Cost and Outcome of Mechanical Ventilation for Life-Threatening Stroke

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Background and Purpose—Hospital mortality rates of 50% to 90% have been reported for stroke patients treated with mechanical ventilation. These data have raised serious questions about the cost-effectiveness of this intervention. We sought to determine how often stroke patients are mechanically ventilated, identify predictors of 30-day survival among ventilated patients, and evaluate the cost-effectiveness of this intervention.

Methods—We identified mechanically ventilated patients in a population-based multiethnic cohort of 510 incidence stroke patients who were hospitalized between July 1993 and June 1996. Factors affecting 30-day survival were identified in a multiple logistic regression analysis. We calculated the cost per patient discharged alive, life-year saved, and quality-adjusted life-year saved using a zero-cost, zero-life assumption.

Results—Ten percent of patients (n=52) were mechanically ventilated. Thirty-day mortality was 65% overall and did not differ significantly by stroke subtype. Glasgow Coma Scale score on the day of intubation (P<0.01) and subsequent neurological deterioration (P=0.02) were identified as predictors of 30-day mortality. The cost (1996 US dollars) of hospitalization per patient discharged alive was $89 400; the cost per year of life saved was $37 600; and the cost per quality-adjusted life-year saved was $174 200. Functional status of most survivors was poor; at 6 months, half were severely disabled and completely dependent. In a worst-case scenario of quality of life preferences, mechanical ventilation resulted in a net deficit of meaningful survival.

Conclusions—Two thirds of mechanically ventilated stroke patients die during their hospitalization, and most survivors are severely disabled. Survival is particularly unlikely if patients are deeply comatose or clinically deteriorate after intubation. In our multiethnic urban population, mechanical ventilation for stroke was relatively cost-effective for extending life but not for preserving quality of life. (Stroke. 2000;31:2346-2353.)

Key Words: cerebrovascular disorders • cost-benefit analysis • critical care • quality of life • stroke outcome • ventilators, mechanical

The risks and benefits of intensive care and mechanical ventilation (MV) for life-threatening stroke have come under increasing scrutiny in recent years. Endotracheal intubation is often performed as a potentially life-saving intervention in stroke patients with depressed level of consciousness, airway compromise, or respiratory failure. However, the prognosis of stroke patients treated with MV is poor, with reported mortality rates of 49% to 93%,1–10 and most survivors are severely disabled. Because care provided in intensive care units (ICUs) is expensive, these data have raised serious questions about the cost-effectiveness and cost-utility of MV for stroke. Although the cost-effectiveness of ICU care for the very elderly,11 those with cancer,12 and those with AIDS13 has been analyzed in recent years, whether MV prolongs meaningful survival in stroke patients at a reasonable cost is unknown.

When the prognosis is poor, deciding whether to intubate stroke patients can be a difficult decision, because withholding MV almost always leads to death within the next 24 to 48 hours,5 whereas intubation can lead to survival with severe neurological deficits. Although some patients may be willing to forgo life support when faced with neurological futility,14 definitive prognostic criteria on which to base decisions to withhold or withdraw care are lacking. Of equal importance, if the decision has been made to provide life support, identification of patients with a poor prognosis may help physicians and families to decide whether to implement heroic interventions to improve neurological outcome, such as decompressive craniectomy,15 intra-arterial thrombolysis,16 or moderate hypothermia.17

We conducted this study to (1) determine how frequently stroke patients are mechanically ventilated, (2) identify predictors of 30-day mortality, and (3) evaluate the cost-
effectiveness of MV for stroke in terms of patients discharged alive, years of life saved, and quality-adjusted life-years (QALYs) saved. To our knowledge, this is the first study to analyze MV in a population-based cohort of stroke patients and the first to specifically evaluate the cost-effectiveness of this intervention.

**Subjects and Methods**

**Study Population**

The study population consists of 510 incidence stroke patients who were hospitalized and prospectively enrolled in the population-based Northern Manhattan Stroke Study (NOMASS) between July 1, 1993, and June 30, 1996. There is a rich ethnic distribution within this community, which consists of approximately 250 000 individuals who reside in a geographic area bounded by 5 zip codes.

Patients were enrolled if they met the following criteria: (1) hospitalized for first stroke between July 1, 1993, and June 30, 1996; (2) aged 39 years at onset of stroke; and (3) resided in Northern Manhattan in a household with a telephone. The methods of case detection in NOMASS have been described previously. The study was approved by the Institutional Review Boards at Columbia-Presbyterian Medical Center and other primary hospitals, and all study was approved by the Institutional Review Boards at Columbia-Presbyterian Medical Center and other primary hospitals, and all participants or their surrogates provided written informed consent.

**Clinical Management and Analysis**

Patients enrolled in NOMASS who were hospitalized at Columbia-Presbyterian Medical Center and treated with MV were prospectively identified and included in the present analysis; we did not include patients treated with MV at other hospitals. During the study period, thrombolytic therapy and hemicraniectomy were not used for patients with cerebral infarction; intracerebral hemorrhage (ICH) patients were offered surgical evacuation or ventricular drainage when indicated; aneurysmal subarachnoid hemorrhage (SAH) patients were treated with early surgical clipping or coil embolization, nimodipine, and hypertensive hypervolemic therapy, but angioplasty was not used to treat medically refractory vasospasm.

Data were collected through review of medical records and neurological examination by the study physicians. Admission CT scans were evaluated for the presence of ICH, SAH, or infarction. Indications for MV were categorized as follows: elective, for airway protection; emergent, for acute neurological deterioration; pneumonia; seizure; pulmonary edema; and pulmonary embolism. Neurological status was evaluated on a daily basis, after temporary discontinuation of sedative or analgesic agents. We recorded National Institutes of Health Stroke Scale score on admission, Glasgow Coma Scale (GCS) scores daily, and Barthel Index (BI) scores before the stroke and 14 days after the stroke. Neurological deterioration was defined as a 2-point decrease in the GCS or worsened neurological deficit (eg, hemiparesis or aphasia), and neurological improvement was defined as a 2-point increase in the GCS or improved neurological deficit; both were categorized as occurring before MV, after MV, or before and after MV. For all patients discharged alive, patients and caregivers were interviewed by telephone or in person 6, 12, and 24 months after the stroke to assess poststroke survival, functional status (BI), and disposition. A final follow-up assessment of all survivors was performed in July 1999. A complete list of other data recorded is available from the authors by request.

**Cost-Effectiveness Analysis**

To evaluate the cost-effectiveness of MV for stroke from the perspective of the hospital, we divided the cost of hospitalization for the entire study cohort (excluding physician fees) by the number of patients discharged alive. To evaluate the cost-effectiveness of MV for stroke from the perspective of the healthcare system, we divided the cost of hospitalization plus the estimated costs of posthospital care (ie, rehabilitation and skilled nursing facility [SNF] expenses) by estimated survival, expressed in both life-years and QALYs. We did not include indirect economic costs related to work loss or reduced productivity. Both survival and costs were continuously discounted at an annual rate of 3%, with a range of 0% to 5% tested in a sensitivity analysis. All costs and cost estimates (Table 1) were adjusted to 1996 US dollars with the use of the medical care component of the consumer price index for all urban consumers and were rounded to the nearest $100. For the purposes of comparison, we performed an Ovid MEDLINE search combining the search terms “cost-benefit analysis” and “quality-adjusted life-years” with “cerebrovascular disorders,” “ventilators, mechanical,” and “intensive care” to identify pertinent studies published since 1990 reporting.
life-years or QALY saved. When more than one analysis of a particular intervention was identified, we selected the study finding the lowest degree of cost-effectiveness or cost-utility for comparison.

**Estimation of Costs**

Financial data from the hospital accounting system were obtained to calculate the cost of hospitalization for each patient. We multiplied line-item charges from each patient’s hospital bill, beginning on the calendar day of intubation, by specific charge-to-cost ratios that were calculated annually for 18 different hospital departments. Charges were converted to costs on the basis of these ratios. Since physicians bill patients separately, there was no way to reliably determine these costs through the accounting system. Therefore, cost of hospitalization does not include physician fees.

Posthospital follow-up data were used to estimate the cost of inpatient and outpatient rehabilitation and SNF care for each patient (Table 1). The costs of additional hospitalization for recurrent stroke or other medical problems were not included. We assumed that all patients discharged home from the hospital or an acute rehabilitation facility (ARF) underwent outpatient rehabilitation and would remain at home until death. We also assumed that all patients residing in a SNF at the time of last follow-up would remain there until death. Patients lost to follow-up after discharge to an ARF were assumed to have subsequently resided at home in the baseline analysis and in a SNF in the high-cost sensitivity analysis. Rehabilitation costs were estimated from a recent examination of stroke-related costs for Medicare patients nationwide suffering a stroke in 1993.24,25 The annual costs for SNF care were estimated on the basis of a study of long-term care insurers in the United States in 1993.25,26 To estimate the cost of SNF care for patients who were initially discharged to an ARF, we assumed that the duration of hospitalization and rehabilitation was 3 months.

**Estimation of Survival**

The date of death was recorded for each patient who died during the follow-up period (range, 3 to 6 years). Duration of survival for those who remained alive or were lost to follow-up at the end of this period was calculated with the use of 1996 age-, sex-, and race-specific estimates of life expectancy provided by the National Center for Health Statistics.27 We assumed a mortality rate for each patient 2.67 times that of the age-adjusted mortality rate for the US population in the baseline analysis, with a range of 1.25 to 4 times tested in the sensitivity analysis.25,28,29 We did not adjust mortality rates on the basis of degree of disability.30

**Value/Preference Assumptions**

To adjust the life-years accumulated by each hospital survivor for quality of life, we assessed functional status within a series of time epochs (0 to 3, 4 to 12, 13 to 24, and 25 to 36 months after stroke) and assigned a utility value for each epoch or fraction thereof. To satisfy the QALY concept, utility values must be based on patient preferences, anchored on perfect health (1.0) and death (0.0), and measured in an interval scale.22 The utility values we used (Table 1) were adapted from a published cost-effectiveness analysis of tissue plasminogen activator for acute stroke, which assigned utility values (with ranges) to the modified Rankin Scale (mRS).23 These utilities were derived from a patient preference survey for stroke outcomes, in which a state of perfect health was assigned 100 (scaled value 1.00), minor disability 51 (0.56), moderate disability 40 (0.44), death 9.8 (0.00), and severe disability 8 (−0.02).32 Because we did not use the mRS in our follow-up assessments, we converted BI scores to mRS categories according to published criteria as follows: BI 95 to 100=mRS 0 to 2; BI 70 to 90=mRS 3; BI 40 to 65=mRS 4; BI 0 to 35=mRS 5.32 We used the 14-day evaluation to estimate functional status during the 0- to 3-month epoch, the 6-month evaluation to estimate the 4- to 12-month epoch, the 1-year evaluation to estimate the 13- to 24-month epoch, and the 2-year evaluation to estimate the 25- to 36-month epoch. Patients followed for at least 6 months were assumed to have a stable future level of disability if they were subsequently lost to follow-up or survived beyond 2 years.29 Because functional capacity was uniformly poor at 14 days, patients with no assessment of functional capacity after the 14-day assessment were assigned a default mRS of 4 (BI 40 to 65), with a range of mRS 0 to 2 and mRS 5 tested in the sensitivity analysis.

**Sensitivity Analysis**

In the baseline analysis we calculated the following primary outcome measures: (1) the cost of hospitalization per patient discharged alive, (2) the number of life-years saved per patient, (3) the cost of hospital plus posthospital care per life-year saved, (4) the number of QALYs saved per patient, and (5) the cost of hospital plus posthospital care per QALY saved. We then performed a series of 1-way sensitivity analyses to evaluate the effect of varying different assumptions on these primary outcome measures, while holding the other variables fixed according to baseline assumptions (Table 1). Finally, to test the outside plausible range of our results, we adjusted all assumptions in the model to test a best-case and worst-case scenario.

**Statistical Analysis**

Continuous variables were compared with 2-tailed tests for normally distributed data and with the Mann-Whitney U test for nonnormally distributed data. Proportions were compared with the χ² test or Fisher’s exact test. For evaluation of prognostic factors, we chose 30-day mortality as the primary end point rather than the duration of poststroke survival because all but one in-hospital death occurred within 30 days and because the functional outcome of most patients surviving beyond this period was extremely poor. Demographic, CT, and clinical variables that were significantly associated with 30-day mortality in a univariate analysis were entered into a multiple logistic regression model to identify independent predictors of 30-day mortality. Survival curves were obtained by the Kaplan-Meier method. Significance was judged at the P<0.05 level.

**Results**

Of 510 hospitalized incidence stroke patients, 52 (10%) were treated with MV. MV was performed in 5% of patients (20/392) with cerebral infarction, 26% of patients with ICH (24/92), and 47% of patients (8/17) with SAH (P<0.0001).

**Patient Characteristics**

Mean age of the 52 study patients was 65 years (range, 34 to 94 years); there were 28 women (54%) and 24 men (46%). Thirty-one were Hispanic (60%), 14 black (27%), and 7 white (13%). The mean admission National Institutes of Health Stroke Scale score was 17.3 (range, 0 to 30), and mean GCS score was 9.6 (range, 3 to 15). The median interval from stroke onset to intubation was 6.5 hours (range, 30 minutes to 12 days); 65% (n=34) were intubated within 24 hours of onset. Indications for MV included elective intubation for airway protection in 52% (n=27), emergent intubation for acute neurological deterioration in 23% (n=12), pneumonia in 12% (n=6), seizures in 6% (n=3), and pulmonary edema or embolism in 6% (n=3); in 1 patient the indication was unknown.

Neurological deterioration occurred in 63% of patients (n=33). Deterioration occurred before intubation in 8 patients (15%), after intubation in 21 (40%), and before and after intubation in 4 (8%). Neurological improvement occurred after intubation in 13 patients (25%); 5 of these subjects had previously experienced deterioration.

**Survival and Outcome**

Overall mortality at 30 days was 65% (34/52); 30-day mortality was 50% (10/20) in patients with cerebral infarction, 71% (17/24) in ICH patients, and 88% (7/8) in SAH patients (P=0.13). All but 1 in-hospital death occurred within
30 days of stroke onset. The mean (±SD) duration of MV was 7.7±10.5 days (range, 1 to 52), mean ICU length of stay was 5.9±4.4 days (range, 1 to 22), and mean hospital length of stay was 18.4±17.4 days (range, 1 to 62). Among those who died in the hospital, the mean interval between stroke onset and death was 8.9±9.9 days; the immediate cause of death was neurological in 77% (n=26, including 12 who died of brain death) and due to a medical complication in 23% (n=9). Twenty-five patients (48%) had a do-not-resuscitate order written during their hospitalization, and do-not-resuscitate status was associated with higher 30-day mortality (84% [21/25] versus 48% [12/25]; P=0.007). MV was actively withdrawn from 4 of the 35 patients who died in the hospital (12%). Of the 17 patients who were discharged alive, 59% (n=10) were discharged to a SNF, 29% (n=5) to an ARF, and 12% (n=2) to home.

Functional capacity 6 months and 1 and 2 years after stroke was generally poor (Table 2). At 6 months, of 16 patients (31%) who were still alive, half were severely disabled and completely dependent (BI=35). At 1 year, among 14 known survivors (27%), only 2 (4%) were moderately independent (BI=70).

Factors Influencing 30-Day Survival
In a univariate analysis, 30-day survival was significantly influenced by 3 variables (Table 3): day of intubation GCS score, neurological deterioration after intubation, and neurological improvement after intubation. In a multiple logistic regression model, neurological deterioration after intubation (coded yes=1, no=0; odds ratio, 22.9; 95% CI, 2.4 to 215.3; P=0.006) and day of intubation GCS score (odds ratio, 0.1, per 1-point increase in GCS score; 95% CI, 0.53 to 0.59; P=0.001) were identified as independent predictors of 30-day mortality (coded yes=1, no=0). Thirty-day mortality was 100% (10/10) among patients with GCS scores of 5 on the day of intubation, 86% (18/21) among patients with GCS scores of 6 who experienced neurological deterioration after intubation, and 25% (5/20) among patients with GCS scores of 6 who had stable or improved deficits after intubation (P<0.0001, χ² test) (Figure).

Cost-Effectiveness Analysis
Mean cost of hospitalization after intubation was $27,300±21,500 (range, $2600 to $87,000). Compared with those who died, patients who survived to 30 days had a significantly longer ICU length of stay (median, 8 versus 3 days; P=0.02) and hospital length of stay (median, 38.5 versus 6 days; P<0.0001) and higher postintubation hospital costs (mean, $46,700 versus $17,000; P<0.0001). The duration of MV was not different between survivors and nonsurvivors (median, 4.5 versus 4 days; P=0.82).

The cost of hospitalization per patient discharged alive was $83,400. In the baseline analysis, 1.72 life-years were saved per patient intubated, at a cost of $37,600 per life-year, and

### TABLE 2. Mortality and Activities of Daily Living Scores After MV for Stroke

<table>
<thead>
<tr>
<th>Interval After Stroke</th>
<th>Dead</th>
<th>Alive</th>
<th>Unknown</th>
<th>BI* (if Known Alive)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95–100</td>
</tr>
<tr>
<td>30 days</td>
<td>34 (65)</td>
<td>18 (35)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>6 months</td>
<td>36 (69)</td>
<td>16 (31)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>1 year</td>
<td>38 (73)</td>
<td>14 (27)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>2 years</td>
<td>40 (77)</td>
<td>9 (17)</td>
<td>3 (6)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

Values are n (%). Percentages are the proportion of all patients (n=52) who were mechanically ventilated after stroke.

*BI is activities of daily living scale in which a score of 100 denotes complete functional independence and a score of 0 denotes total dependence.

### TABLE 3. Univariate Analysis of Variables Associated With 30-Day Mortality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nonsurvivors (n=34)</th>
<th>Survivors (n=18)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y (y)</td>
<td>64±15</td>
<td>67±12</td>
<td>0.62</td>
</tr>
<tr>
<td>Women</td>
<td>17 (50)</td>
<td>11 (61)</td>
<td>0.44</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td>0.86</td>
</tr>
<tr>
<td>Hispanic</td>
<td>21 (62)</td>
<td>10 (56)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>9 (26)</td>
<td>5 (28)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>4 (12)</td>
<td>3 (17)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>21 (62)</td>
<td>15 (83)</td>
<td>0.14</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>8 (24)</td>
<td>4 (22)</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Stroke characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemorrhagic stroke (ICH or SAH)</td>
<td>24 (71)</td>
<td>8 (44)</td>
<td>0.07</td>
</tr>
<tr>
<td>Size &gt;1 lobe</td>
<td>9 (26)</td>
<td>3 (17)</td>
<td>0.42</td>
</tr>
<tr>
<td>Intratentorial location</td>
<td>11 (32)</td>
<td>2 (11)</td>
<td>0.18</td>
</tr>
<tr>
<td>Midline shift &gt;1 cm</td>
<td>8 (24)</td>
<td>1 (6)</td>
<td>0.14</td>
</tr>
<tr>
<td>Intraventricular hemorrhage</td>
<td>19 (56)</td>
<td>7 (39)</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Clinical characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admission NIHSS score</td>
<td>18±8</td>
<td>16±7</td>
<td>0.29</td>
</tr>
<tr>
<td>Admission GCS score</td>
<td>9±5</td>
<td>11±3</td>
<td>0.23*</td>
</tr>
<tr>
<td>Day of intubation GCS score</td>
<td>7±4</td>
<td>9±3</td>
<td>0.03*</td>
</tr>
<tr>
<td>Intubation &lt;=24 h after onset</td>
<td>25 (74)</td>
<td>9 (50)</td>
<td>0.10</td>
</tr>
<tr>
<td>Elective intubation</td>
<td>16 (47)</td>
<td>8 (44)</td>
<td>0.78</td>
</tr>
<tr>
<td>Neurological deterioration after intubation†</td>
<td>22 (65)</td>
<td>3 (17)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Neurological improvement after intubation†</td>
<td>3 (9)</td>
<td>10 (56)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are n (%) or mean±SD. NIHSS indicates National Institutes of Health Stroke Scale.

†Refer to Subjects and Methods for definitions. Data not available in 1 patient.
0.37 QALYs were saved, at a cost of $174,200 per QALY (Table 4). In a 1-way sensitivity analysis, both cost per life-year and cost per QALY were mildly sensitive to survival and discounting assumptions and moderately sensitive to economic assumptions. However, cost per QALY was extremely sensitive to value/preference utility assumptions. Assumption of maximal utility values resulted in a 56% reduction in cost per QALY saved compared with the baseline scenario, whereas assumption of minimal utility values resulted in a net deficit of QALYs. The relative cost-effectiveness of MV for stroke compared with other cerebrovascular25,33–35 and critical care interventions 11–13,36 is shown in Table 5.

### Discussion

In this community-based study, 10% of stroke patients were treated with MV. Two thirds of these patients died during their hospitalization, and most survivors were profoundly disabled. In a multivariate analysis, deep coma on the day of intubation and neurological deterioration after intubation were identified as predictors of 30-day mortality. Compared with other conditions treated in ICUs, MV for stroke was cost-effective for prolonging life. However, compared with other interventions for cerebrovascular disease, MV was not cost-effective for preserving quality of life.

Thirty-day mortality in our patients was 65% (34/52), which is consistent with reported hospital mortality rates of 49% to 93% for intubated stroke patients. Variations in mortality between studies may result from differences in when and where the study was performed, patient demographics, criteria for and timing of intubation, access to ICU care, aggressiveness of medical management, and the frequency of withholding or withdrawing care. The highest mortality rates (>90%) were reported in an older study of patients treated between 1976 and 1986 and by a group who intubated only 2% of ischemic stroke patients and did not treat ventilated patients in an ICU. Stroke subtype did not significantly influence survival in our patients; other studies have also failed to identify differences in mortality between ventilated patients with hemorrhagic and ischemic stroke.1,2,4,6,8

Functional outcome among the patients who survived to discharge in our study was poor. At 1 year, of 27% (n = 14) who were still alive, half were profoundly disabled, and 10% were functionally independent (Table 2). Others have reported more favorable outcomes after MV for stroke. The proportion of hospital survivors discharged to home or an ARF (as opposed to a SNF or hospice) was 55% to 61% in other studies, compared with 41% in our study. Even more
striking, the combined proportion of survivors who were moderately independent (BI \( \geq 70 \)) at long-term follow-up was 53% (66/125) in 6 other studies of MV for stroke,\(^1\),\(^3\),\(^5\),\(^8\),\(^9\) compared with 17% (2/12) at 1 year in our study, despite the fact that mean age and preintubation GCS scores were similar. The reasons for this discrepancy are unclear. The number of long-term survivors in our study was small, which may have led to sample error. However, the potential effects of "referral bias" when hospital-based cohorts are compared with our community-based cohort, as well as the fact that our institution serves many economically disadvantaged ethnic minorities, must also be considered. Our patients may not have had the same financial resources, access to care, and level of motivation to pursue aggressive rehabilitation as patients treated in other studies.

Under baseline assumptions (Table 1), the incremental cost of hospital and posthospital care for our patients was $37 600 per year of life saved and $174 300 per QALY saved. Our estimates of cost per life-year and QALY saved were moderately sensitive to economic assumptions, whereas cost per QALY was extremely sensitive to value/Preference assumptions: in a 1-way sensitivity analysis, use of minimal utility values resulted in a net deficit of QALYs (Table 4). Within a clinical context, this means it is theoretically possible that MV for severe stroke results in an excess of human suffering, at tremendous expense. Previous research confirms that persons assigning values to ranges of health states consider some states to be worse than death,\(^37\) which presumably is why a large proportion of non-brain-dead neuro-ICU patients who die have life support withdrawn.\(^14\) Of note, the range of utilities we tested was based on the preferences of healthy outpatients\(^11\) rather than disabled stroke survivors, who might assign higher values to states of severe impairment than individuals who are in perfect health (the "bargaining down" effect).

Compared with other cerebrovascular and critical care interventions, MV for stroke appears to be relatively cost-effective for prolonging life but not for maintaining quality of life (Table 5). Most critical care cost-effectiveness studies have used a zero-life assumption and expressed their results in terms of life-years saved, because data regarding functional outcome and utilities for calculating QALYs were not available. In terms of life-years saved, MV for stroke is considerably less expensive than conditions that carry poor prospects of long-term survival, such as advanced age, cancer, and AIDS.\(^11\),\(^12\),\(^13\) On the other hand, interventions for cerebrovascular disease have been uniformly subjected to cost-utility analyses, and all appear to be less expensive than MV in terms of QALYs saved. This reflects the fact that under baseline assumptions, many severely impaired long-term survivors in our study were assigned utility values near zero.

Accurate prediction of survival among stroke patients who require MV is important. In a multivariate analysis, we found that a GCS score of 5 (present in 20% of patients) and neurological deterioration after intubation (present in 40%) were predictors of 30-day mortality (\(P<0.0001\), Figure). Depressed level of consciousness has been associated with increased mortality in other studies of MV for stroke,\(^1\),\(^2\),\(^8\) but the effect of clinical improvement or deterioration on outcome has not been analyzed before, despite the strong

<p>| TABLE 5. Cost-Effectiveness of Critical Care and Cerebrovascular Interventions |
|---------------------------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Intervention</th>
<th>Cost (1996 US $)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical care interventions</td>
<td>Per life-year saved</td>
<td></td>
</tr>
<tr>
<td>Mechanical ventilation for stroke*</td>
<td>37 600</td>
<td>Current study</td>
</tr>
<tr>
<td>tPA (versus streptokinase) for myocardial infarction†</td>
<td>43 500</td>
<td>36</td>
</tr>
<tr>
<td>Critical care for solid tumor malignancy‡</td>
<td>116 100</td>
<td>12</td>
</tr>
<tr>
<td>Mechanical ventilation for patients &gt;80 years‡§</td>
<td>148 700</td>
<td>11</td>
</tr>
<tr>
<td>Mechanical ventilation for Pneumocystis carinii and AIDS‡</td>
<td>225 300</td>
<td>13</td>
</tr>
<tr>
<td>Critical care for hematologic malignancy‡</td>
<td>265 500</td>
<td>12</td>
</tr>
<tr>
<td>Cerebrovascular interventions</td>
<td>Per QALY saved</td>
<td></td>
</tr>
<tr>
<td>tPA for cerebral infarction†</td>
<td>(8000)</td>
<td>25</td>
</tr>
<tr>
<td>Carotid endarterectomy for symptomatic carotid stenosis†</td>
<td>4400</td>
<td>35</td>
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<tr>
<td>Transesophageal echocardiography for cerebral infarction†¶</td>
<td>13 000</td>
<td>33</td>
</tr>
<tr>
<td>Carotid endarterectomy for asymptomatic carotid stenosis†</td>
<td>56 900</td>
<td>35</td>
</tr>
<tr>
<td>Ultrasonographic screening for asymptomatic carotid stenosis∥</td>
<td>129 800</td>
<td>34</td>
</tr>
<tr>
<td>Mechanical ventilation for stroke*</td>
<td>174 200</td>
<td>Current study</td>
</tr>
</tbody>
</table>

All costs adjusted to 1996 US dollars using the medical care component of the consumer price index for all urban consumers, rounded to the nearest $100. Values in parentheses represent cost savings. tPA indicates tissue plasminogen activator.

*Based on hospital costs, excludes physician-related costs.
†Based on hospital and physician-related costs.
‡Based on hospital charges, excludes physician-related charges.
§Worst-case scenario.
∥Includes indirect costs.
¶Includes indirect costs.
influence of this variable on clinical decision making. Other reported predictors of increased mortality include loss of brain stem reflexes, older age, bradycardia, early intubation, emergent intubation for neurological deterioration, and male sex (among ischemic stroke patients). We did not record the presence or absence of pupillary responses or other brain stem reflexes in our patients.

Several weaknesses of this study deserve mention. First, we have probably underestimated the true cost of hospital and posthospital care in our patients. Only hospital costs, which constituted 42% of overall costs, were directly measured from our database. Posthospital costs for rehabilitation and SNF care were estimated on the basis of nationwide data in patients who may have had less overall disability, fewer rehabilitation needs, and lower-intensity nursing care than our study population. We also did not include physician fees, which may represent up to 10% of total hospital costs in stroke patients, and costs associated with recurrent hospitalization. Second, the overall level of disability in our multiethnic urban population was more severe than in previous studies of MV for stroke, which may limit the generalizability of our findings. Finally, the fact that life support was actively withdrawn from 4 of the 34 patients who died (12%) may have biased our analysis of mortality predictors, in that the variables we identified (deep coma and deterioration) may have influenced clinical decision making and led to a “self-fulfilling prophesy.” Had life-support been aggressively withheld or withdrawn life support. Large multicenter studies of diverse patient populations are needed to more precisely define predictors of mortality or good functional outcome in stroke patients treated with MV.

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