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A double-hit: End-stage renal disease patients suffer worse outcomes in intracerebral hemorrhage

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Abstract:

BACKGROUND: Intracerebral hemorrhage (ICH) carries significant morbidity and mortality. Previous single-center retrospective analysis suggests that end-stage renal disease (ESRD) is a risk factor for severe ICH and worse outcomes. This investigation aims to examine the impact of ESRD on ICH severity, complications, and outcomes using a multicenter national database.

METHODS: The International Classification of Disease, Ninth and Tenth Revision Clinical Modification codes were used to query the National Inpatient Sample for patients with ICH and ESRD between 2010 and 2019. Primary endpoints were the functional outcome, length of stay (LOS), and in-hospital mortality. Multivariate variable regression models and a propensity-score matched analysis were established to analyze patient outcomes associated with baseline patient characteristics.

RESULTS: We identified 211,266 patients with ICH, and among them, 7,864 (3.77%) patients had a concurrent diagnosis of ESRD. Patients with ESRD were younger (60.85 vs. 67.64, $P < 0.01$) and demonstrated increased ICH severity (0.78 vs. 0.77, $P < 0.01$). ESRD patients experienced higher rates of sepsis (15.9% vs. 6.15%, $P < 0.01$), acute myocardial infarction (8.05% vs. 3.65%, $P < 0.01$), and cardiac arrest (5.94% vs. 2.4%, $P < 0.01$). In addition, ESRD predicted poor discharge disposition (odds ratio [OR]: 2.385, 95% confidence interval [CI]: 2.227–2.555, $P < 0.01$), longer hospital LOS (OR: 1.629, 95% CI: 1.553–1.709, $P < 0.01$), and in-hospital mortality (OR: 2.786, 95% CI: 2.647–2.932, $P < 0.01$).

CONCLUSIONS: This study utilizes a multicenter database to analyze the effect of ESRD on ICH outcomes. ESRD is a significant predictor of poor functional outcomes, in-hospital mortality, and prolonged stay in the ICH population.

Keywords:

Cerebral hemorrhage, kidney failure, patient outcome assessment

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Introduction

Intracerebral hemorrhage (ICH) is a devastating disease that leaves patients with severe morbidity and mortality. The incidence rate of ICH is approximately 24.6/100,000 person per year, with a 34%–45% rate of case mortality and only 12%–39% rate of independence after the incidence.[1,2]

End-stage renal disease (ESRD) patients have an elevated risk of developing ischemic or hemorrhagic stroke due to a variety of underlying pathologies, including vascular remodeling, hypertension, atrial fibrillation, hematologic abnormalities, and genetic susceptibility to brain bleeds. In addition to an increased risk of developing stroke, these patients also display an increased mortality rate compared to non-ESRD patients.[3-6] It has been proposed that cerebral and renal vasculature share many similarities, so patients

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with impaired renal function may be more susceptible to vascular calcification and autoregulation dysfunction that would contribute to an increased risk of hemorrhagic or ischemic stroke.[7-10] In addition, patients with ESRD display higher rates of traditional stroke risk factors, including atrial fibrillation and hypertension.[11] This increased risk of a thromboembolic event in combination with hematologic dysfunction commonly seen in people with ESRD can greatly increase the risk of hemorrhagic conversion of ischemic stroke, causing ICH.

Current literature investigating the role of ESRD on ICH is limited to single-center retrospective studies and none have controlled for the severity of ICH.[1-7] In this study, we aim to investigate the effect of ESRD on ICH outcomes using the National Inpatient Sample (NIS) database, a large, multicenter database.

Methods

Data source

The National Inpatient Dataset (NIS) is a 20% stratified sample of all United States community hospital discharges. It contains information regarding health-care utilization, patient demographics, and outcomes ranging from 1988 to 2022. Since 2012, the NIS has recorded more than 7 million annual visits from community hospitals. As per the Healthcare Utilization Project guidelines, use of the NIS does not require IRB approval because it lacks any patient identifying information.

Patient selection and cohort development

The study sample was derived by utilizing the International Classification of Disease, Ninth and Tenth Revision, Clinical Modification (ICD-9/10-CM) codes to filter for patients from 2010 to 2019. Patients who experienced ICH were identified using ICD-9-CM code: 431; ICD-10-CM code: I61. ESRD patients were identified with ICD-9-CM code: 585.6; ICD-10-CM code: N18.6. All ICD codes characterizing patient characteristics, interventions, and complications are described in Supplementary Table 1.

Baseline demographic and clinical characteristics

The baseline characteristics examined were age, race, and ICH severity. The ICH severity score is a clinical grading scale predicting functional outcomes after spontaneous ICH. This grading score uses ICD codes as surrogate measures for stroke severity and has been validated with prior studies.[12-14] Predictive factors include aphasia, cerebral edema, hemiparesis, hydrocephalus, dysphagia, stupor, and mechanical ventilation. Supplementary Table 2 details the specifics of ICH severity score indices.

Clinical outcomes

Clinical outcomes were defined as functional outcome, length of stay (LOS), and in-hospital mortality. Good functional outcome was designated as a routine discharge home or short-term care facility. Poor functional outcome describes patients with a tracheostomy or gastrostomy, discharge to the long-term care facility, or death.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 28 (IBM SPSS Statistics 28; Armonk, NY, USA). Two-tailed significance level was set at $P < 0.05$. Patient baseline characteristics and ICH severity was assessed using *t*-tests and Pearson's Chi-squared test. Multivariate variable regression models were established to analyze patient outcomes associated with baseline patient characteristics. Propensity-score matched (PSM) cohorts were generated using 1:1 nearest neighbor matching and stratified for ICH prevalence. *P* values, odds ratios, and 95% confidence intervals (CI) are reported when applicable.

Results

Baseline characteristics, treatments, and complications

From 2010 to 2019, 211,266 patients were identified with intracranial hemorrhage, of which 7,864 (3.77%) patients were also diagnosed with ESRD. ESRD patients had a higher probability of being younger (60.9 vs. 67.6, $P < 0.01$), male (57.6% vs. 54.8%, $P < 0.01$) and of Caucasian race (32.7% vs. 15.6%, $P < 0.01$). They also had more severe ICH as measured by the ICH severity index (0.78 vs. 0.77, $P < 0.01$) compared to non-ESRD patients. The ESRD cohort demonstrated larger rates of hypertension (50.6% vs. 49.2%, $P < 0.01$) but lower rates of atrial fibrillation (17.7% vs. 22.9%, $P < 0.01$), obesity (10.9% vs. 15.7%, $P < 0.01$), atherosclerosis (1.19% vs. 2.04%, $P < 0.01$), diabetes (25.2% vs. 31.9%, $P < 0.01$), COPD (2.11% vs. 7.25%, $P < 0.01$), and tobacco use (15.9% vs. 17.8%, $P < 0.01$). In terms of intervention, ESRD patients had lower rates of external ventricular drain (EVD) placement (9.45% vs. 8.23%, $P < 0.01$) and decompressive hemicraniectomy (1.14% vs. 2.30%, $P < 0.01$) (all $P < 0.01$).

When examining the total, nonadjusted cohort, ESRD patients experienced more deep-vein thrombosis (3.92% vs. 3.31%, $P < 0.01$), pulmonary embolism (2.37% vs. 1.80%, $P < 0.01$), pneumonia (17.6% vs. 8.27%, $P < 0.01$), sepsis (15.9% vs. 4.74%, $P < 0.01$), acute myocardial infarction (MI) (8.05% vs. 3.35%, $P < 0.01$), and cardiac arrest (5.94% vs. 1.98%, $P < 0.01$). By contrast, they were observed to have lower rates of urinary tract infection (12.14% vs. 13.62%, $P < 0.01$) when compared to non-ESRD patients [Table 1].

Outcomes of intracerebral hemorrhage patients stratified by end-stage renal disease diagnosis

ESRD patients had higher rates of poor outcomes

Table 1: Comparison of baseline clinical characteristics, interventions, complications, and outcomes of intracerebral hemorrhage patients stratified by end-stage renal disease

	Total cohort, *n* (%)	ESRD, *n* (%)	Non-ESRD, *n* (%)	*P*
n	211,266 (100)	7,864 (3.72)	203,402 (96.28)	
Baseline demographic and clinical characteristics				
Age (years), mean (SEM)	67.39 (0.03)	60.85 (0.16)	67.64 (0.03)	<0.01
White race	128,607 (60.87)	2,896 (36.83)	125,711 (59.5)	<0.01
Female	857,522 (45.03)	62,202 (42.45)	795,320 (45.25)	<0.01
ICH severity	0.77 (0)	0.779 (0)	0.774 (0)	<0.01
Atrial fibrillation	428,366 (22.49)	26,006 (17.74)	402,360 (22.89)	<0.01
Obesity/morbid obesity	291,305 (15.3)	15,920 (10.86)	275,385 (15.67)	<0.01
Atherosclerosis	37,617 (1.98)	1,745 (1.19)	35,872 (2.04)	<0.01
Hypertension	938,687 (49.29)	74,169 (50.6)	864,518 (49.18)	<0.01
Diabetes mellitus	597,192 (31.36)	36,910 (25.18)	560,282 (31.87)	<0.01
Long-term anticoagulant use	153,136 (8.04)	11,317 (7.72)	141,819 (8.07)	<0.01
COPD	130,516 (6.85)	3,095 (2.11)	127,421 (7.25)	<0.01
Tobacco use	335,568 (17.62)	23,286 (15.89)	312,282 (17.76)	<0.01
Interventions				
External ventricular drain	17,487 (8.28)	743 (9.45)	16,744 (8.23)	<0.01
Decompressive hemicraniectomy	4,770 (2.26)	90 (1.14)	4,680 (2.30)	<0.01
Complications				
DVT	7,046 (3.34)	308 (3.92)	6,738 (3.31)	<0.01
PE	3,847 (1.82)	186 (2.37)	3,661 (1.80)	<0.01
Pneumonia	18,209 (8.62)	1,381 (17.56)	16,828 (8.27)	<0.01
UTI	28,650 (13.56)	954 (12.13)	27,696 (13.62)	<0.01
Sepsis	10,883 (5.15)	1,251 (15.91)	9,632 (4.74)	<0.01
AKI	33,457 (15.84)	2,550 (32.43)	30,907 (15.2)	<0.01
Acute MI	7,446 (3.52)	633 (8.05)	6,813 (3.35)	<0.01
Cardiac arrest	4,494 (2.13)	467 (5.94)	4,027 (1.98)	<0.01
Outcomes				
Poor functional outcome	163,522 (77.4)	6,723 (85.49)	156,799 (77.09)	<0.01
In-hospital mortality	46,007 (21.79)	2,966 (37.74)	43,041 (21.17)	<0.01
LOS	9.23 (0.03)	15.06 (0.24)	9.01 (0.03)	<0.01

SEM: Standard error of mean, ICH: Intracerebral hemorrhage, MI: Myocardial infarction, ESRD: End-stage renal disease, COPD: Chronic obstructive pulmonary disease, LOS: Length of stay, DVT: Deep-vein thrombosis, PE: Pulmonary embolism, UTI: Urinary tract infection, AKI: Acute kidney injury

Table 2: Multivariate regression analyzing the impact of end-stage renal disease on outcomes

	Coefficient	*P*	OR (95% CI for OR)
Poor functional outcome	0.869	<0.01	2.385 (2.227–2.555)
In-hospital mortality	1.024	<0.01	2.786 (2.647–2.932)
LOS > average	0.488	<0.01	1.629 (1.553–1.709)

LOS: Length of stay, OR: Odds ratio, CI: Confidence interval

when compared to non-ESRD patients (85.5% vs. 77.1%, $P < 0.01$), in-hospital mortality (37.7% vs. 21.2%, $P < 0.01$), and above average LOS (15.06 days vs. 9.01 days, $P < 0.01$) [Table 1]. The multivariate regression analyzing the impact of ESRD on outcomes showed that the presence of ESRD was a significant predictor of poorer functional outcomes (odds ratio [OR]: 2.385, 95% CI: 2.227–2.555, $P < 0.01$), above average LOS (OR: 1.629, 95% CI: 1.553–1.709, $P < 0.01$), and in-hospital mortality (OR: 2.786, CI: 2.647–2.932, $P < 0.01$) when controlling for age, race, and ICH severity [Table 2].

The PSM analysis resulted in a cohort of 15,731 patients, and those with ESRD continued to show lower rates of EVD placement (9.45% vs. 10.5%, $P = 0.03$) but higher rates of decompressive hemicraniectomy (1.14% vs. 0.00%, $P < 0.01$). In addition, this analysis was in concordance with the multivariate analysis and demonstrated an increased incidence of sepsis (15.9% vs. 6.68%, $P < 0.01$), acute MI (8.05% vs. 3.65%, $P < 0.01$), and cardiac arrest (5.94% vs. 2.40%, $P < 0.01$) [Table 3] in the ESRD cohort.

In terms of outcomes, ESRD patients showed a higher rate of poor functional outcomes (85.5% vs. 76.4%, $P < 0.01$), mortality (37.7% vs. 19.1%, $P < 0.01$), and experienced longer LOS (15.1 vs. 10.1 days, $P < 0.01$) [Table 3]. In addition, ESRD continued to be a significant predictor of poor functional outcome (OR: 2.082, 95% CI: 1.9–2.281, $P < 0.01$), LOS above average (OR: 1.606, 95% CI: 1.501–1.719, $P < 0.01$), and in-hospital mortality (OR: 2.729, 95% CI: 2.519–2.957, $P < 0.01$) [Table 4].

Discussion

In total, 211,266 patients with ICH were identified

Table 3: Propensity score-adjusted cohort comparison of interventions, complications, and outcomes of acute ischemic stroke patients stratified by end-stage renal disease

	Total cohort, *n* (%)	ESRD, *n* (%)	Non-ESRD, *n* (%)	*P*
Interventions				
External ventricular drain	1,570 (9.98)	743 (9.45)	827 (10.52)	0.03
Decompressive hemicraniectomy	90 (0.57)	90 (1.14)	0	<0.01
Complications				
DVT	575 (3.66)	308 (3.92)	267 (3.4)	0.08
PE	363 (2.31)	186 (2.37)	177 (2.25)	0.63
Decompressive hemicraniectomy	1 (0.01)	0	1 (0.01)	0.32
Pneumonia	2,042 (12.98)	1,381 (17.56)	661 (8.41)	<0.01
UTI	1,919 (12.2)	954 (12.13)	965 (12.27)	0.78
Sepsis	1,776 (11.29)	1,251 (15.91)	525 (6.68)	<0.01
AKI	4,095 (26.04)	2,550 (32.43)	1,545 (19.65)	<0.01
Acute MI	920 (5.85)	633 (8.05)	287 (3.65)	<0.01
Cardiac arrest	656 (4.17)	467 (5.94)	189 (2.4)	<0.01
Outcomes				
Poor functional outcome	12,732 (80.96)	6,723 (85.49)	6,009 (76.43)	<0.01
In-hospital mortality	4,466 (28.42)	2,966 (37.74)	1,500 (19.1)	<0.01
LOS	12.58 (0.15)	15.06 (0.24)	10.09 (0.16)	<0.01

MI: Myocardial infarction, ESRD: End-stage renal disease, LOS: Length of stay, DVT: Deep-vein thrombosis, PE: Pulmonary embolism, AKI: Acute kidney injury, UTI: Urinary tract infection

Table 4: Propensity score-adjusted multivariate regression analyzing the impact of end-stage renal disease on outcomes

	Coefficient	*P*	OR (95% CI for OR)
Poor functional outcome	0.733	<0.01	2.082 (1.9–2.281)
In-hospital mortality	1.004	<0.01	2.729 (2.519–2.957)
LOS > average	0.474	<0.01	1.606 (1.501–1.719)

LOS: Length of stay, OR: Odds ratio, CI: Confidence interval

between 2010 and 2019. The incidence of ESRD in ICH patients was 3.77%. Patients with ESRD were younger, more likely to be of white race, and had higher ICH severity on admission. In both the complete ICH population and the PSM cohort, ESRD patients had higher rates of in-hospital complications such as sepsis, pneumonia, acute MI, and cardiac arrest. ESRD patients were less likely to receive an EVD than their non-ESRD matched cohort. Moreover, the rate of decompressive hemicraniectomy was significantly higher in ESRD patients after PSM adjustment. Overall, these variations in treatment and complications can contribute to the increased rates of poor functional outcomes, in-hospital mortality, and longer LOS observed in ESRD patients.

Epidemiology and variations in baseline clinical characteristics

Cerebral microvasculature is reliant on autoregulation to maintain consistent flow during blood pressure (BP) fluctuations. Patients with impaired renal function are prone to cerebral autoregulation dysregulation, which increases their susceptibility to hemorrhage following hyper-perfusion.[15] This is a consequence of chronic conditions such as diabetes mellitus and hypertension, which result in vascular changes such as arterial calcification.[10] The mechanism of hyperperfusion in ESRD patients is related inversely to glomerular filtration rate; as glomerular filtration rate decreases, patients are more like to exhibit cerebral hyperperfusion. Additionally, anemia secondary to renal failure can exacerbate this pathologic hyperperfusion.[16] Hyperperfusion, coupled with the impaired autoregulation of cerebral microvasculature, can lead to an increased incidence of ICH.

Patients who developed ICH in association with ESRD were younger than non-ESRD patients. Previous studies have shown that ESRD patients are more likely to develop cerebrovascular disease and stroke at a younger age when compared to the overall population.[17,18] While ESRD is most common in patients older than 65 (38%), 6% of patients between ages 18 and 44 and 12% of patients between ages 44 and 64 developed ESRD.[19] The development of early-age ESRD and the consequential increased risk of hemorrhage is one explanation for the earlier incidence of ICH development in ESRD populations. In addition, patients with ESRD due to ADPKD could have ICH due to intracranial aneurysmal rupture, as this population is far more likely to develop a ruptured aneurysm at a younger age than the overall population. Although subarachnoid hemorrhage is conventionally considered the type of bleed resulting from aneurysm rupture, approximately 50% of aneurysm ruptures also result in ICH.[20]

ESRD patients also showed higher ICH severity scores than non-ESRD patients. The ICH severity score is a surrogate measure that examines rates of aphasia, cerebral edema, hemiparesis, hydrocephalus, dysphagia,

stupor, and mechanical ventilation to determine the degree of the intracranial bleed in the absence of coded clinical data such as Hunt-Hess, WFNS, or ICH scores. Previous studies have shown that it has a strong correlation to clinical results using similar large datasets such as the NIS.[12-14] The increased severity scores seen in our ESRD patients could be attributed to a variety of underlying pathologies, which could contribute to an increased intracranial bleed burden, including hypertension, platelet dysfunction, and the presence of anticoagulation medication.

Impact of end-stage renal disease on intracerebral hemorrhage treatment and complication

In the PSM analysis, patients with ICH and ESRD have higher rates of decompressive hemicraniectomy and lower rates of EVD placements compared to the non-ESRD population.[19] The increased BP volatility in patients observed with ESRD can result in more severe bleeds and cause a larger shift of brain parenchyma against the skull or cause herniation through the foramen magnum.[21] Interventions aimed at reducing intracranial pressure may be performed at higher rates in this patient population to relieve these risks. This is also supported by the comparable rates of herniation across both cohorts despite the increase in ICH severity of ESRD patients.

Patients with ICH associated with ESRD had lower rates of urinary tract infections (UTI's) compared to non-ESRD patients. The high rate of anuria among ESRD is one possible explanation for the decreased incidence of UTIs.[22] Second, this suggests that the increased rates of sepsis observed in the ESRD cohort are likely related to ventilator associated pneumonia in the context ff increased ventilator use.

Our data showed that patients with ICH and ESRD had higher rates of acute MI and cardiac arrest. Chronic hypertension and hypervolemia due to ESRD can cause ventricular hypertrophy, which decreases coronary flow reserve and increases the risk of ischemia, especially during hypoperfusion.[23] Small-vessel disease, caused by hypertension or increased calcium phosphate deposition, can also exacerbate cardiovascular damage secondary to ESRD.[24] Overall, in ICH patients with ESRD, our observed incidence of cardiac arrest and MI is more than double the incidence in the non-ESRD cohort. This is unsurprising as the risk for coronary artery disease and MI is doubled in association with ICH in the general ESRD population.[25] Given these observations, clinicians should be increasingly cognizant of the heightened risk of MI and cardiac arrest in ICH patients with concomitant ESRD.

Impact of end-stage renal disease on intracerebral hemorrhage outcomes

In both the complete and the PSM cohorts, patients with ICH and ESRD had higher rates of poor functional outcome, in-hospital mortality, and greater than average LOS. This observation was further supported by multivariate analysis, where ESRD patients with ICH have a mortality rate 2.6 times greater than normal and are nearly twice as likely to have a poor functional outcome. With poor functional outcomes occurring in >85% of patients and mortality in 38% of patients, it is apparent that the burden of ICH in these patients is severe. It should be noted that a limitation of our study is that the functional status of patients before ICH was not examined, so it may be a less reliable predictor as ESRD patients already have significant medical comorbidities at baseline. While the poor functional outcome is measured by the percentage of discharge to a higher level of care facility, ESRD patients may have been initially residing in these locations because of their medical complexity. Nevertheless, the mortality rate of 38% seen in our results is significant and could be used to formulate goals of care discussion with the patient and their family.

Limitations

The limitations of this study are primarily because of the nature of the design, a retrospective observational cohort, and its reliance on administrative databases. The use of retrospective analysis precludes any causal relationships from being determined. The NIS is subject to coding errors and inconsistencies, especially across the ICD-9-CM and ICD-10-CM transition. As ICD-9-CM and ICD-10-CM codes are the primary means of identifying patients, temporal relationships between diagnosis and hospital admission cannot be determined. The NIS does not utilize scoring systems such as the modified Rankin scale or the Glasgow Coma Scale. In addition, although it would be insightful to classify patients by creatinine clearance or presence of altered BP, information such as laboratory values, vital signs, and radiographic data are not reported in the NIS database. While the NIH-Stroke Severity Score was used as a template to control for ICH severity in this analysis, a standardized score for neurological deficit after ICH would increase the accuracy of our results. Finally, we are unable to follow patients after hospital discharge. As a result, 30- and 60-day mortality metrics cannot be ascertained.

Conclusions

While the relationship between ESRD and ICH has previously been explored in literature, this is the first study to utilize a multicenter database to explore these disease states and its effects on complications and outcomes. Overall, patients with ICH and ESRD are younger, have more severe ICH, and have higher rates of intracranial pressure-reducing procedures, pneumonia, sepsis, acute kidney injury, acute MI, and

cardiac arrest than non-ESRD patients. The increased rates of complications in patients with ESRD may contribute to the observed worsening of functional outcomes, increased mortality, and longer LOS. Given the large impact of ESRD on both the incidence and outcome of ICH, further research on ICH prevention and management can potentially decrease complication risks and improve outcomes. Nevertheless, nationwide, multicenter analysis such as this can shed light on the clinical course of ICH in patients with ESRD to provide evidence to support clinical decision-making.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Supplementary Table 1: All International Classification of Disease-9/International Classification of Disease-10-clinical modification codes used

	ICD-9 codes	ICD-10 codes
Patient characteristics		
Atrial fibrillation	42731	I480, I481, I482, I4891
Obesity/morbid obesity	2780	E66
Atherosclerosis	440	I70
Hypertension	401	I10, I11, I12, I13
Diabetes mellitus	250	E10, E11
Long-term anticoagulant use	V5861	Z7901
Long-term anticoagulant use	V5863	Z7902
COPD	491, 492	J41, J43
Tobacco	3051	F17200, F17201, F17210, F17211, F17220, F17221, F17290, F17291
Acute ischemic stroke	433, 434	I63
Aphasia	438.1, 784.3	I69.32
Hemiparesis	438.2, 342	I69.35
Herniation	348.4	G93.5
Cerebral edema	348.5	G93.6
Coma	78001, 78003	R402, R403
Stupor	78002, 78009	R400, R404
Dysphagia	7872	R131
Intervention		
External ventricular drain	022	0096
Decompressive hemicraniectomy	0124, 0125, 0136, 0153, 0159	00J00ZZ, 0N800ZZ, 0W9100Z, 0W910ZZ, 0WC10ZZ, 0N500ZZ, 0NB00ZZ, 0NT10ZZ, 0NT30ZZ, 0NT40ZZ, 0NT50ZZ, 0NT60ZZ, 0NT70ZZ, 009000Z, 00900ZZ, 00C00ZZ, 00B70ZZ, 00500ZZ, 00B00ZZ, 00T70ZZ
Mechanical ventilation	967	z99.1
Tracheostomy	31.1, 31.2	0B11
Gastrostomy	43.1, 44.3	0BH6. 0D16
Complications		
DVT	4534, 4538	I824
PE	4151	I26
Pneumonia	480–486	J12–J18
UTI	5990	N390
Acute MI	410	I21
Cardiac arrest	4275	I46
AKI	584, 586	N17
Sepsis	99591	A41

ICD: International Classification of Disease, COPD: Chronic obstructive pulmonary disease, DVT: Deep-vein thrombosis, PE: Pulmonary embolism, MI: Myocardial infarction, AKI: Acute kidney injury, UTI: Urinary tract infection

Supplementary Table 2: Intracerebral hemorrhage stroke severity score

Acute ischemic stroke severity indices	Total cohort, *n* (%)	ESRD, *n* (%)	Non-ESRD, *n* (%)	*P*
Aphasia	62,249 (29.46)	1458 (18.54)	60,791 (29.89)	<0.01
Cerebral edema	67,206 (31.81)	2110 (26.83)	65,096 (32)	<0.01
Coma	34,424 (16.29)	1321 (16.8)	33,103 (16.27)	0.22
Herniation	30,462 (14.42)	1084 (13.78)	29,378 (14.44)	0.10
Hemiparesis	9056 (4.29)	430 (5.47)	8626 (4.24)	<0.01
Hydrocephalus	27,893 (13.2)	1161 (14.76)	26,732 (13.14)	<0.01
Dysphagia	34,243 (16.21)	885 (11.25)	33,358 (16.4)	<0.01
Stupor	2291 (1.08)	47 (0.6)	2244 (1.1)	<0.01
Mechanical ventilation	29,735 (14.07)	1786 (22.71)	27,949 (13.74)	<0.01

ESRD: End-stage renal disease