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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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ABSTRACT

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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.

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INTRODUCTION

107 Delirium is an acute cognitive disorder characterized by altered awareness, attentional deficits,

108 confusion, and disorientation (Sachdev et al., 2014). Current estimates of new-onset delirium

109 underscore the sobering fact that delirium overwhelmingly develops in medical settings (as high as

110 82% in intensive care settings) compared to the community at large (approximately 1%-2%)

111 (Dharmarajan et al., 2017). Critically, research has demonstrated that 30%-40% of all delirium cases

112 are preventable (Dharmarajan et al., 2017, Inouye et al., 2014, Inouye et al., 1999, Neurology, 2016).

113

114 Although delirium reverberates through all age populations, older adults (≥65 years of age) are at

115 greater risk of developing delirium during an acute illness, as are individuals with an underlying

116 neurocognitive disorder (mild cognitive impairment and dementia). New-onset delirium in older

117 patients alone translates to a high financial burden on the health care system (Dittrich et al., 2016,

118 Lundstrom et al., 2005). Despite known efficacy of inpatient delirium preventative strategies and

119 predictive models to identify at-risk patients, new-onset delirium occurrence and the associated

120 expenditures remain unchanged (Davis et al., 2013).

121

122 Delirium represents a global challenge for healthcare managers, healthcare providers, and payors

123 because it increases hospital costs (i.e., prolonged utilization of services and hospital stay) and also

124 decreases hospital revenue (e.g., reimbursement penalties in value-based payment models) (Mate

125 and Compton-Phillips, 2014, Haas et al., 2015, Porter and Kaplan, 2016, Collier, 2012). With the

126 COVID-19 pandemic, administrators have faced several challenges with respect to managing hospital

127 capacity (Eriksson et al., 2017, Bravata et al., 2021). As a result, multiple stakeholders began to

128 review their hospital admission processes with the ultimate goal of improving patient outcomes.

129

130 However, ongoing endeavors to assess the efficacy of delirium prevention strategies have overlooked

131 the key contributing factors, such as the healthcare experience prior to receiving preventive measures

132 on the inpatient wards (e.g., ED experience and bed transfer processes). Therefore, individuals that

133 experience a delay between initial ED arrival and transfer to an inpatient bed (i.e., "delayed bed-flow,"

134 "boarding") may have delayed access to preventative care. Unfortunately, traditional estimates of the

135 association between ED boarding and delirium have been confounded by baseline disease severity

136 and other unmeasured variables. For instance, greater disease severity might reduce the ED

137 boarding time while increase delirium risk.

138

139 We exploited a natural experiment created by exogenous bed competition to examine the impact of

140 prolonged ED boarding (certain days of the week) on the risk of delirium within 72 hours of admission.

141

142 **METHODS**

143 **Study design**

144 We conducted a retrospective study using data abstracted from routine clinical care documented in

145 electronic health records (EHRs) of a large academic medical center between 01/2016 and 12/2018.

146 Our hypothesis was that prolonged ED boarding (i.e., waiting time at the fourth quartile) increases the

147 risk of delirium during an urgent inpatient admission. In our conceptual framework (Figure 1), the

148 association between ED boarding and delirium might be confounded by disease severity and other

149 variables. However, based on the assumption that no one can choose the day of the week they will

150 have a neurological emergency (i.e., strokes are unpredictable), one could putatively exploit the

151 exogenous variation in neurology floor bed competition to indirectly examine the association between

152 ED boarding time and delirium risk.

153
154 [Insert Figure 1]
155

156

157 **Source of participants and data**

158 Between 01/2016 and 12/2018, 79,467 older patients (≥65+ years) were evaluated in our emergency

159 department (ED). From this population, we identified all patients who were subsequently transferred

160 to a specific study neurology hospital floor (n=1,725), which had implemented a systematic program

161 for delirium prevention and screening. We excluded those who did not have at least one delirium

162 assessment completed during the inpatient stay (n=867 out of 1,725), resulting in a final analytical

163 sample of 858 patients (Figure 2).

164

165 [Insert Figure 2]
166
167 Delirium prophylactic protocol and screening: In accordance with national guidelines, the study

168 neurology hospital floor has a delirium screening and prevention program (Neurology, 2016). The

169 prevention program is based on multimodal, nonpharmacologic delirium prevention programs such as

170 the "The Hospital Elder Life Program" (HELP) and incorporates several preventive measures,

171 including redirection, review of medications, avoidance of restraints (Inouye et al., 2006, Inouye et al.,

172 1999). Delirium screening assessments are performed by registered nurses using the modified

173 Confusion Assessment Method (CAM) and documented in the electronic medical record. Previous

174 controlled studies found that these interventions are effective in preventing delirium, cognitive, and

175 functional decline (Inouye et al., 1990, Mitasova et al., 2012). We further detail the program in

176 Supplementary Text 1.

177

178 **Variables**

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

180   *A: Demographic Information:* We acquired basic demographic information (e.g., age, gender, race)

181   and enriched it with measures of socio-economic status (e.g., insurance type) and other pertinent

182   data (e.g., community dwelling vs not) (Table 1, Supplementary Table 1).

183   [Insert Table 1]
184

185   *B. Clinical Information:* We obtained data on presence of known delirium risk factors, such as stroke,

186   visual impairment, and fall, from a validated Clinical Classifications Software (ACUP-AHRQ-CCS) for

187   inpatient stays, which utilizes an ICD-10 diagnosis and procedure categorization scheme

188   (Supplementary Table 2, Supplementary Table 3).

189

190   *C: Process Information*: We abstracted the date and time in which patients arrived at the emergency

191   department. From these variables, we categorized ED arrival date according to days of the week

192   (Monday-Sunday). Second, we created an indicator variable for "Delay", time from ED arrival-to-

193   neurology bed transfer and categorized in quartiles (Delay, yes $\geq$ 13.4 hours vs. no $\leq$ 5.97 hours).

194

195   *D: Outcome Information:* Delirium was assessed using the modified Confusion Assessment Method

196   (CAM), which have been validated in post-stroke populations (94-100% sensitivity, 89-95%

197   specificity, and high inter-rater reliability). At least 49.7% of the study neurology ward patients were

198   assessed (Figure 2). Some patients could be reevaluated the same day as needed. We captured all

199   CAM assessments for each patient and created our primary outcome variable: time from ED arrival to

200   first CAM positive within a 72h observation period (CAM positive indicated delirium). For sensitivity

201   analysis, we also derived a binary indicator variable for delirium (yes vs no within 72h of admission,

202   Supplementary Table 4).

203

204   **Data analytic approach**

205 To address potential confounders for the primary analysis, we estimated the probability (propensity

206 score) of arriving on each day of the week (Monday-Sunday). We used a categorical logistic-

207 regression to predict the odds of arriving on each day of the week. We examined the distribution of

208 propensity scores across different days of the week, examined for normality assumptions, and

209 compared propensity score means across each day of the week and examined how well the

210 propensity score balanced for potential confounders.

211

212 The potential confounders were obtained from linked encounter-level electronic medical record data,

213 and included age, gender, race, site of origin (community dwelling vs not), insurance type, and known

214 comorbidity (e.g., presence of known delirium risk factors such as stroke, visual impairment)). The

215 percentage of patients with missing data for these variables was low (<1%). For missing data, we

216 assumed missingness at random and conducted a complete case analysis.

217

218 We compared time from ED door arrival to first documentation of delirium (CAM positive) within a 72h

219 period among those who arrived on different days of the week using a cox proportional hazards

220 model, with propensity score adjustment (as a continuous linear term). To reduce the potential bias

221 from differential follow-up times and the impact the inpatient care and drugs might have on delirium

222 risk overtime that is unrelated to arrival conditions, we limited the maximal follow-up time to 72h.

223 Censored observations included death, transfer, or discharge before 72h. We examined Schoenfeld

224 residuals to examine for potential violation of the proportional-hazards assumption. We reported

225 hazard ratios and 95% confidence intervals for unadjusted and stepwise adjusted analysis. We

226 estimated at least 90% power to detect a 50% higher hazard of delirium, using an estimated sample

227 of at least 100 patients per day of the week (exponential test, hazard difference, alpha 0.5).

228

229 *Sensitivity analysis:* We conducted additional prespecified sensitivity analysis and examined the

230 robustness and validity of our findings in several ways:

231

232 *Statistical assumptions:* First, we avoided the use of the propensity score and compared time from

233 ED door arrival to first delirium (CAM+) documented within a 72h period among those who arrived on

234 early days of the week (Sunday-Wed = high demand) versus late days of the week (Thursday-

235 Saturday = low demand) using cox proportional hazards models, with and without adjustment for the

236 potential confounders used in the main analysis; Second, we avoided the use of survival analysis

237 (cox proportional hazards assumption might be unrealistic) and estimated the 72h odds of delirium

238 using logistic regression models, assuming no loss to follow-up (given very short follow-up time), with

239 and without adjustment for the potential confounders listed in the main analysis. Third, we observed

240 that the care experience of those who arrive to the ED during day might be different than the care

241 experience of those who arrive at night. We hypothesized that "shift" could explain the effect of ED

242 boarding on delirium risk (e.g., more severe cases arriving at night). Delirium screening was

243 implemented at every shift (day and night). We compared time from ED door arrival to first delirium

244 (CAM+) documented within a 72h period among those who arrived on different days of the week

245 using cox proportional hazards models, with propensity score adjustment plus additional adjustment

246 for time of the day (i.e., using "shift" as a binary predictor, meaning arrival to the ED during day vs

247 night hospital shift).

248

249 *Screening effect:* Systematic delirium screening is hypothesized to naturally increase its detection

250 rate. If ED boarding time increases the 72h delirium risk independent of the destination floor, we

251 expect replication of the results in other samples and settings where delirium prevention protocol was

252 either not done or done differently. For instance, more severe cases (as opposed to systematic

253 screening as in the study floor) are more likely to be screened in a neurological intensive care unit. To

254 examine this assumption, we repeated the analysis expanding the sample to all neurology inpatients

255 (the study floor, one neurological intensive care unit, and one additional neurology floor).

256

257 *Face validity*: We exploited two potential reasons for competing demands for the neurology floor

258 beds: a) On certain days of the week (e.g., week days), neurosurgeons place holds on floor beds to

259 accommodate the post-operative needs of their scheduled patients, whereas there are fewer bed

260 holds on weekends (Supplementary Table 5) ; and b) On certain days of the week (e.g., Sundays),

261 discharges from hospital to another institution (e.g., skilled nursing facilities) are systematically

262 delayed until Monday morning (Supplementary Table 6). With high demand for beds, patients

263 admitted from the ED frequently "board" in the ED on Sunday night or Tuesday night until a floor bed

264 opens. The nursing responsibility transfers from ED nurses to neurology ward nurses when the

265 patient arrives on the inpatient ward.

266

267 **RESULTS**

268 Of the 858 patients who presented to the ED with a neurological emergency, 697 (81.2%) had at least

269 one delirium risk factor in addition to age (e.g., stroke, visual impairment, fall, dementia), with mean

270 age 78 ± 9 years, 51.2% men, and 84.7% white. Patients arriving on different days of the week with

271 neurological emergencies were comparable with respect to age, gender, race, site of origin,

272 insurance type, and comorbidities. Delirium was documented in 234 (30%) patients within the first

273 72h from ED arrival. Table 1 summarizes the demographic characteristics of the patients upon ED

274 arrival.

275

276 This study demonstrated an association between days of the week and delirium. ED arrival on

277 Sundays and Tuesdays were associated with shorter time to delirium onset (Sunday: propensity

278 score adjusted HR= 1.54 for delirium onset, 95%CI:1.36-1.75; Tuesday: propensity score adjusted

279   HR=1.39 for delirium onset, 95%CI:1.22-1.58) in a 72-study follow-up time-frame, using Friday as

280   reference day. These results were similar using different days of the week as reference, and also

281   after adjusting for time of the day (i.e., day vs night shift) (Supplementary Table 7 and 8). For

282   illustrative purposes, we provided unadjusted delirium survival curves (Figures 3A to 3C and

283   Supplementary Figure 1). Findings were similar using the sample of all neurology inpatients (each

284   with different protocols for use/screening for delirium).

285   [Insert Figure 3A]
286

287   [Insert Figure 3B]
288

289   [Insert Figure 3C]
290

291   *This study was Sensitivity analysis*: ED arrival on early days of the week (binary, early meaning

292   Sunday to Wednesday vs late meaning Thursday to Saturday) was still associated with a shorter time

293   from ED arrival to delirium onset using covariate adjustment (covariate adjusted HR: 1.242, 95% CI

294   1.04-1.48), Supplementary Table 9. The adjusted 72h odds of delirium was 1.95-fold greater (95% CI

295   1.05- 3.64) for those arriving to ED on Sunday compared to Saturday, for instance (Supplementary

296   Table 10).

297

298   ED arrival on Sundays was associated with delayed floor admission (waiting time greater than 13.4

299   hours = time from ED arrival to transfer to inpatient bed, p<0.001, Supplementary Table 11) and with

300   lowest proportion of hospital to skilled nursing facility discharges (p<0.001, Supplementary Table 6).

301   Similarly, ED arrival on Tuesdays was associated with delayed floor admission (p<0.001,

302   Supplementary table 11) and with greater proportion of elective pre-surgical admissions on

303   Wednesday morning, p<0.001, Supplementary table 5).

304

305 Figure 4 illustrates the measures of bed competition (i.e., elective pre-surgical admissions and

306 discharges to nursing homes or alike), the overtime proportion of patients who had prolonged ED

307 boarding time (i.e., >13h), and the various 72h-delirium hazard ratios in relation to days of the week.

308 In summary: a) the ED boarding time followed the trends in the measures of bed competition, and b)

309 ED boarding time was associated with the 72h-delirium hazard ratio.

310 [Insert Figure 4]

311

312 **DISCUSSION**

313 Older patients admitted from the ED with neurological emergencies have a substantial risk of

314 developing delirium early in their hospitalization. Our study also reveals that increased "boarding

315 time" (or delayed transfer to the hospital floor) is associated with greater short-term risk of delirium in

316 this natural experiment. While risk factors for delirium are multi-dimensional and time-varying, our

317 study identified areas for process improvement that could have a real link with outcomes leading to

318 improved patient care and decreased health care spending.

319

320 Our study has several strengths including our very large sample size and its reasonably high rate of

321 delirium, making our comparisons robust. By demonstrating an association between prolonged ED

322 lengths of stay and elevated risk of delirium onset during admission, our results are consistent with

323 the evolving literature suggesting that delirium prophylaxis is critical to prevention and that delays in

324 this process increase the risk of the development of delirium.

325

326 Specifically, our study demonstrates that risk of developing delirium during hospitalization is greatest

327 for older patients with acute neurologic conditions who present to the ED on days with higher risk of

328 prolonged ED lengths of stay. One prior study that evaluated the association between ED length of

329 stay and incident delirium, also showed a prolonged ED length of stay (10 hours or greater) prior to

330 admission doubled the risk for delirium onset (Bo et al., 2016); this study, however, excluded patients

331 with acute stroke which is one of the major risk factors for delirium among older adults. Delirium is a

332 frequent complication of stroke (10-42%) (Mitasova et al., 2012, Dahl et al., 2010).

333

334 We theorized that the increased risk of delirium is related to a combination of the care experienced at

335 the ED department and the delayed implementation of delirium prevention measures. For instance, it

336 is also possible that the physical environment of, care limitations of, and/or therapeutics administered

337 in the ED contribute to this short-term increased risk. The physical environment of the ED, with bright

338 lights and high ambient noise level 24 hours a day, is potentially deliriogenic and contrary to the sleep

339 hygiene measures recommended by national delirium prevention guidelines (Grover and Avasthi,

340 2018, Inouye et al., 2000, NICE, 2003).

341

342 This study's results are intuitively and quantitatively valid. Presenting to the hospital earlier in the

343 week, e.g., Sunday and Tuesday, conveyed higher risk of delirium than presenting later in the week,

344 e.g., Saturday. Some delays in admission have been attributable to exogenous factors. For example,

345 we know that during weekends neurological floors have fewer discharges to skilled nursing facilities

346 (SNF), which, in turn, influences the number of beds available for new admissions on those floors.

347 With respect to mid-week days, we recognized that elective admission to neurological floors, medical

348 or surgical, may impact the number of available beds and cause further delays in admission (McHugh

349 et al., 2008). In this study, we exploited the fact that acute emergencies (e.g., stroke) are largely

350 unpredictable, and will continue to occur independent of human's ancient Greek calendar scheme

351 (days of week), surgeon's schedule, or SNF's opening policies.

352

353 In this study, we tested different categorization assumptions for the predictor variable (individual days

354 of the week vs binary), different modeling assumptions (cox proportional hazard vs steady state

355 assumptions), as well as different samples (more homogeneous study floor with high screening rate

356 vs all study floors with low screening rate and a heterogeneous population). The association was

357 stronger with increasing effective sample size (e.g., all samples) and increasing number of

358 assumptions (e.g., propensity score, binary predictor categorization). Overall, our study conclusions

359 about differential short-term delirium risk according to days of the week remained robust across all

360 methods.

361

362 Our face validity exploratory analysis, while hypothesis-generating in our work, creates avenues for

363 further study in optimizing communication paths between ED and Neurology department providers.

364 Prioritizing ED arrivals over elective surgery admissions could improve patient care delivery

365 regardless of baseline medical condition. This further adds to the discussion for multidisciplinary

366 neurological care to use large and real-care data analysis to cross departmental boundaries and

367 rethink in-hospital processes. More importantly, it provides an opportunity to make targeted

368 interventions for high risk patients in a high-volume and critical care environment.

369

370 This study has several limitations. First, it was conducted at a single tertiary academic center with

371 which may limit its generalizability. This center is known for providing excellent quality care in the

372 emergency room, which suggests that our results could represent a conservative estimation of the

373 impact of ED boarding on delirium risk. Because our center is a tertiary academic center, we may

374 have received a greater share of severe cases when compared to community hospitals. In addition,

375 we also limited our main analysis to patients with neurological emergencies. In fact, roughly two thirds

376 of the patients that were included had stroke as a primary diagnosis and this study did not include

377 details of their stroke type, severity at initial presentation in the ED, which would include

378 hemodynamics, cardiac and pulmonary status, and whether or not they had significant altered

379 mentation or level of consciousness. Because number, type, and severity of medical conditions are

380 known risk factors for delirium, our study may have overestimated the general 72h in-hospital delirium

381 prevalence.

382

383 Second, the delirium screening (CAM protocol) was not implemented consistently among the older

384 patients admitted through the ED, with only 50% of patients being screened within the 72h study

385 period. In our main analysis, we chose the study floor that had implemented a systematic protocol for

386 screening at least twice per day to attempt to eliminate the variable of staff judgment when screening.

387 However, the well-trained nurses still used their best judgement about who could have deferred

388 screening in a large proportion of cases. Therefore, it is possible that those at higher risk for delirium

389 (e.g., older age) were more likely to have a documented delirium screening. In a worst-case scenario,

390 if we assume that the in-hospital unconscious selection of patients to screen for delirium was driven

391 by a nurses' judgment (prior probability of potential risk for delirium), we expect that the analytical

392 sample would systematically exclude those healthier patients. However, the nurses' judgment is

393 expected to be independent of the day of the week surgeon's schedule, and SNF's opening policies.

394 In this scenario (extreme case of independent differential misclassification of the outcome), the

395 results could represent an over or underestimate of the true rates of delirium. In this scenario of

396 independent non-differential misclassification of a binary outcome, the estimates are still valid

397 (preserves type I error, alpha set) but is likely conservative (towards the null). Therefore, our results

398 are likely conservative in the main analysis, and potentially biased in an unpredictable direction in the

399 all sample analysis. Further, one could use the reported CAM specificity (95.9%) to obtain the

400 adjusted estimate of the risk (Gusmao-Flores et al., 2012).

401

402 Another common potential source of bias is the misclassification of covariates (e.g., diagnoses). As

403 outlined before, we attempted to mitigate misclassification bias with careful and conservative

404 sensitivity analysis and face validity checks. One additional source of potential misclassification is our

405 use of "elective presurgical admissions" as a proxy for "bed-holds" for surgery. We measured the

406 volume of neurology admissions coming from the elective surgical admission department (as

407 opposed to the ED department or else). An ideal measure of bed competition would actually be the

408 volume of "bed holds" placed by surgeons each day (some eventually become an elective surgical

409 admission while others are canceled for several reasons).

410

411 Our study could not differentiate the effect of prolonged lengths of stay in the ED environment (e.g.,

412 noisy and disruptive day and night) from the effect of delayed initiation of delirium prevention protocol

413 on the neurology floor. Though some EDs do have volunteer-based programs similar to the HELP

414 delirium prevention program (Sanon et al., 2014), there are no studies evaluating the impact of ED-

415 initiated delirium prevention programs on incident delirium.

416

417 The specific or long-term impact of preventive strategies for delirium is an area for further study.

418 Physicians in training have reported delirium prevention education is often sparse and

419 disproportionate to their exposure to high risk patients (Pickett et al., 2019). In addition to enhanced

420 awareness, electronic delirium risk alerts and targeted deployment of hospital resources are all

421 avenues by which delirium screening rates could improve, and thereby outcomes for high risk

422 patients, can be immediately improved.

423

424 Finally, our study was not designed to demonstrate causation (cause-and-effect). A randomized

425 controlled clinical trial would not be feasible or ethical in this vulnerable population of patients with

426 neurological emergencies. Therefore, we conducted this rigorous observational study that identified

427 an association between ED boarding time and the documentation of delirium in the first 72 hours of

428 admission.

429

430   In a healthcare management framework, common factors associated with ED boarding could be

431   grouped into four main categories: a) how primary care and continuity are organized, b) the existence

432   and effectiveness of organizational models and clinical pathways for chronic patients, c) the presence

433   of bottlenecks related to ED's personnel or equipment endowment, and d) how the ED is organized

434   and its connection with the rest of the hospital (Vainieri et al., 2020). Our study may help healthcare

435   managers to identify feasible targets for process improvement in the connection between ED and the

436   rest of the hospital (e.g., a sensible elective surgery's schedule).

437

438   This study design did not seek to determine whether it is prolonged ED boarding time or the delayed

439   Neurology transfer arrival that increased the risk of delirium. Some argue that the ED boarding is

440   "delirium-genic" (i.e., the extra hours in the ED extends the patient's exposure to noisy, cold, stressful,

441   and unwelcoming environment without direct exposure to external light). In contrast, the delirium

442   prevention protocols include steps to minimize potential environmental insults. Nevertheless, this

443   study provides some feasible suggestions for process improvement that are still within the scope of

444   healthcare managers, such as better alignment between discharge volume needs and SNF's

445   admitting hours. This represents a new category for process improvement in the healthcare

446   management framework: relationships between hospitals and post-acute care facilities.

447

448

449   **CONCLUSION**

450   Older patients admitted from the ED with neurologic conditions have a substantial risk of developing

451   delirium early in their hospitalization. Prolonged wait for transfer to the hospital floor appear to be

452   associated with increased risk of delirium in this natural experiment. Hospital complications such as

453   delirium might be prevented by early initiation of prophylaxis protocols and transfer from the ED to the

454   hospital bed. Healthcare managers may improve outcomes and reduce spending by removing

455   bottlenecks in the clinical pathways across primary care, emergency rooms, operating rooms, and

456   post-acute services.

457

458   **Declaration of Conflicting Interests**

459   The Authors declare that there is no conflict of interest.
460

461

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537 **SUPPLEMENTAL MATERIALS**

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

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541 [Insert Supplementary Figure 1]

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546 **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.

547 **Legend:** EHR = Electronic Health Record.
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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.

583 **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.

584 **Legend:** CCS Codes = Clinical Classifications Software (ACUP-AHRQ-CCS).
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586 **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).

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

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601 **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)	

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

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

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	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

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

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

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	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

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

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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

634 **Supplementary Table 11 – Days of the Week vs Delay**

	Overall 858	< 4.97 hours (No Delay) 211	> 13.4 hours (Delay) 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)

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

ED Boarding + Bed Competition => Increased Delirium Risk

Product-Limit Survival Estimates
With Number of Subjects at Risk

	0	12	24	36	48	60	72
No	546	493	444	392	344	289	251
Ye	231	201	175	143	120	98	71

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

	0	12	24	36	48	60	72
No	667	603	540	470	407	340	284
Yes	110	91	79	65	57	47	38

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

Log-Rank p-value: 0.030

Product-Limit Survival Estimate
With Number of Subjects at Risk

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]

Clinical severity
Diagnosis/comorbidities
Demographics

U

S

Bed Competition
[Days of the Week]

Z*

A

Y

ED Boarding
Time

72h Delirium Risk

N

Discharge delay
[wait for Nursing home admission]