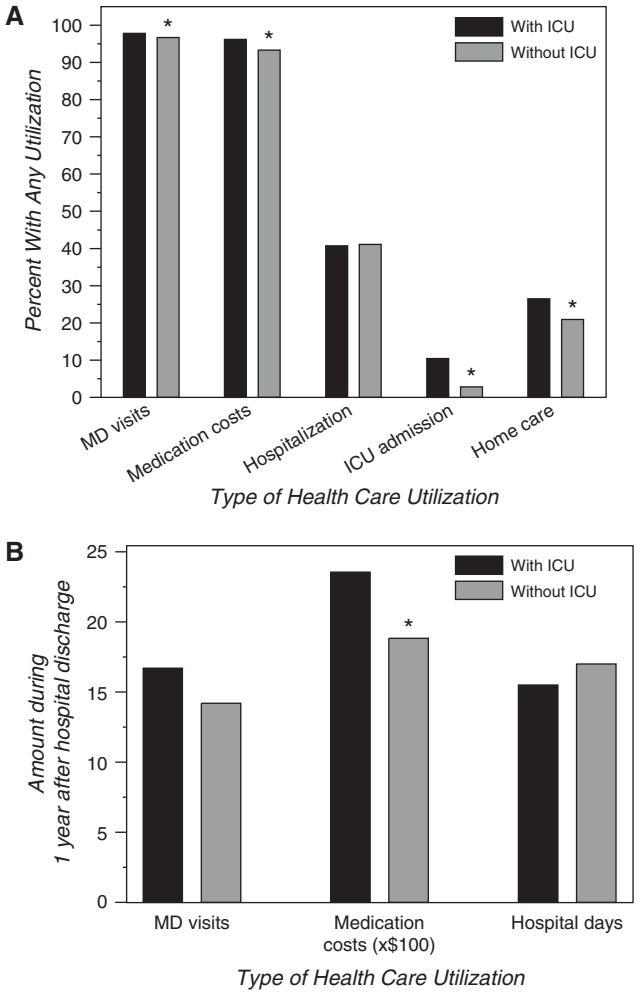

Figure 1. Annualized medical resource use in the year after hospital discharge for survivors of nonobstetrical hospital episodes, by whether hospitalization included time in intensive care unit (ICU). (*A*) Fraction with any usage. (*B*) Mean values of continuous parameters. Total of 31,486 hospitalizations with ICU care, 703,499 without ICU care; except for home care use, which included only 7 years of data, where N were, respectively, 24,564 and 553,727. Medication costs indexed to 2013 Canadian dollars, excludes institutionalized persons. *$P < 0.001$, comparing hospitalizations with versus without ICU care (Fisher exact test, *t* test). MD = medical doctor.

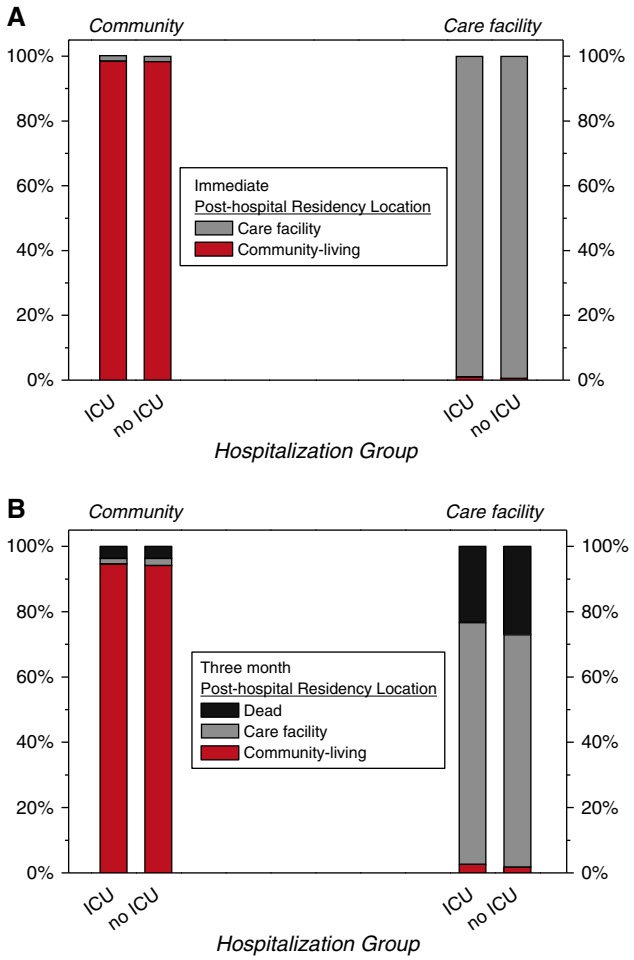

Figure 2. Stacked bar comparison of patients' prehospital and post-hospital residency locations after nonobstetrical hospitalization, among 31,486 survivors who received intensive care unit (ICU) care and 703,499 survivors who did not receive ICU care. (*A*) Residency location immediately after hospital discharge. (*B*) Residency location 3 months after hospital discharge.

hospitalization, 1.5% were discharged to care facilities; 3 months later, 3.7% had died and 1.6% were living in chronic care facilities (Figure 2). These figures are similar to those for the 703,499 hospital survivors who did not require ICU care (Figure 2, Table E7).

Of the ICU patients who were initially discharged to home, 0.4% had moved to a nursing home at 3 months, whereas 3.8% initially discharged to a chronic care facility moved in the opposite direction.

Discussion

This population-based analysis of outcomes in unselected adult ICU patients included understudied, longer-term outcomes with relevance to patients and society (1).

The most novel aspect of our study is its assessment of post-hospital residence location and medical resource use. Most prior studies of ICU-related outcomes have had one or more limitations: restriction to short-term outcomes, evaluation of a specific patient type or diagnostic entity, or assessing patients admitted to one or a few ICUs. Thus, there are few prior data to directly compare with our findings.

We found high mortality rates related to ICU care, being 19.0% in the hospital and 21.7% within 6 months. In other population-based studies, hospital mortality was 20.0% in Calgary (26) and 14.3% in British Columbia (27), and 6-month mortality was 14.1% among older Medicare patients in the United States (4). Lower mortality in the United States may reflect lower average severity of illness, reflected in lower need for artificial life support in American ICUs (28–30). Hospital mortality from other large ICU studies has varied from 13 to 19% (28, 30–32).

We found no temporal trend in mortality. In comparison, Australia-New Zealand data showed a 4% decline in hospital mortality from 1993 to 2003 (33). After age adjustment, our hospital mortality was higher among female ICU patients, as has been noted in studies that were not population-based (30, 31). Consistent with our findings, Welch and colleagues found that hospital mortality among English ICU patients was higher for those with lower SES (34). Finally, we found that mortality after ICU care appears to have two phases, with a higher rate of death in the first 1 to 3 months after admission and a much lower subsequent rate. These different rates in the two phases appear to have distinct determinants (35).

The ability to live independently is a salient aspect of quality of life (9, 36). We found that the fractions of ICU survivors living in care facilities prehospital, immediately post-hospital, and 3 months later were, respectively, 1.2, 2.7, and 2.5%. These values were all slightly, and similarly, lower than for those hospitalized without need for ICU care (2.5, 4.1, and 3.8%). This consistent difference may represent end-of-life care decisions made in Canadian chronic care facilities to not send very ill residents to hospitals. Other data, mostly from the United States, show much higher rates of living in chronic care facilities after ICU care (4, 37–41). In the only population-based analysis, 18% of older Medicare survivors of ICU care were living in chronic care facilities 1 year later (4). The reasons for such a large difference between this figure and our data is unclear, as there are no major differences in availability or use of nursing home beds between Canada and the United States (42–44). The 1.5% rise we observed in care facility residency prehospital to post-hospital among surviving ICU patients was similar to the 1.7% value for hospitalized adults who did not require ICU care. Wunsch and colleagues also found that rates of living in chronic care facilities after hospitalization was similar for those who did, and did not, need ICU care (4).

Another aspect of independence is the need for home care services. For our ICU patients who were discharged to home, 26.5% used such services in the following year. This was higher than the 20.9% for non-ICU hospital survivors ($P < 0.001$). And 24% of ICU survivors who were not using home care services before hospitalization needed them post-hospitalization, compared with 16% of non-ICU hospital survivors. The only other evaluation of this outcome we could identify was among 103 survivors of the adult respiratory distress syndrome (ARDS), showing substantial dollar costs of such care (45).

Although there was substantial use of outpatient physician visits, hospitalization, and prescription drugs in the year after ICU care, these parameters differed little, or not at all, compared with hospitalized people who did not require ICU care. We were unable to identify any studies that assessed the number of outpatient physician visits among ICU survivors, although small studies of Canadian survivors of ARDS have shown substantial monetary costs of such care (2, 45). Those investigators also reported that average pharmacy costs in the year after hospitalization were $1,441, compared with our value of $2,355 in our much larger, unselected cohort (2).

In the year after surviving the ICU-containing hospitalization, 40.7% of patients were rehospitalized, with a mean of 15.5 hospital days per patient. This was similar to the values for non-ICU hospitalizations of 41.1% and 17.0 days. Two prior population-based studies have assessed this outcome. Among older Medicare patients admitted to ICUs in the United States, 43% were rehospitalized within 1 year (4). In British Columbia, the mean number of subsequent hospital-days per year of follow-up was 5.3 for those who survived the follow-up period and 32.6 for those who died (46); they also found that the values were similar for those who survived hospitalizations without needing ICU care.

The largest difference in post-hospital use between ICU and non-ICU patients was in ICU admission in the subsequent year. Those values were, respectively, 10.4 and 2.8% ($P < 0.001$). Although several studies have evaluated ICU readmission during the same hospitalization, we were unable to identify prior studies that have assessed ICU readmission in subsequent hospitalizations.

Our study had limitations. First, the outcome of residency in a care facility underestimates those who could not live independently, as this does not include people who left hospital to live at the homes of family members. Second, we were unable to evaluate some important long-term outcomes, such as self-rated health and ability to perform activities of daily living. However, we evaluated outcomes expected to be related to those outcomes, specifically use of medical resources, ability to live at home, and use of home care services. Third, our results derive from a Canadian province with a publicly funded universal health care system and may not be generalizable to other settings. Fourth, despite including a large and population-based sample, the modest population of Manitoba is such that our analysis included only 12 ICUs, and this may further limit generalizability of our findings. Finally, our main results did not separately assess patient subgroups, such as those admitted for cardiac disorders. Although there are numerous ways that the ICU population could be subclassified (e.g., diagnosis, type of ICU, procedures performed just before ICU), we specifically chose to take a broad view. We made this choice partly to counter the limitation of prior studies, recognizing that either approach has advantages and disadvantages. But our data do allow some such assessment, as our multivariable models of post-hospital physician visits and pharmacy costs (Tables E3 and E4) included categories of main hospital diagnosis. Cardiovascular disorders is one of those diagnostic categories, capturing cardiac disorders and cardiac surgery. Those models demonstrated that patients in hospital for cardiovascular disorders generally had significantly lower use of both these resources compared with other diagnoses.

The validity of our study derives, in part, from evaluating a large, unselected, population-based cohort of ICU patients. Its value derives from assessing outcomes of relevance to patients and society that go beyond those typically considered. As pointed out by a 2002 Brussels Roundtable (1), the value of ICU care is tied to such outcomes. Patients' decisions to accept the kind of invasive care provided in ICUs depends sensitively on estimates of their subsequent levels of independence and functioning (9, 36). Also, improved delineation of post-hospital supports needed by ICU survivors can be useful for policy makers and others responsible for planning the healthcare system of the future, especially in light of increasing ICU use over time (47, 48). ■

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