Title
Suicide Risk Among Hospitalized Versus Discharged Deliberate Self-Harm Patients: Generalized Random Forest Analysis Using a Large Claims Data Set

Journal
American Journal of Preventive Medicine, 62(4)

ISSN
0749-3797

Authors
Goldman-Mellor, Sidra J
Bhat, Harish S
Allen, Michael H
et al.

Publication Date
2022-04-01

DOI
10.1016/j.amepre.2021.08.028

Peer reviewed

HHS Public Access
Author manuscript
Am J Prev Med. Author manuscript; available in PMC 2023 April 01.

Published in final edited form as:
Am J Prev Med. 2022 April ; 62(4): 558–566. doi:10.1016/j.amepre.2021.08.028.

Suicide risk among hospitalized vs. discharged deliberate self-harm patients: Generalized random forest analysis using a large claims dataset

Sidra Goldman-Mellor, Ph.D.*,
Department of Public Health; School of Social Sciences, Humanities, and Arts; University of California, Merced; Merced CA 95343, USA.

Harish S. Bhat, Ph.D.,
Department of Applied Mathematics; School of Natural Sciences; University of California, Merced; Merced CA 95343, USA.

Michael H. Allen, M. D.,
Johnson Depression Center, University of Colorado School of Medicine, Aurora, CO 80045, USA.

Michael Schoenbaum, Ph.D.
Division of Services and Intervention Research, National Institute of Mental Health; Bethesda, MD, USA.

Abstract

INTRODUCTION.—Suicide rates are extremely high among emergency department (ED) patients seen for deliberate self-harm. Inpatient hospitalization is often recommended for these patients, but evidence on the suicide-prevention effects of hospitalization is scarce. Confounding by indication and challenges to implementing randomized designs are barriers to advances in this field.

METHODS.—We used 2009–2012 statewide data on 57,312 self-harm ED patients from California, linked to mortality records. We estimated naïve 12-month and 30-day suicide risks among patients who were hospitalized vs. discharged. We then applied generalized random forest (GRF) methods to estimate the average treatment effect of hospitalization on suicide, conditioning on observable covariates. Associations were calculated separately for gender- and age-specific subgroups. Analyses were conducted February 2019-August 2021.

RESULTS.—In naïve analyses, suicide risk was significantly higher in hospitalized vs. discharged patients in each subgroup. In 12-month models accounting for observed covariates via GRF methods, hospitalized males had 5.4 more suicides per 1,000 patients (95% CI: 3.0, 7.8), hospitalized patients aged 10–29 had 2.4 (1.1, 3.6) more suicides per 1,000, and those aged ≥50 had 5.8 (0.5,11.2) more suicides per 1,000, compared to corresponding discharged patients.

---

*Corresponding author: Sidra Goldman-Mellor, Ph.D., Department of Public Health, School of Social Sciences, Humanities, and Arts, University of California, Merced; Merced, CA 95343, USA, (209) 228-2498, sgoldman-mellor@ucmerced.edu.

Author contributions: S.G.M. and H.S.B. contributed equally to this work. They conceived of the study, conducted the literature search, and led the interpretation and manuscript writing. S.G.M. acquired the study data. H.S.B. conducted the data analysis. M.S. and M.A. contributed to the interpretation of results and manuscript writing.

Conflicts of interest: The authors report no potential conflicts of interest.

Hospitalization was not significantly associated with suicide among females nor among patients aged 30–49 in GRF analyses. Patterns were similar in 30-day GRF models.

CONCLUSIONS.—ED personnel intend to hospitalize the self-harm patients with high suicide risk; our study suggests this goal is largely realized. Analyses that control for confounding by observable covariates did not find clear evidence that hospitalization reduces suicide risk, and could not rule out the possibility of iatrogenic effects.

Suicide rates have risen each year since 2005 in the United States, where in 2019 suicide was the 10th leading cause of death.[1] Healthcare settings, particularly emergency departments (EDs), are important for identifying individuals at high suicide risk.[2,3] Suicide rates among ED patients presenting with deliberate self-harm are 56 times higher than those of demographically matched population controls.[4] Improving survival among these patients is critical to achieving clinical and health system suicide prevention goals.[2]

Inpatient hospitalization is often thought to be indicated for ED self-harm patients, especially those deemed to be at high suicide risk, and may be necessary for those with serious physical injuries.[5] Nationwide, 65% of self-harm patients are hospitalized or transferred.[6] Inpatient admission can theoretically provide self-harming patients with a safe environment, comprehensive psychiatric assessment, access to psychological and pharmaceutical treatment, and improved linkage with outpatient care,[7–9] which may reduce suicide risk. However, empirical evidence on the clinical effects of inpatient admission on these patients' suicide risk is very limited. Only a few studies exist, nearly all from the United Kingdom;[10,11] these studies report mostly null associations between inpatient admission and suicide[11,12] after attempting to account for baseline factors. Additional research in this area is needed to inform clinical practice, especially given the U.S. context of severely constrained psychiatric bed capacity[2,13–15] and high costs of inpatient admission. Such research is particularly important in light of the possibility that, for some subsets of patients, hospitalization may inflict iatrogenic harm (e.g., through traumatizing or stigmatizing experiences such as restraint and seclusion, forcible disrobing and catheterization, forced medication, abuse by staff or other patients, and economic burden[16–19]), or that concerns about hospitalization could deter care-seeking.

Definitively ascertaining the causal effect of inpatient admission on subsequent suicide is challenging, and perhaps infeasible in practice. Self-harm patients are not randomly allocated to inpatient admission. A wide range of factors potentially influence both admission decisions for self-harm patients and those patients' future suicide risk, resulting in confounding by indication. While some of these factors (which include clinical practice guidelines,[17] patients' sociodemographic characteristics and clinical severity,[20] clinician attitudes and perceptions,[21] and system-level financial and logistical constraints[9,22–24]) are observable, others may not be. Meanwhile, assessing the effects of hospitalization via randomized designs presents substantial logistical and ethical challenges;[25] other methods of causal inference, such as instrumental variables analysis, may also not be feasible in practice.[15,26]

Because the question of whether hospitalization prevents suicides is important, and because the methods necessary to achieve a definitive answer may not be feasible, this study aimed to learn as much as possible from currently available observational data on 12-month suicide mortality risk among ED self-harm patients who were admitted as inpatients vs. those who were discharged to the community. First, these groups' respective absolute 12-month suicide risk (naïve analysis) were assessed. Then, statistical adjustment via a generalized random forest (GRF) approach was used to attempt to estimate the conditional average treatment effect; i.e., the difference in expected suicide incidence with *vs*. without hospitalization, conditioned on *observed* covariates.[27,28] Because there may be heterogeneity by age and gender in how inpatient admission affects suicide risk,[22,29–31] the analysis was stratified by these factors.

METHODS

Data

Discharge data were obtained from the California Office of Statewide Health Planning and Development (OSHPD) on all deliberate self-harm visits from January 2009 – December 2011 to all California-licensed EDs by individuals aged ≥10 years with a California residential zip code. A deliberate self-harm visit was defined as one that included an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) External Cause of Injury code (E-code) of E950.0–958, in any diagnostic position. California has mandated 100% reporting of external cause-of-injury codes since 1990.[32] Each patient's first qualifying ED visit during the study period was defined as his or her index visit, with the index date defined as the date of ED presentation.

OSHPD provided information on all individuals in this ED self-harm cohort to the California Department of Public Health Vital Records, which assessed vital status in California death records and provided information on date, cause and manner of death for all matching decedents who died in 2009–2012 (excluding those who died out of state, <1% of the total).[33] All data obtained and used by the study team were de-identified. This study was approved by the Institutional Review Boards of the California Health and Human Services Agency and the University of California, Merced. Analyses were conducted February 2019-August 2020.

Measures

Patient disposition at index visit was used to ascertain "treatment" (i.e., hospitalization) status. Patients were considered admitted if their disposition indicated that they were transferred to a psychiatric hospital or psychiatric unit of a general hospital, short-term general hospital, children's hospital, federal healthcare facility, or other hospital facility. No attempt was made to distinguish between transfers to psychiatric hospitals vs. other types of admissions, as this information was not available for all patient records. Patients were considered discharged if their disposition indicated routine discharge, left against medical advice, or were discharged to home health care. Patients whose index visits resulted in a disposition other than inpatient admission or discharge to community, or who died on the date of the index visit, were excluded from analysis (n=1,921, or 3%).

The outcomes of interest were suicide within 30 days and one year of the index date. Suicide was defined as any death with ICD-10 codes X60-X84, Y87.0, or U03 as the primary listed cause. Individuals who did not link to California mortality records from 365 days after the index date were presumed alive for this period.

Observed covariates consisted of patient- and hospital-level characteristics (not including hospitalization status or outcome) described in Table 1. Patient characteristics measured during the 12 months prior to the individual's index visit (e.g., total number of ED visits) were ascertained using unique patient identifiers that allowed us to link all ED and inpatient visits made by that patient to any state-licensed California hospital during the 12-month window.

Statistical Methodology

The generalized random forest method used here generalizes tree and forest methods that have enjoyed considerable success in the context of predictive modeling,[34,35] and was chosen for its superior performance in simulation studies and its theoretical properties.[27,28] To explain GRFs, it is helpful to begin with a commonly used method, nearest-neighbor matching. Both methods employ the potential outcomes framework, which posits two random variables ($Y^{(1)}$ and $Y^{(0)}$) that quantify the outcomes that would have been observed with and without treatment, respectively.[36] Where $\mathbf{x}_i$ denotes the covariate vector for patient *i*, and given two patients' vectors $\mathbf{x}_i$ and $\mathbf{x}_j$, the distance between them is measured using the Euclidean norm. In the nearest neighbor matching approach, given a covariate vector $\mathbf{x}$, two groups are formed: (1) the *k* vectors nearest to $\mathbf{x}$ corresponding to patients who were treated, and (2) the *k* vectors nearest to $\mathbf{x}$ corresponding to patients who were not treated. Then, the difference between average outcomes for groups (1) and (2) is the estimated conditional average treatment effect at $\mathbf{x}$, i.e., $\boldsymbol{\tau}(\mathbf{x}) = E[\ Y^{(1)} - Y^{(0)} \mid X = \mathbf{x}\ ]$. In short, $\boldsymbol{\tau}(\mathbf{x})$ represents the estimated treatment effect for each individual patient $\mathbf{x}$ – the effect if she had vs. had not received treatment.

Generalized random forests improve upon this framework. Instead of forming groups based on Euclidean-norm distance, each tree in the forest recursively partitions the covariate space. The process starts with a subsample S of the full data set that is used only for tree-building. Any candidate split, e.g., a rule of the form "XCountyOfResidence = Rural", will partition S into two subsets S1 (where the rule is satisfied) and S2 (where the rule is not satisfied). GRFs choose splits that maximize the difference between each subset's conditional average treatment effect (CATE); these splits tease out the covariate dependence in $\boldsymbol{\tau}(x)$.

Once each tree in the forest has been built, a subsample T of the full dataset (disjoint from S) is used for model evaluation. New patient observations from subsample T are fed into each tree, culminating in groups of observations that respond similarly to being treated/untreated. Finally, estimates from all trees are aggregated using a local weighting rule to reduce variance. Further technical details regarding the causal random forest method are available by request.

In simulation studies, GRFs yield estimates of $\boldsymbol{\tau}(\mathbf{x})$ with 5–10 times less mean-squared error than estimates produced by nearest-neighbor methods.[27,28] The generalized random forest method assumes that, *conditional on available covariates and assuming no residual confounding by unobservable covariates*, treatment assignment is independent of potential outcomes. This property together with other technical conditions leads to proofs of consistency and asymptotic normality.[27,28]

The dataset was stratified into two gender subgroups (males and females) and, separately, three age subgroups (patients aged 10–29 years, 30–49 years, and ≥50 years), resulting in five analytic groups. A generalized random forest was fit for each group using the R open-source package "grf".[37] After fitting the GRF, values of $\boldsymbol{\tau}(\mathbf{x})$ for each patient observation were computed in each gender and age group. The mean of $\boldsymbol{\tau}(\mathbf{x})$ is the CATE: the estimated overall difference in suicide deaths associated with hospitalization. All CATE values are multiplied by 1,000 and can be interpreted as differences in suicide risk per 1,000 individuals. Positive values of CATE correspond to increases in suicide risk associated with hospitalization, while negative values correspond to decreases in suicide risk.

To calculate how strong the associations between unmeasured confounders and the treatment and outcome variables would need to be to explain the study results, the E-value bias calculator developed by VanderWeele and colleagues[38] was applied to each gender and age group.

RESULTS

The sample included 57,312 qualifying index patient deliberate self-harm events. Approximately 58% (n=33,419) of these patients were female. Nearly half (44.4%; n=25,424,) were aged 10–29 years, while one-third (n=20,448; 35.7%) were aged 30–49 and 20% (n=11,440) were aged ≥50. Patient characteristics at these index events are shown in Table 2. Approximately two-thirds of these index visits (n=37,386; 65.2%) resulted in inpatient admission. Disposition records indicated that most (97.3%) discharged patients were routinely discharged.

State mortality records identified a total of 400 unique suicide deaths within one year of index patient visit, for an overall risk of 7 per 1,000; 110 of these deaths (27.5%) occurred within 30 days. As context, the suicide rate in California's general population during this period was 0.10 per 1,000.[39] Absolute (unconditional) suicide risk was approximately two times higher among hospitalized vs. discharged patients in each gender and age group (Table 3).

Separate GRF models estimating the association between hospitalization and suicide risk were fit for the gender groups and age groups; the resulting CATE values (i.e., the estimated difference in suicide deaths associated with hospitalization) and their 95% confidence intervals, as well as the proportion of all of $\boldsymbol{\tau}(\mathbf{x})$ values that were positive, are shown in Table 3. Among women, values of the difference in expected suicide incidence with *vs*. without hospitalization, conditional on covariates (i.e., CATE), were typically positive, but the confidence intervals around the CATE estimate included zero. This suggests that after accounting for *observed* confounders, hospitalization was not associated with suicide risk for women. Among men, the 12-month risk CATE was 5.39 additional suicides per 1,000 patients, and the 95% confidence interval (3.02, 7.75) did not include 0; for 30-day risk, the CATE was 1.68 per 1,000 (0.39, 2.98). This suggests that for males there was a small increase in suicide risk associated with hospitalization. For patients aged 10–29 and ≥50 years, the 12-month CATE estimates and their 95% CIs were all positive, indicating that hospitalization was associated with an excess of 2.37 and 5.84 suicides per 1,000 patients, respectively, in these age groups, after accounting for observed confounders. For patients aged 30–49 years, the 95% confidence intervals around the CATE estimate included zero. In 30-day risk models, hospitalization was associated with an excess 3.70 suicides per 1,000 patients (1.40, 6.00) in the ≥50 age group, but the confidence intervals for the other age groups included zero.

E-value bias analyses were used to estimate how strong any associations between unobserved confounders and the treatment and outcome variables would need to be to account for the observed higher 12-month suicide risk in hospitalized vs. discharged patients. Unobserved confounders would explain the observed associations if they collectively increased the risk of suicide by a factor of ≥3 and were at least 3 times more common among hospitalized vs. discharged patients (E-values: women, 5.08; men, 4.27; ages 10–29, 4.48; ages 30–49, 3.21; ages ≥50, 3.12).

DISCUSSION

This study is, to our knowledge, the first US population-based investigation of the association between inpatient admission and suicide risk among emergency department patients seen for deliberate self-harm. In naïve analyses of statewide data from California, self-harm patients who were admitted had substantially higher suicide risk in the subsequent year than those who were discharged. In analyses that adjust for observable covariates using generalized random forest methods, this excess suicide risk among hospitalized patients persisted among some patients (males and patients aged 10–29 or ≥50 years), albeit to a smaller degree, and disappears among others (i.e., females and those aged 30–49 years).

The lack of a randomized treatment variable argues against causal inferences from these analyses. We cannot distinguish between two potential interpretations of our findings. On the one hand, the true effect of hospitalization *could* be null or even harmful, at least for some groups, and the adjusted analyses are valid estimates of these effects. Benefits of hospitalization would appear to be small. The largest effect is negative, 5 additional suicides per 1,000 patients over 12 months among men, equating to a number needed to harm (NNH) of 200 for that group.

Alternatively, although the GRF method was carefully applied, it assumes the data are not confounded; yet in fact, the available administrative data lacked information on many potentially important factors, including whether patients were involuntarily admitted, their social environments, recent life stressors, medication use, etc. Hence, the alternative interpretation is that the true effect of hospitalization on suicide risk *could* be beneficial, but residual confounding by indication and selection bias obscure this benefit in the analyses. For female patients and those aged 30–49 years, in whom no significant difference in 30-day or 12-month suicide rates was found between hospitalized vs. discharged patients after adjusting for observable characteristics, there may be more room for the possibility that hospitalization is actually beneficial, if one assumes there was additional adverse selection in hospitalization based on characteristics clinicians could observe but this research could not. Still, the E-value estimates of the magnitude of unmeasured factors that would be required to offset observed results make this possibility less likely.

The current findings are broadly consistent with the scant prior research on this topic, most of which was conducted in the United Kingdom. One observational study found that the unconditional association between admission and higher suicide risk was reduced to only marginal significance after adjusting for baseline patient factors. There was some indication of excess suicide risk among young adults and reduced risk among older adults.[12] Two very small randomized trials from the U.K. also reported null associations between inpatient admission and suicidal behavior outcomes, but did not have power to examine suicide deaths.[10,11] Other studies have used instrumental variable analysis or covariate adjustment to estimate the effect of routine hospital management of ED self-harm patients on risk of repeat self-harm.[26,40,41]

Considerably more research is needed before findings from this, or similar, studies are used to inform clinical or health system decision-making. Future research should prioritize the following goals: [1] Replicating the current findings using large electronic health record systems that contain more nuanced information. [2] Implementing an instrumental variable design, wherein deliberate self-harm patients are randomly assigned to an intervention that is expected to reduce the rate of inpatient admission, without actually manipulating hospitalization itself.[42] [3] Examining other outcomes such as non-fatal suicidal behavior, external-cause mortality, and all-cause mortality.[4] [4] Identifying safe alternatives to hospitalization and best practices in recovery-oriented inpatient and post-discharge care that mitigate suicide risk, particularly for groups whose average suicide risk may be increased by hospitalization.[2]

Limitations

This study had several limitations beyond the caveats addressed above. Disposition codes in administrative data are imprecise, and patients' hospitalization status may have been different than what was recorded; we also could not assess whether patients were admitted involuntarily. The clinical value of these analyses is limited as the "treatment" variable was very broadly defined, and it was not possible to examine length of hospitalization or specific treatments provided during hospitalization. It could be argued that the longer hospitalizations of prior eras may have been more effective than the brief hospitalizations common today. Furthermore, due to heterogeneity across providers, the experience of hospitalization itself likely varies considerably for different patients. Research has documented extraordinary variation in suicide rates among patients hospitalized for self-harm, suggesting that there are real differences in hospital care;[43] there was no way to account for this. The effects of hospitalization on suicide risk could differ systematically by patient phenotypes other than those examined here, resulting in heterogeneity that was not observed. Lastly, this study focused on one state in the United States from 2009–2012 during which hospitalization of psychiatric patients increasingly focused on brief stabilization and continued outpatient care. As such, it may reflect failures in transitions in care that are necessary for this model to be successful. The findings may not generalize to other years or systems, especially given increasing rates of suicide and changes in hospital accreditation policies related to self-harm.[3,44,45]

Conclusions

Admission is a routine clinical decision point for ED personnel treating patients presenting with deliberate self-harm. Findings from this observational study did not identify clear clinical benefit of hospital admission of these patients with respect to suicide prevention, and could not rule out the possibility of some iatrogenic effects. Additional research is needed to build on this work using approaches that can address causation, and to identify subgroups of self-harm patients who may experience particular benefits or harms with hospitalization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Financial support: This project was funded through National Institutes of Health grant R15 MH113108-01 to S.G.M. and through a grant from the University of California Firearm Violence Research Center to S.G.M. and H.S.B. The sponsors had no role in the study design; collection, analysis, or interpretation of data; writing of the report, or decision to submit the article for publication. The views expressed here are those of the authors, and not necessarily those of the National Institute of Mental Health, Department of Health and Human Services, or the federal government. No financial disclosures were reported by the authors of this paper.

References

1. Kochanek KD, Xu J, Arias E. Mortality in the United States, 2019; 2020.
2. U.S. Department of Health and Human Services (HHS) Office of the Surgeon General, National Action Alliance for Suicide Prevention. 2012 National Strategy for Suicide Prevention: Goals and Objectives for Action; 2012.
3. The Joint Commission. Detecting and treating suicide ideation in all settings. Sentin Event Alert. 2016;(56):1–7. www.jointcommission.org/assets/1/18/SEA_56_Suicide.pdf.
4. Goldman-Mellor SJ, Olfson M, Lidon-Moyano C, Schoenbaum M. Association of suicide and other mortality with emergency department presentation. JAMA Netw Open. 2019;2(12):e1917571. [PubMed: 31834399]
5. Substance Abuse and Mental Health Services Administration. Suicide Assessment Five-Step Evaluation and Triage (SAFE-T); 2009.
6. Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System (WISQARS): Non-fatal injury reports. National Center for Injury Prevention and Control. www.cdc.gov/ncipc/wisqars. Published 2020. Accessed March 27, 2021.
7. Lilley R, Owens D, Horrocks J, et al. Hospital care and repetition following self-harm: Multicentre comparison of self-poisoning and self-injury. Br J Psychiatry. 2008;192(6):440–445. [PubMed: 18515895]
8. Hughes JL, Anderson NL, Wiblin JL, Asarnow JR. Predictors and outcomes of psychiatric hospitalization in youth presenting to the emergency department with suicidality. Suicide Life-Threatening Behav. 2016;47:193–204.
9. Carroll R, Metcalfe C, Gunnell D. Hospital management of self-harm patients and risk of repetition: Systematic review and meta-analysis. J Affect Disord. 2014;168:476–483. [PubMed: 25128754]
10. Waterhouse J, Platt S. General hospital admission in the management of parasuicide. A randomised controlled trial. Br J Psychiatry. 1990;156:236–242. [PubMed: 2180527]

11. Jones G, Gavrilovic JJ, McCabe R, Becktas C, Priebe S. Treating suicidal patients in an acute psychiatric day hospital: A challenge to assumptions about risk and overnight care. J Ment Heal. 2008;17(4):375–387.
12. Kapur N, Steeg S, Turnbull P, et al. Hospital management of suicidal behaviour and subsequent mortality: A prospective cohort study. Lancet Psychiatry. 2015;2(9):809–816. [PubMed: 26254717]
13. Bastiampillai T, Sharfstein SS, Allison S. Increase in US suicide rates and the critical decline in psychiatric beds. JAMA - J Am Med Assoc. 2016;316(24):2591–2592.
14. National Action Alliance for Suicide Prevention: Research Prioritization Task Force. A Prioritized Research Agenda for Suicide Prevention: An Action Plan to Save Lives. Rockville, MD; 2014. http://actionallianceforsuicideprevention.org/sites/actionallianceforsuicideprevention.org/files/Agenda.pdf.
15. Kessler RC. Clinical epidemiological research on suicide-related behaviors - where we are and where we need to go. JAMA Psychiatry. 2019;76(8):777–778. [PubMed: 31188420]
16. Large MM, Ryan CJ. Disturbing findings about the risk of suicide and psychiatric hospitals. Soc Psychiatry Psychiatr Epidemiol. 2014;49(9):1353–1355. [PubMed: 25028199]
17. Jacobs DG, Baldessarini RJ, Conwell Y, et al. APA Practice Guideline: Assessment and Treatment of Patients With Suicidal Behaviors; 2003.
18. Paksarian D, Mojtabai R, Kotov R, Cullen B, Nugent KL, Bromet EJ. Perceived trauma during hospitalization and treatment participation among individuals with psychotic disorders. Psychiatr Serv. 2014;65(2):266–269. [PubMed: 24492906]
19. Berg SH, Rørtveit K, Aase K. Suicidal patients' experiences regarding their safety during psychiatric inpatient care: a systematic review of qualitative studies. BMC Health Serv Res. 2017;17(1):1–13. [PubMed: 28049468]
20. Unick GJ, Kessell E, Woodard EK, Leary M, Dilley JW, Shumway M. Factors affecting psychiatric inpatient hospitalization from a psychiatric emergency service. Gen Hosp Psychiatry. 2011;33(6):618–625. [PubMed: 21816482]
21. McCann TV, Clark E, McConnachie S, Harvey I. Deliberate self-harm: Emergency department nurses' attitudes, triage and care intentions. J Clin Nurs. 2007;16(9):1704–1711. [PubMed: 17459135]
22. Baca-García E, Diaz-Sastre C, Resa EG, et al. Variables associated with hospitalization decisions by emergency psychiatrists after a patient's suicide attempt. Psychiatr Serv. 2004;55(7):792–797. [PubMed: 15232019]
23. Suominen K, Lönnqvist J. Determinants of psychiatric hospitalization after attempted suicide. Gen Hosp Psychiatry. 2006;28(5):424–430. [PubMed: 16950379]
24. Marriott R, Horrocks J, House A, Owens D. Assessment and management of self-harm in older adults attending accidents and emergency: A comparative cross-sectional study. Int J Geriatr Psychiatry. 2003;18(7):645–652. [PubMed: 12833309]
25. ClinicalTrials.gov [Internet]. Identifier NCT04089254, Suicide Treatment Alternatives for Teens (START). 2019. https://clinicaltrials.gov/ct2/show/NCT04089254. Accessed April 27, 2021.
26. Carroll R, Metcalfe C, Steeg S, et al. Psychosocial assessment of self-harm patients and risk of repeat presentation: An instrumental variable analysis using time of hospital presentation. PLoS One. 2016;11(2):1–13.
27. Athey S, Tibshirani J, Wager S. Generalized random forests. Ann Stat. 2019;47(2):1148–1178.
28. Wager S, Athey S. Estimation and Inference of Heterogeneous Treatment Effects using Random Forests. J Am Stat Assoc. 2018;113(523):1228–1242.
29. Preyde M, Parekh S, Warne A, Heintzman J. School reintegration and perceived needs: The perspectives of child and adolescent patients during psychiatric hospitalization. Child Adolesc Soc Work J. 2017;34(6):517–526.
30. Mutschler C, Lichtenstein S, Kidd SA, Davidson L. Transition experiences following psychiatric hospitalization: A systematic review of the literature. Community Ment Health J. 2019;55(8):1255–1274. [PubMed: 31104176]

31. Dockery L, Jeffery D, Schauman O, et al. Stigma- and non-stigma-related treatment barriers to mental healthcare reported by service users and caregivers. Psychiatry Res. 2015;228(3):612–619. [PubMed: 26115840]
32. Abellera J, Annest JL, Conn JM, Kohn M. How States Are Collecting and Using Cause of Injury Data: 2004 Update to the 1997 Report. Atlanta, GA; 2005.
33. Zingmond D. Linkage Documentation: Death Statistical Master File Linkage to OSHPD Databases (PDD, EDD, and ASD) with Three Year Mortality Outcomes for All Eligible Records; Years 2005 to 2009. Los Angeles, CA; 2010.
34. Hastie T, Tibshirani R, Friedman J. The Elements of Statistical Learning. New York, NY: Springer New York; 2009.
35. Loh WY. Fifty years of classification and regression trees. Int Stat Rev. 2014;82(3):329–348.
36. Rubin DB. Estimating causal effects of treatments in randomized and nonrandomized studies. J Educ Psychol. 1974;66(5):688–701.
37. Tibshirani J, Athey S, Wager S. grf: Generalized Random Forests. 2020. https://cran.r-project.org/package=grf.
38. VanderWeele TJ, Ding P. Sensitivity analysis in observational research: Introducing the E-Value. Ann Intern Med. 2017;167(4):268–274. [PubMed: 28693043]
39. Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System (WISQARS) Fatal Injury Reports: National, regional, and state (restricted), 1999–2017. https://webappa.cdc.gov/sasweb/ncipc/mortrate.html. Published 2017. Accessed February 20, 2019.
40. Steeg S, Emsley R, Carr M, Cooper J, Kapur N. Routine hospital management of self-harm and risk of further self-harm: Propensity score analysis using record-based cohort data. Psychol Med. 2018;48(2):315–326. [PubMed: 28637535]
41. Kapur N, Steeg S, Webb R, et al. Does clinical management improve outcomes following self-harm? Results from the Multicentre Study of Self-Harm in England. PLoS One. 2013;8(8).
42. Schoenbaum M, Unutzer J, McCaffrey D, Duan N, Sherbourne C, Wells K. The effects of primary care depression treatment on patients' clinical status and employment. Health Serv Res. 2002;37(5):1145–1158. [PubMed: 12479490]
43. Large MM, Kapur N. Psychiatric hospitalisation and the risk of suicide. Br J Psychiatry. 2018;212(5):269–273. [PubMed: 30056818]
44. Yoon J, Bruckner TA. Does deinstitutionalization increase suicide? Health Serv Res. 2009;44(4):1385–1405. [PubMed: 19500164]
45. Gibbons RD, Hur K, Mann JJ. Suicide rates and the declining psychiatric hospital bed capacity in the United States. JAMA Psychiatry. 2017;74(8):849. [PubMed: 28614559]
46. U.S. Department of Agriculture Economic Research Service. Rural-Urban Commuting Area Codes, version 3.10. https://ruralhealth.und.edu/ruca. Published 2014. Accessed February 7, 2018.
47. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. J Clin Epidemiol. 1994;47(11):1245–1251. [PubMed: 7722560]
48. Geolytics Estimates Premium. 2011.
49. Goldman-Mellor S, Kwan K, Boyajian J, et al. Predictors of self-harm emergency department visits in adolescents: A statewide longitudinal study. Gen Hosp Psychiatry. 2019;56:28–35. [PubMed: 30553125]

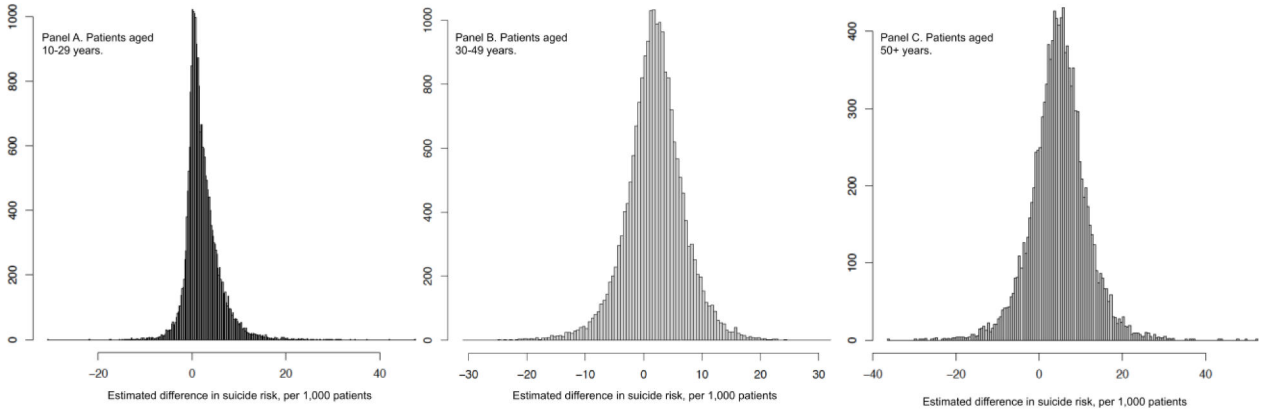

Figure 1.

Histograms depicting estimated difference in suicide risk associated with hospitalization, conditional on covariates, for each individual patient (i.e., $\boldsymbol{\tau}(\mathbf{x})$). Panel A: patients aged 10–29 years; panel B: patients aged 30–49 years; panel C: patients ≥50 years. Values for $\boldsymbol{\tau}(\mathbf{x})$ are shown scaled to deaths per 1,000.

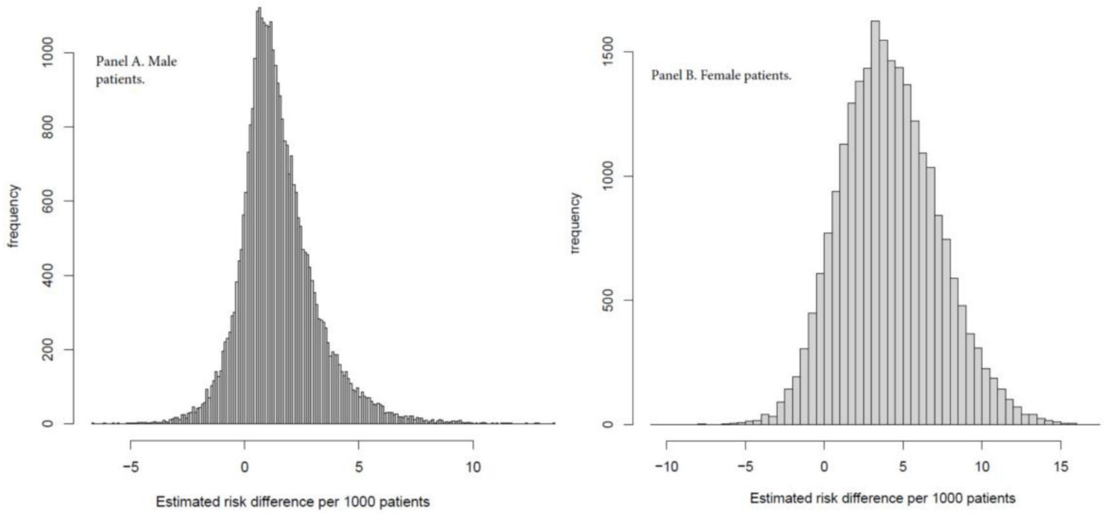

Figure 2.

Histograms depicting estimated difference in suicide risk associated with hospitalization, conditional on covariates, for each individual patient (i.e., $\boldsymbol{\tau}(\mathbf{x})$). Panel A: male patients; panel B: female patients. Values for $\boldsymbol{\tau}(\mathbf{x})$ are shown scaled to deaths per 1,000.

Table 1.

Patient- and facility-level characteristics included in generalized random forest model.

Patient characteristics ascertained at index deliberate self-harm visit
Patient age
Patient gender
Patient race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, Asian, other)
Payer: Private insurance (referent group), Medicaid, Medicare, self-pay, other
Method of self-harm injury: Poisoning (referent group), cutting/piercing injury, hanging/strangulation, jumping from high place, firearm, other
Urbanicity of patient's residential zipcode (metropolitan, micropolitan, small town/rural)[46]
Day of week
Diagnosis of comorbid anxiety disorder (ICD-9 codes 293.84, 300.00–300.5, 300.89, 300.9, 308.x, 309.81)
Diagnosis of comorbid mood disorder (293.83, 296.x, 300.4, 311.x)
Diagnosis of comorbid psychotic disorder (293.81, 293.82, 295.x, 297.x, 298.x)
Diagnosis of comorbid alcohol use disorder (291.x, 303.x, 305.x, 357.5, 425.5, 535.3x, 571.0–571.3, 760.71, 980.0)
Diagnosis of comorbid drug use disorder (292.x, 304.x, 305.1–305.93, 648.30–648.34, V65.42)
Diagnosis of comorbid suicidal ideation (V62.84)
Diagnosis of comorbid altered mental status (780.97)
Patient Charlson Comorbidity Index score (0, 1–4, or ≥5)[47]
Median household income in patient's residential zipcode (from 2010 American Community Survey)[48]
Patient characteristics ascertained during 12 months prior to index visit
Patient history of any inpatient admission with a diagnosis for adjustment, anxiety, attention-deficit/conduct, cognitive, developmental, impulse control, mood, personality, psychotic, alcohol-related, drug-related, or other behavioral disorder, or for deliberate self-harm.
Patient history of ED visit with diagnosis of drug use disorder
Patient history of ED visit with diagnosis of alcohol use disorder
Patient history of ED visit with diagnosis of schizophrenia or other psychotic disorder
Patient history of ED visit with diagnosis of mood disorder
Patient history of ED visit with diagnosis of anxiety disorder
Patient history of ED visit with diagnosis of deliberate self-harm
Patient's total number of ED visits in past year (0, 1–4, ≥5 visits)
Patient history of residential mobility (1 zipcode, >1 zipcode, no past-year visits observed)[49]
Facility characteristics in year of patient's index self-harm visit
Total annual ED encounters, divided into quartiles
Availability of a psychiatric ED clinician on call (any vs. none)
Number of psychiatric bed licenses (0, ≤30, >30)

Table 2.

Sociodemographic characteristics of deliberate self-harm patients, according to gender, age group and disposition.

Patient characteristics at index visit	Female patients		Male patients		Patients aged 10–29 years		Patients aged 30–49 years		Patients aged ≥50 years	
	Discharged (n=11,161)	Admitted (n=22,258)	Discharged (n=8,765)	Admitted (n=15,128)	Discharged (n=10,940)	Admitted (n=14,479)	Discharged (n=6,449)	Admitted (n=13,985)	Discharged (n=2,537)	Admitted (n=8,895)
Female sex, n (%)	--	--	--	--	6,122 (56.0)	8,740 (60.3)	3,610 (56.0)	8,382 (59.9)	1,429 (56.3)	5,126 (57.7)
Age, mean (SD)	31.2 (14.3)	37.0 (16.3)	31.5 (13.9)	38.1 (16.4)	20.8 (4.5)	21.3 (4.5)	38.8 (5.8)	39.8 (5.9)	57.9 (8.6)	59.9 (9.9)
Race/ethnicity, n (%)										
Non-Hispanic White	6,244 (55.9)	13,096 (58.8)	4,784 (54.6)	9,054 (59.9)	5,431 (49.6)	6,999 (48.3)	3,189 (59.2)	8,552 (61.1)	1,778 (70.1)	6,599 (74.1)
Non-Hispanic Black	1,079 (9.7)	2,004 (9.0)	858 (9.8)	1,345 (8.9)	1,167 (10.7)	1,522 (10.5)	579 (9.0)	1,245 (8.9)	191 (7.5)	582 (6.5)
Hispanic	2,688 (24.1)	5,010 (22.5)	2,241 (25.6)	3,417 (22.6)	3,143 (28.7)	4,399 (30.4)	1,412 (21.9)	2,948 (21.1)	373 (14.7)	1,080 (12.1)
Asian/Pac. Islander	409 (3.7)	1,095 (4.9)	268 (3.1)	569 (3.8)	370 (3.4)	721 (5.0)	226 (3.5)	597 (4.3)	81 (3.2)	346 (3.9)
Non-Hispanic Other	741 (6.6)	1,053 (4.7)	6114 (7.0)	743 (4.9)	829 (7.6)	843 (5.8)	412 (6.4)	657 (4.7)	114 (4.5)	296 (3.3)
Insurance type, n (%)										
Private	4,249 (38.1)	8,639 (38.8)	2,732 (31.2)	4,472 (29.6)	4,087 (37.4)	5,382 (37.2)	2,009 (31.2)	4,807 (34.4)	885 (34.9)	2,922 (32.9)
Medicare	703 (6.3)	2,798 (12.6)	653 (7.5)	2,300 (15.2)	231 (2.1)	347 (2.4)	566 (8.8)	1,699 (12.2)	559 (22.0)	3,052 (34.3)
Medicaid	3,583 (32.1)	6,620 (29.8)	2,454 (28.0)	4,238 (28.0)	3,584 (32.8)	5,070 (35.0)	1,872 (29.0)	4,082 (29.2)	581 (22.9)	1,706 (19.2)
Self-pay	2,351 (21.1)	3,550 (16.0)	2,651 (30.3)	3,476 (23.0)	2,715 (24.8)	3,022 (20.9)	1,840 (28.5)	3,001 (21.5)	447 (17.6)	1,003 (11.3)
Other	275 (2.5)	638 (2.9)	275 (3.1)	628 (4.2)	323 (3.0)	658 (4.5)	162 (2.5)	396 (2.8)	65 (2.6)	212 (2.4)

TABLE 3.

Unconditional and mean conditional average treatment effect (CATE) values for suicide risk associated with hospitalization.

Demographic group	Absolute suicide risk per 1,000 patients		Unconditional suicide risk difference between admitted vs. discharged patients		Estimated conditional average treatment effect (CATE) of inpatient admission on suicide risk		
	Discharged patients	Admitted patients	Risk difference per 1,000 patients	95% CI	Risk difference per 1,000 patients	95% CI	Proportion of all τ(x) values in age group that were positive
Panel A. 30-day suicide risk.							
Gender							
Females	0.63	1.53	0.90	[0.21, 1.59]	0.63	[−0.46, 1.73]	79.5%
Males	1.48	3.07	2.22	[0.96, 3.48]	1.68	[0.39, 2.98]	83.7%
Age group							
10–29 years	0.27	0.48	0.21	[−0.27, 0.68]	0.42	[−0.13, 0.97]	85.3%
30–49 years	1.71	2.57	0.87	[−0.45, 2.18]	0.29	[−1.84, 2.41]	69.8%
≥50 years	2.37	5.28	2.91	[0.50, 5.33]	3.70	[1.40, 6.00]	97.7%
Panel B. 12-month suicide risk.							
Gender							
Females	2.06	5.80	3.74	[2.43, 5.04]	1.28	[−0.72, 3.27]	86.0%
Males	5.48	13.22	7.74	[5.36, 10.13]	5.39	[3.02, 7.75]	92.0%
Age group							
10–29 years	1.65	4.14	2.50	[1.21, 3.79]	2.37	[1.11, 3.64]	92.9%
30–49 years	4.96	9.43	4.47	[2.12, 6.81]	2.12	[−1.22, 5.47]	79.7%
≥50 years	8.28	15.39	7.11	[2.76, 11.47]	5.84	[0.53, 11.16]	94.1%