

# One-Year Trajectories of Care and Resource Utilization for Recipients of Prolonged Mechanical Ventilation

## A Cohort Study

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**Background:** Growing numbers of critically ill patients receive prolonged mechanical ventilation. Little is known about the patterns of care as patients transition from acute care hospitals to postacute care facilities or about the associated resource utilization.

**Objective:** To describe 1-year trajectories of care and resource utilization for patients receiving prolonged mechanical ventilation.

**Design:** 1-year prospective cohort study.

**Setting:** 5 intensive care units at Duke University Medical Center, Durham, North Carolina.

**Participants:** 126 patients receiving prolonged mechanical ventilation (defined as ventilation for  $\geq 4$  days with tracheostomy placement or ventilation for  $\geq 21$  days without tracheostomy), as well as their 126 surrogates and 54 intensive care unit physicians, enrolled consecutively over 1 year.

**Measurements:** Patients and surrogates were interviewed in the hospital, as well as 3 and 12 months after discharge, to determine patient survival, functional status, and facility type and duration of postdischarge care. Physicians were interviewed in the hospital to elicit prognoses. Institutional billing records were used to assign costs for acute care, outpatient care, and interfacility transportation. Medicare claims data were used to assign costs for postacute care.

**Results:** 103 (82%) hospital survivors had 457 separate transitions in postdischarge care location (median, 4 transitions [interquartile

range, 3 to 5 transitions]), including 68 patients (67%) who were readmitted at least once. Patients spent an average of 74% (95% CI, 68% to 80%) of all days alive in a hospital or postacute care facility or receiving home health care. At 1 year, 11 patients (9%) had a good outcome (alive with no functional dependency), 33 (26%) had a fair outcome (alive with moderate dependency), and 82 (65%) had a poor outcome (either alive with complete functional dependency [4 patients; 21%] or dead [56 patients; 44%]). Patients with poor outcomes were older, had more comorbid conditions, and were more frequently discharged to a postacute care facility than patients with either fair or good outcomes ( $P < 0.05$  for all). The mean cost per patient was \$306 135 (SD, \$285 467), and total cohort cost was \$38.1 million, for an estimated \$3.5 million per independently functioning survivor at 1 year.

**Limitation:** The results of this single-center study may not be applicable to other centers.

**Conclusion:** Patients receiving prolonged mechanical ventilation have multiple transitions of care, resulting in substantial health care costs and persistent, profound disability. The optimism of surrogate decision makers should be balanced by discussions of these outcomes when considering a course of prolonged life support.

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The 300 000 patients per year who receive life support in intensive care units (ICUs) for much longer than average have been labeled as receiving “prolonged mechanical ventilation” (1, 2). These patients utilize a disproportionately large amount of health care resources and have relatively poor long-term outcomes (2–4). Patients report diminished quality of life, have important functional and cognitive limitations, require prolonged informal caregiving assistance, and have high 1-year mortality rates (5–7). Despite these outcomes, the number of patients per year receiving prolonged mechanical ventilation will probably exceed 600 000 within a decade, with associated hospital costs of \$50 billion to \$60 billion (2). Decision makers’ hope for patient survival coupled with an incomplete understanding of the specific implications of providing prolonged mechanical ventilation may contribute to the increasing incidence (8).

Patients receiving prolonged mechanical ventilation incur disproportionately high acute care costs and utilize postacute care facilities more frequently than other patient groups, which makes them of special interest to health care payers, such as the Centers for Medicare & Medicaid Ser-

vices, and to the postacute care industry (3). Due in part to substantial annual costs, the high reimbursement rates for facility-based care, and the high margins reported by postacute care facilities, the Deficit Reduction Act of 2005 directed the Centers for Medicare & Medicaid Services to reform the current system of postacute care payment (9).

For these reasons, a clearer description of patients’ postdischarge paths through different care facilities, the associated burden of functional limitations, and patient-level

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**Context**

A growing number of patients opt for prolonged mechanical ventilation, often with the understanding that their chances for recovery are good.

**Contribution**

In this study, 126 patients in intensive care units who required prolonged mechanical ventilation had high mortality and multiple transitions of care, incurring estimated costs of \$3.5 million per patient over the following 12 months. Only 11 patients were alive with no functional dependencies at 1 year.

**Caution**

The care and transitions all took place in a single medical center and region.

**Implication**

Patients requiring prolonged mechanical ventilation have complicated courses and poor outcomes that often contrast with initial expectations for recovery.

—The Editors

factors associated with high resource utilization and poor outcomes can assist in clinical decision making, institutional planning, payment reform, and the design of future interventions targeted to these unique patients. Therefore, we aimed to describe the overall trajectories of care location and costs for a consecutively enrolled cohort of patients receiving prolonged mechanical ventilation.

**METHODS****Study Design and Participants**

We conducted a 1-year, prospective cohort study in the adult general surgical, trauma, neurologic, cardiothoracic surgery, cardiac, and medical ICUs at Duke University Medical Center, Durham, North Carolina. Participants, including 126 patients and their 126 surrogates and 54 primary ICU physicians, were enrolled beginning in April 2006 through daily screening of ICUs by study staff, with follow-up completed in April 2008. Details about rates of enrollment, exclusion, and declining to participate, as well as characteristics of the surrogates and physicians, are provided elsewhere (5).

Patients were eligible for the study if they were age 18 years or older and met either of 2 common definitions of prolonged mechanical ventilation: mechanical ventilation for 21 or more days with less than 48 hours of unassisted breathing or 4 or more days of ventilation and placement of a tracheostomy for an expected prolonged requirement for ventilatory support (10). Exclusion criteria were lack of an identifiable surrogate; English-language fluency poor enough to require a translator; tracheostomy placement for either emergency indications or an ear-, nose-, or throat-related diagnosis; or preadmission receipt of a tracheos-

tomy. We defined the surrogate as the person most involved in the decision to place a tracheostomy and the one most likely to provide most of the postdischarge care. Enrolled physicians were self-identified as the primary ICU physician for each patient.

**Data Collection and Variables**

We collected data from medical records, administrative billing records, and participant interviews. Study staff abstracted clinical data from patients' charts and hospital electronic records to record admitting diagnoses and operative procedures, sociodemographic characteristics, Charlson comorbidity scores (11), acute physiology scores representing illness severity on the day of tracheostomy placement (12), mechanical ventilation course, and hospital and ICU lengths of stay.

Patients, surrogates, and physicians were interviewed in person within 48 hours of meeting study eligibility criteria. Follow-up interviews were performed with patients and surrogates either by telephone or in person 3 and 12 months later, with 3-month interviews primarily informing vital status and resource utilization calculations. We completed 100% of interviews with surrogates and patients, excluding patients who had died (36 patients [29%] at 3 months and 56 patients [44%] at 12 months) or who showed clinically significant cognitive impairment (36 patients [29%] at 3 months and 31 patients [25%] at 12 months), as defined by a score of less than 20 on the Folstein Mini-Mental State Questionnaire (13). The 6-item activities of daily living instrument (14) quantified dependencies in basic functioning, including bathing, dressing, feeding, transferring from bed to chair, bladder and bowel control, and use of the toilet.

Quality of life was assessed with the EuroQol-5D (EQ-5D) (15, 16), an instrument with evidence of validity in survivors of critical illness and as a surrogate-completed proxy measure. We adjusted survival for quality of life by multiplying each patient's 3- and 12-month EQ-5D index scores (1 = excellent quality of life; -0.1 = worse than death) by the total days alive in the 2 periods (0 to 3 months and 4 to 12 months) preceding each measurement. We defined poor quality of life as an index score of 0.44 or lower, 2 SDs below the U.S. population average for persons aged 55 to 65 years (17). We defined good quality of life as a score greater than 0.80, the U.S. population average for similar age groups, and fair quality of life as intermediate scores (18). Because nearly one third of patients were too disabled to complete interviews during follow-up, we used surrogate assessments of patients' quality of life and functional status in analyses. Scores on the EQ-5D were highly correlated ( $r = 0.94$ ;  $P < 0.001$ ) between surrogates and cognitively intact patients. Surrogates and physicians also reported whether they expected patients to survive and to have complete functional independence at 1 year, with responses of "strongly agree" or "agree" considered as "high expectations" and "don't know," "disagree,"

or “strongly disagree” recorded as “low expectations” for either item.

Data on resource utilization were obtained by reviewing medical records, administrative billing records, and participant interviews (Appendix, available at [www.annals.org](http://www.annals.org)). We determined costs for the primary hospitalization by using itemized charges from each patient’s administrative billing record and converting these to costs by using department-specific cost-to-charge ratios obtained from the Centers for Medicare & Medicaid Services hospital cost reports (19). We used participant interviews to record any hospital readmission, postacute care facility admission, or use of home health service. Duration of care for each episode, including length of ICU stay during readmissions, was verified by review of medical records whenever possible. We estimated costs for postdischarge care episodes by using 2006 region-specific mean daily ICU, hospital, and postacute care costs obtained from Medicare claims. Physician costs were estimated at 17% of hospital costs, as in previous analyses (20). Clinic visits and ambulatory surgical procedures were recorded from medical charts and assigned costs on the basis of relevant Current Procedural Terminology codes. Air and ground transportation costs were assigned for interfacility transfers on the basis of administrative billing records.

### Statistical Analysis

The primary outcomes of the study were 1-year survival, functional status, and health care–associated resource utilization. We also described health outcomes by combining 1-year survival and functional status into 3 simple categories designated to be equally interpretable by patients, surrogates, and physicians: good outcome (alive with no dependencies in activities of daily living), fair outcome (alive with 1 to 5 dependencies in activities of daily living), or poor outcome (either dead or alive with dependencies in all 6 activities of daily living).

We present categorical data as numbers (percentages) and continuous data as means (SDs) or medians (interquartile ranges [IQRs]). We examined factors associated with grouped health outcomes (good, fair, or poor) as appropriate for data distribution by using Pearson chi-square and Fisher exact tests for categorical variables and analysis of variance tests or Kruskal–Wallis tests for continuous variables. Because cost data were skewed, we used log-transformed values in analyses. Additional ventilator outcomes data are shown in the Appendix. We used Stata software, version 11 (StataCorp, College Station, Texas) for all analyses and considered a *P* value less than 0.05 to be significant.

### Role of the Funding Source

The Duke University Institutional Review Board approved all study procedures. No external funding was received for this study.

**Table 1. Baseline Characteristics and Hospital Discharge Disposition\***

Characteristic	Value
<b>Age, y</b>	
Mean (SD)	55 (16)
Range	19–85
<b>Female, n (%)</b>	50 (40)
<b>Race or ethnicity, n (%)</b>	
White	67 (53)
Black	48 (38)
Native American	7 (5)
Asian	2 (2)
Hispanic	2 (2)
<b>Place of residence before admission, n (%)</b>	
Home	124 (98)
Nursing facility	2 (2)
<b>Employment status, n (%)</b>	
Employed full- or part-time	41 (32)
Not currently employed, retired, or disabled	85 (68)
<b>Less than high school education, n (%)†</b>	
Patients	15 (12)
Surrogates	9 (8)
<b>Insurance status, n (%)</b>	
Private	72 (57)
Government (Medicare or Medicaid)	34 (27)
Self-pay	20 (16)
<b>Median comorbid conditions (IQR)</b>	2 (0–4)
<b>Median dependencies in ADLs (IQR)</b>	0 (0–0)
<b>Primary ICU admission diagnosis, n (%)‡</b>	
Respiratory failure	29 (23)
Neurologic	29 (23)
Trauma	27 (21)
Postoperative	26 (21)
Septic shock	10 (8)
Cardiac	5 (4)
<b>Median Acute Physiology Score (IQR)§</b>	
ICU day 1	19 (15–24)
Day of tracheostomy placement	15 (12–19)
<b>Median ventilator days (IQR)</b>	
Before tracheostomy	11 (8–17)
Total	27 (18–24)
<b>Median length of stay (IQR), d</b>	
ICU	26 (22–42)
Hospital	39 (28–57)
<b>Hospital discharge disposition, n (%)</b>	
Home without paid home health care	6 (5)
Home with paid home health care	14 (11)
Long-term acute care facility	36 (29)
Skilled nursing facility	17 (13)
Rehabilitation facility	23 (18)
Other hospital	3 (2)
Still in acute care hospital at 1 y	1 (1)
Inpatient hospice facility	3 (2)
Dead	23 (18)

ADL = activity of daily living; ICU = intensive care unit; IQR = interquartile range.

\* Out of 126 patients, unless noted otherwise.

† Out of 108 patients, because 18 (14%) patients did not answer.

‡ Categories include respiratory (pneumonia, aspiration, and pulmonary embolus), neurologic (ischemic stroke, subarachnoid hemorrhage, the Guillain–Barré syndrome, and status epilepticus), trauma, nontrauma surgical (immediate postoperative general and cardiothoracic), and cardiac (myocardial infarction and out-of-hospital cardiac arrest).

§ From APACHE (Acute Physiology and Chronic Health Evaluation) II classification (12).

|| Out of 125 patients, because 1 patient did not have tracheostomy.

**Table 2. Patient and Process-of-Care Outcomes at 1 Year After Discharge\***

Outcome	Value
<b>Survival, n (%)</b>	70 (56)
<b>Quality of life in survivors at 1 y, n (%)†</b>	
Good	19 (27)
Fair	17 (24)
Poor	34 (49)
<b>Median total quality-adjusted life-days over 1 y (IQR)‡</b>	66 (16–223)
<b>Disposition at 1 y, n (%)</b>	
Home without paid home care	11 (9)
Home with paid home care	47 (37)
Skilled nursing facility	10 (8)
Inpatient rehabilitation facility	1 (1)
Residing in a hospital, never discharged	1 (1)
Dead	56 (44)
<b>Location of death over 1 y, n (%)§</b>	
Withdrawal of mechanical ventilation in hospital	22 (39)
Receiving full support on ventilator in hospital or facility	24 (43)
Hospice	7 (13)
Home	3 (5)
<b>Mechanical ventilation outcomes, n (%)</b>	
Weaned from ventilator	86 (68)
During initial hospitalization	69
At long-term acute care facility	13
At skilled nursing facility	4
At another hospital	1
Not weaned from ventilator	40 (32)
Alive, still ventilated at 1 y	3
Died, ventilator-dependent	37
<b>Median duration of ventilator support (IQR), d  </b>	
If weaned from ventilator	21 (16–37)
If never weaned from ventilator	42 (33–74)
<b>Transitions among care locations over 1 y, n (%)¶</b>	
To a lower or an equal level of care	305 (65)
To a higher level of care	152 (35)
Readmissions**	150
Inpatient rehabilitation to skilled nursing facility	2
<b>Hospital readmissions, by diagnostic category, n (%)††</b>	
Sepsis	56 (45)
Respiratory failure	26 (21)
Surgical complications	22 (17)
Neurologic complications	7 (6)
Other medical	39 (31)
<b>Median postacute care utilization (IQR), d‡‡</b>	
Long-term acute care facility	29 (21–70)
Skilled nursing facility	42 (27–228)
Rehabilitation facility	28 (21–45)
Home health services	84 (34–250)

IQR = interquartile range.

\* Out of 126 patients, unless noted otherwise.

† Out of 70 patients. Quality of life was determined by surrogate assessment using EuroQol-5D index score. A score  $\leq 0.44$  is poor, 0.45 to 0.79 is fair, and  $\geq 0.80$  is good.

‡ Calculated by adjusting all days alive during 1 y with corresponding EuroQol-5D index scores obtained at 3- and 12-mo follow-up.

§ Out of 56 patients.

|| 86 patients were eventually weaned from ventilator support, and 40 patients were never weaned from ventilator support.

¶ Out of 457 transitions. A total of 88 patients moved to a lower or an equal level of care, and 69 patients moved to a higher level of care. The total patients who moved to either lower or higher levels of care includes 58 patients who had transitions to both higher and lower levels of care.

\*\* In 68 of the 102 patients discharged from the index hospitalization to a destination other than hospice.

†† Out of 150 readmissions. Readmission categories include sepsis (urinary tract infection, pneumonia, catheter infections, and other), respiratory failure (congestive heart failure, pneumonia, pulmonary embolism), surgical complications or repeated surgery related to primary admission, neurologic complications (seizure, intracerebral hemorrhage, subdural hematoma), or other medical conditions (dehydration, mental status change, gastrointestinal hemorrhage, admission for chemotherapy, fall, renal failure, pancreatitis, gastrostomy complication).

‡‡ 43 admissions to long-term acute care facilities in 38 patients, 63 admissions to skilled nursing facilities in 36 patients, 54 admissions to rehabilitation facilities in 28 patients, and 44 episodes of home health service in 36 patients.

## RESULTS

### Baseline Characteristics and Hospital Course

Patients were middle-aged, insured, and well-educated and had few premorbid functional limitations or medical comorbid conditions on average (Table 1). Admission diagnoses were nearly equivalent in proportion among trauma, nontrauma surgical, neurologic, and medical causes. Patients had a median of 27 ventilator days (IQR, 18 to 27 days) and a median hospital stay of 39 days. A total of 86 (68%) patients were ultimately weaned from ventilation (Appendix Table 1, available at [www.annals.org](http://www.annals.org)). The 23 patients (18%) who died in the hospital had a greater length of stay than did survivors (53 days [IQR, 33 to 82 days] vs. 28 days [IQR, 27 to 52 days]) and received more ventilator days (46 days [IQR, 32 to 81 days] vs. 25 days [IQR, 20 to 34 days];  $P = 0.001$ ). All patients who died during the initial hospitalization were receiving ventilation via tracheostomy at the time of death. Most (74%) survivors were discharged to a postacute care facility.

### One-Year Outcomes and Trajectories of Care

At 1 year, 70 patients (56%) were alive, although only 11 (9%) were independently functioning and only 19 (27%) had a good quality of life (Table 2). Of these survivors, 68 were ultimately decannulated, all within 1 month of ventilator weaning. Those who died during follow-up lived a median of only 79 days (IQR, 46 to 125 days). Patients had 457 transitions in care location (median, 4 transitions [IQR, 3 to 5 transitions]) during follow-up (Figure 1), receiving a total of 14 552 days of inpatient hospital and facility care. There were 150 readmissions in 68 (67%) of the 103 hospital survivors. Most readmissions (96 [65%] patients) occurred within 3 months; nearly half were related to sepsis (Appendix Table 2, available at [www.annals.org](http://www.annals.org)). The average patient spent 74% (95% CI, 68% to 80%) of all days alive in a hospital or postacute care facility or was receiving home health care; 61% (CI, 54% to 68%) of study days were facility-based. Only 3 patients (2%) were both initially discharged to their home and remained there, whereas only 3 of 54 previously employed patients (6%) ever returned to work. A total of 19 surrogates (27%) reported a good quality of life for 1-year survivors.

At 1 year, 11 patients (9%) had a good health outcome, 33 (26%) had a fair outcome, and 82 (65%) had a poor outcome (Table 2). Only 23 patients (18%) either improved in outcome category or maintained a good outcome between 3 and 12 months (Figure 2). All 1-year survivors in the fair- and good-outcome groups were residing at home, except for 1 fair-outcome survivor, who resided in a nursing facility. Compared with patients with poor outcomes, those with fair outcomes had more transitions (median, 5 transitions [IQR, 4 to 7 transitions] vs. 2 transitions [IQR, 0 to 5 transitions]) and were more likely both to be readmitted (53% vs. 27%;  $P = 0.02$ ) and to receive facility-based postacute care (81% vs. 61%;  $P = 0.03$ ).



Patients with a poor outcome were older, had more comorbid conditions, and were more frequently discharged while still receiving mechanical ventilation than those with better outcomes (Table 3). Those with fair outcomes were most frequently uninsured and were less severely ill on the day of tracheostomy placement. Patients with fair and poor outcomes were discharged in equal proportions to long-term acute care and skilled nursing facilities (42 [51%] vs. 16 [48%]). Patients with good outcomes tended to be admitted with trauma and were more frequently discharged home than other patients. The proportion of patients with moderate or greater severity of illness (acute physiology scores >15) on the day of tracheostomy was the same in those with poor outcomes (64%) and good outcomes (63%). The proportion of surrogates with high expectations for either survival or functional independence did not differ on the basis of subsequent health outcome categorization ( $P > 0.05$  for all). Physicians were somewhat less optimistic about patients' survival, although they reported high expectations for functional independence for 36 (44%) patients who later had poor outcomes, 17 (52%)

who later had fair outcomes, and 11 (100%) who later had good outcomes ( $P = 0.002$ ).

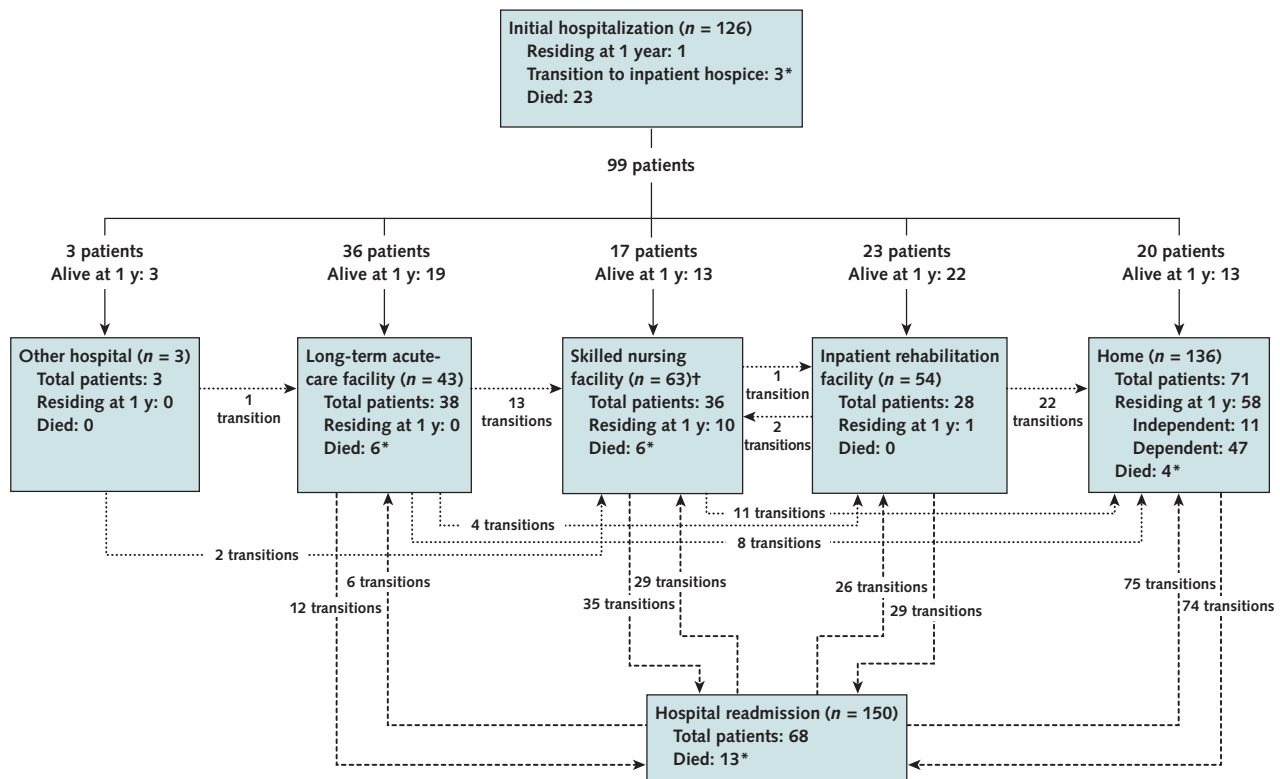
### Resource Utilization

The mean total 1-year cost of health care for cohort members was \$306 135 (SD, \$285 467), whereas cost for the entire cohort exceeded \$38.5 million (Table 4). Most of the cost (\$28.1 million, or 73%) was incurred by the initial hospitalization. The highest mean cost for postacute care was for persons receiving long-term acute care (\$91 277), followed by those receiving care in a skilled nursing facility (\$31 892), care in an inpatient rehabilitation facility (\$21 244), and home health service care (\$6669). Outpatient costs averaged \$551, although transportation costs exceeded \$10 000 per patient. The 1-year costs did not differ by health outcome ( $P = 0.40$ ) (Appendix Table 3, available at [www.annals.org](http://www.annals.org)).

### DISCUSSION

Our study offers new insights into a growing population of relatively understudied critically ill patients. Over 1

Figure 1. Trajectories of care for patients in the prolonged mechanical ventilation cohort over the first year after discharge.

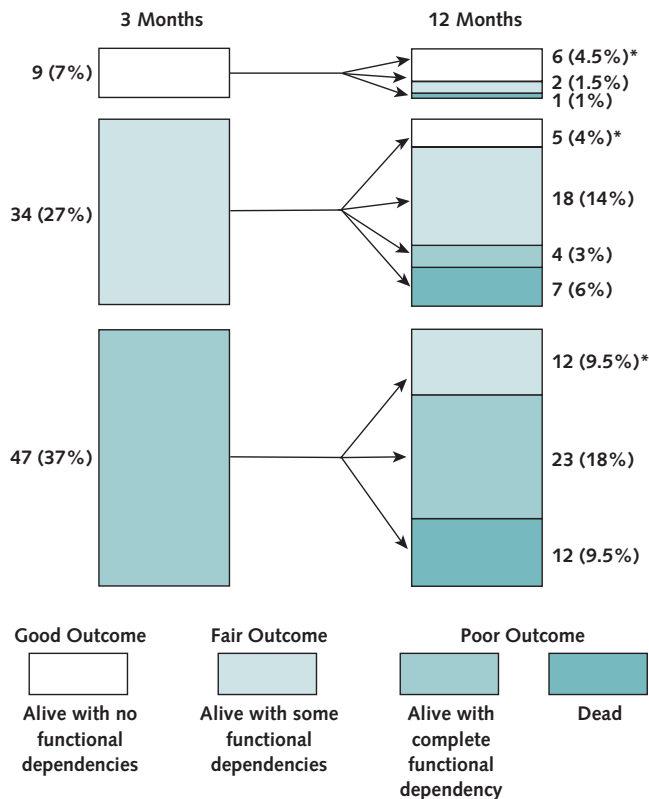


Arrows between care locations indicate both the direction of patient transitions and the total number of patients transferred between locations over 1 year. Solid lines represent initial transitions between the hospital and other locations. Dashed lines represent subsequent hospital readmissions and discharges involving postdischarge care locations. Dotted lines represent transitions among postdischarge care locations, including home. Each box summarizes the total numbers of both readmissions and patients admitted, as well as how many patients remained or died in each location of care at 1 year.

\* 7 transitions to inpatient hospice and death not shown (3 from the acute hospitalization and 1 each from home, long-term acute care facility, skilled nursing facility, and hospital readmission).

† 1 transition from skilled nursing facility to skilled nursing facility not shown.

Figure 2. Patient trajectories at 1 year, by health outcome.



Each bar shows patients at 3- and 12-mo intervals, grouped by survival and number of functional limitations in basic activities of daily living. The arrows indicate group members' subsequent longitudinal transitions to other health outcomes. For example, between 3 and 12 months, 34 patients with a fair 3-month outcome improved to a good outcome ( $n = 5$ ), remained at fair outcome ( $n = 18$ ), or worsened to a poor outcome ( $n = 4$ ) or died ( $n = 7$ ). Percentages in both 3- and 12-mo outcomes categories are calculated by including 36 (29%) patients (not shown) who were dead at 3 mo.

\* These 23 (18%) patients improved or remained in the good-outcome grouping between 3 and 12 mo.

year, 126 patients who received prolonged mechanical ventilation had a median of 4 transitions of care location each and spent nearly 75% of all days in hospitals, in postacute care facilities, or at home receiving paid home care. Survivors at 1 year were left with a serious burden of pervasive, persistent disability despite aggressive care that cost a total of \$38 million, or approximately \$3.5 million for each 1-year survivor without serious functional dependencies.

These findings are important for patients, families, clinicians, and policymakers. First, the effect on the U.S. health care system of patients receiving prolonged mechanical ventilation has probably been substantially underestimated (2, 3, 21). Past estimates (22, 23) of these patients' resource utilization have not focused on cumulative acute and postdischarge care. We found that whereas the initial hospitalization accounted for most costs, postacute care facilities and readmissions contributed substantially to

resource utilization. The pattern of patient death may have accentuated this distribution of costs, because patients who died during hospitalization had an average length of stay more than 2 weeks longer than that of those who survived. Because the risk for death remained high throughout follow-up, the opportunity to utilize postdischarge resources was attenuated. Still, the high cost of acute critical care is clearly a major factor, because cohort members' hospital costs alone were 15 times greater than those of an average Medicare patient with critical illness (24). Also, the readmission rate we observed was nearly 50% higher than that reported in Medicare beneficiaries who survive a hospitalization that includes mechanical ventilation (25). It is therefore troubling that the number of patients receiving prolonged mechanical ventilation is expected to increase substantially over the coming decade (2).

These data also are relevant to efforts to reform post-acute care payment, initiated with the Deficit Reduction Act of 2005 (26). Payments for prolonged mechanical ventilation are widely disparate, with acute care hospitals often receiving far less than postacute care facilities (27). Some have proposed basing payment for the treatment of patients with chronic, critical illness on the quality of longitudinal care, to reward lower-cost providers who can reduce costly transitions and readmissions (28, 29). However, the singularly high readmission rate from post-acute care may be associated with patient characteristics that are impossible to modify, such as age and comorbid conditions, and should be investigated further before a benchmark rate is considered as a quality modifier of payment (30). The complexity of patients' trajectories of care highlights the need to define quality indicators for this population that are transportable across institution type, with the goals of improving patients' overall care and the efficiency with which care is delivered (26).

Several studies (7, 31–33) have shown the extensive effect of critical illness on the physical, mental, and financial well-being of patients and their families. However, both the magnitude of disability and the infrequency of postdischarge recovery are noteworthy. Our findings that patients with poor outcomes were more likely to be elderly, have comorbid conditions, and be receiving ventilation at discharge are generally similar to those of other studies (34, 35), as is our observation that illness severity scores at the time of tracheostomy do not accurately discriminate between patients with good or poor outcomes. Similarly, we observed that most patients with a good functional recovery were admitted because of trauma (36). However, patients with intermediate outcomes—those who are alive but with moderate functional dependency—may be the most challenging to manage, because of the perceived uncertainty associated with their prognosis. These previously high-functioning patients were less severely ill than other patients. Despite their decision makers' initial optimism, however, they rarely improved over time, instead cycling frequently between postacute care facilities and hospitals.

**Table 3. Baseline and Hospital Characteristics Associated With 1-Year Health Outcomes\***

Characteristic	Health Outcome at 1 Year†			P Value‡
	Poor (n = 82)	Fair (n = 33)	Good (n = 11)	
Mean age (SD), y	59 (14)	47 (17)	51 (22)	0.001
≥1 dependency in activities of daily living, n (%)	13 (16)	6 (18)	1 (9)	0.19
Median comorbid conditions (IQR), n	2 (1–4)	1 (0–3)	0 (0–2)	0.001
Insurance status, n (%)				0.04
Private	43 (53)	19 (58)	10 (91)	
Government (Medicare or Medicaid)	29 (35)	4 (12)	1 (9)	
Self-pay	10 (12)	10 (30)	0 (0)	
Primary ICU admission diagnostic category, n (%)§				0.02
Trauma	9 (11)	13 (39)	5 (45)	
Nontrauma surgical	28 (34)	5 (15)	3 (27)	
Medicine	45 (55)	15 (45)	3 (27)	
Acute Physiology Score >15 on day of tracheostomy, n (%)	52 (63)	12 (36)	7 (64)	0.03
Physicians with high expectations for, n (%)				
Survival	36 (44)	24 (73)	11 (100)	<0.001
Functional independence	36 (44)	17 (52)	11 (100)	0.002
Outcome for which surrogates had high expectations, n (%)				
Survival	74 (90)	32 (97)	11 (100)	0.30
Functional independence	54 (66)	25 (76)	11 (100)	0.05
Mechanical ventilation at hospital discharge, n (%)	42 (52)	5 (15)	1 (9)	<0.001
Discharge disposition, n (%)				<0.001
Home	8 (10)	6 (18)	6 (55)	
Long-term acute care, skilled nursing facility, other hospital	42 (51)	16 (48)	2 (18)	
Inpatient rehabilitation facility	9 (11)	11 (33)	3 (27)	
Dead	23 (28)	0 (0)	0 (0)	
Median number of transitions of care location (IQR)	2 (0–5)	5 (4–7)	2 (2–5)	0.001

ICU = intensive care unit; IQR = interquartile range.

\* Out of 126 patients.

† Health outcome categories are defined as good (alive with no dependencies in activities of daily living), fair (alive but with 1 to 5 dependencies in activities of daily living), and poor (either alive and completely dependent or dead).

‡ Based on Pearson chi-square test, Fisher exact test, 1-way analysis of variance, or Kruskal–Wallis test.

§ Categories include trauma, nontrauma surgical (immediate postoperative general and cardiothoracic), and medicine (pulmonary, infectious disease, neurologic, and cardiac diagnoses).

**Table 4. Resource Utilization at 1 Year\***

Resource	Mean Individual Cost (SD), \$	Cohort Total Cost, \$
<b>Total costs at 1 y</b>	306 135 (285 467)	38 577 935
<b>Initial hospitalization</b>	223 406 (278 165)	28 149 128
<b>Postacute care</b>	57 730 (77 735)	5 504 902
Long-term acute care facility	91 277 (103 017)	3 468 519
Skilled nursing facility	31 892 (34 727)	1 148 122
Rehabilitation facility	21 244 (15 718)	594 839
Home health services	6669 (4754)	293 422
<b>Hospital readmissions</b>	54 818 (87 204)	3 727 631
<b>Transportation costs†</b>	10 906 (6951)	1 155 998
<b>Outpatient costs‡</b>	551 (585)	40 276

\* Out of 126 patients.

† Includes air and ground transport between acute and postacute care facilities.

‡ Includes emergency department visits, clinic visits, and outpatient surgeries.

Our study confirms that prolonged mechanical ventilation is a highly resource-intensive condition with a generally poor outcome. However, the circumstances under which decision making about prolonged mechanical ventilation occur are not ideal, probably favoring the pursuit of aggressive care (8). First, the content of physician–surrogate communication is inadequate for fully shared decision making (37). Nelson and colleagues (8) reported that 80% and 93% of surrogates of patients with prolonged mechanical ventilation received no information about possible functional dependency or expected 1-year survival, respectively. Second, both clinicians and surrogates substantially overestimate prospects for recovery and do not anticipate the amount and intensity of caregiving that will be required (5). A new prognostic model (34) has shown promise for this population but requires further validation. Third, previous research (38) has shown that most internists are uncomfortable discussing uncertain prognoses, as may be the case for a patient who survives an acute critical illness but still requires life support. However,

surrogates acknowledge the inevitable uncertainty in critical illness outcomes and still desire prognostic estimates in the setting of end-of-life decisions (39). Finally, the complexities of critical illness can be hard for providers to explain in terms that surrogates understand and value. The simple health outcome groupings we have reported may help in this regard and may also lend themselves to incorporation in future decision-support tools for this population. El-Jawahri and colleagues (40) have shown that decision tools that use simple categorizations of choices and outcomes are more effective than verbal descriptions alone in end-of-life considerations.

We enrolled critically ill patients near the time of tracheostomy. This is when the physician determines that timely ventilator liberation is unlikely and the surrogate decision maker acknowledges that the patient would desire prolonged life support. Although tracheostomy is being performed increasingly earlier in the course of ventilation, little persuasive evidence suggests that either early (<1 week) or late (>2 to 3 weeks) timing confers important clinical benefit (41–43). This uncertainty has probably contributed to the substantial variation in practice seen across physicians, hospitals, and regions (44).

Our study has several limitations. We used participant self-reports to quantify the duration of postdischarge care. Although this strategy may result in inaccuracies, data suggest that costs would be underestimated rather than inflated (45, 46). Similarly, we could not quantify the notable financial strain of critical illness on patients and their caregivers, also reducing its true economic effect. In addition, although we enrolled participants consecutively and few participants (20%) declined, our findings may not represent patients receiving prolonged mechanical ventilation at other institutions or those who have different sociocultural or linguistic backgrounds. The Durham, North Carolina, area has a relatively high long-term acute care facility penetration compared with other regions of the United States, which may lead to more care transitions. Further study in larger data sets may allow a more robust characterization of potentially modifiable risk factors for resource utilization.

The incidence of prolonged mechanical ventilation will probably increase in the coming years, consuming substantial health care resources in the process. Given the disproportionately high costs and associated disability of prolonged mechanical ventilation, clinicians need to reconsider their approach to its provision. Currently, the decision-making process for prolonged mechanical ventilation is marked by unrealistic expectations and poor communication. It seems prudent that, in the context of prolonged mechanical ventilation, physicians not only discuss long-term outcomes with surrogates in terms that they can easily understand but also explicitly convey the probable demands of treatment and the future functional dependence patients will probably have.

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## APPENDIX: COST CALCULATIONS

All costs are adjusted for inflation by the medical component of the consumer price index for the U.S. Southeastern region, urban, to 2007 U.S. dollars (47).

### Initial Hospitalization

Costs for the primary hospitalization (including physician fees) during which patients were enrolled in the study were determined by using itemized charges from each patient's administrative billing record and were converted to costs by using department-specific cost-to-charge ratios obtained from the Centers for Medicare & Medicaid Services Healthcare Cost Information System (19).

### Hospital Readmissions

Costs for subsequent hospital admissions were obtained by combining reported ICU and hospital lengths of stay with estimated average daily ICU and hospital costs by using the Centers for Medicare & Medicaid Services Medicare Provider Analysis Review. First, we used all 2006 Medicare Provider Analysis Review to identify all discharged patients in the Durham, North Carolina, hospital referral region (as defined by the Dartmouth Atlas) involving intensive care. Next, we estimated total costs for each hospitalization by multiplying departmental charges with departmental cost-to-charge ratios from the Medicare cost reports. We then used observed ICU and hospital lengths of stay to estimate average daily costs, weighting initial, second, and subsequent ICU days by using a previously validated approach (45, 46). After adjustment by the medical component of the consumer price index, daily hospital ward costs were \$1303. For patients requiring ICU care, costs were estimated at \$8545 for day 1, \$4126 for day 2, and \$2231 for subsequent days of care. Professional fees were estimated by adding 17% of hospital costs (20).

### Long-Term Acute Care Facilities

Using the Medicare Provider Analysis Review database, we evaluated all patients transferred to a long-term acute care facility from an acute care hospital in the Durham, North Carolina, hospital referral region in 2006. Total daily costs were estimated at \$1657 from the sum of department-specific charges multiplied by department-specific cost-to-charge ratios obtained from 2006 Medicare costs reports (45, 46).

### Skilled Nursing Facilities

Using the Medicare Provider Analysis Review database, we first identified all 2006 admissions to skilled nursing facilities (out of 8122 admissions to 39 facilities) among persons living in the 3-digit ZIP code 277xx, which encompasses Durham, North Carolina, and the surrounding area. Next, we obtained average daily costs (\$260) by multiplying total charges for the 8112 Medicare admissions to these facilities by the skilled nursing facility-specific cost-to-charge ratio taken from the Medicare Healthcare Cost Report Information System database, dividing by the length of stay.

### Rehabilitation Facilities

We used a procedure similar to that described for skilled nursing facilities to determine daily rehabilitation facility costs (\$458).

### Home Health Care Costs

We calculated home health care costs per Medicare guidelines described in the 2007 Federal Register (48). In general, a base payment (\$2337 in 2007) is made for the first 60 days of care that is itself adjusted for clinical status, functional status, and recent service utilization, as well as geographical differences in wage. This overall case-mix assessment, done using the Outcome and Assessment Information Set instrument, is a composite measure of clinical status, functional status, and recent service utilization. In this model, we assumed patients fit the case-mix category of C1F2S2, representing low to moderate disability.

Therefore, we multiplied the 2007 base payment (\$2337) by the case-mix adjustment factor corresponding to C1F2S2 (0.9393) to obtain the standard 60-day rate (\$2195). Next, we multiplied the case-mix-adjusted rate by the labor factor (0.77082) and adjusted this to the wage index of Durham County, North Carolina (0.9816), to calculate the adjusted labor component of the total cost (\$1661). The nonlabor component was calculated by multiplying the nonlabor proportion (0.22918) by the case-mix-adjusted rate (\$2195). Finally, the total home health care costs were calculated to be \$2164 by adding the labor and nonlabor components. For persons receiving 4 or more days of home health care, a per diem rate of \$48 was applied, assuming the care of a home health care aide (rather than nurse). Home ventilation was assigned a cost of \$950 per month (49).

### **Interfacility Transportation**

Hospital data were reviewed to account for all episodes of air (helicopter and fixed-wing airplane) travel to and from the study hospital during the initial hospitalization. Ground ambulance transport was assumed to occur during all transitions

between hospitals and postacute care facilities. Operational costs (labor, supplies, and vehicle) were obtained from institutional billing sources to estimate transportation episode costs per episode (\$2983 for ground transportation and \$9270 for air transportation).

### **Outpatient Clinic and Ambulatory Surgery Costs**

Patient charts were abstracted to quantify episodes of care in the emergency department, outpatient clinics, and ambulatory surgeries during follow-up. Costs were derived from average North Carolina service payments based on Current Procedural Terminology codes listed in the American Medical Association database (50). For emergency department and clinic visits, we assigned costs based on codes 99284 and 99213 (level 3 established patient return visit), respectively. Costs for ambulatory surgical procedures were estimated on the basis of procedures documented in the medical record by using relevant Current Procedural Terminology codes. These data were incomplete for 8 (6%) patients and were missing for 4 (3%) patients.

**Appendix Table 1. Mechanical Ventilation and 1-Year Outcomes, by Ventilator Status\***

Characteristic	All Patients (n = 126)	Weaned From Ventilator (n = 86)	Not Weaned From Ventilator (n = 40)
Median days of mechanical ventilation (IQR)	27 (18–24)	21 (16–37)	43 (33–74)
<b>Duration of mechanical ventilation, n (%)</b>			
<7 d	3 (2)	3 (3)	0
7–13 d	13 (10)	13 (15)	0
14–20 d	24 (19)	22 (26)	2 (5)
≥21 d	86 (68)	48 (56)	38 (95)
<b>Duration of ventilation before tracheostomy, d†</b>			
Median (IQR)	11 (8–17)	10 (7–16)	14 (9–17)
Range	3–47	3–47	3–30
Tracheostomy decannulated, n (%)	82 (65)	82 (95)	0
Median length of hospital stay (IQR), d	39 (28–57)	38 (28–52)	43 (31–77)
<b>Hospital discharge disposition, n (%)</b>			
Home without paid home health care	6 (5)	6 (7)	0
Home with paid home health care	14 (11)	12 (14)	2 (5)
Long-term acute care facility	36 (29)	24 (28)	12 (30)
Skilled nursing facility	17 (13)	15 (17)	2 (5)
Rehabilitation facility	23 (18)	23 (27)	0
Other hospital	3 (2)	3 (3.5)	0
Still in acute care hospital at 1 y	1 (1)	0	1 (3)
Inpatient hospice facility	3 (2)	3 (3.5)	0
Dead	23 (18)	0	23 (57)
Median transitions in care location (IQR), n‡	4 (2–6)	5 (3–7)	2 (1–3)
Percentage of all days alive receiving facility-based care or home health care (95% CI)§	74 (68–80)	62 (54–70)	100 (100–100)
1-y survival, n (%)	70 (56)	67 (78)	3 (8)
<b>1-y health outcome, n (%)  </b>			
Good	9 (7)	9 (11)	0
Fair	34 (27)	33 (38)	1 (3)
Poor	83 (66)	44 (51)	39 (97)

IQR = interquartile range.

\* Out of 126 patients.

† Does not include 1 patient who never had tracheostomy.

‡ Transitions of care location over 1 y for 103 hospital survivors overall. There were 86 hospital survivors among those weaned from ventilators and 17 hospital survivors among those who were never weaned from ventilators.

§ Includes acute hospitalization, postacute care facilities, and home health care received during the entire study period (1 y).

|| Health outcome categories measured at 1 y and defined as good (alive with no dependencies in activities of daily living), fair (alive but with 1 to 5 dependencies in activities of daily living), and poor (either alive and completely dependent or dead).



**Appendix Table 2. Patient and Process-of-Care Outcomes at 3 Months\***

Outcome	Value
Survival, <i>n</i> (%)	90 (71)
Disposition, <i>n</i> (%)	
Home without paid home care	13 (10)
Home with paid home care	19 (15)
Long-term acute care facility	10 (8)
Skilled nursing facility	14 (11)
Inpatient rehabilitation facility	12 (10)
Other hospital (transfer or readmission)	13 (10)
Residing in acute care hospital, never discharged	6 (5)
Dead	36 (29)
Liberated from ventilator and alive, <i>n</i> (%)	78 (87)
Patients readmitted, <i>n</i> (%)†	62 (60)
Quality of life in 3-mo survivors, <i>n</i> (%)‡	
Good	12 (13)
Fair	24 (27)
Poor	54 (60)
Median total quality-adjusted life-days (IQR)§	21 (14–35)
Health outcome, <i>n</i> (%)	
Good	9 (7)
Fair	47 (37)
Poor	70 (56)
Mean total costs (SD), \$¶	278 733 (279 855)

IQR = interquartile range.

\* Out of 126 patients, unless noted otherwise.

† Out of 103 hospital survivors. These 62 patients were readmitted for 96 separate episodes.

‡ Out of 90 patients. We determined quality of life by assessment of 3-mo survivors' surrogates by using the EuroQol-5D index score. Scores  $\leq 0.44$  were considered poor, 0.45 to 0.79 were considered fair, and  $\geq 0.80$  were considered good.

§ Calculated by adjusting all days alive during 3 mo with corresponding EuroQol-5D index scores obtained at 3-mo follow-up.

|| Health outcome categories measured at 3 mo and defined as good (alive with no dependencies in activities of daily living), fair (alive but with 1 to 5 dependencies in activities of daily living), and poor (either alive and completely dependent or dead).

¶ Includes acute and postacute care facilities.

**Appendix Table 3. Trajectories of Care and Resource Use at 1 Year, by Ventilator and Health Outcomes\***

Characteristic	Median Transitions of Care (IQR), <i>n</i>	<i>P</i> Value†	Median Readmissions (IQR), <i>n</i>	<i>P</i> Value†	Median Postacute Care Days (IQR), <i>n</i>	<i>P</i> Value†	Mean Total Costs (SD), \$	<i>P</i> Value†
<b>Mechanical ventilation characteristics and outcomes</b>								
Mechanical ventilation <21 d ( <i>n</i> = 40)	4 (2–6)	0.10	1 (0–2)	0.35	86 (25–285)	0.08	226 114 (167 101)	0.03
Mechanical ventilation ≥21 d ( <i>n</i> = 86)	3 (0–6)		1 (0–2)		51 (0–213)		343 819 (320 161)	
Mechanical ventilation <28 d ( <i>n</i> = 65)	4 (2–6)	0.02	1 (0–2)	0.10	80 (23–304)	0.007	235 229 (141 057)	0.004
Mechanical ventilation ≥28 d ( <i>n</i> = 61)	2 (0–6)		0 (0–2)		43 (0–116)		381 690 (370 540)	
<14 ventilator days before tracheostomy ( <i>n</i> = 72)	3 (1–5)	0.99	1 (0–2)	0.59	51 (17–250)	0.50	305 741 (356 426)	0.99
≥14 ventilator days before tracheostomy ( <i>n</i> = 54)	3 (1–6)		1 (0–2)		62 (0–237)		306 660 (148 362)	
Weaned from ventilation ( <i>n</i> = 86)‡	5 (3–7)	0.001	2 (0–2)	0.001	82 (32–290)	0.001	274 823 (157 475)	0.08
Not weaned from ventilation ( <i>n</i> = 40)	0 (0–2)		0 (0)		0 (0–41)		373 456 (447 585)	
<b>Health outcomes§</b>								
Good ( <i>n</i> = 9)	2 (2–5)	0.001	0 (0–2)	0.005	22 (14–45)	0.02	316 476 (326 988)	0.40
Fair ( <i>n</i> = 34)	5 (4–7)		2 (1–3)		80 (49–258)		321 757 (185 483)	
Poor ( <i>n</i> = 83)	2 (0–5)		0 (0–2)		44 (0–264)		151 751 (80 534)	
<b>Quality of life  </b>								
Good ( <i>n</i> = 19)	4 (2–5)	0.05	1 (0–2)	0.04	55 (21–112)	0.04	230 835 (119 741)	0.50
Fair ( <i>n</i> = 17)	6 (4–7)		2 (2–3)		288 (38–327)		320 884 (179 454)	
Poor ( <i>n</i> = 34)	5 (2–7)		2 (1–3)		145 (56–310)		346 374 (469 166)	

IQR = interquartile range.

\* Out of 126 patients.

† *P* values based on 1-way analysis of variance or Kruskal–Wallis tests.

‡ During the 1-y follow-up.

§ Health outcome categories measured at 1-y follow-up and defined as good (alive with no dependencies in activities of daily living), fair (alive but with 1 to 5 dependencies in activities of daily living), and poor (either alive and completely dependent or dead).

|| Quality of life determined by assessment of 1-y survivors' surrogates using the EuroQol-5D index score. Scores ≤0.44 were considered poor, 0.45 to 0.79 were considered fair, and ≥0.80 were considered good.