

Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix 1. Bivariate Probit Model

Adjusted relative risk ratios (21) of psychiatric inpatient readmission for individuals administered ECT compared to individuals not administered ECT were estimated using the following IV model specification of the bivariate probit regression model (12):

$$(1a) \quad Y_1 = 1[\mathbf{X}_1\boldsymbol{\beta}_1 + \delta Y_2 + \varepsilon_1 > 0],$$

$$(1b) \quad Y_2 = 1[\mathbf{X}_2\boldsymbol{\beta}_2 + \varepsilon_2 > 0],$$

$$\text{where } \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} | \mathbf{X} \sim \mathcal{N} \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right),$$

where Y_1 is a binary indicator for readmission; Y_2 is a binary indicator for ECT administration; \mathbf{X}_1 and \mathbf{X}_2 are sets of covariates; $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$ and δ are parameters to be estimated; ε_1 and ε_2 are error terms; \mathcal{N} represents the bivariate standard normal distribution; and ρ is the correlation between ε_1 and ε_2 . δ represents the effect of ECT administration on readmission risk. Equations 1a and 1b are estimated jointly, and in doing so Y_2 in Equation 1a is replaced by its estimated probability, which is estimated using Equation 1b. This estimated probability conceptually represents the likelihood of being offered ECT. IV estimates of δ —the effect of greater availability of ECT—are consistent even in the presence of unmeasured confounders if \mathbf{X}_2 contains one or more variables (called instrumental variables or *instruments*) that are correlated with Y_2 but are not correlated with ε_1 , conditional on \mathbf{X}_1 (12-14). The key IV in this study was a hospital's mean proportion of inpatients that are treated with ECT. The conceptual rationale for this instrument being a valid instrument is that ECT's level of availability to a particular patient is driven by attributes of the treating hospital and its geographic location, such as the restrictiveness of state regulations governing treatment with ECT, and these factors are presumed to be largely independent of a patient's illness severity or clinical need for ECT. The statistical significance of ρ can be used as a specification test of the ordinary probit and propensity score matching regression specifications, which require for internal validity that $\rho = \text{corr}(\varepsilon_1, \varepsilon_2) = 0$.

eAppendix 2. Sensitivity Analyses

In supplemental sensitivity analyses, regression models were run using ordinary probit regression and using one-to-one propensity score matching (see eTable 2. By contrast to the IV probit method, ordinary probit regression estimates and propensity score matching estimates of treatment effects are biased and inconsistent if the set of measured covariates omits any factors that are correlated with both ECT treatment and readmission risk. To test the sensitivity of the IV findings to hospital-level unmeasured confounders, IV probit regressions were also estimated using state-level prevalence of ECT delivery, rather than hospital-level ECT prevalence, as the identifying instrument. Finally, we examined whether hospital propensity to use ECT was correlated with readmission risk among psychiatric inpatients who did not have a MDD, bipolar disorder, or schizoaffective disorder diagnosis and were not administered ECT. A negative correlation between hospital propensity to use ECT and readmission risk among these inpatients, who are unlikely candidates for ECT administration, would cast doubt on a causal interpretation of our IV-probit estimates.

eTable 1. Bivariate Results

Thirty-day psychiatric inpatient readmission rates among inpatients with affective disorders, by sample characteristics (weighted)^a

	N	Readmitted %	95% CI	F _{1,162672}	P Value
Overall	162,691	12.2	11.9-12.4		
ECT delivered during stay					
No	160,205	12.2	11.9-12.5	ref.	
Yes	2,486	9.9	8.7-11.0	14.6	<0.001
Age (years)					
18-25	24,746	11.2	10.6-11.9	ref.	
26-45	65,000	13.6	13.1-14.1	31.7	<0.001
46-64	56,542	12.2	11.8-12.7	5.6	0.02
65-74	9,677	9.8	8.9-10.7	6.7	0.01
>74	6,726	8.3	7.3-9.3	23.1	<0.001
Gender					
Male	72,036	13.3	12.9-13.7	ref.	
Female	90,655	11.2	10.9-11.6	54.2	<0.001
Race-ethnicity					
White, non-Hispanic	55,539	12.1	11.8-12.4	ref.	
Black, non-Hispanic	21,715	12.9	12.2-13.6	3.7	0.05
Hispanic	18,376	13.0	12.2-13.9	4.0	0.05
Other race-ethnicity	15,448	10.6	9.8-11.4	11.6	0.001
Diagnosis group					
Major depressive disorder	68,287	9.5	9.2-9.9	ref.	
Bipolar disorder	65,961	12.3	11.9-12.8	93.3	<0.001
Schizoaffective disorder	28,443	15.0	14.4-15.6	217.4	<0.001
Substance use disorder diagnosis					
No	98,426	11.6	11.3-12.0	ref.	
Yes	64,265	13.1	12.7-13.6	27.7	<0.001
Medical comorbidity^b					
No	122,713	11.7	11.4-12.0	ref.	
Yes	39,978	13.4	12.8-13.9	27.2	<0.001
Length-of-stay (days)					
1-7	105,648	9.7	9.5-9.9	ref.	
8-14	34,415	13.0	12.6-13.4	226.8	<0.001
9-21	11,667	14.4	13.7-15.1	170.3	<0.001
22-28	4,421	13.4	12.3-14.4	46.3	<0.001
More than 28	8,132	11.9	11.1-12.6	34.4	<0.001

Source of payment^c					
Private insurance	48,633	9.2	8.8-9.7	ref.	
Medicare	47,884	13.5	13.0-14.0	168.4	<0.001
Medicaid	38,531	13.4	12.8-14.0	129.8	<0.001
Other insurance	11,950	11.4	10.4-12.4	14.5	<0.001
Uninsured	15,693	10.1	9.2-10.9	3.1	0.08
Hospital type					
Urban, medium or large	99,714	12.6	12.3-12.9	ref.	
Urban, small	44,771	11.2	10.7-11.7	20.7	<0.001
Non-urban	15,173	9.7	8.9-10.5	43.0	<0.001
Unknown location	3,033	17.6	15.5-19.8	20.5	<0.001
Hospital delivers any inpatient ECT					
No	100,638	13.0	12.6-13.3	ref.	
Yes	63,677	11.0	10.5-11.4	54.7	<0.001

^a See Methods for a description of the weighting procedure

^b Equals 1 if the patient had an ICD-9 diagnosis code in any position for intracranial lesions/ masses/ inflammation/ infection/ hemorrhage, hemorrhagic stroke, myocardial infarction, dysrhythmias, malfunctioning cardiac device, valvular disease, heart failure, epilepsy, dementia, and other contraindications to anesthesia; 0 otherwise.

^cRepresents primary source of payment

eTable 2. Probit Regression Estimates of the Likelihood of 30-Day Readmission^a

	Ordinary Probit					IV Probit				
	coef	z	P Value	95% CI		coef	z	P Value	95% CI	
ECT delivered during stay	0.020	0.53	0.60	-0.054	0.093	-0.309	-2.29	0.02	-0.573	-0.045
Age	0.012	5.61	<0.001	0.008 -	0.016	0.012	5.60	<0.001	0.008 -	0.016
Age²/1000	-0.155	-6.77	<0.001	-0.200	-0.110	-0.154	-6.70	<0.001	-0.199	-0.109
Female	-0.070	-5.06	<0.001	-0.098	-0.043	-0.070	-5.02	<0.001	-0.097	-0.043
Race-ethnicity (ref: white, non-Hispanic)										
Black non-Hispanic	-0.027	-1.31	0.19	-0.067	0.013	-0.029	-1.44	0.15	-0.069	0.011
Hispanic	-0.023	-1.04	0.30	-0.067	0.021	-0.026	-1.17	0.24	-0.070	0.018
Other race-ethnicity	-0.110	-4.33	<0.001	-0.160	-0.060	-0.113	-4.46	<0.001	-0.163	-0.064
Diagnosis group (ref: major depressive disorder)										
Bipolar disorder	0.151	9.33	<0.001	0.119 -	0.182	0.145	8.84	<0.001	0.113 -	0.177
Schizoaffective disorder	0.255	13.32	<0.001	0.218 -	0.293	0.247	12.64	<0.001	0.209 -	0.286
Substance use disorder	0.035	2.37	0.02	0.006 -	0.063	0.032	2.19	0.03	0.003 -	0.061
Medical comorbidity^b	0.097	6.11	<0.001	0.066 -	0.129	0.097	6.07	<0.001	0.065 -	0.128
Length-of-stay	-0.001	-1.58	0.12	-0.001	0.0001	-0.001	-1.47	0.14	-0.001	0.0002
Hospital type										
Urban small hospital	-0.033	-1.85	0.07	-0.069	0.002	-0.031	-1.72	0.09	-0.066	0.004
Non-urban hospital	-0.090	-3.13	0.002	-0.146	-0.033	-0.087	-3.03	0.002	-0.143	-0.031
Hospital location unknown	0.099	2.25	0.02	0.013	0.185	0.097	2.20	0.03	0.011 -	0.183
Hospital delivers any inpatient ECT	-0.050	-3.42	0.001	-0.079	-0.021	-0.040	-2.61	0.01	-0.071	-0.010
p						0.193	2.89	0.004	0.063 -	0.317

^aRegression models also included state fixed effects and a binary indicator for censored observations where discharge was within 30 days of the end of the calendar year.

^bEquals 1 if the patient had an ICD-9 diagnosis code in any position for intracranial lesions/masses/inflammation/infection/hemorrhage, hemorrhagic stroke, myocardial infarction, dysrhythmias, malfunctioning cardiac device, valvular disease, heart failure, epilepsy, dementia, and other contraindications to anesthesia; 0 otherwise.

eTable 3. One-to-One Propensity Score Matching Estimate of the Average Treatment Effect of ECT on 30-Day Readmission Risk (N=4,940)

	ECT (n=2,470)	No ECT (n=2,470)	Difference	SE	t-stat (P Value)
Average treatment effect among the treated	0.099	0.092	0.007	0.009	0.75 (0.23)

eTable 4. Thirty-Day Readmission Risk by Hospital ECT Prevalence Among Inpatients Who Were Not Administered ECT and Did Not Have a Major Depressive Disorder, Bipolar Disorder, or Schizoaffective Disorder Diagnosis

ECT Prevalence (%)	N	Mean
Less than 1.0	283,528	7.5
1 to 2	12,946	7.4
2 to 3	4,832	8.1
3 to 4	4,060	6.3
More than 4	3,482	6.4
Overall	308,848	7.5
Pearson correlation between ECT prevalence and 30-day readmission risk	coef. (P)	-0.0006 (0.7348)