Intensive Care Unit (ICU) – Managed Elderly Hospitalizations with Dementia in Texas, 2001–2010: A Population-Level Analysis

Authors' Contribution:
Study Design **A**
Data Collection **B**
Statistical Analysis **C**
Data Interpretation **D**
Manuscript Preparation **E**
Literature Search **F**
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Background: The demand for critical care services among elderly with dementia outpaces that of their non-dementia elderly counterparts. However, there are scarce data on the corresponding attributes among ICU-managed patients with dementia.

Material/Methods: We used the Texas Inpatient Public Use Data File to examine temporal trends of the demographics, burden of comorbidities, measures of severity of illness, use of healthcare resources, and short-term outcomes among hospitalizations aged 65 years or older with a reported diagnosis of dementia, who were admitted to ICU (D-ICU hospitalizations) between 2001 and 2010. Average annual percent changes (AAPC) were derived.

Results: D-ICU hospitalizations (n=276,056) had increasing mean (SD) Charlson comorbidity index [1.7 (1.5) *vs.* 2.6 (1.9)], with reported organ failure (OF) nearly doubling from 25% to 48.5%, between 2001–2001 and 2009–2010, respectively. Use of life support interventions was infrequent, but rose in parallel with corresponding changes in respiratory and renal failure. Median total hospital charges increased from $26,442 to $36,380 between 2001–2002 and 2009–2010. Routine home discharge declined (–5.2%/year [–6.2%– –4.1%]) with corresponding rising use of home health services (+7.2%/year [4.4–10%]). Rates of discharge to another hospital or a nursing facility remained unchanged, together accounting for 60.4% of discharges of hospital survivors in 2010. Transfers to a long-term acute care hospital increased 9.2%/year (6.9–11.5%). Hospital mortality (7.5%) remained unchanged.

Conclusions: Elderly D-ICU hospitalizations have increasing comorbidity burden, with rising severity of illness, and increasing use of health care resources. Though the majority survived hospitalization, most D-ICU hospitalizations were discharged to another facility.

MeSH Keywords: Critical Care • Dementia • Health Care Costs • Multiple Organ Failure • Outcome Assessment (Health Care)

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Background

The rapidly growing elderly population [1] is expected to lead to a corresponding accelerated increase in those diagnosed with dementia [2], with disproportionately high use of health care resources among the latter [3,4], which can include admission to ICU among hospitalized patients. However, as dementia remains an incurable, progressive illness, there has been increasing concern that with advanced disease, provision of critical care may not translate into improved quality of life [5] and may be inconsistent with patients' goals of care [6].

Nevertheless, recent studies documented increasing use of ICU at end-of-life (EOL) among elderly with dementia [7], and ICU-managed patients were shown to account for 1 in 2 EOL hospitalizations in this population [8]. In addition, we recently reported a rapid rise in demand for critical care services among elderly hospitalizations with dementia in Texas, outpacing the contemporaneous growth rate of the elderly population in the state and that of ICU admissions among elderly without reported diagnosis of dementia [9]. At the present rate of growth, dementia-associated hospitalizations are projected to account for 1 in 4 ICU admissions among the elderly in 2020 [9], and would add to a documented increasing strain on the critical care system in the United States [10]. However, the drivers of the observed rising demand for critical care among elderly with dementia are unknown.

Data on the evolving attributes of the ICU-managed population of elderly diagnosed with dementia may inform health care policy and clinical practice, assist in optimizing future allocation of limited critical care resources, and may enhance data-driven discussions by clinicians about patients' goals of care and, when applicable, end-of-life. However, although the epidemiology and clinical features of hospitalizations among patients with dementia have been studied extensively [3,11], there has been paucity of data on ICU-managed elderly with a diagnosis of dementia. Specifically, no contemporary population-level data were reported to date on the evolving demographic characteristics, burden of non-dementia comorbidities, severity of illness, life-support interventions, fiscal burden of hospitalizations involving critical care, and hospital disposition of elderly patients with a diagnosis of dementia who require ICU care. Rather, while several studies examined use of ICU as part of patients' transitions of care [7,12,13], reports on ICU-managed patients with dementia were limited, for the most part, to single-center reports [14,15] and a population-based investigation limited to the temporal patterns of use of mechanical ventilation in the United States (US) [16].

Given the aforementioned data gaps, the present study was designed to examine the temporal trends of population-level demographics, burden of comorbidities, measures of severity of illness, use of health care resources, and short-term outcomes of ICU-managed elderly patients with a diagnosis of dementia in Texas.

Material and Methods

Setting and data sources

The Texas Inpatient Public Use Data File (TIPUDF) was used to perform a retrospective, population-based cohort study of ICU-managed elderly state residents with a diagnosis of dementia. The TIPUDF is an administrative data set maintained by the Texas Department of State Health Services [17]. The use of the data set has been previously described [18]. Briefly, TIPUDF includes detailed de-identified inpatient discharge data on the demographic, clinical, resource utilization, and outcome domains from state-licensed hospitals, and captures 93% to 97% of all hospital discharges in the state. The Institutional Review Board of Texas Tech Health Sciences Center has determined that the present study is exempt from formal review due to use of publicly available, de-identified data.

Study population

We identified hospitalizations aged 65 years or older with a reported diagnosis of dementia and with ICU admission (termed D-ICU hospitalizations in the remainder of the manuscript) during the years 2001–2010. A diagnosis of dementia was based on reported *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes (Supplementary file 1), modeled on previously described approach [16,19,20]. An admission to ICU was defined as presence of an Intensive Care Unit charge greater than $0.

Data collection

We collected data on patients' age, gender, race/ethnicity (categorized as non-Hispanic black [black], non-Hispanic white [white], Hispanic, and other), co-morbid conditions (based on the Deyo modification of the Charlson Comorbidity Index [21]), type and number of failing organs [22,23] (Supplementary Table 1), life-support interventions (mechanical ventilation, central venous catheterization, and new hemodialysis; new hemodialysis was defined as a combination of a hemodialysis code and a code for acute renal failure) (Supplementary Table 2), hospital length of stay, total hospital charges, and discharge disposition at the end of hospitalization. The categories of patients' discharge disposition at the end of hospitalization were grouped as death, hospice, home (with and without home health), another hospital, nursing facility, and other (leave against medical advice and unknown). End-of-life hospitalizations were defined as those ending with

either death or discharge to hospice [8]. Because patients with chronic critical illness are increasingly discharged to long-term acute care hospitals [24], we further examined the use of these facilities among patients discharged to another hospital. Discharge destination (excluding EOL hospitalizations) was used as proxy of residual morbidity. The number of failing organs was used as proxy for severity of illness [25].

Data analysis

Because TIPUDF provides discharge-level, rather than patient-level information, we reported identified ICU-managed events as number of hospitalizations.

The state of Texas masks gender data of hospitalizations with a diagnosis of infection with the human immunodeficiency virus (HIV), and those with ethanol or drug abuse. Thus, analyses involving gender were restricted to hospitalizations without the aforementioned 3 diagnoses.

Linear regression analyses of log-transformed data were used to examine the temporal trends of examined demographics, clinical attributes, use of healthcare resources, and outcomes, and to derive a corresponding relative average annual percent change (AAPC). We further examined the change in the annual volume of invasive mechanical ventilation between 2001 and 2010 to allow comparison to an earlier study [16]. Total hospital charges were adjusted to the Consumer Price Index [26] (2010 dollars).

Group data are reported as numbers (percentages) for categorical variables and mean (standard deviation [SD]) or median (interquartile range [IQR]) for continuous variables, as appropriate. χ^2 tests were used to compare categorical data. Ninety-five percent confidence intervals (95% CI) were calculated. We used SAS version 9.3 (SAS Institute, Cary, NC, USA) and MedCalc version 15.6 (MedCalc Software, Ostend, Belgium) software for data analyses. A 2-sided p value <0.05 was considered significant.

Results

There were 276,056 D-ICU hospitalizations during study period, of which 62.5% were female, and 39.9% were aged ≥85 years. There has been rapid rise in the volume of D-ICU hospitalizations. Details of the demographic characteristics and comorbidities are outlined in Table 1. There has been slow progressive decrease in female hospitalizations, while those among aged ≥85 years rose 9% between 2001 and 2010. The majority of D-ICU hospitalizations were white, followed by Hispanics. However, there has been slow decrease among the former group, while the proportion of Hispanics among

D-ICU hospitalizations rose 33% over the past decade. Non-dementia comorbidities were increasingly reported in nearly all D-ICU hospitalizations and the mean Charlson comorbidity index rose 5.6%/year. The rate of D-ICU hospitalizations with ≥2 non-dementia comorbidities rose between 2001–2002 from 37.8% to 54.6% (P<.001). Congestive heart failure, diabetes, and lung disease remained the most common among examined comorbidities during study period. Infection with human immunodeficiency virus was extremely rare (49 hospitalizations). The frequency of all examined comorbidities, except myocardial infarction, rose, though variably, with the fastest rise from 2001 to 2010 (340%) for renal disease.

The patterns of organ failure and used health care resources are detailed in Table 2. Between 2001 and 2010 the rate of any organ failure doubled from 25.2% to 50.4%, while that of ≥3 organ failures rose over 800%. The rate of all organ failures rose progressively, though at variable pace, with fastest being the renal and hepatic systems. The 4 most common affected systems (respiratory, neurological, cardiovascular and renal) remained unchanged. However, their rank has changed over study period, with renal failure becoming the most common.

Mechanical ventilation, new hemodialysis, and central venous catheterization were used infrequently. Use of non-invasive mechanical ventilation rose 26.9%/year, nearly 5-fold faster than that for invasive mechanical ventilation. The annual volume of invasive mechanical ventilation increased 302% from 2001 to 2010. New hemodialysis was rarely initiated, though its use rose rapidly at 23.4%/year. Hospital length of stay remained unchanged during study period. The median hospital charges increased progressively, rising 47% between 2001 and 2010, and the total hospital charges for the whole cohort rose from 480 million to 2.34 billion dollars.

The discharge disposition patterns of D-ICU hospitalizations are outlined in Table 3. Hospital mortality was 7.5% for the whole cohort and remained unchanged, while there was rapid rise in discharge to hospice. Home discharge decreased progressively (–2%/year), while the rate of use of home health services nearly doubled by 2010. Transfers to another hospital remained unchanged. However, discharge to a long-term acute care hospital rose 9.2%/year and accounted for 50.8% of all transfers to another hospital by 2010. Transfer to a nursing facility was the most common overall destination at end of hospitalization, with the rate of transfer remaining unchanged.

Discussion

We found that over the last decade there has been increasing burden of comorbidities, rising development of organ failure, and corresponding increased use of health care resources

Table 1. The demographic characteristics and comorbidities of ICU-managed hospitalizations with a diagnosis of dementia, 2001–2010.

Group	2001–2002 n=28,305	2003–2004 n=35,911	2005–2006 n=55,676	2007–2008 n=71,660	2009–2010 n=84,504	AAPC (95% CI)[a]	P-value
Female[b] (%)	64.4	64.1	62.7	62	61.5	−0.6 (−0.8 to −0.4)	<0.001
Age ≥85 years (%)	38.3	38.1	38.5	40.5	41.6	1.1 (0.6 to 1.6)	0.002
Race/ethnicity[c] (%)							
Hispanic	14.2	14.6	16.4	17	18.7	3.4 (2.0 to 4.8)	<0.001
black	12.9	13.2	12.9	12.9	12.6	−0.4 (−0.9 to 0.2)	0.188
white	67.4	66.5	65.3	65.9	64.1	−0.5 (−0.9 to −0.1)	0.048
other	5.3	5.6	5.2	4.1	4.6	−3.2 (−5.9 to −0.4)	0.028
Charlson comorbidity index[d]	1.7 (1.5)	1.8 (1.4)	2.3 (1.8)	2.5 (1.9)	2.6 (1.9)	5.6 (4.1 to 7.1)	<0.001
Comorbidities[e] (%)							
One or more comorbidity	91.1	90.8	91.8	92.9	93.2	0.3 (0.2 to 0.5)	0.001
Myocardial infarction	11.4	9.9	12.2	12.8	12.4	2.0 (−0.2 to 4.2)	0.069
Congestive heart failure	30.3	31.4	36.4	36.3	34.9	2.1 (0.7 to 3.4)	0.007
Cerebrovascular disease	17.6	16.9	18.1	18.5	18.8	1.1 (0.3 to 1.8)	0.014
Peripheral vascular disease	10.2	10.6	15.2	16.4	16.7	7.1 (4.7 to 9.5)	<0.001
Chronic lung disease	19.8	20	25.2	27	27.4	5.5 (3.6 to 7.3)	<0.001
Connective tissue disease	1.1	1.2	1.6	1.9	2.3	9.7 (6.9 to 12.5)	<0.001
Diabetes mellitus	21.3	22.4	27.9	30.8	32.3	5.7 (4.5 to 6.9)	<0.001
Renal disease	5.8	6.5	14.2	20.5	24.3	19.7 (15.3 to 24.2)	<0.001
Liver disease	1.1	1.2	1.8	2.2	2.5	10.7 (8.0 to 13.4)	<0.001
Malignancy	4	3.8	4.9	4.9	5.1	3.5 (1.5 to 5.6)	0.004

[a] AAPC – average annual percent change (95% confidence intervals); [b] The denominator used to derive female/male percentage for the cohort was based on hospitalizations with available gender designation; no significant change was noted in the annual rate of masked gender (P=.454); [c] Percent figures are rounded; race/ethnicity designation was missing in 300 hospitalizations (0.1%); [d] Mean (standard deviation); [e] Non-dementia comrbidities based on the Deyo-Charlson comorbidity index.

among D-ICU hospitalizations. These trends were associated, in turn, with rising rate of EOL hospitalizations and increasing use of post-acute care resources, likely reflecting increased residual morbidity among survivors.

The causes of the small decline in the proportion of females and the rising rates of those aged 85 years and of Hispanics among D-ICU hospitalizations are uncertain, though the latter change may reflect in part the changing demographics in the state [27]. However, the design of the study precludes inference about the sources of these trends and the contribution of possibly changing risks of critical illness among males, older patients, and Hispanics versus the evolving demographics in prevalent dementia population in the state remains to be determined.

Our data indicate an increasing burden of non-dementia comorbidities over the past decade among D-ICU hospitalizations. The change may simply reflect reported rise in the burden of chronic illness among the elderly in the US [28]. However, we found that the frequency of 2 or more non-dementia comorbidities among D-ICU hospitalizations, though similar to that among elderly Medicare patients with at least 2 or more comorbid conditions in 1999–2000 [29], increased by 2009–2010 at double the rate (44.4% *vs.* 21.6%) among the former. In addition, the reported frequencies of diabetes and renal disease among D-ICU hospitalizations in 2002, though similar to those reported at the time among Medicare patients [30], rose at a much faster rate in the former group. Thus, notwithstanding the differences in scope, methods of data acquisition, and examined comorbidities, the observed aforementioned patterns

Table 3. Discharge disposition of ICU-managed hospitalizations with a diagnosis of dementia, 2001–2010.

Group (%)[b]	2001–2002 n=28,305	2003–2004 n=35,911	2005–2006 n=55,676	2007–2008 n=71,660	2009–2010 n=84,504	AAPC (95% CI)[a]	P-value
End-of-life hospitalization[c]	10.7	10.5	13.2	14.1	14.7	4.5 (2.9 to 6.1)	<0.001
Death	8.5	6.9	7.6	7.6	7.1	−1.4 (−3.7 to 0.9)	0.176
Hospice	2.2	3.6	5.6	6.5	7.5	15.7 (11.7 to 20.0)	<0.001
Home	38	38.6	35.1	33.8	33.3	−2.0 (−2.6 to −1.3)	<0.001
Routine home	31.4	29.6	24.3	22.5	21.6	−5.2 (−6.2 to −4.1)	<0.001
Home health care	6.6	8.9	10.7	11.3	11.7	7.2 (4.4 to 10.0)	<0.001
Another hospital	10.4	12.2	12.9	12.5	12.7	1.7 (−1.6 to 5.1)	0.266
Long-term care hospital[d]	–	3.6	4.6	5.8	6.3	9.2 (6.9 to 11.5)	<0.001
Nursing facility	37.6	38.3	38.6	39.3	38.9	−12.7 (−1.8 to 1.1)	0.589
Other[e]	3.3	0.4	0.3	0.3	0.4	−12.7 (−35.3 to 9.9)	0.232

[a] AAPC – average annual percent change (95% confidence interval); [b] Percent figures are rounded; [c] End-of-life hospitalizations were those with either hospital death or discharge to hospice; [d] Examination of annual changes was limited to the years 2003–2010, as the first discharges to a long-term care facility were reported in 2003; [e] Leave against medical advice and unknown discharge destination.

of organ failure in critically ill elderly patients with or without dementia. However, similar findings of the most common types of organ failure in the elderly were reported by other investigators [33,34].

There are limited data on use of life-support interventions in elderly critically ill patients with dementia. The examined life-support interventions were used infrequently in the present cohort. However, the rate of their use rose rapidly, reflecting the rising rates of organ failure. Pisani and colleagues have reported markedly higher rates of use of mechanical ventilation and hemodialysis in a small single-center study of elderly with dementia [14]. However, their patients had markedly higher severity of illness, with 3-fold higher hospital mortality than the present cohort. In another study, the annual volume of invasive mechanical ventilation among elderly hospitalizations with dementia in the US increased more than 150% between 2001 and 2010 [16], rising at half the corresponding growth rate at the present cohort. However, the sources of the latter difference are unclear, as the investigators did not provide other clinical data.

The fiscal burden of D-ICU hospitalizations has not been previously directly examined. The progressive increase in hospital charges for individual hospitalizations over the past decade is likely related to increased comorbidity burden and severity of illness. The later changes and the rapid rise in D-ICU hospitalizations led to nearly 5-fold growth of total hospital charges, reaching 2.3 billion dollars for the whole cohort in 2010. The lack of significant change in hospital length of stay likely indicates increasing care intensity, and given an increasingly sicker cohort may reflect improved care efficiencies and increased discharge to long-term acute care facilities, which nearly doubled during study period.

The evolving trends of hospital mortality, discharge to hospice and overall EOL hospitalizations involving the present cohort were recently reported [8]. The unchanged hospital mortality among patients with increasing burden of comorbidity and severity of illness may suggest improving outcomes. However, the concomitant rapid rise in discharge to hospice does not support this proposition. Moreover, it is likely that the present outcome data further underestimate changes in short-term mortality, as increasing number of survivors were transferred to long-term acute care hospitals, which are associated with substantial early death [24]. Although the majority survived hospitalization, D-ICU hospitalizations were associated with increasing residual morbidity, as indicated by decreased overall home discharge, near-doubling in use of home health services and, as noted, increasing transfers to long-term acute care facilities, suggestive of rising occurrence of chronic critical illness [24]. Thus, only 1 in 5 D-ICU hospitalizations had routine home discharge by 2010 and the majority of non-EOL hospitalizations were transferred to another institution throughout study period. Our findings contrast the report by Callahan and colleagues who found, using a nationally representative sample, nearly double the rate of routine home discharge (52.2%) among hospitalized elderly with dementia [12]. The difference likely reflects in part an expected higher residual morbidity among ICU-managed patients, as compared to all hospitalizations.

Although we characterized the trends of specific attributes of D-ICU hospitalizations, the design of the present study precludes determination of the factors underlying the rapid rise in demand for critical care services in the elderly population with dementia, which has been increasingly outpacing that of the general elderly population [9,16]. However, several possible hypotheses may be considered. Decreasing threshold for ICU admission may increase apparent demand for critical care services. However, the present findings suggest an increasingly sicker population with worsening short-term outcomes.

A substantial number of patients with dementia remain undiagnosed [35]. Although gains in diagnosis may have increased the population with recognized dementia, there are no data to indicate a substantial, progressive improvement in the diagnosis of dementia in the community or hospital setting. Increased survival of patients with dementia has been proposed by Qui and colleagues, based on serial cross-sectional surveys in Sweden [36] and could have contributed to the rising demand for critical care services. However, there has been no corroborating population data in the US, and survival estimates in this population can be challenging [37].

Alternatively, the rise in demand for critical care services may reflect a rapid rise in prevalent dementia. However, available estimates suggest that the rate of growth in the volume of D-ICU hospitalizations outpaced the rate of change of the number of people living with Alzheimer's dementia in Texas from 2000 to 2010 (25.9%) [38], and that of the overall projected growth for the dementia population [2].

Nevertheless, the aforementioned reported changes in prevalent dementia may have been underestimates. Another possible contributor to the growth of the population with dementia may have been related to the increasing patient survivorship following critical illness. Increased survivorship of the critically ill reflects a combination of substantial drop in case fatality [39], coupled with rising burden of critical illness [40], with the latter affecting disproportionately the elderly population [10]. Over five million patients are admitted annually to an ICU in the US [41], with the majority surviving hospitalization [39,41]. Nevertheless, survivors of critical illness have high rates of hospital readmission, including to an ICU [42], and frequent occurrence of cognitive dysfunction sequelae have been increasingly recognized [43]. New (incident) dementia was reported in 12–18% survivors of critical illness without prior diagnosis [19,44]. In a study by Guerra and colleagues, the incidence of a new diagnosis of dementia in the 3 years following ICU admission among elderly Medicare patients was 2 to 3-fold higher than that in similar age-stratified cohorts in the general population [19]. A more recent prospective study by Pandharipande and colleagues demonstrated common occurrence of new dementia-like cognitive dysfunction at 1 year

following critical illness, though the affected cognitive function domains in the latter study were broader than those seen characteristically in Alzheimer's dementia [45].

The mechanisms underlying the association between critical illness and subsequent cognitive dysfunction remain elusive [43,45]. The documented association may represent previously unrecognized dementia, accelerated clinical course of existing dementia, newly developed dementia unrelated to critical illness, or actual causal role of critical illness events with or without preceding dementia [19,46]. However, while the distinction between the aforementioned possibilities is crucial for development of preventive and interventional tools, it may be hypothesized that the increasing survivorship of critically ill elderly could have had a considerable contribution to the observed rise of demand for critical care services noted in the present cohort and by others [16]. Moving beyond the critical care-related focus of the present study, the prevalent long-term sequelae among the increasing number of survivors of critical illness may need to be considered in addition to the contemporary modeling approach [2] in future projections of cognitive dysfunction in the general population.

The study has several limitations. We used a retrospective design with its attendant limitations. In addition, administrative data provide limited clinical detail and we could not examine changes in the sources of ICU admission (i.e., emergency department, wards) or the specific indications for ICU transfer during hospitalization. However, population-level data can transcend the increasingly recognized variability in local patient mix, threshold for ICU admission [47,48], processes of care [48] and discharge practices [49], and may provide broader perspective on the examined population.

Although we used similar code-based approach to that of other investigators [16,19], use of ICD-9 codes to identify hospitalizations with dementia may have led to misclassification in some cases. Previous report documented sensitivity and specificity of 85% and 89%, respectively, using similar ICD-9 codes [20]. In addition, the severity of dementia could not be determined and it has been suggested that administrative data may underestimate milder stages of dementia [3], related in part to prevalent underestimation of pre-existing cognitive dysfunction [14,36]. However, it is unlikely that the aforementioned classification limitations biased the observed temporal trends.

In addition, established severity-of-illness scores cannot be derived from administrative data and we used the number of failing organs as a surrogate measure. However, similar approach was employed by other investigators [25], and the number of failing organs was associated with incremental risk of death of critically ill patients [25,50].

Because the state of Texas does not provide tools to convert hospital charges to costs, we reported hospital charges rather than costs of care, limiting comparisons with other cost data.

Finally, although we examined a cohort of D-ICU hospitalizations in a large state with a diverse population, the characteristics of elderly patients admitted to ICU, the used resources, and short-term outcomes may vary across states and nationally.

Conclusions

To our knowledge, the present study represents the first population-level examination of the temporal trends of the demographic, clinical, resource use, and outcome attributes of elderly patients with dementia admitted to ICU. D-ICU hospitalizations in the present cohort had incremental burden of non-dementia comorbidity and rising severity of illness. Though

used infrequently, the examined life support interventions were incrementally employed, and the fiscal burden of D-ICU hospitalizations rose substantially. Although most D-ICU hospitalizations survived to discharge, the majority required transfer to another facility, with decreasing routine home discharge, suggesting incremental residual morbidity.

The present findings support previous concerns [5–7] about a broad benefit of ICU care among elderly with dementia and highlight the need to refine clinicians' ability to identify those who stand to benefit from critical care interventions, and to explore system- and practice-related interventions to better align use of critical care services with patients' goals of care.

Acknowledgment

Supplementary Material

International Classification of Diseases, Ninth Edition, Clinical Modification codes for identification of hospitalizations with dementia (Where only 3 or 4-digit codes are listed, all associated subcodes are included.): 290.0-290.4, 291.1, 291.2, 292.82, 292.83, 294.0, 294.1, 294.8, 294.9, 331.0, 331.1, 331.2, 331.7, 331.82, 331.9, 797

Supplementary Table 1. International Classification of Diseases, Ninth Edition, Clinical Modification codes for classification of organ failure (Where only 3 or 4-digit codes are listed, all associated subcodes are included.)

Category	ICD-9-CM codes
Respiratory	518.81, 518.82, 518.5, 518.84, 786.09, 799.1, 96.7–96.72
Cardiovascular	458.8, 458.9, 785.50, 785.51, 785.52, 785.59
Renal	584
Hepatic	570, 572.2,573.4
Hematologic	286.6, 286.7, 286.9, 287.4, 287.5
Metabolic	276.2
Neurologic	293.0, 293.1, 348.1, 348.3, 780.01, 780.09

Supplementary Table 2. International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) codes for selected life-support procedures.

Category	ICD-9-CM codes
Invasive mechanical ventilation	96.70–96.72
Noninvasive mechanical ventilation	93.90
Central venous catheterization	38.96, 38.97
Hemodialysis	38.95

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