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Hospital Complications Among Older Adults: Better Processes Could Reduce the Risk of Delirium

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Short Tittle: Better Processes Could Reduce the Risk of Delirium

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Hospital Complications Among Older Adults: Better Processes Could Reduce the Risk of Delirium

ABSTRACT

Using observational data and variation in hospital admissions across days of the week, we examined the association between ED boarding time and development of delirium within 72 hours of admission among patients aged 65+ years admitted to an inpatient neurology ward. We exploited a natural experiment created by potentially exogenous variation in boarding time across days of the week because of competition for the neurology floor beds. Using proportional hazard models adjusting for socio-demographic and clinical characteristics in a propensity score, we examined the time to delirium onset among 858 patients: 2/3 were admitted for stroke, with the remaining admitted for another acute neurologic event. Among all patients, 81.2% had at least one delirium risk factor in addition to age. All eligible patients received delirium prevention protocols upon admission to the floor and received at least one delirium screening event. While the clinical and social-demographic characteristics of admitted patients were comparable across days of the week, patients with ED arrival on Sunday or Tuesday were more likely to have had delayed floor admission (waiting time greater than 13 hours) and delirium (adjusted HR=1.54, 95%CI:1.37-1.75). Delayed initiation of delirium prevention protocol appeared to be associated with greater risk of delirium within the initial 72 hours of a hospital admission.

Keywords: Quality of Care/Patient Safety, Mental Health, Hospitals, Integrated Delivery Systems, Health Care Organizations and Systems, Clinical Practice Patterns, Aging, Access/Demand/Utilization of Services, Geriatrics

INTRODUCTION

Delirium is an acute cognitive disorder characterized by altered awareness, attentional deficits, confusion, and disorientation (Sachdev et al., 2014). Current estimates of new-onset delirium underscore the sobering fact that delirium overwhelmingly develops in medical settings (as high as 82% in intensive care settings) compared to the community at large (approximately 1%-2%) (Dharmarajan et al., 2017). Critically, research has demonstrated that 30%-40% of all delirium cases are preventable (Dharmarajan et al., 2017, Inouye et al., 2014, Inouye et al., 1999, Neurology, 2016).

Although delirium reverberates through all age populations, older adults (≥65 years of age) are at greater risk of developing delirium during an acute illness, as are individuals with an underlying neurocognitive disorder (mild cognitive impairment and dementia). New-onset delirium in older patients alone translates to a high financial burden on the health care system (Dittrich et al., 2016, Lundstrom et al., 2005). Despite known efficacy of inpatient delirium preventative strategies and predictive models to identify at-risk patients, new-onset delirium occurrence and the associated expenditures remain unchanged (Davis et al., 2013).

Delirium represents a global challenge for healthcare managers, healthcare providers, and payors because it increases hospital costs (i.e., prolonged utilization of services and hospital stay) and also decreases hospital revenue (e.g., reimbursement penalties in value-based payment models) (Mate and Compton-Phillips, 2014, Haas et al., 2015, Porter and Kaplan, 2016, Collier, 2012). With the COVID-19 pandemic, administrators have faced several challenges with respect to managing hospital capacity (Eriksson et al., 2017, Bravata et al., 2021). As a result, multiple stakeholders began to review their hospital admission processes with the ultimate goal of improving patient outcomes.

However, ongoing endeavors to assess the efficacy of delirium prevention strategies have overlooked the key contributing factors, such as the healthcare experience prior to receiving preventive measures on the inpatient wards (e.g., ED experience and bed transfer processes). Therefore, individuals that experience a delay between initial ED arrival and transfer to an inpatient bed (i.e., "delayed bed-flow," "boarding") may have delayed access to preventative care. Unfortunately, traditional estimates of the association between ED boarding and delirium have been confounded by baseline disease severity and other unmeasured variables. For instance, greater disease severity might reduce the ED boarding time while increase delirium risk.

We exploited a natural experiment created by exogenous bed competition to examine the impact of prolonged ED boarding (certain days of the week) on the risk of delirium within 72 hours of admission.

METHODS

Study design

We conducted a retrospective study using data abstracted from routine clinical care documented in electronic health records (EHRs) of a large academic medical center between 01/2016 and 12/2018. Our hypothesis was that prolonged ED boarding (i.e., waiting time at the fourth quartile) increases the risk of delirium during an urgent inpatient admission. In our conceptual framework (Figure 1), the association between ED boarding and delirium might be confounded by disease severity and other variables. However, based on the assumption that no one can choose the day of the week they will have a neurological emergency (i.e., strokes are unpredictable), one could putatively exploit the exogenous variation in neurology floor bed competition to indirectly examine the association between ED boarding time and delirium risk.

[Insert Figure 1]

Source of participants and data

Between 01/2016 and 12/2018, 79,467 older patients (≥65+ years) were evaluated in our emergency department (ED). From this population, we identified all patients who were subsequently transferred to a specific study neurology hospital floor (n=1,725), which had implemented a systematic program for delirium prevention and screening. We excluded those who did not have at least one delirium assessment completed during the inpatient stay (n=867 out of 1,725), resulting in a final analytical sample of 858 patients (Figure 2).

[Insert Figure 2]

Delirium prophylactic protocol and screening: In accordance with national guidelines, the study neurology hospital floor has a delirium screening and prevention program (Neurology, 2016). The prevention program is based on multimodal, nonpharmacologic delirium prevention programs such as the "The Hospital Elder Life Program" (HELP) and incorporates several preventive measures, including redirection, review of medications, avoidance of restraints (Inouye et al., 2006, Inouye et al., 1999). Delirium screening assessments are performed by registered nurses using the modified Confusion Assessment Method (CAM) and documented in the electronic medical record. Previous controlled studies found that these interventions are effective in preventing delirium, cognitive, and functional decline (Inouye et al., 1990, Mitasova et al., 2012). We further detail the program in Supplementary Text 1.

Variables

This study combines demographic (A), clinical (B), process (C), and outcome (D) information:

A: Demographic Information: We acquired basic demographic information (e.g., age, gender, race) and enriched it with measures of socio-economic status (e.g., insurance type) and other pertinent data (e.g., community dwelling vs not) (Table 1, Supplementary Table 1).

[Insert Table 1]

B. Clinical Information: We obtained data on presence of known delirium risk factors, such as stroke, visual impairment, and fall, from a validated Clinical Classifications Software (ACUP-AHRQ-CCS) for inpatient stays, which utilizes an ICD-10 diagnosis and procedure categorization scheme (Supplementary Table 2, Supplementary Table 3).

C: Process Information: We abstracted the date and time in which patients arrived at the emergency department. From these variables, we categorized ED arrival date according to days of the week (Monday-Sunday). Second, we created an indicator variable for “Delay”, time from ED arrival-to-neurology bed transfer and categorized in quartiles (Delay, yes ≥ 13.4 hours vs. no ≤ 5.97 hours).

D: Outcome Information: Delirium was assessed using the modified Confusion Assessment Method (CAM), which have been validated in post-stroke populations (94-100% sensitivity, 89-95% specificity, and high inter-rater reliability). At least 49.7% of the study neurology ward patients were assessed (Figure 2). Some patients could be reevaluated the same day as needed. We captured all CAM assessments for each patient and created our primary outcome variable: time from ED arrival to first CAM positive within a 72h observation period (CAM positive indicated delirium). For sensitivity analysis, we also derived a binary indicator variable for delirium (yes vs no within 72h of admission, Supplementary Table 4).

Data analytic approach

To address potential confounders for the primary analysis, we estimated the probability (propensity score) of arriving on each day of the week (Monday-Sunday). We used a categorical logistic-regression to predict the odds of arriving on each day of the week. We examined the distribution of propensity scores across different days of the week, examined for normality assumptions, and compared propensity score means across each day of the week and examined how well the propensity score balanced for potential confounders.

The potential confounders were obtained from linked encounter-level electronic medical record data, and included age, gender, race, site of origin (community dwelling vs not), insurance type, and known comorbidity (e.g., presence of known delirium risk factors such as stroke, visual impairment)). The percentage of patients with missing data for these variables was low (<1%). For missing data, we assumed missingness at random and conducted a complete case analysis.

We compared time from ED door arrival to first documentation of delirium (CAM positive) within a 72h period among those who arrived on different days of the week using a cox proportional hazards model, with propensity score adjustment (as a continuous linear term). To reduce the potential bias from differential follow-up times and the impact the inpatient care and drugs might have on delirium risk overtime that is unrelated to arrival conditions, we limited the maximal follow-up time to 72h. Censored observations included death, transfer, or discharge before 72h. We examined Schoenfeld residuals to examine for potential violation of the proportional-hazards assumption. We reported hazard ratios and 95% confidence intervals for unadjusted and stepwise adjusted analysis. We estimated at least 90% power to detect a 50% higher hazard of delirium, using an estimated sample of at least 100 patients per day of the week (exponential test, hazard difference, alpha 0.5).

Sensitivity analysis: We conducted additional prespecified sensitivity analysis and examined the robustness and validity of our findings in several ways:

Statistical assumptions: First, we avoided the use of the propensity score and compared time from ED door arrival to first delirium (CAM+) documented within a 72h period among those who arrived on early days of the week (Sunday-Wed = high demand) versus late days of the week (Thursday-Saturday = low demand) using cox proportional hazards models, with and without adjustment for the potential confounders used in the main analysis; Second, we avoided the use of survival analysis (cox proportional hazards assumption might be unrealistic) and estimated the 72h odds of delirium using logistic regression models, assuming no loss to follow-up (given very short follow-up time), with and without adjustment for the potential confounders listed in the main analysis. Third, we observed that the care experience of those who arrive to the ED during day might be different than the care experience of those who arrive at night. We hypothesized that "shift" could explain the effect of ED boarding on delirium risk (e.g., more severe cases arriving at night). Delirium screening was implemented at every shift (day and night). We compared time from ED door arrival to first delirium (CAM+) documented within a 72h period among those who arrived on different days of the week using cox proportional hazards models, with propensity score adjustment plus additional adjustment for time of the day (i.e., using "shift" as a binary predictor, meaning arrival to the ED during day vs night hospital shift).

Screening effect: Systematic delirium screening is hypothesized to naturally increase its detection rate. If ED boarding time increases the 72h delirium risk independent of the destination floor, we expect replication of the results in other samples and settings where delirium prevention protocol was either not done or done differently. For instance, more severe cases (as opposed to systematic screening as in the study floor) are more likely to be screened in a neurological intensive care unit. To examine this assumption, we repeated the analysis expanding the sample to all neurology inpatients (the study floor, one neurological intensive care unit, and one additional neurology floor).

Face validity: We exploited two potential reasons for competing demands for the neurology floor beds: a) On certain days of the week (e.g., week days), neurosurgeons place holds on floor beds to accommodate the post-operative needs of their scheduled patients, whereas there are fewer bed holds on weekends (Supplementary Table 5) ; and b) On certain days of the week (e.g., Sundays), discharges from hospital to another institution (e.g., skilled nursing facilities) are systematically delayed until Monday morning (Supplementary Table 6). With high demand for beds, patients admitted from the ED frequently “board” in the ED on Sunday night or Tuesday night until a floor bed opens. The nursing responsibility transfers from ED nurses to neurology ward nurses when the patient arrives on the inpatient ward.

RESULTS

Of the 858 patients who presented to the ED with a neurological emergency, 697 (81.2%) had at least one delirium risk factor in addition to age (e.g., stroke, visual impairment, fall, dementia), with mean age 78 ± 9 years, 51.2% men, and 84.7% white. Patients arriving on different days of the week with neurological emergencies were comparable with respect to age, gender, race, site of origin, insurance type, and comorbidities. Delirium was documented in 234 (30%) patients within the first 72h from ED arrival. Table 1 summarizes the demographic characteristics of the patients upon ED arrival.

This study demonstrated an association between days of the week and delirium. ED arrival on Sundays and Tuesdays were associated with shorter time to delirium onset (Sunday: propensity score adjusted HR= 1.54 for delirium onset, 95%CI:1.36-1.75; Tuesday: propensity score adjusted

HR=1.39 for delirium onset, 95%CI:1.22-1.58) in a 72-study follow-up time-frame, using Friday as reference day. These results were similar using different days of the week as reference, and also after adjusting for time of the day (i.e., day vs night shift) (Supplementary Table 7 and 8). For illustrative purposes, we provided unadjusted delirium survival curves (Figures 3A to 3C and Supplementary Figure 1). Findings were similar using the sample of all neurology inpatients (each with different protocols for use/screening for delirium).

[Insert Figure 3A]

[Insert Figure 3B]

[Insert Figure 3C]

This study was Sensitivity analysis: ED arrival on early days of the week (binary, early meaning Sunday to Wednesday vs late meaning Thursday to Saturday) was still associated with a shorter time from ED arrival to delirium onset using covariate adjustment (covariate adjusted HR: 1.242, 95% CI 1.04-1.48), Supplementary Table 9. The adjusted 72h odds of delirium was 1.95-fold greater (95% CI 1.05- 3.64) for those arriving to ED on Sunday compared to Saturday, for instance (Supplementary Table 10).

ED arrival on Sundays was associated with delayed floor admission (waiting time greater than 13.4 hours = time from ED arrival to transfer to inpatient bed, p<0.001, Supplementary Table 11) and with lowest proportion of hospital to skilled nursing facility discharges (p<0.001, Supplementary Table 6). Similarly, ED arrival on Tuesdays was associated with delayed floor admission (p<0.001, Supplementary table 11) and with greater proportion of elective pre-surgical admissions on Wednesday morning, p<0.001, Supplementary table 5).

Figure 4 illustrates the measures of bed competition (i.e., elective pre-surgical admissions and discharges to nursing homes or alike), the overtime proportion of patients who had prolonged ED boarding time (i.e., >13h), and the various 72h-delirium hazard ratios in relation to days of the week. In summary: a) the ED boarding time followed the trends in the measures of bed competition, and b) ED boarding time was associated with the 72h-delirium hazard ratio.

[Insert Figure 4]

DISCUSSION

Older patients admitted from the ED with neurological emergencies have a substantial risk of developing delirium early in their hospitalization. Our study also reveals that increased "boarding time" (or delayed transfer to the hospital floor) is associated with greater short-term risk of delirium in this natural experiment. While risk factors for delirium are multi-dimensional and time-varying, our study identified areas for process improvement that could have a real link with outcomes leading to improved patient care and decreased health care spending.

Our study has several strengths including our very large sample size and its reasonably high rate of delirium, making our comparisons robust. By demonstrating an association between prolonged ED lengths of stay and elevated risk of delirium onset during admission, our results are consistent with the evolving literature suggesting that delirium prophylaxis is critical to prevention and that delays in this process increase the risk of the development of delirium.

Specifically, our study demonstrates that risk of developing delirium during hospitalization is greatest for older patients with acute neurologic conditions who present to the ED on days with higher risk of prolonged ED lengths of stay. One prior study that evaluated the association between ED length of stay and incident delirium, also showed a prolonged ED length of stay (10 hours or greater) prior to admission doubled the risk for delirium onset (Bo et al., 2016); this study, however, excluded patients with acute stroke which is one of the major risk factors for delirium among older adults. Delirium is a frequent complication of stroke (10-42%) (Mitasova et al., 2012, Dahl et al., 2010).

We theorized that the increased risk of delirium is related to a combination of the care experienced at the ED department and the delayed implementation of delirium prevention measures. For instance, it is also possible that the physical environment of, care limitations of, and/or therapeutics administered in the ED contribute to this short-term increased risk. The physical environment of the ED, with bright lights and high ambient noise level 24 hours a day, is potentially deliriogenic and contrary to the sleep hygiene measures recommended by national delirium prevention guidelines (Grover and Avasthi, 2018, Inouye et al., 2000, NICE, 2003).

This study's results are intuitively and quantitatively valid. Presenting to the hospital earlier in the week, e.g., Sunday and Tuesday, conveyed higher risk of delirium than presenting later in the week, e.g., Saturday. Some delays in admission have been attributable to exogenous factors. For example, we know that during weekends neurological floors have fewer discharges to skilled nursing facilities (SNF), which, in turn, influences the number of beds available for new admissions on those floors. With respect to mid-week days, we recognized that elective admission to neurological floors, medical or surgical, may impact the number of available beds and cause further delays in admission (McHugh et al., 2008). In this study, we exploited the fact that acute emergencies (e.g., stroke) are largely unpredictable, and will continue to occur independent of human's ancient Greek calendar scheme (days of week), surgeon's schedule, or SNF's opening policies.

In this study, we tested different categorization assumptions for the predictor variable (individual days of the week vs binary), different modeling assumptions (cox proportional hazard vs steady state assumptions), as well as different samples (more homogeneous study floor with high screening rate vs all study floors with low screening rate and a heterogeneous population). The association was stronger with increasing effective sample size (e.g., all samples) and increasing number of assumptions (e.g., propensity score, binary predictor categorization). Overall, our study conclusions about differential short-term delirium risk according to days of the week remained robust across all methods.

Our face validity exploratory analysis, while hypothesis-generating in our work, creates avenues for further study in optimizing communication paths between ED and Neurology department providers. Prioritizing ED arrivals over elective surgery admissions could improve patient care delivery regardless of baseline medical condition. This further adds to the discussion for multidisciplinary neurological care to use large and real-care data analysis to cross departmental boundaries and rethink in-hospital processes. More importantly, it provides an opportunity to make targeted interventions for high risk patients in a high-volume and critical care environment.

This study has several limitations. First, it was conducted at a single tertiary academic center with which may limit its generalizability. This center is known for providing excellent quality care in the emergency room, which suggests that our results could represent a conservative estimation of the impact of ED boarding on delirium risk. Because our center is a tertiary academic center, we may have received a greater share of severe cases when compared to community hospitals. In addition, we also limited our main analysis to patients with neurological emergencies. In fact, roughly two thirds of the patients that were included had stroke as a primary diagnosis and this study did not include details of their stroke type, severity at initial presentation in the ED, which would include hemodynamics, cardiac and pulmonary status, and whether or not they had significant altered mentation or level of consciousness. Because number, type, and severity of medical conditions are known risk factors for delirium, our study may have overestimated the general 72h in-hospital delirium prevalence.

Second, the delirium screening (CAM protocol) was not implemented consistently among the older patients admitted through the ED, with only 50% of patients being screened within the 72h study period. In our main analysis, we chose the study floor that had implemented a systematic protocol for screening at least twice per day to attempt to eliminate the variable of staff judgment when screening. However, the well-trained nurses still used their best judgement about who could have deferred screening in a large proportion of cases. Therefore, it is possible that those at higher risk for delirium (e.g., older age) were more likely to have a documented delirium screening. In a worst-case scenario, if we assume that the in-hospital unconscious selection of patients to screen for delirium was driven by a nurses' judgment (prior probability of potential risk for delirium), we expect that the analytical sample would systematically exclude those healthier patients. However, the nurses' judgment is expected to be independent of the day of the week surgeon's schedule, and SNF's opening policies. In this scenario (extreme case of independent differential misclassification of the outcome), the results could represent an over or underestimate of the true rates of delirium. In this scenario of independent non-differential misclassification of a binary outcome, the estimates are still valid (preserves type I error, alpha set) but is likely conservative (towards the null). Therefore, our results are likely conservative in the main analysis, and potentially biased in an unpredictable direction in the all sample analysis. Further, one could use the reported CAM specificity (95.9%) to obtain the adjusted estimate of the risk (Gusmao-Flores et al., 2012).

Another common potential source of bias is the misclassification of covariates (e.g., diagnoses). As outlined before, we attempted to mitigate misclassification bias with careful and conservative sensitivity analysis and face validity checks. One additional source of potential misclassification is our use of “elective presurgical admissions” as a proxy for “bed-holds” for surgery. We measured the volume of neurology admissions coming from the elective surgical admission department (as opposed to the ED department or else). An ideal measure of bed competition would actually be the volume of “bed holds” placed by surgeons each day (some eventually become an elective surgical admission while others are canceled for several reasons).

Our study could not differentiate the effect of prolonged lengths of stay in the ED environment (e.g., noisy and disruptive day and night) from the effect of delayed initiation of delirium prevention protocol on the neurology floor. Though some EDs do have volunteer-based programs similar to the HELP delirium prevention program (Sanon et al., 2014), there are no studies evaluating the impact of ED-initiated delirium prevention programs on incident delirium.

The specific or long-term impact of preventive strategies for delirium is an area for further study. Physicians in training have reported delirium prevention education is often sparse and disproportionate to their exposure to high risk patients (Pickett et al., 2019). In addition to enhanced awareness, electronic delirium risk alerts and targeted deployment of hospital resources are all avenues by which delirium screening rates could improve, and thereby outcomes for high risk patients, can be immediately improved.

Finally, our study was not designed to demonstrate causation (cause-and-effect). A randomized controlled clinical trial would not be feasible or ethical in this vulnerable population of patients with neurological emergencies. Therefore, we conducted this rigorous observational study that identified an association between ED boarding time and the documentation of delirium in the first 72 hours of admission.

In a healthcare management framework, common factors associated with ED boarding could be grouped into four main categories: a) how primary care and continuity are organized, b) the existence and effectiveness of organizational models and clinical pathways for chronic patients, c) the presence of bottlenecks related to ED's personnel or equipment endowment, and d) how the ED is organized and its connection with the rest of the hospital (Vainieri et al., 2020). Our study may help healthcare managers to identify feasible targets for process improvement in the connection between ED and the rest of the hospital (e.g., a sensible elective surgery's schedule).

This study design did not seek to determine whether it is prolonged ED boarding time or the delayed Neurology transfer arrival that increased the risk of delirium. Some argue that the ED boarding is "delirium-genic" (i.e., the extra hours in the ED extends the patient's exposure to noisy, cold, stressful, and unwelcoming environment without direct exposure to external light). In contrast, the delirium prevention protocols include steps to minimize potential environmental insults. Nevertheless, this study provides some feasible suggestions for process improvement that are still within the scope of healthcare managers, such as better alignment between discharge volume needs and SNF's admitting hours. This represents a new category for process improvement in the healthcare management framework: relationships between hospitals and post-acute care facilities.

CONCLUSION

Older patients admitted from the ED with neurologic conditions have a substantial risk of developing delirium early in their hospitalization. Prolonged wait for transfer to the hospital floor appear to be associated with increased risk of delirium in this natural experiment. Hospital complications such as delirium might be prevented by early initiation of prophylaxis protocols and transfer from the ED to the hospital bed. Healthcare managers may improve outcomes and reduce spending by removing bottlenecks in the clinical pathways across primary care, emergency rooms, operating rooms, and post-acute services.

Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

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SUPPLEMENTAL MATERIALS

Supplementary Figure 1: Delirium Free Survival Probability (High Demand Days).

[Insert Supplementary Figure 1]

Supplementary Table 1 - Demographic Information Details

Variable	Source	Type	Description
Age at Admission	EHR	Integer	Calculated using the date of birth and date of admission to the Emergency Department (ED).
Gender	EHR	Binary	Recorded gender of the patient. (Male=1, Female=0)
Race	EHR	Text	Recorded race reclassified as: White= White or Caucasian. Black= Black or African America. Other= Asian; Hispanic or Latino; American Indian or Alaska Native. NA = Unavailable or Declined.
Admission Source	EHR	Text	Recorded source of admission reclassified as: Home or Self Care = Self-referral or Physician or Clinic Referral. Institutionalized = Skilled Nursing Facility; Psych, Substance Abuse, or Rehab Hospital; Outside Health Care Facility; Outside Hospital or Ambulatory Surgery Center.
Primary Insurance	EHR	Text	Recorded primary insurance, reclassified as: Medicare = Medicare. Commercial = Blue Cross Blue Shield; Tufts Health Plan; Harvard Pilgrim; Neighborhood Health Plan and AllWays Health Partners. Others: Medicaid, Free Care; Workers Comp / Motor Vehicle; Other Government; Self-pay and International.

Legend: EHR = Electronic Health Record.

Supplementary Table 2 – Clinical Information (diagnosis) – Delirium Risk Factors

Supplementary Table 2 - Clinical Information (Day of the Week)

	Overall	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**p**
	858	132	116	119	125	123	130	113	
Stroke = Yes (%)	536 (62.5)	88 (66.7)	69 (60.0)	65 (54.6)	76 (60.8)	74 (60.2)	86 (66.2)	78 (69.0)	0.263
Acute Cerebrovascular disease = Yes (%)	496 (57.9)	82 (62.1)	65 (56.5)	61 (51.3)	66 (52.8)	70 (56.9)	80 (61.5)	72 (63.7)	0.334
Epilepsy = Yes (%)	59 (6.9)	9 (6.8)	8 (7.0)	9 (7.6)	15 (12.0)	4 (3.3)	7 (5.4)	7 (6.2)	0.22
Dementia* = Yes (%)	2 (0.2)	0 (0.0)	1 (0.9)	0 (0.0)	1 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	0.523
Fall = Yes (%)	18 (2.1)	2 (1.5)	5 (4.3)	1 (0.8)	1 (0.8)	4 (3.3)	3 (2.3)	2 (1.8)	0.438
All Fractures = Yes (%)	13 (1.5)	1 (0.8)	1 (0.9)	1 (0.8)	1 (0.8)	4 (3.3)	3 (2.3)	2 (1.8)	0.583
Brain trauma = Yes (%)	83 (9.7)	14 (10.6)	7 (6.1)	14 (11.8)	16 (12.8)	10 (8.1)	13 (10.0)	9 (8.0)	0.604
Other ill defined cerebrovascular disease = Yes (%)	9 (1.1)	3 (2.3)	1 (0.9)	0 (0.0)	3 (2.4)	0 (0.0)	2 (1.5)	0 (0.0)	0.224
Syncope = Yes (%)	12 (1.4)	1 (0.8)	4 (3.5)	2 (1.7)	0 (0.0)	2 (1.6)	2 (1.5)	1 (0.9)	0.41
Transient Cerebral ischemia= Yes (%)	49 (5.7)	9 (6.8)	4 (3.5)	9 (7.6)	9 (7.2)	3 (2.4)	8 (6.2)	7 (6.2)	0.522
Visual impairment = Yes (%)	74 (8.6)	11 (8.3)	11 (9.6)	9 (7.6)	7 (5.6)	7 (5.7)	14 (10.8)	15 (13.3)	0.325

Legend: * Includes only ICD-10 codes related to dementia.

Supplementary Table 3 - Clinical Information Details – Delirium Risk Factors

Variable	Source	Type	Description
Cerebrovascular Accidents	Code	Binary (Y=1, N=0)	Cerebrovascular A binary: CCS codes: 109, 111, 112, 110, 112, 113.
Acute Cerebrovascular disease	Code	Binary (Y=1, N=0)	Acute cerebrovascular disease: CCS code 109.
Epilepsy	Code	Binary (Y=1, N=0)	Epilepsy: CCS code 83.
Dementia	Code	Binary (Y=1, N=0)	ICD-10 codes: F0150, F0151, F0280, F0281, F0390, F0391, F1026, F1027, F1096, F1097, F1327, F1397, F1817, F1827, F1897, F1917, F1927, F1997, G300, G301, G308, G309, G3101, G3109, G311, G312, G3183 and R4181
Fall	Code	Binary (Y=1, N=0)	Fall: CCS code 2603.
All Fractures	Code	Binary (Y=1, N=0)	All fractures: CCS codes 226 to 231.
Brain trauma	Code	Binary (Y=1, N=0)	Brain trauma: CCS code 233.
Other ill-defined cerebrovascular disease	Code	Binary (Y=1, N=0)	Other and ill-defined cerebrovascular disease: CCS code 111.
Syncope	Code	Binary (Y=1, N=0)	Syncope: CCS code 245.
Transient Cerebral ischemia	Code	Binary (Y=1, N=0)	Transient cerebral ischemia: CCS code 112.
Visual impairment	Code	Binary (Y=1, N=0)	Visual impairment: CCS codes 89 or 87 or 86 or 90 or 91.

Legend: CCS Codes = Clinical Classifications Software (ACUP-AHRQ-CCS).

Supplementary Table 4 - Modified CAM Assessments Information

Variable	Source	Type	Description
CAM date and time	EHR	date and time	Date and Time when the CAM assessment was performed.
CAM assessment result	EHR	text	Recorded CAM assessment result (4 levels): 0. Negative (no delirium) 1. Positive(delirium) 2. Unable to Assess - Brain Injury/Severe Cognitive Deficit 3. Unable to Assess - Sedation Score 4 or great OR RASS less than or equal to -4
First Recorded CAM	Code	date and time	Timestamp representing the first time a CAM assessment was performed on the patient.
First Positive CAM	Code	date and time	Timestamp representing the first time a CAM assessment was recorded as positive for delirium. NA: No delirium recorded OR Unable to assess.
CAM by 72h	Code	text	Variable created to identify the following scenarios: Delirium: at least oneCAM assessment was recorded as positive during the first 72 hours from admission. No Delirium: at least one assessment was recorded as negative and none as positive during the first 72 hours from admission. NA: No CAM assessment was recorded during the first 72 hours from admission.
CAM Any Day	Code	text	Variable created to identify the following scenarios: Delirium: at least one CAM assessment was recorded as positive during the encounter (admission to discharge). No Delirium: at least one assessment was recorded as negative and none as positive during the encounter (admission to discharge). NA: No CAM assessment was recorded either positive or negative during the encounter (admission to discharge).
Number of CAM assessments	Code	integer	Number of CAM assessments were recorded during the encounter (admission to discharge).
Admission to first CAM recorded	Code	integer	Number of hours between the admission and the first CAM assessment recorded.
Admission to first positive CAM recorded	Code	integer	Number of hours between the admission and the first positive CAM assessment recorded (delirium).

Legend: EHR = Electronic Health Record. CAM = Confusion Assessment Method

Supplementary Table 5 – Admission Department (not ED) vs Days of the Week

	Overall	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	p-value
	5838	538	985	917	1009	1001	894	494	
Admission Department* (%)									<0.001
Study Neurology Floor	3719 (63.7)	507 (94.2)	583 (59.2)	519 (56.6)	517 (51.2)	584 (58.3)	551 (61.6)	458 (92.7)	
Perioperative Dept	1686 (28.9)	14 (2.6)	299 (30.4)	305 (33.3)	420 (41.6)	344 (34.4)	285 (31.9)	19 (3.8)	
Other	433 (7.4)	17 (3.2)	103 (10.5)	93 (10.1)	72 (7.1)	73 (7.3)	58 (6.5)	17 (3.4)	

Legend: * Not included: admissions to Emergency Department and then transferred to the Study Neurology Floor.

Supplementary Table 6 – Discharge from Study Neurology Floor vs Days of the Week

	Overall	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	p-value
	7296	605	843	1099	1276	1335	1286	852	
Discharge Disposition = Institutionalized* (%)	2294 (32.3)	82 (14.3)	272 (33.3)	412 (38.1)	471 (37.9)	453 (34.7)	422 (33.3)	182 (22.4)	<0.001

Legend: * Includes: Skilled Nursing Facility; Psych, Substance Abuse, or Rehab Hospital; Outside Health Care Facility; Outside Hospital or Ambulatory Surgery Center.

Supplementary Table 7 – Cox Regression with Propensity Score (Friday as Reference)

	Hazard Ratio (95% CI)	p-value
Sunday	1.542 (1.361- 1.748)	<.0001
Monday	1.233 (1.088- 1.397)	0.0010
Tuesday	1.387 (1.220-1.577)	<.0001
Wednesday	1.204 (1.055-1.374)	0.0059
Thursday	1.121 (0.990-1.271)	0.0724
Saturday	1.142 (1.007-1.294)	0.0380

Supplementary Table 8 – Cox Regression with Propensity Score plus Shift (Friday as Reference)

	Hazard Ratio (95% CI)	p-value
Sunday	1.543 (1.361-1.749)	<.0001
Monday	1.234 (1.089-1.399)	0.0010
Tuesday	1.389 (1.221-1.579)	<.0001
Wednesday	1.204 (1.055-1.374)	0.0060
Thursday	1.121 (0.990-1.271)	0.0727
Saturday	1.142 (1.007-1.294)	0.0379
Shift (Day)	0.989 (0.920-1.064)	0.7756

Supplementary Table 9 – Cox Regression with Propensity Score (High Demand Days)

	Hazard Ratio (95% CI)	p-value
High Demand Days	1.242 (1.045-1.477)	0.0140
Estimated Propensity Score	0.761 (0.262-2.207)	0.6145

Legend: Estimated Propensity Score HR 0.761 (0.262-2.207)

Supplementary Table 10 – Logistic Model for Delirium as Outcome – Fully Adjusted

	Odds Ratio (95% CI)	p-value
Day of the Week (reference: Saturday)		
Sunday	1.955 (1.050-3.643)	0.2259
Monday	1.177 (0.601-2.307)	0.2069
Tuesday	1.725 (0.900-3.306)	0.6101
Wednesday	2.676 (1.417-5.052)	0.0056
Thursday	1.471 (0.768-2.815)	0.7917
Friday	1.392 (0.734-2.641)	0.5878
Age at Admission	1.072 (1.051-1.094)	<.0001
Gender (reference: Female)	0.895 (0.641-1.252)	0.5180
Race (reference: non-white)	0.709 (0.424-1.184)	0.1884
Primary Insurance		
Commercial	0.161 (0.031-0.837)	0.2440
Medicaid	0.127 (0.013-1.205)	0.3486
Medicare	0.146 (0.028-0.754)	0.1371
Delirium Risk Factor	1.048 (0.671-1.637)	0.8356
Admission Source (reference: Home or Self Care)	0.558 (0.399-0.781)	0.0007

Supplementary Table 11 – Days of the Week vs Delay

	Overall	< 4.97 hours (No Delay)	> 13.4 hours (Delay)
	858	211	215
Days of the Week (%)			
Sunday	132 (15.4)	33 (15.6)	35 (16.3)
Monday	116 (13.5)	20 (9.5)	32 (14.9)
Tuesday	119 (13.9)	34 (16.1)	40 (18.6)
Wednesday	125 (14.6)	25 (11.8)	36 (16.7)
Thursday	123 (14.3)	35 (16.6)	26 (12.1)
Friday	130 (15.2)	30 (14.2)	25 (11.6)
Saturday	113 (13.2)	34 (16.1)	21 (9.8)

Legend: Delay means ED to neurology floor waiting time greater than 13.4 hours.

Supplementary Table 12 – Sensitivity Analysis

	Model 1, HR (95% CI)		Model 2, HR (95% CI)		Model 3, HR (95% CI)		Model 4, HR (95% CI)		Model 5, HR (95% CI)		Model 6, HR (95% CI)	
	Hazard Ratio	**p-value**	**Hazard Ratio**	**p-value**	**Hazard Ratio**	**p-value**	**Hazard Ratio**	**p-value**	**Hazard Ratio**	**p-value**	**Hazard Ratio**	**p-value**
High Demand Days of the Week	1.231 (1.040-1.459)	0.0160	1.219 (1.029-1.445)	0.0293	1.224 (1.033-1.451)	0.0199	1.224 (1.032-1.452)	0.0203	1.245 (1.048-1.479)	0.0128	1.242 (1.045-1.477)	0.0140
Age at admission			0.992 (0.982-1.002)	0.1167	0.991 (0.981-1.001)	0.0920	0.991 (0.981-1.001)	0.0922	0.991 (0.980-1.001)	0.0798	0.991 (0.980-1.001)	0.0796
Gender (reference Female)					1.069 (0.900-1.269)	0.4490	1.069 (0.900-1.269)	0.4491	1.085 (0.911-1.291)	0.3606	1.086 (0.912-1.293)	0.3519
Race(reference non-white)							0.996 (0.791-1.254)	0.9744	0.957 (0.746-1.229)	0.7331	0.955 (0.742-1.229)	0.7196
Primary Insurance												
Commercial									0.823 (0.257-2.631)	0.7422	0.823 (0.257-2.635)	0.7434
Medicaid									0.989 (0.272-3.589)	0.9865	0.987 (0.272-3.583)	0.9843
Medicare									0.795 (0.250-2.530)	0.6979	0.796 (0.250-2.534)	0.6996
Delirium Risk Factor (0)									0.857 (0.686-1.070)	0.1725	0.855 (0.684-1.068)	0.1679
Admission Source (Home or Self Care)											1.012 (0.843-1.215)	0.8949

Supplementary Text 1 – Statistical Code

```
data data1;
proc contents data=data1;
run;
proc freq data = data1;
tables WeekDayAd*Delay;
run;

**Overall sample data;
proc freq data = data1;
tables FinancialClassDSC*WeekDayAd/chisq;
run;

proc freq data = data1;
tables (cereb_vasc_A acute_cereb_dis epilepsy fall all_fract
brain_trauma  other_ill_def_cereb_dis syncope trans_cereb_isc
visual_imp dementia);
run;

proc freq data = data1;
tables dementia;
run;

proc freq data = data1;
tables Delirium_risk_factor;
run;

proc freq data = data1 ;
table  AdmitSourceDSC*WeekDayAd/chisq;
run;

proc freq data = data1 ;
table  WhiteYN;
run;

proc freq data = data1 ;
```

```
table  CAM_72h_ad;
run;

proc freq data = data1 ;
table  CAM_72h_tr;
run;

*Outcomes analysis;
proc lifetest data=data1 plots= s(atrisk ) notable ;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
  strata WeekDayAd;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
  strata Wednesday;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
  strata Sunday;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
  strata Tuesday;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;
```

```
proc lifetest data=data1 plots= s(atrisk ) notable ;
  strata High_demand_days;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
  strata WeekDayAd_2;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
where Wednesday = "Yes";
  strata WednesdayNight;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk ) notable ;
where Tuesday = "Yes";
  strata TuesdayNight;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

/* PS: parametric estimation */
proc logistic data=data1 ;
class Gender WhiteYN FinancialClassDSC AdmitSourceDSC cereb_vasc_A
acute_cereb_dis epilepsy fall all_fract brain_trauma
other_ill_def_cereb_dis syncope trans_cereb_isc visual_imp dementia;
model WeekDayAd = AgeAtAdmission Gender WhiteYN FinancialClassDSC
AdmitSourceDSC cereb_vasc_A acute_cereb_dis epilepsy fall all_fract
brain_trauma  other_ill_def_cereb_dis syncope trans_cereb_isc
visual_imp dementia;
output out=est_ps2 p=p_qsmk2;
run;
```

```
proc print data=est_ps2 ;
      id A;
      var AgeAtAdmission Gender WhiteYN FinancialClassDSC
AdmitSourceDSC  cereb_vasc_A acute_cereb_dis epilepsy fall all_fract
brain_trauma  other_ill_def_cereb_dis syncope trans_cereb_isc
visual_imp p_qsmk2 survival_ad72h_d deliriumcnsr dementia;
run;

proc univariate data= est_ps2;
      var p_qsmk2;
run;

proc means data= est_ps2;
      var p_qsmk2;
      class WeekDayAd;
run;

proc means data= est_ps2;
      var p_qsmk2;
      class Gender;
run;

proc means data= est_ps2;
      var p_qsmk2;
      class WhiteYN;
run;

proc means data= est_ps2;
      var p_qsmk2;
      class FinancialClassDSC;
run;

proc means data= est_ps2;
      var p_qsmk2;
      class AdmitSourceDSC;
run;
```

```
proc univariate data= est_ps2;
     var p_qsmk2;
run;

proc phreg data=est_ps2;
    class  WeekDayAd (ref = "6 Friday")  ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd p_qsmk2 /
details rl ties=efron ;
title "cox regression using Propensity scores*";
output out=Outp xbeta=Xb resdev=Dev;
run;

*The following statements plot the residuals against the linear
predictor scores;
   title "Residuals check ";

   proc sgplot data=Outp;
      yaxis grid;
      refline 0 / axis=y;
      scatter y=Dev x=Xb;
      run;

proc phreg data=est_ps2;
    class  WeekDayAd (ref = "6 Friday") Shift   ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd  Shift
p_qsmk2 / details rl ties=efron;
title "cox regression using Propensity scores*";
run;

/* PS: parametric estimation */
proc logistic data=data1 ;
class Gender WhiteYN FinancialClassDSC   AdmitSourceDSC cereb_vasc_A
acute_cereb_dis epilepsy fall all_fract brain_trauma
other_ill_def_cereb_dis syncope trans_cereb_isc visual_imp dementia;
model WeekDayAd_2 = AgeAtAdmission Gender WhiteYN FinancialClassDSC
AdmitSourceDSC cereb_vasc_A acute_cereb_dis epilepsy fall all_fract
```

```
brain_trauma  other_ill_def_cereb_dis syncope trans_cereb_isc
visual_imp dementia;
output out=est_ps p=p_qsmk;
run;

proc print data=est_ps;
     id A;
     var AgeAtAdmission Gender WhiteYN FinancialClassDSC
AdmitSourceDSC cereb_vasc_A acute_cereb_dis epilepsy fall all_fract
brain_trauma  other_ill_def_cereb_dis syncope trans_cereb_isc
visual_imp p_qsmk survival_ad72h_d deliriumcnsr dementia;
run;

proc univariate data= est_ps;
     var p_qsmk;
run;

proc phreg data=est_ps;
    class  WeekDayAd_2  ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2 p_qsmk /
details rl ties=efron;
title "cox regression using Propensity scores*";
run;

*Outcomes - sensitivity 1;
proc lifetest data=data1 plots= s(atrisk cl) notable ;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc lifetest data=data1 plots= s(atrisk cl) notable ;
  strata WeekDayAd_2;
  time survival_ad72h_d * deliriumcnsr(1);
  title "Short-term Delirium Survival curve";
run;

proc phreg data=data1;
```

```
    class  WeekDayAd_2  ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2  / details
rl ties=efron;
title "Crude model";
run;

proc phreg data=data1;
    class  WeekDayAd_2  ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission  / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender  WhiteYN ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender WhiteYN  / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender WhiteYN FinacialClassDSC
Delirium_risk_factor;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender WhiteYN FinacialClassDSC
Delirium_risk_factor/ details rl ties=efron;
run;
```

```
proc phreg data=data1;
    class  WeekDayAd_2  Gender WhiteYN FinacialClassDSC
Delirium_risk_factor AdmitSourceDSC;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender WhiteYN FinacialClassDSC  Delirium_risk_factor
AdmitSourceDSC/ details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender WhiteYN FinacialClassDSC
Delirium_risk_factor AdmitSourceDSC;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender WhiteYN FinacialClassDSC  Delirium_risk_factor
AdmitSourceDSC/ details rl ties=efron;
title "fully adjusted model";
run;

**sensitivity analysis  - cox with individual variables = high
demand;

proc phreg data=data1_Lunder7;
    class  WeekDayAd_2  ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2  / details
rl ties=efron;
title "Crude model";
run;

proc phreg data=data1;
    class  WeekDayAd_2  ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission  / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender ;
```

```
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2 
AgeAtAdmission Gender / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2 
AgeAtAdmission Gender / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender  WhiteYN ;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2 
AgeAtAdmission Gender WhiteYN  / details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender WhiteYN Fi_ncialClassDSC 
Delirium_risk_factor;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2 
AgeAtAdmission Gender WhiteYN Fi_ncialClassDSC 
Delirium_risk_factor/ details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender WhiteYN Fi_ncialClassDSC 
Delirium_risk_factor AdmitSourceDSC;
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2 
AgeAtAdmission Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor 
AdmitSourceDSC/ details rl ties=efron;
run;

proc phreg data=data1;
    class  WeekDayAd_2  Gender WhiteYN Fi_ncialClassDSC 
Delirium_risk_factor AdmitSourceDSC;
```

```
    model survival_ad72h_d * deliriumcnsr(0)= WeekDayAd_2
AgeAtAdmission Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC/ details rl ties=efron;
title "fully adjusted model";
run;

**Sensitivity analysis;
proc logistic data=data1 ;
class WeekDayAd_2  Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  WeekDayAd_2 AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

proc logistic data=data1 ;
class WeekDayAd  Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  WeekDayAd AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

**Validity check 1;
proc logistic data = data1 ;
class WeekDayAd_2  Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
model Delay_2 = WeekDayAd_2 AgeAtAdmission Gender WhiteYN
Fi_ncialClassDSC  Delirium_risk_factor AdmitSourceDSC;
title "Validity check1 - Logistic model for delay as outcome - fully
adjusted ";
run;
proc logistic data = data1 ;
```

```
class WeekDayAd (ref = "7 Saturday")  Gender WhiteYN
Fi_ncialClassDSC  Delirium_risk_factor AdmitSourceDSC;
model Delay_2 = WeekDayAd AgeAtAdmission Gender WhiteYN
Fi_ncialClassDSC  Delirium_risk_factor AdmitSourceDSC;
title "Validity check1 - Logistic model for delay as outcome - fully
adjusted ";
run;

**Validity check 2;
proc logistic data=data1 ;
class WeekDayAd_2  Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  WeekDayAd_2 AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

proc logistic data=data1 ;
class WeekDayAd (ref = "5 Thursday") Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  WeekDayAd AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

proc freq data = data1_Lunder7;
tables Delirium;
run;

proc logistic data=data1 ;
class WeekDayAd (ref = "5 Thursday") Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
```

```
model Delirium (ref = "No Delirium") =  WeekDayAd AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

**negative checks;
proc logistic data=data1 ;
class Shift  Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  Shift AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

proc logistic data=data1 ;
class isWeekend  Gender WhiteYN Fi_ncialClassDSC
Delirium_risk_factor AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  isWeekend AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;

proc logistic data=data1;
class t_shift  Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
model CAM_72h_ad (ref = "No Delirium") =  t_shift AgeAtAdmission
Gender WhiteYN Fi_ncialClassDSC  Delirium_risk_factor
AdmitSourceDSC;
title "Sensitivity analysis - Logistic model for delirium as outcome
- fully adjusted ";
run;
```

```
***end;
```

Supplementary Text 2 - Delirium Prevention Protocol

The delirium prevention and management program was a multimodal, nonpharmacologic delirium prevention program based in part on the “The Hospital Elder Life Program” (HELP). The prevention program was developed by an interdisciplinary committee which included physicians, nurses, occupational therapists, physical therapists, speech and language pathologists. Further input was obtained from pharmacists, case managers, social workers, and nutritionists. The recommendations from the committee were disseminated to nurses through a combination of in-service educational conferences, one-on-one discussions with nursing leadership, and continued feedback from multidisciplinary discussions. Physician residents were trained through a combination of in-service educational conferences, patient simulations, and continued feedback from multidisciplinary discussions. Therapists were trained though specialty specific discussions and educational materials.

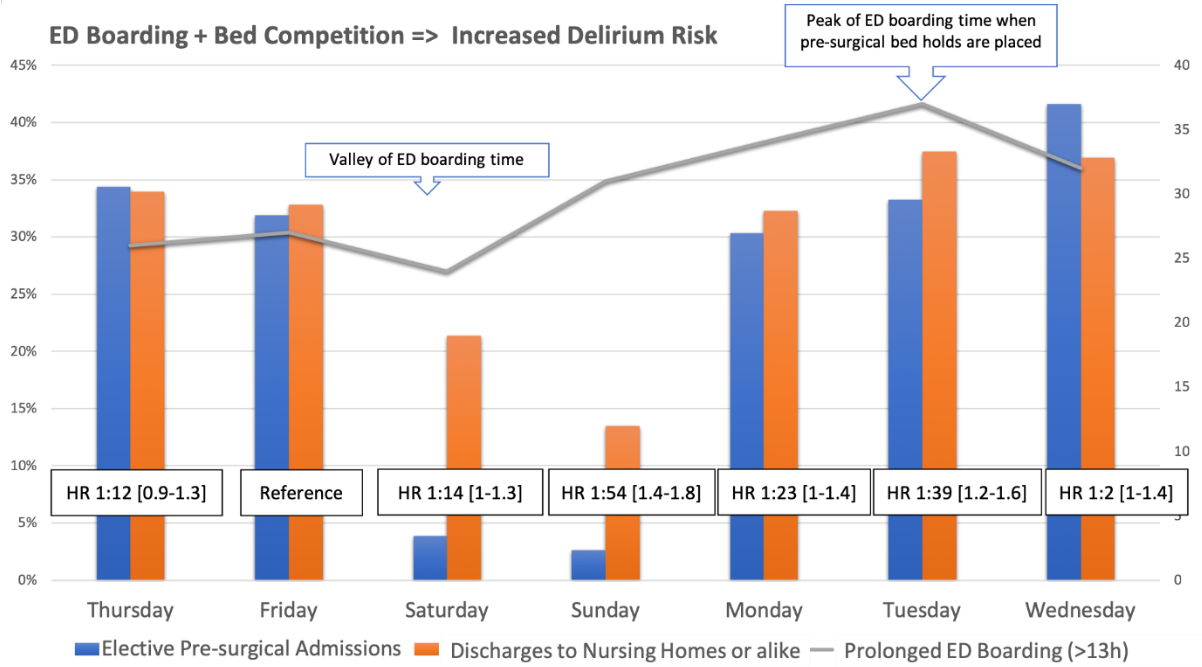
Delirium screening: Patients were screened every shift for delirium by their primary neurology trained registered nurse, using a modified Confusion Assessment Method (CAM). Nurses were prompted on an electronic flowsheet to identify whether core CAM delirium features were present: 1) Acute onset or fluctuating course, 2) Inattention. If both features were positive, then nurses were prompted for the presence of 3) Disorganized thinking or 4) Altered level of consciousness. A positive delirium screen was defined by the presence of both features 1 and 2 with additionally either feature 3 or 4.

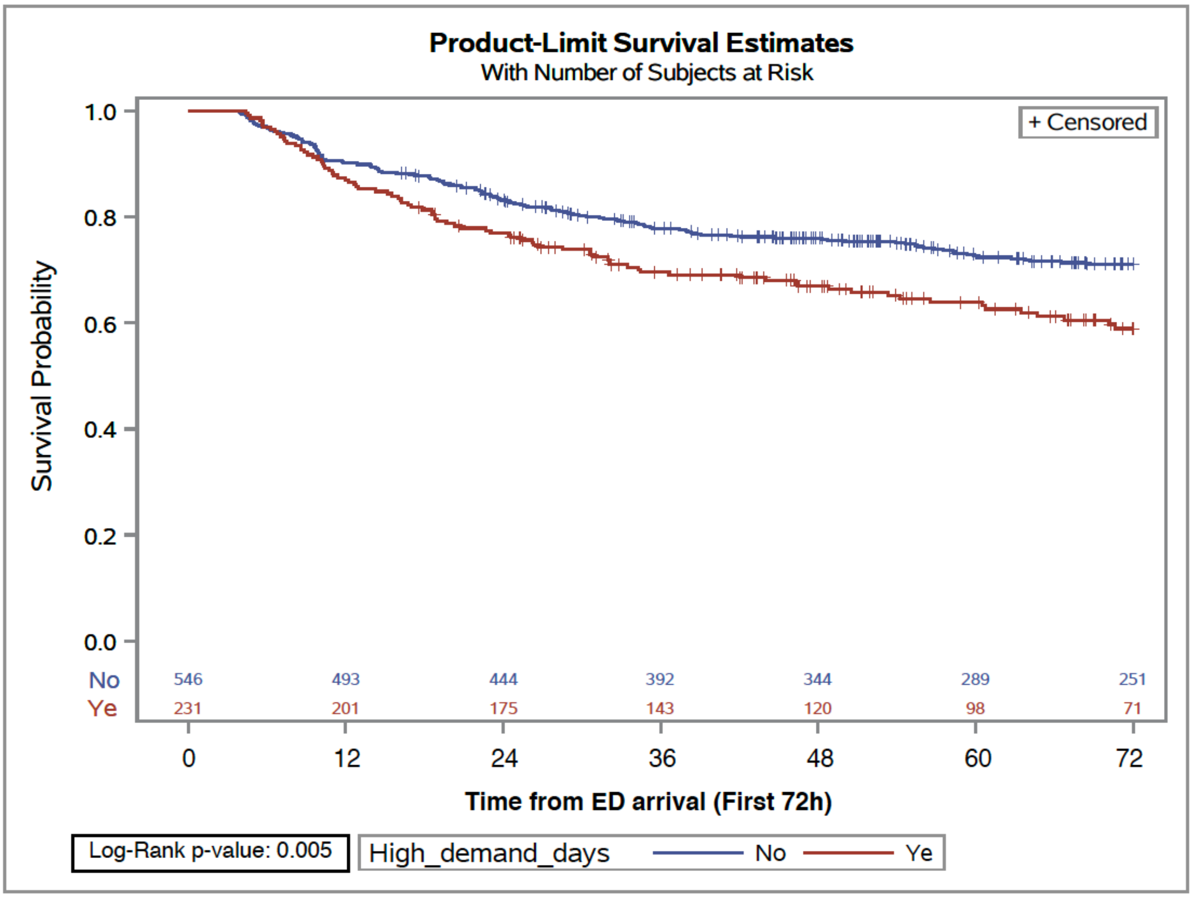
Delirium Prevention and Management: The following criteria were formally used to determine an increased risk of delirium: Age >65 or cognitive impairment. Additional criteria were considered as clinically indicated. All patients were discussed daily at interdisciplinary rounds, attended by physicians, nursing staff, case managers, a social worker, and occupational and physical therapists. As part of the round structure, the primary nurse was prompted to identify whether a patient was at risk for delirium or had screened positive for delirium. All patients at risk of delirium or who had screened positive for delirium were discussed to reaffirm that appropriate nonpharmacologic measures were being used. Measures were derived from prior delirium guidelines and prevention programs, including the United Kingdom National Institute for Health and Care Excellence (NICE) delirium guidelines and the Hospital Elder Life Program (HELP) (NICE, 2003, Inouye et al., 2000). Measures included orientation/redirection verbally and through the use of an updated whiteboard, decreased overnight awakening, keeping lights on and shade up during the day, early mobilization as tolerated, use of sensory aids such as glasses and hearing aids, avoidance of restraints, assessment of pain, elimination of unnecessary catheters/lines, review of medications, and encouraging fluid intake when appropriate.

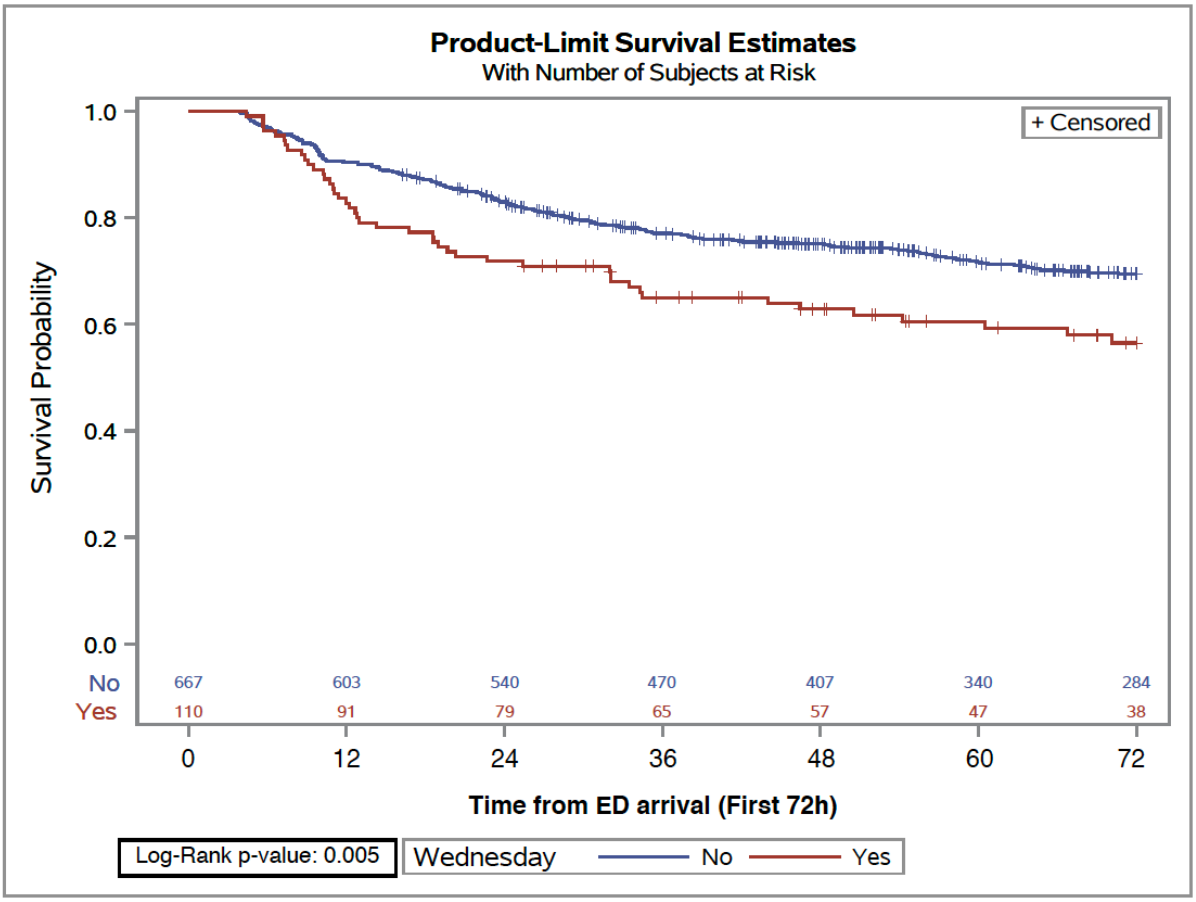
Demographic Information (Day of the Week)

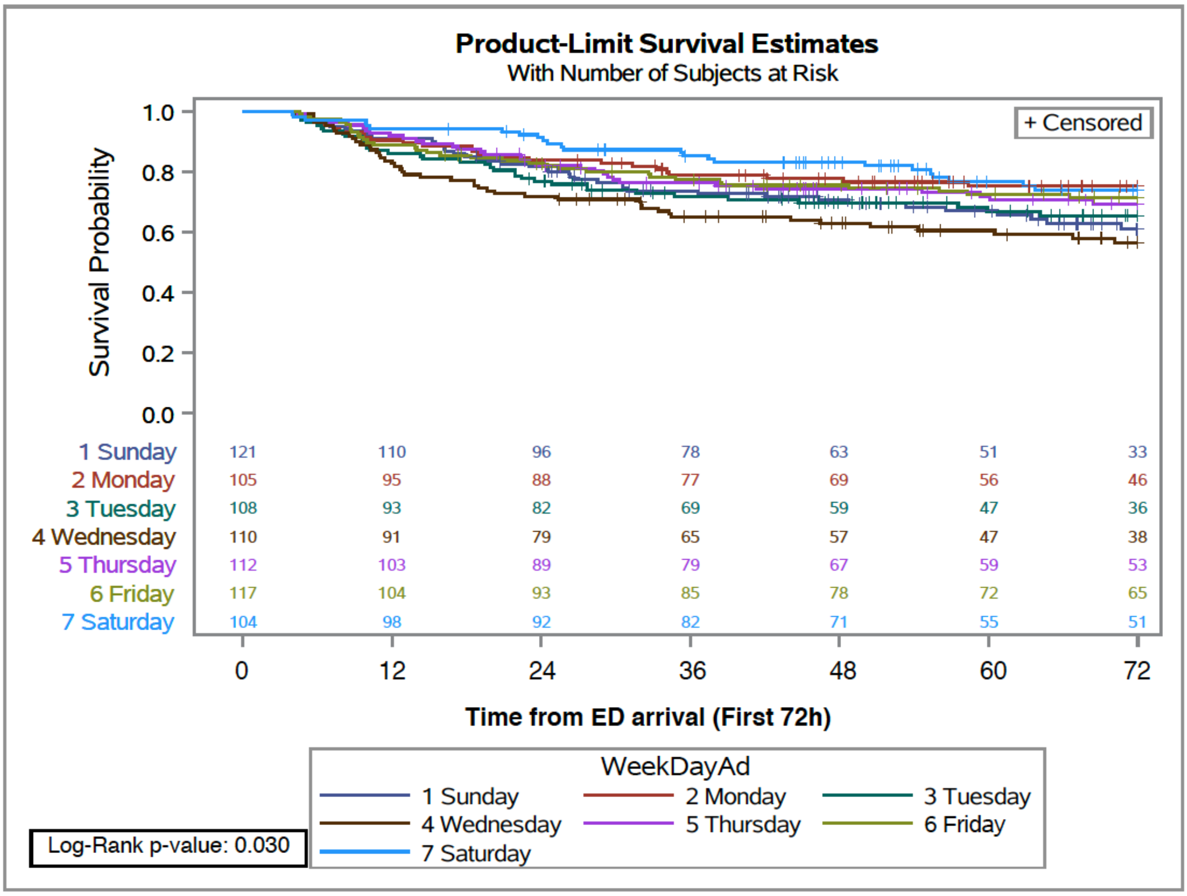
	Overall	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	p-value
	858	132	116	119	125	123	130	113	
Age at admission (mean (SD))	77.99 (8.58)	77.54 (7.99)	77.97 (8.58)	77.02 (8.54)	78.46 (8.77)	78.33 (9.45)	78.35 (8.13)	78.29 (8.75)	0.832
Gender = Male (%)	439 (51.2)	65 (49.2)	60 (51.7)	70 (58.8)	63 (50.4)	64 (52.0)	63 (48.5)	54 (47.8)	0.681
Admission Source = Institutionalized* (%)	324 (37.8)	59 (44.7)	40 (34.5)	46 (38.7)	34 (27.2)	46 (37.4)	50 (38.8)	49 (43.4)	0.096
Race (%)									0.394
Black	49 (5.9)	3 (2.3)	9 (7.8)	8 (6.8)	13 (10.8)	6 (5.2)	5 (3.9)	5 (4.5)	
Other **	60 (7.2)	11 (8.5)	6 (5.2)	10 (8.5)	7 (5.8)	7 (6.0)	9 (7.1)	10 (9.0)	
White	727 (87.0)	115 (89.1)	100 (87.0)	100 (84.7)	100 (83.3)	103 (88.8)	113 (89.0)	96 (86.5)	
Primary Insurance (%)									0.545
Commercial***	221 (25.9)	32 (24.2)	28 (24.1)	27 (23.1)	31 (25.2)	29 (23.6)	45 (34.6)	29 (25.7)	
Medicare	610 (71.4)	98 (74.2)	86 (74.1)	86 (73.5)	90 (73.2)	91 (74.0)	80 (61.5)	79 (69.9)	
Other****	23 (2.7)	2 (1.5)	2 (1.7)	4 (3.4)	2 (1.6)	3 (2.4)	5 (3.8)	5 (4.4)	

Legend: * Includes: Skilled Nursing Facility; Psych, Substance Abuse, or Rehab Hospital; Outside Health Care Facility; Outside Hospital or Ambulatory Surgery Center. ** includes: = Asian; Hispanic or Latino; American Indian or Alaska Native. *** includes: Blue Cross Blue Shield; Tufts Health Plan; Harvard Pilgrim; Neighborhood Health Plan and Allways Health Partners. **** includes: Medicaid, Free Care; Workers Comp / Motor Vehicle; Other Government; Self-pay and International.

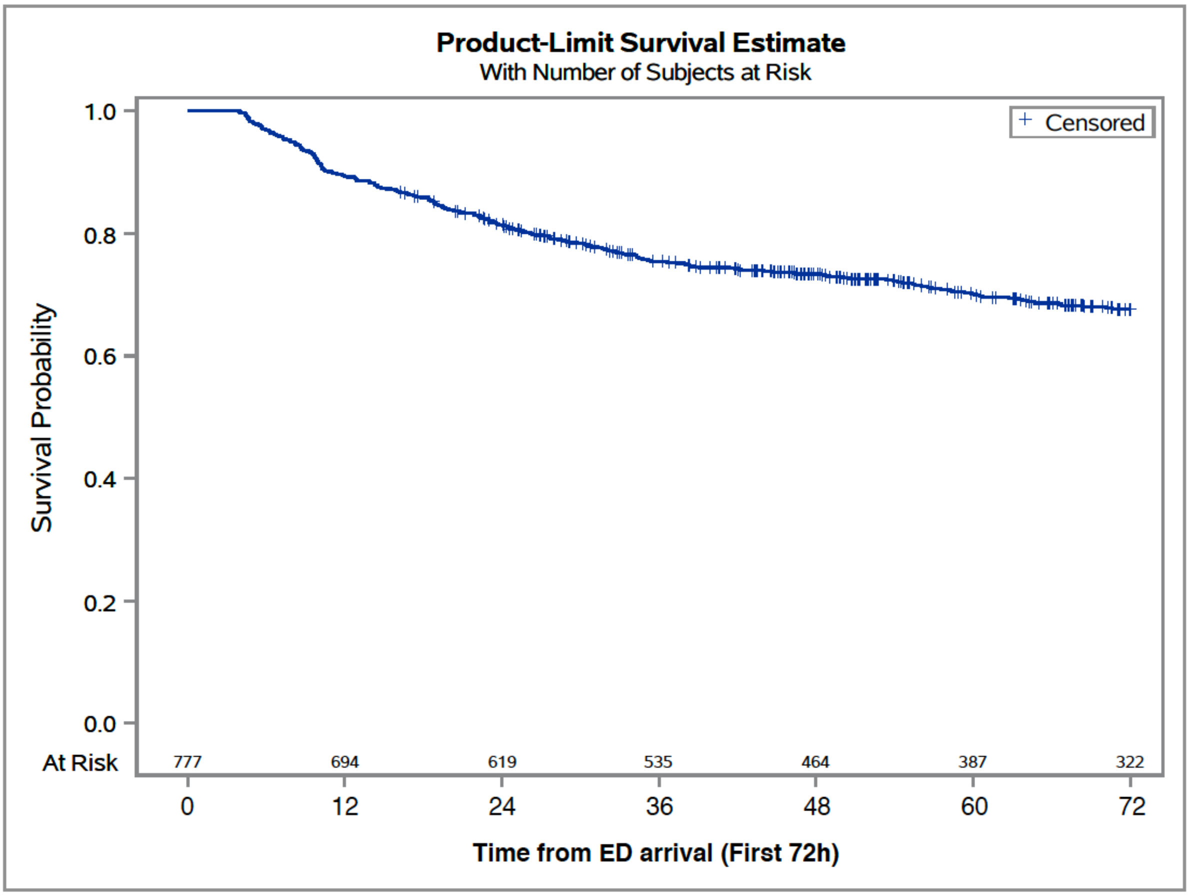



Product-Limit Survival Estimates
With Number of Subjects at Risk
+ Censored
Survival Probability
1.0
0.8
0.6
0.4
0.2
0.0
No 546 493 444 392 344 289 251
Ye 231 201 175 143 120 98 71
0 12 24 36 48 60 72
Time from ED arrival (First 72h)
Log-Rank p-value: 0.005
High_demand_days No Ye

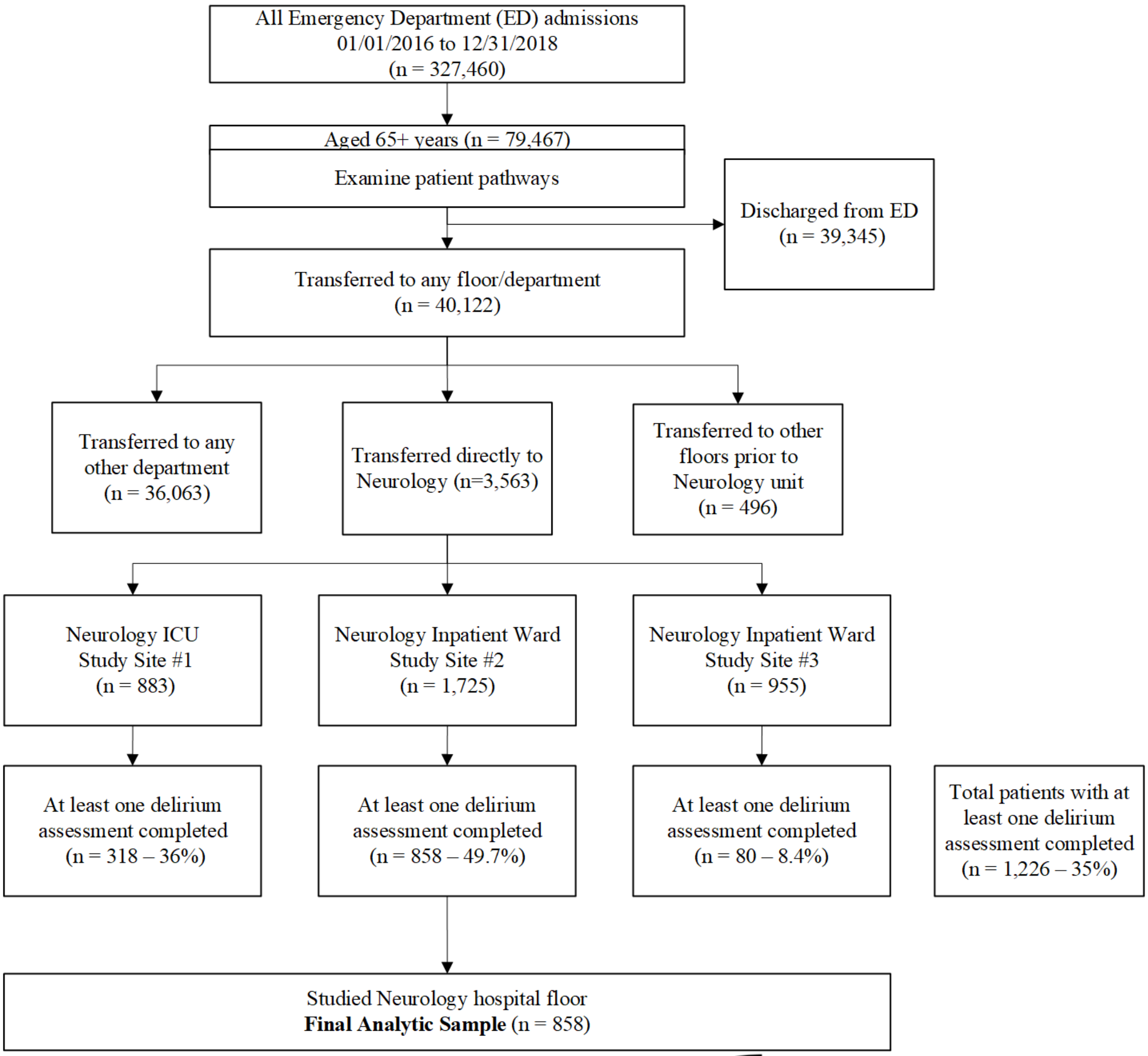

Product-Limit Survival Estimates
With Number of Subjects at Risk
+ Censored
Survival Probability
1.0
0.8
0.6
0.4
0.2
0.0
No 667 603 540 470 407 340 284
Yes 110 91 79 65 57 47 38
0 12 24 36 48 60 72
Time from ED arrival (First 72h)
Log-Rank p-value: 0.005
Wednesday No Yes

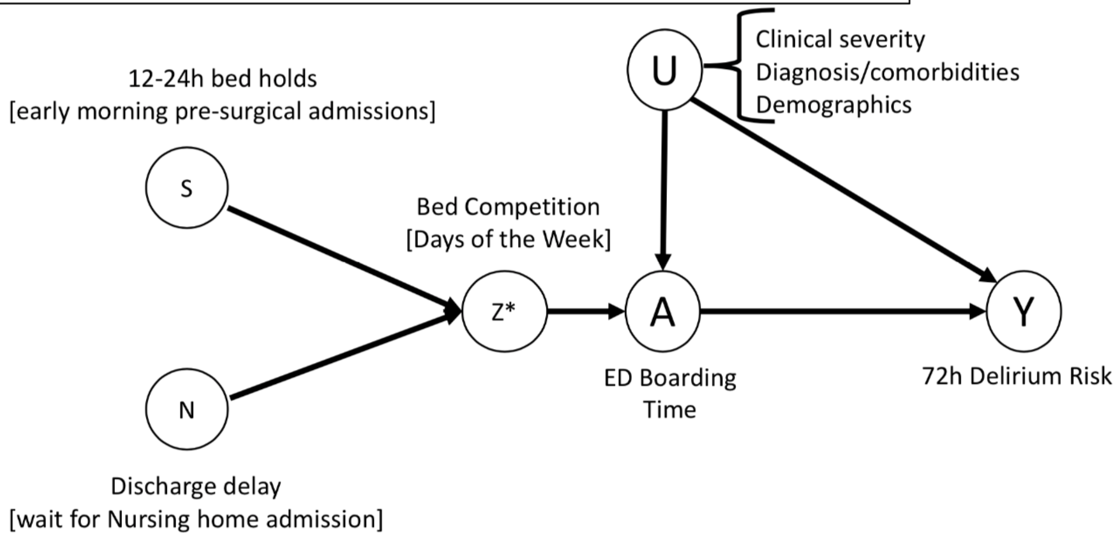


Product-Limit Survival Estimates
With Number of Subjects at Risk
+ Censored
Survival Probability
1.0
0.8
0.6
0.4
0.2
0.0
1 Sunday 121 110 96 78 63 51 33
2 Monday 105 95 88 77 69 56 46
3 Tuesday 108 93 82 69 59 47 36
4 Wednesday 110 91 79 65 57 47 38
5 Thursday 112 103 89 79 67 59 53
6 Friday 117 104 93 85 78 72 65
7 Saturday 104 98 92 82 71 55 51
0 12 24 36 48 60 72
Time from ED arrival (First 72h)
WeekDayAd
1 Sunday
2 Monday
3 Tuesday
4 Wednesday
5 Thursday
6 Friday
7 Saturday
Log-Rank p-value: 0.030



Product-Limit Survival Estimate
With Number of Subjects at Risk
+ Censored
Survival Probability
1.0
0.8
0.6
0.4
0.2
0.0
At Risk 777 694 619 535 464 387 322
0 12 24 36 48 60 72
Time from ED arrival (First 72h)


All Emergency Department (ED) admissions
01/01/2016 to 12/31/2018
(n = 327,460)
Aged 65+ years (n = 79,467)
Examine patient pathways
Discharged from ED
(n = 39,345)
Transferred to any floor/department
(n = 40,122)
Transferred to any other department
(n = 36,063)
Transferred directly to Neurology (n=3,563)
Transferred to other floors prior to Neurology unit
(n = 496)
Neurology ICU
Study Site #1
(n = 883)
Neurology Inpatient Ward
Study Site #2
(n = 1,725)
Neurology Inpatient Ward
Study Site #3
(n = 955)
At least one delirium assessment completed
(n = 318 – 36%)
At least one delirium assessment completed
(n = 858 – 49.7%)
At least one delirium assessment completed
(n = 80 – 8.4%)
Total patients with at least one delirium assessment completed
(n = 1,226 – 35%)
Studied Neurology hospital floor
Final Analytic Sample (n = 858)


12-24h bed holds
[early morning pre-surgical admissions]
S
N
Discharge delay
[wait for Nursing home admission]
Bed Competition
[Days of the Week]
Z*
U
Clinical severity
Diagnosis/comorbidities
Demographics
A
ED Boarding Time
Y
72h Delirium Risk