Appendix E1
Codebook

Appendix Codebook

The following text includes SAS commands to implement the analyses described in the Methods section of the manuscript. All covariates are defined at the end of this Appendix Codebook.

The predictor variable of interest is: iRgrp1. In the primary analysis, iRgrp1 is a binary indicator for 'High ED Crowding' on the day of admission, which is a facility normalized measure of daily diversion hours as described in the Methods. (Table 2) In a sensitivity analysis, iRgrp1 is a categorical variable for the number of diversion hours (0, 0-5,>5) on the day of admission. (Table 3)

1. Module A: Logistic Mixed-Effects Regression for Inpatient Death

In the primary analysis (Table 2), the dependent variable INPT_DTH is death anytime during the inpatient stay. In a sensitivity analysis, the dependent variable INPT_DTH is death in the first three days of the inpatient stay. (Results section)

```
proc glimmix data=indata method=laplace noclprint;
       where sex in ("1","2");
       class oshpd_id sex iRgrp1 pdccs white admtmth_num_R ;
       model INPT_DTH(event='1')=age5yr sex white iRgrp1 admtmth_num_R weekend
       chf valve pulmcirc perivasc para neuro chrnlung dm dmcx hypothy renlfail
       liver ulcer aids lymph mets tumor arth coag obese wghtloss lytes bldloss
       anemdef alcohol drug psych depress htn_c oshpd_id /dist=binary solution
       cl;
       random intercept /subject=pdccs;
       output out=Pred_death pred=pred resid=r;
       title2 "IntraH Model1 - Facility FE + PDCCS RE - InptDeath";
run;
```

2. Modules B and C: Linear Mixed-Effects Regression Model for LOS (Module B) and COST (Module C)

The dependent variable for Module B is loglos, which is a log transform of length-of-stay as described in the Methods.

The dependent variable for Module C is logcost, which is a log transform of cost as described in the Methods. The below SAS statement illustrates Module B; Module C substitutes logcost for loglos.

```
proc mixed data=indata covtest noclprint;
       where sex in ("1","2");
       class oshpd_id sex iRgrp1 pdccs white admtmth_num_R;
       model loglos = age5yr sex white iRgrp1 white admtmth_num_R weekend
       chf valve pulmcirc perivasc para neuro chrnlung dm dmcx hypothy renlfail
       liver ulcer aids lymph mets tumor arth coag obese wghtloss lytes bldloss
       anemdef alcohol drug psych depress htn_c oshpd_id
       /solution cl outp=pred_los residual vciry;
       random intercept /subject=pdccs type=un;
       title2 "IntraH Model1 - Facility FE + PDCCS RE - log(LOS) or log(COST)";
run;
```

3. Bootstrapping CI Module: Logistic Mixed-Effects Regression for Inpatient Death, LOS, Cost

The Methods section describes the approach to estimating attributable population impact of high ED crowding on the outcomes.

```
%macro bootCI(seedno,setno);
proc surveyselect data=Indata method=urs samprate=1 outhits
       seed=&seedno out=bootsample;
       strata oshpd_id iRgrp1;
run;
data extraDH;
       set bootsample;
       where sex in ("1","2") and iRgrp1=1;
       INPT_DTH=.; loglos=.; lcost1=.; iRgrp1=0; dummy=1;
```

```
run;
data indata_boot;
       set bootsample extraDH;
run;

Execute Module A;
Execute Module B;
Execute Module C;
%mend;

%macro runboot;
%do i=1 %to nsim;
    %let x=%eval(1000*(%eval(941+10*&i.)));
    %bootCI(&x,&i);
%end;
%mend;

%runboot;
```

Covariate Definitions

Source of variables are explained in the Methods.

age5yr	age in 5 year intervals
sex	gender
white	white race
admtmth_num_R	month of admission
weekend	weekend admission
chf	comorbidity: congestive heart failure
valve	comorbidity: valvular disease
pulmcirc	comorbidity: pulmonary circulation disorders
perivasc	comorbidity: peripheral vascular disease
para	comorbidity: paralysis
neuro	comorbidity: neurological disorders
chrnlung	comorbidity: chronic pulmonary disease
dm	comorbidity: diabetes without chronic complications
dmcx	comorbidity: diabetes with chronic complications
hypothy	comorbidity: hypothyroidism
renlfail	comorbidity: renal failure
liver	comorbidity: liver disease
ulcer	comorbidity: chronic peptic ulcer disease
aids	comorbidity: HIV and AIDS
lymph	comorbidity: lymphoma
mets	comorbidity: metastatic cancer
tumor	comorbidity: solid tumor without metastasis
arth	comorbidity: rheumatoid arthritis
coag	comorbidity: coagulation deficiency
obese	comorbidity: obesity
wghtloss	comorbidity: weight loss
lytes	comorbidity: fluid and electrolyte disorders
bldloss	comorbidity: blood loss anemia
anemdef	comorbidity: deficiency anemias
alcohol	comorbidity: alcohol abuse
drug	comorbidity: drug abuse
psych	comorbidity: psychoses
depress	comorbidity: depression
htn_c	comorbidity: hypertension
oshpd_id	unique hospital identifier
pdccs	primary discharge CCS code

Table E1. Characteristics of included and excluded hospitals.

Variable	Included	Excluded
Number of hospitals (n)	187	97
Number of hospitals in county, No. (%)*		
1	3 (15)	19 (49)
2	2 (10)	7 (18)
>2	15 (75)	13 (33)
Hospital-level profile of ED visitors		
Age, mean (SD), y†	39.7 (5.4)	37.5 (7.6)
Male, mean (SD), %	46.2 (3.3)	46.3 (3.1)
Nonwhite, mean (SD), %*	53 (22.1)	43.5 (25.0)
Income in US $1,000, mean (SD)*	48.9 (11.7)	44 (11.8)
Insurance: Med-Cal+uninsured, mean (SD), %†	39.6 (19.1)	45 (19.4)
Population density, mean log scale (SD)*	7.1 (1.3)	5.1 (1.5)
Hospital characteristics, No. (%)		
Teaching status†	19 (10.2)	3 (3.1)
Ownership, No. (%)*		
County	13 (7.0)	4 (4.1)
For profit	51 (27.3)	12 (12.4)
Nonprofit	123 (65.8)	81 (83.5)
Trauma center (%)	33 (17.7)	9 (9.5)

*$P<.01$.
†$P<.05$.

Table E2. Admissions by hospital characteristics and ED crowding.

Hospital Characteristic	Facilities (n=187)	No. (%) Admissions, Total (n=995,379)	Admissions, High ED Crowding (n=197,325; 20%)	Admissions, Normal ED Crowding (n=798,054; 80%)
Ownership*				
Not for profit	123 (65.8)	741,302 (74.5)	147,927 (75.0)	593,375 (74.4)
For profit	51 (27.3)	166,604 (16.7)	30,405 (15.4)	136,199 (17.1)
County	13 (7.0)	87,473 (8.9)	18,993 (9.6)	68,480 (8.6)
Trauma center*	33 (17.7)	277,918 (27.9)	61,455 (31.1)	216,463 (27.1)
Teaching*	19 (10.2)	164,675 (16.5)	36,716 (18.6)	127,955 (16.0)
Med-Surg hospital beds, No.*				
<100	49 (26.2)	121,365 (12.2)	19,365 (9.8)	102,000 (12.8)
100–399	134 (71.7)	826,712 (83.1)	167,030 (84.7)	659,682 (82.7)
≥400	4 (2.1)	47,302 (4.8)	10,930 (5.5)	36,372 (4.6)

*$P<.05$.

Table E3. Full inpatient mortality model results.*

Variables	OR	Inpatient Mortality, N=995,358, 95% CI
High ED crowding	1.05	1.02–1.08
Covariates		
Age in 5 y	1.15	1.14–1.15
Male	1.04	1.01–1.06
Nonwhite	0.95	0.92–0.98
Calendar month (ref=January)		
February	0.87	0.82–0.91
March	0.84	0.80–0.89
April	0.85	0.81–.090
May	0.80	0.75–0.84
June	0.82	0.77–0.86
July	0.85	0.80–0.89
August	0.83	0.78–0.88
September	0.85	0.80–0.89
October	0.92	0.87–0.97
November	0.91	0.86–0.96
December	0.98	0.93–1.03
Weekend (ref=weekday)	1.06	1.03–1.08
Comorbidities		
Congestive heart failure	1.56	1.52–1.61
Valvular disease	0.99	0.95–1.04
Pulmonary circulation disorders	1.47	1.40–1.55
Peripheral vascular disease	1.23	1.18–1.28
Paralysis	1.21	1.16–1.27
Neurologic disorders	1.44	1.39–1.49
Chronic pulmonary disease	1.13	1.10–1.16
Diabetes w/o chronic complications	0.98	0.96–1.01
Diabetes w/chronic complications	0.89	0.85–0.94
Hypothyroidism	0.93	0.90–0.97
Renal failure	1.57	1.53–1.62
Liver disease	1.79	1.71–1.88
Chronic peptic ulcer disease	1.10	0.77–1.56
HIV and AIDS	1.39	1.06–1.82
Lymphoma	1.75	1.58–1.93
Metastatic cancer	3.53	3.37–3.69
Solid tumor w/o metastasis	1.89	1.79–2.01
Rheumatoid arthritis	1.18	1.10–1.27
Coagulation deficiency	2.70	2.60–2.80
Obesity	0.82	0.78–0.86
Weight loss	1.62	1.55–1.68
Fluid and electrolyte disorders	2.04	1.99–2.09
Blood loss anemia	0.97	0.90–1.05
Deficiency anemias	0.80	0.78–0.83
Alcohol abuse	1.12	1.06–1.18
Drug abuse	0.99	0.92–1.06
Psychoses	0.81	0.76–0.86
Depression	0.78	0.75–0.82
Hypertension	0.79	0.77–0.81

*Primary diagnosis included approximately 200 categories and was modeled as a random effect.

Table E4. Full length-of-stay model results.*

Variables	Ratio	Length of Stay, N=995,358, 95% CI
High ED crowding	1.008	1.005–1.012
Covariates		
Age in 5 y	1.01	1.009–1.010
Male	0.995	0.992–0.998
Nonwhite	1.01	1.007–1.014
Calendar month (ref=January)		
February	0.838	0.832–0.844
March	0.937	0.930–0.943
April	0.94	0.933–0.946
May	0.964	0.958–0.971
June	0.961	0.954–0.968
July	0.966	0.959–0.972
August	0.968	0.961–0.976
September	0.961	0.955–0.968
October	0.97	0.963–0.976
November	0.975	0.968–0.982
December	0.995	0.988–1.002
Weekend (ref=weekday)	1.004	1.001–1.07
Comorbidities		
Congestive heart failure	1.196	1.190–1.202
Valvular disease	0.118	1.111–1.126
Pulmonary circulation disorders	1.239	1.227–1.251
Peripheral vascular disease	1.094	1.087–1.101
Paralysis	1.288	1.277–1.298
Neurologic disorders	1.185	1.179–1.192
Chronic pulmonary disease	1.135	1.130–1.140
Diabetes w/o chronic complications	1.055	1.051–1.060
Diabetes w/chronic complications	1.136	1.129–1.144
Hypothyroidism	1.033	1.028–1.038
Renal failure	1.054	1.049–1.059
Liver disease	1.087	1.078–1.095
Chronic peptic ulcer disease	1.131	1.077–1.089
HIV and AIDS	1.209	1.164–1.256
Lymphoma	1.167	1.144–1.191
Metastatic cancer	1.133	1.121–1.144
Solid tumor w/o metastasis	1.079	1.068–1.091
Rheumatoid arthritis	1.088	1.077–1.099
Coagulation deficiency	1.351	1.340–1.362
Obesity	1.118	1.112–1.124
Weight loss	1.55	1.537–1.563
Fluid and electrolyte disorders	1.29	1.285–1.295
Blood loss anemia	1.367	1.350–1.384
Deficiency anemias	1.253	1.249–1.258
Alcohol abuse	1.111	1.103–1.119
Drug abuse	1.063	1.055–1.071
Depression	1.07	1.069–1.080
Hypertension	1.06	1.057–1.064

*Primary diagnosis included approximately 200 categories and was modeled as a random effect.

Table E5. Full-cost model results.*

	Costs, N=844,219	
Variables	**Ratio**	**95% CI**
High ED crowding	1.011	1.007–1.015
Covariates		
Age in 5 y	0.994	0.994–0.995
Male	1.037	1.033–1.040
Nonwhite	1.004	1.001–1.008
Calendar month (ref=January)		
February	0.903	0.897–0.910
March	0.999	0.992–1.007
April	1.001	0.994–1.009
May	1.019	1.011–1.026
June	1.012	1.005–1.020
July	1.018	1.010–1.025
August	0.997	0.989–1.005
September	0.99	0.983–0.998
October	0.988	0.981–0.995
November	0.985	0.978–0.993
December	0.995	0.988–1.003
Weekend (ref=weekday)	0.999	0.996–1.003
Comorbidities		
Congestive heart failure	1.24	1.233–1.247
Valvular disease	1.12	1.113–1.129
Pulmonary circulation disorders	1.272	1.258–1.285
Peripheral vascular disease	1.143	1.134–1.151
Paralysis	1.233	1.223–1.244
Neurologic disorders	1.171	1.164–1.178
Chronic pulmonary disease	1.161	1.156–1.167
Diabetes w/o chronic complications	1.072	1.067–1.076
Diabetes w/chronic complications	1.174	1.165–1.182
Hypothyroidism	1.029	1.023–1.034
Renal failure	1.065	1.059–1.071
Liver disease	1.089	1.080–1.099
Chronic peptic ulcer disease	1.137	1.079–1.197
HIV and AIDS	1.221	1.174–1.269
Lymphoma	1.213	1.187–1.240
Metastatic cancer	1.134	1.122–1.147
Solid tumor w/o metastasis	1.073	1.061–1.086
Rheumatoid arthritis	1.086	1.074–1.097
Coagulation deficiency	1.485	1.472–1.498
Obesity	1.146	1.139–1.152
Weight loss	1.546	1.532–1.560
Fluid and electrolyte disorders	1.302	1.297–1.307
Blood loss anemia	1.43	1.411–1.449
Deficiency anemias	1.238	1.233–1.243
Alcohol abuse	1.107	1.099–1.115
Drug abuse	1.039	1.031–1.047
Psychoses	1.119	1.111–1.128
Depression	1.032	1.026–1.038
Hypertension	1.071	1.068–1.075

*Primary diagnosis included approximately 200 categories and was modeled as a random effect.