FINAL PROGRESS REPORT

1. TITLE PAGE

Title: Reducing Hospital Readmission Rates by Implementing an Inpatient Tobacco Cessation Service Driven by Interactive-Voice Recognition (IVR) Technology

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2. STRUCTURED ABSTRACT

Purpose: This study explored the effect of an inpatient tobacco dependence treatment service (TDTS) on 30, 90 and 180 day hospital readmissions and healthcare charges within 1-year post-discharge.

Scope: MUSC implemented a TDTS consistent with Joint Commission standards, which recommend that hospitals screen patients for smoking, provide cessation support, and follow-up contact to prevent relapse.

Methods: To examine the TDTS effect on readmission and costs, three secondary datasets were linked (EHR data, tobacco cessation program data, statewide healthcare utilization data). Odds ratios were calculated with program exposure as independent variable and readmission as dependent variable using logistic regression models. Total healthcare charges were compared for patients with and without TDTS exposure using a GLM regression model. Cost of TDTS intervention delivery and cost per smoker were calculated.

Results: At 30 days post-discharge, smokers exposed to the TDTS had lower odds of readmission (OR=0.77; p=0.031). At 90 and 180-days, odds of readmission remained lower in the TDTS group (ORs =.87 and .86 respectively), but not statistically significant. Overall mean healthcare charges for smokers exposed to the TDTS was $7,299 lower than for those without TDTS exposure (p=.047). TDTS cost per smoker was $34.21.

Key Words: Tobacco cessation, readmissions, healthcare costs, cost-benefit

3. PURPOSE

The purpose of this study was to examine the effect of an interactive voice-response (IVR)-driven inpatient TDTS service that operationalized the Joint Commission standards for tobacco cessation on healthcare utilization and costs. Aim 1 was to examine the inpatient hospital cessation program effect on hospital readmission at 30, 90 and 180 days, both on an overall population of patients and for those with CMS readmission penalty conditions. Aim 2 was to calculate the inpatient hospital cessation program costs and potential cost savings.

4. SCOPE

Background

Tobacco use causes approximately 480,000 deaths each year in the United States (1), taking an economic toll of nearly $300 billion per year (1)(2). It is also a risk factor for hospitalization, and hospital readmission due to cardiac (3-8), pulmonary (9), and surgical and wound healing-related conditions (10-15). The benefits of smoking cessation are well-documented. For individuals who have had a heart attack, stopping smoking can decrease the risk of subsequent heart attacks, sudden cardiac death, and total mortality by 50% (16). Stopping smoking can slow the decline in lung function and improve prognosis in patients with coronary obstructive pulmonary disease (COPD) (17). Stopping smoking can also reduce the risk of cancer and stroke and improve prognosis for those with these diseases (18).

Prior studies have demonstrated the benefit of providing inpatient tobacco cessation support combined with follow-up calls after hospitalization for smoking cessation (19-27). In 2012 the Joint Commission (JC) recommended that all current smokers identified upon hospitalization receive tobacco cessation services as an inpatient and be followed up within 1 month after hospital discharge to increase long-term cessation rates (28). Still, few hospitals have so far fully implemented the JC tobacco measures due to extra costs, the voluntary nature of the standard, and the lack of evidence demonstrating clinical and financial benefits to the hospital and insurers (29, 30). However, recent changes in national health policy have incentivized health care providers to improve the delivery of tobacco cessation efforts. For example, in 2011 the Centers for Medicare and Medicaid Services (CMS) began incentivizing health care providers to meet the requirements for meaningful use assessment of tobacco use (31). CMS established penalties for readmissions starting in October 2012 to encourage hospitals to reduce hospital readmissions among patients with high volume, high cost chronic conditions and procedures, many of which are related to cigarette smoking (32). In 2018, these penalty conditions now include acute myocardial infarction (MI), heart failure, stroke, pneumonia, COPD, hip and knee replacements and coronary artery bypass grafting (32). In addition, CMS has begun to introduce bundled payment for care improvement, which pays providers a fixed rate to provide care for patients based on their diagnosis, which is designed to improve the quality of care and reduce healthcare costs. These national policies have provided incentive to healthcare administrators to actively seek strategies that can help to reduce unplanned readmissions and healthcare costs. The current study was conducted to evaluate the effect of an IVR-driven TDTS program on 30, 90 and 180 day unplanned readmissions and healthcare costs within 1-year following hospital discharge.

Context

Beginning in early 2014, the Medical University of South Carolina (MUSC) implemented an automated TDTS using IVR technology and a TDTS Registry (TelASK Technologies Inc.) to meet the JC tobacco treatment standards. This innovative TDTS Registry interfaces with the hospital's admission and discharge records to identify tobacco users, automatically refers these patients into hospital tobacco cessation services, and then uses IVR technology to follow-up with patients 3, 14, and 30 days after discharge to assess tobacco use and transfer patients to additional community resources for cessation support if needed. A previous study which describes the TDTS in greater detail found that those exposed to the full service (bedside counselor + IVR follow-up calls) had 2-fold higher quit rate 1 month after discharge compared with those who received only IVR follow-up calls (20). This project extends prior evaluations of the automated tobacco cessation service using IVR technology by examining the effect of the TDTS on unplanned hospital readmission assessed at 30, 90, and 180 days after hospitalization. The current study tests the hypothesis that among current smokers, hospital readmission

rates and healthcare costs will be lower among those exposed to the TDTS compared with those not exposed to the TDTS.

Study Setting and Participants
The study population included current smoking acute care patients admitted and discharged from the MUSC hospital between November 1, 2014 and June 31, 2015. At MUSC, approximately 21% of patients report being current smokers. The MUSC hospital is a major tertiary care hospital located in Charleston, SC with over 30,000 adult hospital admissions annually. All current smokers admitted to the hospital were eligible for the TDTS, but not all patients received the service. Reasons for not receiving the service included being discharged before the bedside consult was provided and failure to answer any of the 18 IVR follow-up calls made within 30 days after discharge from the hospital.

5. METHODS

Intervention
A secondary data analysis was conducted to evaluate the MUSC TDTS. Beginning in early 2014, the Medical University of South Carolina (MUSC) implemented an automated tobacco cessation service using IVR technology to allow us to meet the JC tobacco treatment standards. The innovative system interfaces with the hospitals admission and discharge records to identify tobacco users, automatically refers these patients into hospital tobacco cessation services, and then uses interactive voice recognition (IVR) technology to follow-up with patients after hospitalization to assess tobacco use and transfer patients to additional community resources for cessation support if needed. MUSC has employed a single bedside tobacco cessation specialist to visit patients while in the hospital, assess their nicotine dependence and develop a post-hospitalization treatment plan. A challenge has been reaching patients while hospitalized since many patients have short lengths of stay and thus are discharged before the bedside counselor has a chance to intervene with them. However, of those reached 83% accept the service. Unless the patient refuses the service, all identified tobacco users identified with valid phone numbers are automatically referred into the IVR follow-up system and called 3, 14, 30, 90 and 180 days after hospital discharge.

Study Design
An exploratory study design was built upon in-place data capture mechanisms to allow us to efficiently link data across 3 datasets to test the hypotheses that hospitalized readmission rates will be lower among patients exposed to the TDTS compared with those not exposed to the service. These datasets included: (1) the MUSC electronic health record database, which provided information about tobacco use status for all hospitalized patients; (2) the TDTS Registry, which provided information about which hospitalized patients participated in the MUSC TDTS and level of service received; and (3) the Statewide Hospital Utilization Datasets, which provided information about subsequent readmission rates and demographic and clinical covariates. This study compared unplanned readmissions at 30, 90, and 180 days after discharge among adult current smokers who were exposed to the TDTS and those who did not receive the service. Exposure to the TDTS was defined in 2 ways as follows: (1) the exposed group received either a bedside consult and/or responded to at least 1 IVR follow-up call versus the unexposed group who received neither a bedside consult nor responded to any of the IVR follow-up calls; and (2) level of exposure to the TDTS was further defined as high, low, and unexposed, with high exposure defined as receiving the bedside consult (regardless of whether they responded to any post-discharge IVR follow-up calls), low exposure defined as responding only to the post-discharge IVR follow-up calls, and unexposed as defined above.

Data Sources and Collection
The current study was conducted by linking data from three datasets, which included (1) the MUSC electronic health record database, which provided information about tobacco use status for all hospitalized patients; (2) the TDTS Registry, which provided information about which hospitalized patients participated in the MUSC TDTS and level of service received; and (3) the Statewide Hospital Utilization Datasets, which provided information about subsequent readmission rates and demographic and clinical covariates. Data linkage was accomplished in 2 steps. First, data from the TDTS database were linked with MUSC electronic health record data using patient medical record number (MRN) as the

linking variable or name and date of birth to confirm linkage of 2 diverging MRN' s for the same dataset. Once these MUSC internal datasets were linked, the merged dataset was sent to the SC Office of Research and Statistics (SC ORS) via file transfer protocol to carry out linkage with the SC health care utilization hospital discharge dataset. Data linkage at the SC ORS was performed using probabilistic matching on key patient identifiers (first, last, and middle name; date of birth; address; sex; race; and admit/discharge dates); patient identifiers such as MRN, name, data of birth, and address were subsequently omitted from the final dataset.

Measures

Independent Variable: TDTS Exposure: TDTS Exposure was defined in two ways: 1) the exposed group received either a bedside consult and/or responded to at least one IVR follow-up call versus the unexposed group who received neither a bedside consult nor responded to any of the IVR follow-up calls; and 2) level of exposure to the TDTS was further defined as high, low, and unexposed, with high exposure defined as receiving the bedside consult (regardless of whether they responded to any post-discharge IVR follow-up calls), low exposure defined as responding only to the post-discharge IVR follow-up calls, and unexposed as defined above.

Dependent Variable: Unplanned Hospital Readmissions: The main dependent outcome variables for evaluating TDTS program effect on readmissions were unplanned hospital readmissions measured at 30, 90, and 180 days after the discharge date of the index hospital admission at the MUSC hospital. An index admission was defined as the initial event for which the patient sought care (such as an initial heart attack or hip/knee replacement procedure) and had been discharged (33). Index admissions that resulted in the admission to psychiatric care, had lengths of stay longer than 30 days, the patient was discharged against medical advice, or had died were excluded from analysis. To be consistent with how CMS calculates readmission rates, we excluded readmissions due to planned care components such as cardiac rehabilitation or staged myocardial infarction surgical procedures, but included readmissions due to unplanned problems such as septicemia, dehydration, or stroke (33). The rationale for excluding planned readmissions was that these readmissions often represent components of quality care (33). The CMS nationally standardized algorithm was used to assess both procedure codes and discharge diagnoses for each readmission to record if hospital admissions were planned or unplanned. Consistent with CMS methodology, readmissions within 1 day of discharge from the index visit were excluded.

Dependent Variables: Healthcare Charges and Cost of the TDTS: Two main dependent outcome variables were examined for the cost analysis: 1) healthcare utilization charges for patients with and without exposure to the TDTS over a 1-year period after index admission at the MUSC hospital; and 2) the cost of implementing the TDTS.

Health Care Charges. One-year healthcare charges following an index admission were estimated for patients who did and did not receive the TDTS. These charges consisted of all inpatient, ambulatory surgery and ED charges that patients in the study cohort incurred in SC during the 1-year period after the index admission. Inpatient charges for the same type of admission can vary widely based on hospital mission (for-profit, non-profit, etc.) and insurance status of the individual. To reduce this variability, we calculated standardized inpatient charges by Diagnosis Related Group (DRG). Standardized inpatient charges were calculated based on summing all admission charges for each DRG and dividing by the number of admissions to obtain the mean charge per DRG, which was then applied to each admission based on its assigned DRG. Overall 1-year healthcare charges, consisting of overall inpatient, ambulatory surgery and ED visit charges, were then compared for adult current smokers with and without TDTS exposure. These analyses were repeated to compare cost outcomes for varying levels of the TDTS (i.e. low intensity vs. no exposure; high intensity vs. no exposure; low vs. high intensity exposure to the TDTS).

Cost of the TDTS. The costs of the intervention included salary support for the full time TTS at 100% effort and part time nurse manager at 30% effort based upon published median salaries (34), office space and equipment prorated to the TTS and program manager's effort on project, and costs associated with the IVR follow-up calls and TDTS Registry which involved a contract with an outside

vendor (TelASK Technologies Inc.). Some costs were fixed costs associated with establishing the program (e.g., IT support to set up the TDTS registry, office equipment for new staff), while other costs were recurring, such as salary costs for TDTS staff and TelASK per patient charges that were based on the estimated number of hospitalized MUSC patients who are current smokers (35).

The cost of TDTS implementation was calculated for Year 1 when program start-up costs were absorbed and for subsequent years. Year 1 TDTS costs were calculated as the sum of fixed and recurring costs in Year 1. Total TDTS cost per smoker was calculated as the total program cost in Year 1 divided by the number of smokers eligible to receive TDTS that year (35). These analyses were repeated to calculate the total TDTS cost in subsequent years. MUSC costs were incurred in 2015 and adjusted to 2017 dollar values based on the U.S. Department of Labor CPI Inflation Calculator (36).

Covariates: Demographic and clinical covariates included the patients age in years, race/ethnicity (white, black, hispanic, other), sex (male, female), insurance status (uninsured, Medicare, Medicaid, private, other), length of stay during hospitalization, Charlson Score categories (none, mild, moderate, severe), and number of comorbidities (37) as assessed during the patients' index hospitalization at MUSC.

Statistical Analyses

To test the hypothesis that exposure to the TDTS would reduce unplanned readmission rates, we first compared unplanned 30-day hospital readmission rates for patients who did and did not receive the TDTS. Next, we compared 30-day readmission rates for patients who received varying levels of TDTS intensity (no exposure vs. low exposure, no exposure vs. high exposure, and low exposure vs. high exposure). We repeated these same analyses at 90 and 180 days post-discharge to examine if this altered the assessment of the impact of the TDTS program. Finally, we conducted sub-analyses to examine the effect of the program (TDTS exposure, no TDTS exposure) among patients with CMS conditions on 30, 90 and 180 day readmission.

Continuous and categorical variables were assessed using t tests and $\chi 2$ tests respectively. To reduce potential program exposure selection bias from nonrandomized data, propensity scores were calculated balancing on age, sex, race, insurance status, Charlson score, indicator variable for length of stay (dichotomized as lower or higher than median), and comorbidities (i.e., congestive heart failure, stroke, COPD, asthma, diabetes, hepatitis, multiple sclerosis, hypertension, etc.). Continuous and categorical variables were then reassessed using inverse probability treatment (propensity) weights to ensure similar distribution across baseline characteristics. We used inverse propensity score– weighted logistic regression models, with program exposure as the primary independent variable and 30 (90 and 180)-day readmission rates as the dependent variable. In a first step, the relationship of TDTS participation with unplanned readmission was examined. We then adjusted for putative covariates that included age, race, sex, insurance status, and number of comorbidities. Covariates were added to the model to examine whether program exposure remained statistically significantly associated with 30 (90 and 180)-day readmission rates after controlling for potential covariates. Each covariate considered for inclusion was examined individually for a relationship with 30 (90 and 180)-day readmission. In the second step, those variables with a P-value < 0.25 were included in an initial model. Next, the potential confounder variable in the initial model with highest P -value was removed and the model was refit. If the removal of the potential confounder variable did not result in a significant improvement in model fit (as indicated by a change in the model-2 log likelihood), then the variable was retained for later steps. The removal and subsequent testing of change in model fit was repeated until all nonsignificant potential confounders were tested. For subgroup analysis, only study subjects diagnosed with ≥ 1 CMS conditions, propensity score models, and logistic models were conducted analogous to the main analysis. However, due to the small sample size of this subpopulation, categories that had small sample sizes such as " other" insurance status (2 cases) and hispanic race (4 cases) were excluded from analysis and comorbidities with small sample sizes (eg, multiple sclerosis had only 1 case in this subpopulation) were excluded from propensity score analysis. Statistical significance was assessed at the 0.05 α level. All analyses were conducted using SAS 9.4 (Cary, NC).

To test the hypothesis that exposure to the TDTS would reduce overall 1-year healthcare charges, we first compared actual healthcare charges for patients who did and did not receive the TDTS using

student t-tests. Total charges were calculated as the sum of inpatient, ambulatory surgery and ED charges. After standardizing inpatient data by DRG-group, we compared overall standardized inpatient hospital, ambulatory surgery and ED charges for patients with and without TDTS exposure. As a final step, we compared overall adjusted standardized total inpatient, ambulatory surgery and ED charges for patients with and without TDTS exposure. These analyses were repeated to evaluate cost outcomes by level of TDTS received. Continuous and categorical variables were compared using t-tests and chi-square tests respectively. We then adjusted standardized inpatient, ambulatory surgery and ED charges for putative covariates including age, race/ethnicity, insurance status, Charlson Score and number of comorbidities in generalized linear models with a gamma distribution and log link. Covariates were added to the model to examine whether program exposure was statistically associated with standardized inpatient, ambulatory surgery and ED charges, after controlling for potential covariates. Marginal effects of TDTS exposure and TDTS intensity were estimated post regression. Statistical significance was assessed at the 0.05 α level, using STATA 15 (College Station, Texas).

Limitations

Several limitations should be considered. First, the study was conducted using secondary data to evaluate the effects of an evidence-based TDTS on hospital readmission and cost outcomes. While an RCT study design would provide a more controlled and robust test of the impact of the TDTS service by creating study groups likely to have a similar distribution of characteristics that might influence these outcomes, such a study would require a large sample of patients and would be expensive carry out. In this study real world evaluation of an existing TDTS we attempted to control for suspected confounders of hospital readmissions and costs using both propensity weighting and statistical control of key covariates to minimize bias between the group of smokers exposed to the TDTS service and those not exposed. Second, we were unable to obtain actual cost data, therefore, charges were utilized as proxy for healthcare costs. Hospital inpatient charges for the same type of admission can vary widely based on hospital mission (for-profit, non-profit, etc.) and insurance status of the individual. To reduce this variability in inpatient charges, we calculated standardized charges by Diagnosis Related Group (DRG) by summing all admission charges for each DRG and dividing by the number of admissions to obtain a mean charge for each DRG. The mean charge per DRG was then applied to each admission based on its assigned DRG. The use of standardized DRGs has the potential to inflate p-values. Third, the study did not have optimal statistical power to be able to detect a statistically significant difference between groups, particularly when comparing sub-groups of participants with low, high and no program exposure.

6. RESULTS

Principal Findings

The findings from this study suggest that an inpatient TDTS program that is designed to operationalize the JC standards for tobacco cessation can help to decrease unplanned hospital readmissions and healthcare costs. At 30 days post-discharge, smokers exposed to the TDTS had a lower odds of readmission (OR=0.77; p=0.031), compared to smokers who were not exposed to the TDTS. At 90 and 180-days, odds of readmission remained lower in the TDTS group (ORs =.87 and .86 respectively), but were not statistically significant.

The overall adjusted mean healthcare charges for smokers exposed to the TDTS was $7,299 lower than for those who did not receive TDTS services (p=.047). The TDTS cost per smoker was modest by comparison at $34.21 per smoker eligible for the service. In SC, the cost to charge ratio is between 30-40%, meaning actual healthcare costs are approximately 30-40% of charges, which would translate into an average of $2,190-$2,920 lower cost per smoker who received the TDTS service. Within the context of our study in which 1,640 patients received the TDTS over an 8-month period, this would equal a healthcare cost savings ranging from $3.6-$4.8 million, accounting for the cost of program delivery and cost savings per patient. These data suggest that between 54-72 smokers would need to receive TDTS services to cover the cost of delivering the service.

Outcomes

As shown in Table 1, a total of 3081 smokers with eligible index admissions were assessed; 1441 were not exposed to TDTS and 1640 received some level of exposure (n=764 and 876 for low and high exposure, respectively). More than half of the smokers were male (59.1% and 52.5% for non-exposed and exposed, respectively) with an overall mean age of 48.6 years. Mean length of stay was 5.1 days (median = 3.0 d).

Table 1: Characteristics of the Study Sample

	Unadjusted			Propensity Score Weighted		
	Control *(n=1441)*	**Intervention** *(n=1640)*	P-Value	**Control** *(n=1439)*	**Intervention** *(n=1640)*	P-Value
DEMOGRAPHICS						
Age (Years)	47.6 (16.3)	49.4 (14.9)	0.0020	48.6 (16.9)	48.6 (14.5)	0.9529
Male	851 (59.1%)	861 (52.5%)	0.0003	(55.5%)	(55.6%)	0.9597
Race			0.5141			0.9998
White	879 (61.0%)	978 (59.6%)		(60.1%)	(60.2%)	
Black	527 (36.6%)	608 (37.1%)		(37.0%)	(36.9%)	
Hispanic	15 (1.0%)	24 (1.5%)		(1.3%)	(1.3%)	
Other	20 (1.4%)	30 (1.8%)		(1.6%)	(1.6%)	
Insurance			0.0021			1.0000
Uninsured	399 (27.7%)	381 (23.2%)		(25.3%)	(25.3%)	
Medicare	378 (26.2%)	519 (31.6%)		(29.1%)	(29.1%)	
Medicaid	279 (19.4%)	308 (18.8%)		(19.2%)	(19.0%)	
Private	337 (23.4%)	394 (24.0%)		(23.6%)	(23.8%)	
Other	48 (3.3%)	38 (2.3%)		(2.8%)	(2.8%)	
CLINICAL CHARACTERISTICS						
Charlson Score Categories			0.0011			0.1539
None	863 (59.9%)	901 (54.9%)		(58.2%)	(56.3%)	
Mild	348 (24.1%)	502 (30.6%)		(25.8%)	(29.3%)	
Moderate	135 (9.4%)	142 (8.7%)		(9.5%)	(8.5%)	
Severe	95 (6.6%)	95 (5.8%)		(6.5%)	(5.9%)	
Total Comorbidities	1.5 (1.5)	1.6 (1.5)	0.0214	1.6 (1.5)	1.6 (1.4)	0.9878
Length of Stay	5.3 (5.3)	5.0 (4.6)	0.0869	5.3 (5.4)	5.0 (4.5)	0.1703

Data represented as mean (SD) for continuous variables and number (%) for categorical or only (%) for propensity score weighted categorical.

Statistically significant differences between the no exposure and any exposure groups were observed for several of the baseline characteristics including age, sex, insurance status, Charlson score, and total comorbidities; however, after balancing using inverse probability treatment weights, none of the differences remained statistically significant, therefore indicating successful balancing of baseline characteristics between the exposure groups using propensity score methods.

As shown in **Table 2,** at 30 days post-discharge, unadjusted readmission rates were statistically significantly lower in TDTS exposed smokers compared with unexposed smokers (Δ= 2.6%; P= 0.02). Similarly, unadjusted readmission rates were statistically significantly different between the high, low, and no TDTS exposure smokers (8.8%, 9.8%, 11.9% respectively; P= 0.05).

Table 2. Hospital readmission rates of smokers by level of intervention (N=3081)

	30 Day	90 Day	180 Day
	Unadjusted Proportions	Unadjusted Proportions	Unadjusted Proportions
Control	11.9 %	18.6%	24.3%
Intervention	9.3%	16.6%	21.9%
P-value	*0.019*	*0.147*	*0.108*
Control	11.9%	18.6%	24.3%
Low	9.8%	17.3%	22.4%
High	8.8%	15.9%	21.4%
P-value	*0.050*	*0.258*	*0.239*

Table 3 displays adjusted propensity-scored weighted hospital readmission odds ratios of smokers by level of TDTS intervention. When 30-day readmission was assessed and adjusted for covariates, smokers exposed to any level of TDTS maintained a statistically significant reduction with a decrease of 23% in the statistically significant reduction with a decrease of 23% in the odds of readmission (OR= 0.77; P= 0.031; controlling for age, race, insurance status, and number of comorbidities) regardless of having a lower sample size of smokers (and consequently lower power). There was no statistically significant reduction in odds of readmission when low TDTS exposure was compared with no exposure (OR= 0.87, P= 0.29; controlling for insurance and comorbidities) but when high TDTS exposure was compared with no exposure the odds of readmission were reduced by 27% (P= 0.02, controlling for age and insurance). Although the comparison of high TDTS exposure to low exposure showed no statistically significant difference in the odds of readmission (OR= 0.86, P= 0.36; controlling for age and comorbidities), high exposure appeared to affect 30-day readmission rates positively (Table 3).

Table 3. Adjusted propensity-score-weighted hospital readmission odds ratios of smokers by level of TDTS intervention

	30 Day	90 Day	180 Day
	OR (95% CI)	OR (95% CI)	OR (95% CI)
N	*3079*	*3079*	*3079*
Control	1.00	1.00	1.00
Intervention	0.77 (0.61, 0.98)	0.87 (0.72, 1.05)	0.86 (0.73, 1.02)
P-value	*0.031*[1]	*0.145*[2]	*0.078*[2]
N	*2200*	*2200*	*2200*
Control	1.00	1.00	1.00
Low	0.87 (0.66, 1.09)	0.95 (0.76, 1.19)	0.93 (0.76, 1.14)
P-value	*0.294*[3]	*0.657*[3]	*0.494*[3]
N	*2315*	*2270*	*2268*
Control	1.00	1.00	1.00
High	0.73 (0.55, 0.95)	0.82 (0.66, 1.02)	0.82 (0.67, 1.00)
P-value	*0.021*[4]	*0.079*[4]	*0.048*[2]
N	*1635*	*1681*	*1682*
Low	1.00	1.00	1.00
High	0.86 (0.61, 1.19)	0.86 (0.66, 1.11)	0.87 (0.69, 1.10)
P-value	*0.356*[5]	*0.238*[6]	*0.250*[6]

[1] Covariates: age, race, insurance status, and number of comorbidities; [2] Covariates: age, insurance status, and number of comorbidities; [3] Covariates: insurance status and number of comorbidities; [4] Covariates: age and insurance status; [5]Covariates: age and number of comorbidities; [6]Covariates: number of comorbidities.

When these analyses were repeated for readmission at 90 and 180 days' post-discharge (using inverse probability of treatment weight and adjusted for covariates), no statistically significant effects of exposure on readmission rates were observed, although differences in readmission rates were in the expected direction consistent with the 30-day readmission results. Exploratory subgroup analyses were performed on 369 smokers who had been diagnosed with at least 1 of the CMS conditions, of whom 40, 65, and 92 were readmitted at 30, 90 and 180 days post-discharge, respectively. Within this small subsample, there was a consistent trend towards lower readmissions among smokers exposed to any level of the TDTS intervention at each of the 30-, 90-, and 180-day intervals, after adjusting for covariates. When 30-day readmissions were assessed, smokers exposed to the TDTS had an 11% reduction in the odds of readmission (OR= 0.89; P> 0.05). At the 90-day interval, there was a similar 10% reduction in the odds of readmission (OR= 0.90; P> 0.05). At 180 days, smokers exposed to the TDTS had a more robust 43% reduction in the odds of readmission (OR= 0.57; P= 0.005).

Exploratory subgroup analyses were performed on 369 smokers who had been diagnosed with at least 1 of the CMS conditions, of whom 40, 65, and 92 were readmitted at 30, 90 and 180 days post-discharge, respectively. Within this small subsample, there was a consistent trend towards lower readmissions among smokers exposed to any level of TDTS intervention at each of the 30-, 90-, and 180-day intervals, after adjusting for covariates. When 30-day readmissions were assessed, smokers exposed to the TDTS had an 11% reduction in odds of readmission (OR= 0.89; P> 0.05). At the 90-day interval, there was a similar 10% reduction in odds of readmission (OR= 0.90; P> 0.05). At 180 days, smokers exposed to the TDTS had a more robust 43% reduction in odds of readmission (OR= 0.57; P= 0.005).

Table 4 presents the association between TDTS exposure and 1-year healthcare charges. The overall unadjusted 1-year mean charge of care for TDTS exposed and unexposed patients were $52,539 (SD = $90,031) and $59,132 (SD = $105,283), respectively (p=.03), favoring lower charges for patients in the TDTS exposed group. These overall charges were comprised of inpatient, ambulatory surgery and ED charges, each of which were in the direction of lower charges in the TDTS exposed group.

Table 4: Unadjusted 1-Year Mean, Median, Interquartile Range and Confidence Intervals of Charges by Level of Exposure to the TDTS*

	Unexposed to TDTS (n=1,439)	Exposed to TDTS (n=1,640)	P-Value	Low Exposure to TDTS (n=764)	High Exposure to TDTS (n=871)	P-Value
Total Charges						
Mean (SD) [95% CI]	$59,132 ($105,283) [$53,688;$64,576]	$52,539 ($90,031) [$48,178;$56,899]	**0.03**	$51,937 ($84,273) [$45,952;$57,922]	$52,557 ($94,411) [46,278;$58,835]	**0.44**
Inpatient Charges*						
Mean SD [95% CI]	$43,337 ($90,434) [$38,661;$48,014]	$38,413 ($75,549) [$34,754;$42,072]	**0.05**	$37,647 ($71,703) [$32,554;$42,739]	$38,552 ($78,139) [$33,356;$43,749]	**0.40**
Ambulatory Surgery Charges						
Mean SD [95% CI]	$7,088 ($20,598) [$6,023;$8,154]	$6,720 ($19,911) [$5,755;$7,684]	**0.31**	$7,687 ($22,030) [$6,123;$9,252]	$5,906 ($17,874) [$4,717;$7,094]	**0.04**
ED Charges						
Mean SD [95% CI]	$8,705 ($19,488) [$7,697;$9,713]	$7,405 ($18,094) [$6,529;$8,281]	**0.03**	$6,602 ($15,146) [$5,526;$7,678]	$8,098 ($20,348) [$6,744;$9,451]	**0.048**

**P-values compare Unexposed vs Exposed and Low vs High Intervention based on the student t-test.*
***Inpatient charges are DRG-adjusted.*

Overall unadjusted mean charges between the low and high intensity TDTS exposed groups were similar. Overall 1-year charges for the low vs. high intensity groups were $51,937 (SD = $84,273) and $52,557 (SD = $94,411), respectively (p=.44). In terms of the inpatient, ambulatory surgery and ED charges that contribute to the overall charges, the low and high intensity groups had similar inpatient charges. The high intensity group had higher outpatient and ED visit charges (p=.036 and .048, respectively) compared to the low intensity group.

Table 5 presents the association between TDTS exposure and 1-year healthcare charges, controlling for covariates of age, race/ethnicity, insurance status, Charlson score and number of comorbidities. Comparing overall healthcare charges for the TDTS exposed vs. unexposed patient groups, mean charges for the TDTS exposed group were $7,299 lower than for the unexposed group (p=.047). Charges for inpatient, ambulatory surgery and ED visits were $5,242 (p=.10), $699 (p=.36) and $1,547 (p=.02) lower respectively for the TDTS exposed group compared to the unexposed group. Overall mean charges for the low intensity TDTS group vs. the unexposed group also indicated lower charges in the low intensity group, but this result was not statistically significant at the p<0.05 level ($8,006 lower, p=.08). Overall mean charges for the high intensity TDTS group vs. the unexposed group revealed a marginally lower charge of $6,949 (p=.12). Overall mean charges for the high vs. low intensity groups were similar, with charges in the high intensity group on average $120 higher than in the low intensity group (p=.98).

Table 5: Adjusted Difference in 1-Year Healthcare Charges by Level of Exposure to the TDTS*

	Exposed vs. Unexposed N=3,079	**High vs. Unexposed** N=2,315	**Low vs. Unexposed** N=2,220	**High vs. Low** N=1,635
Total Charges				
Difference	-$7,299	-$6,949	-$8,006	-$120
P-value	0.047	0.12	0.08	0.98
95% CI	[-$14,499;$-100]	[-$15,752;$1,854]	[$-16,989;$976]	[-$9,789;$9,549]
Inpatient Charges**				
Difference	-$5,242	-$4,356	-$6,450	$1,071
P-value	0.10	0.24	0.11	0.81
95% CI	[-$11,475:$990]	[-$12,097;$3,023]	[-$14,390;$1,488]	[-$7,463;$9,607]
Ambulatory Surgery Charges				
Difference	-$699	-$1,517	-$126	-$1,604
P-value	0.36	0.06	0.91	0.15
95% CI	[-$2,200;$801]	[-$3,087;$51]	[-$2,317;$2,064]	[-$3,772;$563]
ED Charges				
Difference	-$1,547	-$1,034	-$1,933	$725
P-value	0.02	0.22	0.02	0.40
95% CI	[-$2,870;-$223]	[-$2,672;$603]	[-$3,483:-$382]	[-$972;$2,424]

**Adjusted for baseline covariates: age, race, insurance status, Charlson Score and number of comorbidities.*
***Inpatient charges are reported as DRG-standardized charges*

An overview of the costs for development and implementation of the MUSC Quits TDTS is presented in **Table 6**. The total TDTS cost in the first year of operation, which included program start-up costs, was estimated to be $158,140, which translates to $34.21 per smoker eligible for the service over a 12-month period. Removing start-up costs, we estimate that the overall annual TDTS program cost would be $143,140, which translates to $30.97 per smoker eligible for the service over a 12-month period. TDTS costs were primarily driven by two factors: 1) staffing costs for the TTS and program manager which accounted for 52% of the overall costs and 2) the TelASK cost that is charged per estimated number of hospitalized smokers, which reflected 45% of overall costs.

Table 6: Cost of Implementing the Tobacco Dependence Treatment Service (TDTS)

Cost	Description	Year 1 (Inclusive of Start Up Cost)	Subsequent Years
Salary costs	Full time Tobacco Treatment Specialist with a master of social work degree ($61,140 salary/fringe @ 100% effort)	$61,140	$61,140
	Part time TDTS program manager with an RN degree ($72,636 salary/fringe @ 30% effort)	$21,790	$21,790
Office space and equipment*	Office space for counselor and program manager (182 total *ft²* of space @ MUSC price of $23.75 *per ft²*)	$1,961	$1,961
	Office computer, printer, desk and chair for counselor and project staff	$2,785	$0
TelASK costs	TelASK initiation charge	$15,000	$0
	TelASK charge of $12 per estimated 4,622 hospitalized smokers per year	$55,464	$55,464
Total program cost per year		$158,140	$143,140
Total program cost per smoker **		$34.21	$30.97

**The cost of office space and equipment are prorated to the 100% effort of the counselor and the 30% effort of the program manager.*

***The total program cost per smoker eligible is calculated as total program cost divided by the total number of smokers eligible to receive the TDTS over a 12-month period (i.e., 385 smokers per month x 12 = 4622 smokers per year). The costs in Year 2 exclude the costs for setting up the TDTS in Year 1.*

Discussion

The current study found that unplanned hospital readmission rates were 23% lower at 30-days post-discharge among hospitalized smokers who received a TDTS (p=.031), with results also favoring lower readmissions in the intervention group at 90 and 180 days. Overall mean healthcare charges for smokers exposed to the TDTS was $7,299 lower than for those without TDTS exposure (p=.047), with a TDTS cost per smoker of $34.21.

Our study findings related to the effect of the TDTS on hospital readmissions mirror results from three prior studies that we identified in the literature.(23, 38, 39) In our study, there was also a stronger association observed between program exposure and readmission rates for the high intensity group than for the low intensity group. For example, when compared to the control group, the OR for readmission in the high and low intensity groups were 0.73 (p=.021) and 0.87 (p=.243) respectively. Across these comparison studies conducted in patients hospitalized for mental health (39), cardiac care (23), and overall hospital conditions (38) respectively, exposure to a TDTS was associated with robust reduction in hospital readmissions within 1-2 years post-discharge. Only one of these studies, which was conducted in Ontario Canada among a group of overall hospitalized patients, evaluated the effect of a TDTS on 30-day readmissions (38). Thus, the current study is the first US-based study to examine the effect of a TDTS on 30-day readmissions, adding to the evidence-base that delivery of TDTS interventions may have a clinically meaningful effect on short-term hospital readmission rates.

While quitting smoking has been shown to reduce long-term hospitalization rates, less is known about the effect of quitting smoking on 30-day hospital readmission rates. The finding of a 23% reduction in 30 day unplanned readmission rates among TDTS participants in the current study is especially promising, as this research was conducted within the context of a “real world” TDTS designed to reach all patients

to the extent possible with some level of TDTS. The reduction in unplanned hospital readmissions was more strongly positive for those who received bedside counseling combined with IVR follow-up calls. This result is consistent with the influence of smoking cessation since our prior study of the TDTS patients who received the bedside consult were twice as likely to report not smoking compared to those who received just the IVR follow-up calls (35). Although tobacco cessation has not been a focus of evaluation as a strategy for prevention of 30-day readmissions, there is strong biological plausibility for how a TDTS may reduce 30-day readmissions (18). Specifically, quitting smoking lowers a person's heart rate, blood pressure and blood sugar, improves pulmonary function, circulation and wound healing, and enables cancer treatments to work more effectively. Since most of these health gains are achieved shortly after quitting smoking, it is plausible that quitting smoking has great potential as a strategy to reduce 30-day readmission rates.

We also conducted sub-analyses to explore the TDTS intervention effect on hospital readmissions at 30, 90 and 180 days among patients with CMS readmission penalty conditions. Despite being underpowered to evaluate these outcomes, a consistent trend was observed in the direction of lower readmissions in the TDTS exposure group. These findings provide additional evidence supporting the potential role of TDTS interventions on reduction of 30-day readmissions within a CMS readmission penalty condition cohort.

As mentioned previously, a key finding from this study was that healthcare charges were $7,299 lower among hospitalized smokers exposed to the TDTS (p=.047). In SC, the cost to charge ratio is between 30-40%, meaning actual healthcare costs are approximately 30-40% of charges, resulting in an average of $2,190-$2,920 lower cost per smoker who received the TDTS service. Within the context of our study in which 1,640 patients received the TDTS over an 8-month period, this would translate into a healthcare cost savings ranging from $3.6-$4.8 million, accounting for the cost of program delivery and cost savings per patient. These data suggest that between 54-72 smokers would need to receive TDTS services to cover the cost of delivering the service. The overall costs of implementing the TDTS were modest relative to the potential savings in estimated healthcare costs.

The cost for delivering the TDTS compares favorably with the cost of programs relying on either clinical staff or IVR technology to deliver follow up cessation support calls. Typical program costs for provision of inpatient smoking cessation services and follow-up reported in the literature range from $74 to $189 per patient (40) (41) (42). The lower average program cost per smoker with the MUSC TDTS likely reflects the minimal nature of the intervention delivered which involved one full-time TTS, a part-time TDTS program manager, and provision of automated IVR follow-up calls. Because of limited staffing and budget, the MUSC TDTS only reached 53% of the eligible smoker population in the hospital and did not include provision of medications to patients. A larger investment in the service would have allowed us to reach more smokers and in turn might further reduce health care costs, although we did not observe differences in healthcare charges between low and high intensity arms of the TDTS.

This study contributes most notably to the economic literature evaluating possible benefits of providing smoking cessation services to hospitalized patients by using actual program and healthcare utilization data, rather than modeling these charges as other studies have done. In this study we utilized actual TDTS costs, along with actual healthcare charges for inpatient, ambulatory surgery and ED charges accrued by patients within 1-year after hospital discharge. While these data are observational, the findings show that a TDTS consistent with JC standards for smoking cessation can be affordably implemented and potentially yield substantial healthcare savings.

To date, tobacco cessation has not been established as an influential driver for reduction in hospital readmissions and healthcare costs. This study provides evidence that a TDTS consistent with JC smoking cessation standards may help to markedly impact these outcomes, consistent with what might be expected given the well documented hazards of smoking. While these findings need replication in other healthcare institutions to confirm the magnitude of observed benefit, the results should encourage healthcare administrators to consider investing in a JC-styled TDTS.

Conclusions
In summary, the current study provides exploratory evidence that an evidence-based TDTS may help to reduce short-term hospital readmission rates and healthcare costs among smokers. While our findings are promising, evidence will be needed from rigorous RCTs to further confirm these findings. For healthcare administrators who have to make difficult decisions about what clinical and preventive services to provide for patients, this evidence will be a crucial next step for encouraging health system investments in TDTS program delivery as a routine and sustainable clinical practice.

7. List of Publications and Products

Manuscripts

Cartmell KB, Dooley M, Mueller M, et al. Effect of an evidence-based inpatient tobacco dependence treatment service on 30, 90 and 180 day hospital readmission rates. Med Care 2018 April;56(4):358-63. PMID: 29401186.

Cartmell KB, Dismuke CE, Dooley M, et al. Effect of an Evidence-Based Inpatient Tobacco Dependence Treatment Service on 1-Year Post-Discharge Healthcare Costs. Med Care; In Press, 2018.

Nahhas GJ, Wilson D, **Cartmell KB,** et al. Feasibility of implementing a hospital-based "opt-out" tobacco cessation service. Nicotine Tob Res 2017 Aug 1;19(8):937-43. PMID: 27928052.

Presentations

Cartmell KB, Nahhas G, Warren G, et al. Implementation of comprehensive inpatient tobacco cessation services following Joint Commission recommendations: lessons learned and recommendations; 2015 Oct 31-Nov 4; Chicago, IL. APHA 143rd Annual Meeting and Expo.

Cartmell KB, Nahhas GJ, Kilpatrick D, et al. Implementation of an automated patient screening, referral and tracking system to expand the delivery of tobacco cessation services to patients in a large academic medical center; 2016 Dec 14-15; Washington, DC. 9th Annual Conference on the Science of Dissemination and Implementation in Health.

Cartmell KB, Dismuke CE, Nahhas GJ, et al. Reducing healthcare costs by implementing an inpatient tobacco cessation service; 2017 Mar 22-24; Austin, TX. National Conference on Nicotine or Health.

Cartmell KB, Nahhas GJ, Dooley M, et al. Reducing hospital readmission rates by implementing an inpatient tobacco dependence treatment service; 2017 Mar 22-24; Austin, TX. National Conference on Nicotine or Health.

Dooley M, **Cartmell KB,** Mueller M, et al. Comparison of Four Methods to Control Selection Bias: An Example from a Smoking Cessation Study; 2018 Jan 10-12; Charleston, SC. 12thInternational Conference on Health Policy Statistics.

Cartmell KB, Dismuke CE, Mueller M, et al. Reducing healthcare costs by implementing an inpatient tobacco dependence treatment service; 2018 Feb 21-24; Baltimore, MD. Society for Research on Nicotine and Tobacco Annual Meeting.

Cartmell KB, Nahhas GJ, Dismuke CE, et al. Reducing healthcare costs by implementing an inpatient tobacco dependence treatment service; 2018 Mar 7-9; Cape Town, South Africa. 17th World Conference on Tobacco or Health: Uniting the World for a Tobacco Free Generation.

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