Cost-effectiveness of a nurse-delivered, inpatient smoking cessation intervention

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Abstract

Randomized controlled trials have shown that inpatient tobacco cessation interventions are highly efficacious and cost-effective. However, the degree to which smoking interventions implemented in nonrandomized, real-world practice settings are effective, and consequently, cost-effective, remains unclear. This study evaluated the cost-effectiveness of a nurse-delivered, inpatient smoking cessation intervention, Tobacco Tactics, compared with usual care within the context of an observational, real-world study design. In this quasi-experimental study, five Michigan hospitals ($N = 1,370$ patients) were assigned to implement either Tobacco Tactics or usual care during October 2011–May 2013. Statistical analysis was conducted during January 2017–February 2018. Controlling for confounding using stabilized inverse probability of treatment weights, incremental cost-effectiveness ratios were calculated and cost-effectiveness acceptability curves were generated. The per person cost of tobacco cessation services in the intervention group exceeded that of usual care (\$175.52 vs. \$67.80; $p < .001$). The intervention group had a higher propensity-adjusted self-reported quit rate compared to the control group (15.7% vs. 7.0%; $p < .0001$). The propensity-adjusted incremental cost-effectiveness ratio was \$1,325 per quit (95% confidence interval: \$751–\$2,462), with 99.9% probability of being cost-effective at a willingness to pay of \$5,000 per quit. The Tobacco Tactics intervention was found to be cost-effective and well within the range of incremental cost-per-quit findings from other studies of tobacco cessation interventions, which range from \$918 to \$23,200, adjusted for inflation.

Keywords

Cost-effectiveness, Tobacco cessation, Prevention, Quasi-experimental design, Intervention

INTRODUCTION

Tobacco cessation is one of the most cost-effective health care services in the USA. Although a majority of prior research has focused on office-based interventions, inpatient interventions have also been shown to be highly effective [1, 2]. Tobacco cessation interventions that have been evaluated cost less than \$100,000 per quality-adjusted life year and are, thus, cost-effective if one assumes this as a commonly used standard. This corresponds with a short-term incremental cost per quit in the range from \$918 to \$23,200, adjusted for inflation [3–8].

Many existing studies of the efficacy and cost-effectiveness of smoking cessation interventions have used long-term models based on cost and effectiveness observed in randomized controlled trials [9]. Yet, maintaining the high success rates of these interventions is challenging in routine clinical practice. Thus, the National Institutes of Health (NIH) funded several inpatient smoking cessation implementation trials [10]. One of those studies was a pragmatic implementation trial of Tobacco Tactics, a nurse-delivered, smoking cessation intervention for hospitalized smokers. Tobacco Tactics was more effective than usual care in helping smokers quit [11]. Although there is evidence of the cost-effectiveness of a nurse-delivered tobacco cessation intervention delivered in community hospital settings generated via decision modeling [12,13], we know of no published studies that have evaluated the cost-effectiveness of a nurse-delivered inpatient smoking cessation intervention implemented in a real-world setting. This article uses data from an implementation trial to determine whether the nurse-delivered Tobacco Tactics intervention is cost-effective compared with usual care in an inpatient setting.

METHODS

Design

The study protocol, implementation, and effectiveness of the results of the Tobacco Tactics intervention have been previously published [14–16]. This study was a pragmatic, quasi-experimental trial in community hospitals in the Michigan Trinity Health system from 2010 through 2015. The trial was designed to be conducted in six hospitals matched on size and proportion of minority patients. Data from one site was not available, leaving five sites for study. To reduce investigator bias, a random number generator was used to assign the hospitals to Tobacco Tactics and usual care control conditions [16]. Approval of human studies was obtained from the University of Michigan and Trinity Health.

Sample

Inclusion criteria for the study were hospitalized patients who (a) smoked a cigarette within one month prior to hospitalization, (b) were at least 18 years of age, and (c) had a projected hospital stay of at least 24 hr. Excluded were smokers who were (a) involved in a concurrent smoking cessation trial, (b) non-English speaking, or (c) not cognitively or physically able to participate.

Procedures

Qualifying smokers were identified from the electronic medical record (EMR) and were asked to provide written informed consent to participate. Using the follow-up method developed by Dillman, patients were mailed surveys 30 days and 6 months after discharge [17,18]. For those who returned surveys or cotinine tests, research assistants (not blinded) made follow-up calls to obtain quit status. For those who could not be contacted by telephone, a programmer (blinded) downloaded smoking status and quit date from the EMR. A research nurse (not blinded) then reviewed text notes for patients who were readmitted to the hospital to estimate participants' 6-month cessation status. Midway through the study, nurses in intervention hospitals were trained in the Tobacco Tactics intervention, which included (a) a brochure; (b) a cessation DVD; (c) the Tobacco Tactics manual; (d) a 1-800-QUIT-NOW card; (e) nurse behavioral counseling and pharmaceuticals; (f) physician reminders to offer brief advice to quit coupled with medication sign-off; and (g) follow-up phone booster calls by trained hospital volunteers. Volunteers were given a script that covered three aspects of providing support to smokers, namely (a) positive reinforcement; (b) handling thoughts about smoking; and (c) strategies to cope with cravings. Volunteers provided only behavioral support and referred all medical questions or unanticipated situations/crises to case managers or 911. Details can be found in previously published studies [19–21]. Cost and quit rates in patients at intervention hospitals after nurses were trained were compared with all other patients. Although usual care was standard of care in the control hospitals, the intervention was standard of care in the intervention hospitals, and all smokers, whether or not they enrolled in the study, were eligible to receive the intervention. Results for patients at intervention hospitals before nurses were trained were comparable to the results for patients at usual care hospitals; in the interests of analytic simplicity, these groups were combined to form the usual care group.

Measures

Patient characteristics and effectiveness

This study was part of a group of smoking cessation implementation trials initiated in 2010 with

support from the National Institutes of Health [10]. Investigators agreed to use a common set of effectiveness measures and patient variables. Patient characteristics included demographics, comorbidities at the time of discharge from index hospital stay [22], the Alcohol Use Disorders Identification Test-C (AUDIT-C) for alcohol use [23,24], and self-rated functional health and well-being via the SF-36 [25]. Because the Society for Research on Nicotine and Tobacco biochemical verification guidelines indicate that “in large-population, low-intensity intervention trials, biochemical validation is neither feasible nor necessary,” [26] the investigators in all of these NIH trials agreed to a common primary outcome measure, the one used in this study. This was the 7-day point prevalence self-reported quit rate obtained 5–8 months post-discharge either from the EMR or from a mail or phone survey. A subsample of nonrandomly chosen participants also received biochemical validation at 6 months. Biochemical validation was sent only to those who reported quitting in the follow-up survey. As published in a prior paper [15], there was consistency between self-report and biologically verified status in the 448 participants who were assessed by both methods. Self-report had a sensitivity of 96% and a specificity of 86% relative to tobacco status verified by cotinine. As self-report data were more complete, this outcome measure was used for the cost-effectiveness analysis (CEA).

Cost of smoking cessation services

Cost-effectiveness was assessed as cost per quit. Because this measure is often reported in tobacco cessation cost-effectiveness studies, there are many benchmarks available for comparison. Cost-effectiveness was assessed from the viewpoint of the sponsor of smoking cessation services; in the context of this study, these costs were borne by the hospital and/or insurance plan under the assumption that medications would be covered in full with no patient cost-sharing. The rationale for taking this perspective was that, if the patient had a prescription for these medications and filled it, it was most likely covered by the sponsor since currently, Medicare, Medicaid, and most private insurance plans cover cessation medications. The Affordable Care Act requires health insurers to cover, without cost-sharing, any preventive services strongly recommended by the U.S. Preventive Services Task Force [27]. The time horizon was the period until the end of trial follow-up. Costs were expressed in 2011 U.S. dollars and included the cost of medications given during the initial hospital stay, during rehospitalizations over the next 6 months, medications taken outside of hospital, and labor and material costs associated with hospital-provided cessation services.

Medication costs

Medications included nicotine replacement therapy (NRT; nicotine patch, inhaler, nasal spray, gum, and lozenge), bupropion, and varenicline. Data on medications provided in the hospital were extracted from the EMR for each participant. Medication cost was determined by multiplying charges by the Medicare cost-to-charge ratio specific to each hospital and year. Patient reports of medications used outside the hospital were assigned the cost of each medication in the Federal Supply Schedule [28], with an additional 21% for administrative overhead [29], and a \$5.00 dispensing fee [30]. It was assumed that NRT was dispensed with a minimum of 14 days' supply and only in multiples of 7 days' supply and that bupropion and varenicline were dispensed with a minimum of a 30-day supply.

Costs associated with labor and materials

Start-up costs included the initial 1-hr training of all nurses and the programmer time to adapt the EMR for the intervention. Additional costs included the nurses' time to deliver the intervention, brief physician advice, and follow-up phone calls made by volunteers. The cost of registered nurse time was estimated using the accounting data from the U.S. Department of Veterans Affairs, which was \$53.02 per hour in 2011 [31]. The VA cost data were used because they are publically available, include the cost of both wages and benefits, are an average over a health system that is national in scope, and represent prevailing wages of hospital-based nurses, as Federal law requires VA to pay the prevailing wage in each region. The time nurses spend in direct contact with patients is supported by other activities, including documentation, staff meetings, administrative tasks, charting, and sick leave. An additional 77% labor cost was applied for these support activities [32]. A survey administered to nurses found that they spent 15 min per patient providing the intervention and 1 min providing usual care, brief counseling.

Brief physician advice to quit was assigned a cost based on 30 s of physician time at an hourly rate of \$106, with an additional 30% for the cost of benefits and employer taxes [33]. The cost of phone calls during the follow-up period was estimated using a cost of \$14 per hour. Although these calls were made by volunteers, it was assumed that paid staff would be needed to replicate this part of the intervention in clinical practice.

Statistical analysis

Characteristics of the study population were reported as percentages, or for continuous variables, as means with standard deviations. To allow an unbiased comparison between the intervention and usual care groups, we adjusted for the propensity to receive the intervention with stabilized inverse

probability of treatment weights (SIPTW) [34, 35]. This method reweights observations as if treatments had been assigned at random, with higher weights assigned to unlikely treatment group assignments and lower weights assigned to likely assignments. The weights were derived from a logistic regression of the propensity to receive the intervention. The independent variables in this regression include all covariates listed in Table 1.

Propensity adjustment assumes that the intervention and usual care populations are comparable. The recommended method of testing this assumption is graphical evaluation of the overlap in the groups' propensity to receive the intervention (Figure 1) [36]. In addition, the ability of the propensity adjustment to balance the intervention and usual care control groups was evaluated by determining standardized differences of all baseline covariates, using a threshold of greater than 0.1 to indicate imbalance [37]. For continuous variables, standardized differences were calculated using Cohen's *d*, which can be interpreted as a measure of the average difference between means expressed in standard deviation units. The mean is replaced with a proportion in the case of binary baseline variables.

Incremental cost-effectiveness ratios (ICERs) were calculated as the difference in the mean tobacco-related costs incurred by intervention versus usual care control group, divided by the difference in their percentage quit. Bootstrap sampling was used to estimate the uncertainty of the ICER values, with the probability of selection set by the SIPTW. Study observations were sampled at random with replacement 100,000 times, and an ICER was determined for each replicate. Cost-effectiveness acceptability curves were generated to identify the percentage of ICER estimates that were cost-effective at different values for the willingness to pay per quit [38]. All statistical analyses were conducted during January 2017–February 2018.

RESULTS

Study population demographic, clinical, and smoking-related characteristics

The final study cohort consisted of 1,370 patients, 313 of whom were in the intervention group (22.8%). As expected in a quasi-experimental trial, there were differences between the intervention and usual care groups (see Table 1). Compared with patients in the usual care group, those in the intervention group tended to be older and nonwhite, more likely to be discharged with an infectious disease or circulatory disease, less likely to be discharged with a mental health disorder or a perinatal disease, more likely to have selected comorbidities, smoked slightly fewer cigarettes per day at study entry, have fewer past quit attempts, and less likely to report use of other tobacco products.

Table 1 | Unweighted participant characteristics and standardized differences before and after application of stabilized inverse probability of treatment weights

Covariates	Intervention status		Standardized differences	
	Intervention group (N = 313)	Usual care control group (N = 1,057)	Before	After
	Mean (SD)	Mean (SD)		
Age	51.8 (12.7)	46.8 (15.0)	0.36	0.364
Number of cigarettes per day	13.5 (8.6)	15.9 (12.8)	-0.22	-0.054
Number of past quit attempts	1.6 (2.9)	4.0 (20.9)	-0.16	-0.098
	N (%)	N (%)		
Male	145 (46.3)	522 (49.4)	0.06	-0.027
White	224 (71.6)	827 (78.2)	0.15	0.057
High school education or less	181 (57.8)	584 (55.3)	-0.04	0.005
Married or had domestic partner	98 (31.3)	337 (31.9)	0.02	-0.021
Employed	79 (25.2)	314 (29.7)	0.10	0.078
Other tobacco use	14 (4.5)	123 (11.6)	0.27	-0.026
Problematic alcohol use	84 (26.8)	383 (36.2)	0.21	-0.026
Primary insurance				
Self-pay/none	60 (19.1)	174 (16.5)	-0.07	-0.048
Medicare	112 (35.8)	344 (32.5)	-0.07	-0.065
Medicaid	48 (15.3)	184 (17.4)	0.06	0.003
Veterans Affairs	0 (0.0)	1 (0.1)	0.04	0.039
Other public	10 (3.2)	19 (1.8)	-0.09	0.027
Private	83 (26.5)	335 (31.7)	0.11	0.097
Primary discharge diagnosis				
Infectious diseases	38 (12.1)	58 (5.5)	-0.24	0.07
Neoplasms	13 (4.2)	32 (3.0)	-0.06	-0.014
Endocrine disorders	19 (6.1)	47 (4.5)	-0.07	-0.012
Diseases of the blood	3 (1.0)	6 (0.6)	-0.04	0.0002
Mental disorders	4 (1.3)	92 (8.7)	0.35	0.083
Diseases of the nervous system	10 (3.2)	31 (2.9)	-0.02	0.02
Diseases of the circulatory system	54 (17.3)	125 (11.8)	-0.15	-0.002
Diseases of the respiratory system	32 (10.2)	90 (8.5)	-0.06	0.014
Diseases of the digestive system	42 (13.4)	138 (13.1)	-0.01	-0.034
Diseases of the genitourinary system	12 (3.8)	38 (3.6)	-0.01	0.017
Perinatal disease	1 (0.3)	76 (7.2)	0.37	0.231
Diseases of the skin	14 (4.5)	42 (4.0)	-0.02	-0.012
Diseases of the musculoskeletal system	27 (8.6)	68 (6.4)	-0.08	-0.006
Injury and poisoning	29 (9.3)	106 (10.0)	0.03	-0.049
Comorbidities (secondary discharge diagnoses)				
Infectious diseases	53 (16.9)	138 (13.1)	-0.11	-0.096
Neoplasms	17 (5.4)	49 (4.6)	-0.04	0.007
Endocrine disorders	219 (70.0)	606 (57.3)	-0.26	-0.128
Diseases of the blood	77 (24.6)	238 (22.5)	-0.05	-0.096
Mental disorders	145 (46.3)	544 (51.5)	0.03	0.037
Diseases of the nervous system	103 (32.9)	291 (27.5)	-0.12	-0.033
Diseases of the circulatory system	187 (59.7)	543 (51.4)	-0.17	-0.087
Diseases of the respiratory system	135 (43.1)	335 (31.7)	-0.24	-0.07
Diseases of the digestive system	117 (37.4)	369 (34.9)	-0.05	-0.122
Diseases of the genitourinary system	84 (26.8)	212 (20.1)	-0.16	-0.037
Perinatal disease	1 (0.3)	74 (7.0)	0.07	0.292
Diseases of the skin	21 (6.7)	92 (8.7)	0.07	-0.072
Diseases of the musculoskeletal system	93 (29.7)	240 (22.7)	-0.16	-0.051

(Continued)

Table 1 | Continued

Covariates	Intervention status		Standardized differences	
	Intervention group (N = 313)	Usual care control group (N = 1,057)	Before	After
	Mean (SD)	Mean (SD)		
Injury and poisoning	72 (23.0)	182 (17.2)	-0.14	-0.056
Self-rated health status				
Excellent	3 (1.00)	35 (3.3)	-0.09	-0.0002
Very good	16 (5.1)	118 (11.2)	-0.13	0.165
Good	100 (32.0)	354 (33.5)	0.03	0.004
Fair	116 (37.1)	327 (30.9)	0.22	-0.081
Poor	77 (24.6)	222 (21.0)	0.16	-0.015
Self-care activities				
No problem	218 (69.6)	702 (66.4)	-0.06	0.04
Slight problem	44 (14.1)	168 (15.9)	0.05	0.004
Moderate problem	17 (5.4)	102 (9.7)	0.17	-0.059
Severe problem	23 (7.4)	51 (4.8)	-0.10	-0.028
Unable	11 (3.5)	26 (2.5)	-0.06	0.023
Usual activities				
No problem	132 (42.2)	468 (44.3)	0.05	0.048
Slight problem	68 (21.7)	232 (22.0)	0.01	0.077
Moderate problem	38 (12.1)	165 (15.6)	0.10	-0.142
Severe problem	26 (8.3)	87 (8.2)	-0.002	-0.021
Unable	49 (15.7)	101 (9.6)	-0.18	0.014

Fig. 1 | Propensity score evaluation—boxplot.

Unweighted standardized differences between the intervention and usual care control groups exceeded an absolute value of 0.10 for 23 of the 59 baseline characteristics (Table 1). The SIPTWs for individual cohort members ranged from 1.0 to 27.8, with a mean of 1.94 and a median of 1.33. After application of weights, standardized differences exceeded an absolute value of 0.10 for only

6 of the 59 baseline characteristics, demonstrating improvement in covariate balance in the weighted sample compared with the unweighted sample. The propensity estimates showed overlap between those in the intervention and usual care control groups, further indicating the weighted sample balanced baseline covariates between the two groups (Figure 1).

Table 2 | Ambulatory medication characteristics

	Intervention status		<i>p</i> value*
	Intervention group (<i>N</i> = 313)	Usual care control group (<i>N</i> = 1,057)	
Number of patients reporting ambulatory medication use	<i>N</i> (%)	<i>N</i> (%)	
Patch	76 (24.3)	272 (25.7)	.6
Gum	28 (9.0)	71 (6.7)	.18
Lozenge	9 (2.9)	26 (2.5)	.68
Inhaler	22 (7.0)	50 (4.7)	.11
Nasal spray	6 (1.9)	20 (1.9)	.98
Bupropion	20 (6.4)	35 (3.3)	.01
Varenicline	20 (6.4)	35 (3.3)	.01
Days using ambulatory pharmacotherapy (among those who reported any use)	Mean (<i>SD</i>)	Mean (<i>SD</i>)	
Patch	13.9 (22.7)	11.4 (16.2)	.34
Gum	4.9 (11.5)	6.7 (13.3)	.66
Lozenge	1.9 (2.0)	5.8 (12.8)	.52
Inhaler	15.5 (7.9)	20.5 (26.8)	.66
Nasal spray	14.0 (0)	20.0 (14.1)	.65
Bupropion	48.5 (48.4)	44.1 (45.7)	.57
Varenicline	35.1 (25.6)	39.8 (29.7)	.60

*Wilcoxon rank sum test used to calculate *p* value.

Ambulatory medication characteristics

The intervention group reported greater use of bupropion (6.4% vs 3.3%, *p* = .01) and varenicline (6.4% vs. 3.3%, *p* = .01) in the 6 months following the index hospitalization compared with the usual care control group (Table 2). Among participants reporting any use of ambulatory medication, the groups showed no difference in the number of days using each medication type.

Cost and effectiveness outcomes

Costs

Costs per patient are shown in Table 3. An unweighted analysis found the mean cost per study participant was \$173.61 in the intervention group and \$67.80 in the control group (*p* < .0001). Medication cost, both inpatient and ambulatory, was \$78.78 in the intervention group and \$62.32 in the usual care control group. Mean labor and materials cost were \$94.83 and \$5.48 per person in the intervention and usual care control groups, respectively. Labor costs in the intervention group costs included \$53.64 for nurse administration of the intervention, \$1.15 for the time associated with a physician reminder, \$15.49 for the time spent on follow-up calls to participants, \$19.91 for nurse training, and \$0.58 for the time spent by the programmer modifying the EMR. Material costs included \$1.64 for pocket guides, \$0.43 for brochures, and \$1.46 for Tobacco Tactics manuals, \$0.35 for videos, and \$0.18 for 1-800-QUIT-NOW cards. Start-up costs (the cost of nurse training and EMR programming) were \$20.49 per smoker treated or an average of \$2,318 per site that initiated the Tobacco Tactics program.

Self-reported quit status

Both unweighted and weighted analyses showed that the intervention group had a higher quit rate than the usual care control group (Table 4). The weighted quit rate was 15.7% (95% confidence interval [CI]: 11.8%–19.6%) in the intervention group and 7.0% (95% CI: 5.5%–8.5%) in the usual care control group (*p* < .0001).

Incremental cost-effectiveness ratios and cost-effectiveness acceptability curves

The unweighted ICER was \$980 per quit (95% CI: \$652–\$1,712; Table 4). Figure 2a shows the unweighted cost-effectiveness acceptability curve for self-reported quit status. The probability that the intervention was cost-effective is represented on the vertical axis, and the maximum dollar amount a decision-maker is willing to pay per quit is depicted on the horizontal axis. The Tobacco Tactics intervention had a greater than 99.9% probability of being cost-effective at cost-effectiveness thresholds of \$5,000 per quit. The SIPTW-weighted ICER was \$1,325 per quit (95% CI: \$751–\$2,462; Table 4). Figure 2b shows the SIPTW-weighted cost-effectiveness acceptability curve. The Tobacco Tactics intervention had a 99.9% probability of being cost-effective at a willingness to pay of \$5,000 per quit when utilizing the SIPTW-weighted ICER.

DISCUSSION

This study showed that Tobacco Tactics was cost-effective relative to usual smoking cessation care provided to hospitalized patients. Differences in medication use were observed for bupropion

Table 3 | Mean smoking cessation cost by treatment group assignment

	Intervention status	
	Intervention group (N = 313)	Usual care control group (N = 1,057)
Inpatient medication costs by type		
Patch	Mean (\$SD)	Mean (\$SD)
	\$5.91 (\$16.82)	\$6.33 (\$15.13)
Gum	\$0.20 (\$1.84)	\$0.66 (\$5.00)
Lozenge	\$0.00 (\$0.00)	\$0.03 (\$0.72)
Inhaler	\$0.00 (\$0.00)	\$0.00 (\$0.00)
Nasal Spray	\$0.00 (\$0.00)	\$0.05 (\$1.55)
Bupropion	\$1.84 (\$18.12)	\$0.74 (\$4.48)
Varenicline	\$0.20 (\$3.00)	\$0.16 (\$3.50)
Total inpatient medication costs per person	\$8.17 (\$24.87)	\$7.97 (\$17.97)
Ambulatory medication costs by type		
Patch	\$11.19 (\$40.47)	\$10.10 (\$31.91)
Gum	\$2.63 (\$22.00)	\$2.70 (\$22.82)
Lozenge	\$0.33 (\$2.72)	\$0.86 (\$12.95)
Inhaler	\$27.97 (\$118.11)	\$24.02 (\$163.56)
Nasal Spray	\$1.54 (\$11.03)	\$1.82 (\$14.72)
Bupropion	\$2.81 (\$15.54)	\$1.34 (\$10.18)
Varenicline	\$24.15 (\$105.95)	\$13.51 (\$86.40)
Total ambulatory medication costs per person	\$70.61 (\$179.36)	\$54.35 (\$202.47)
Total medication costs per person	\$78.78 (\$184.41)	\$62.32 (\$203.70)
Labor costs		
Nurse administration of intervention	\$53.64 (\$62.64)	\$5.48 (\$6.60)
MD reminder (30 s)	\$1.15	\$0
Follow-up phone calls	\$15.49	\$0
Nurse training	\$19.91	\$0
EMR programmer (40 hr)	\$0.58	\$0
Material costs		
Brochures	\$0.43	\$0
Manuals	\$1.46	\$0
1-800-QUIT-NOW card	\$0.18	\$0
Pocket guides	\$1.64	\$0
Videos	\$0.35	\$0
Total labor and material costs per person	\$94.83	\$5.48
Total overall costs	\$173.61 (\$195.26)	\$67.80 (\$203.73)

and varenicline, but were not observed for NRT. We believe that many settings have adopted the use of NRT to assist patients with withdrawal symptoms in the hospital, and therefore, the intervention may have made little difference in this regard. The propensity-adjusted incremental cost per quit of \$1,325 was well within the range of incremental cost per quit findings from other studies of tobacco cessation interventions, which range from \$918 to \$23,200, adjusted for inflation [3–8]. The ICER was modestly higher than ICERs from cost-effectiveness analyses of other nurse-delivered, inpatient smoking cessation interventions. In a model-based CEA of a smoking cessation intervention delivered to persons hospitalized with acute myocardial infarction, the estimated incremental cost per quit was \$592, adjusted for inflation [12]. In a model-based CEA of the Ottawa Model for Smoking Cessation, which is similar to Tobacco Tactics, the estimated incremental

cost per quit ranged from \$450 for COPD patients to \$583 for patients with unstable angina pectoris, adjusted for deflation and converted to U.S. dollars [13]. However, the self-reported quit rates for intervention and usual care control groups input into the models for both of these studies were much higher than the self-reported quit rates observed in this study, perhaps because of the homogenous samples of persons with smoking-related diseases in these other studies compared to our study sample, which was quite heterogeneous.

The Tobacco Tactics intervention was designed to be consistent with the Joint Commission requirements, which necessitate comprehensive, evidence-based smoking cessation treatment during hospitalization. Required components include documentation of tobacco use among admitted patients, provision of cessation counseling and medication while hospitalized, a referral at discharge for

Table 4 | Crude and propensity-adjusted cost, effectiveness, and incremental cost-effectiveness of intervention relative to usual care

Measures	Intervention group (N = 313)		Control group (N = 1,057)	
	Crude	Weighted	Crude	Weighted
Intervention cost, mean (95% CI)	\$173.61 (\$151.90–\$195.40)	\$174.80 (\$152.40–\$197.20)	\$67.80 (\$55.50–\$80.10)	\$67.97 (\$55.39–\$80.56)
Self-reported % quit (95% CI)	17.6% (13.3%–21.8%)	15.7% (11.8%–19.6%)	6.8% (5.3%–8.3%)	7.0% (5.5%–8.5%)
ICER	\$980 (\$652–\$1,712)	\$1,325 (\$751–\$2,462)	—	—

CI, confidence interval; ICER incremental cost-effectiveness ratios.

cessation counseling, and a prescription for cessation medication. The results suggest that the Tobacco Tactics intervention may be a cost-effective approach for hospitals that report on the Joint Commission's tobacco cessation performance measure set [39] to achieve those performance metrics.

Even if hospital-based tobacco cessation interventions such as Tobacco Tactics are cost-effective, health care payers may not yet realize the life-saving value of tobacco interventions and typically do not reimburse hospitals for their cost. Although the Affordable Care Act mandates that Medicare, Medicaid, and private insurance plans provide smoking cessation services with no cost-sharing, smoking cessation interventions delivered by hospital staff to inpatients cannot be separately billed (i.e., hospitals will not receive any additional reimbursement for nurse-delivered tobacco cessation services). As shown in Table 3, the cost to the hospital of offering Tobacco Tactics is relatively modest, at \$105 per patient. Financial incentives are positively realized when the hospital is also the insurer or payer, such as Kaiser Permanente and the Veterans Health Administration, as they bear the financial risk for the consequences of not providing preventive care.

Some of the costs of delivering the Tobacco Tactics intervention may vary if replicated in other hospitals or sustained over time. For example, nurse training costs represented approximately 20% of total labor and material costs and once all nurses are trained, training costs would be lower as only new nurses would require the training. Although there is a cost associated with modifying the EMR to document delivery of Tobacco Tactics according to Joint Commission standards, this is a one-time cost. Start-up costs were an average of \$2,318 per hospital, an outlay that is sufficiently modest and should not represent a barrier to initiating the program at new sites. Even if start-up costs were high, ongoing costs to maintain the intervention are lower and distributed across an increasing number of patients over time.

In this implementation trial, patients in the usual care control hospitals received a surprising amount of smoking cessation pharmacotherapy during the study period. For nearly all types of medications, patients in the usual care control hospitals received a similar amount of medications as patients in the intervention hospitals, which may simply reflect the widespread use of pharmacotherapy by U.S. smokers. Although SIPTW adjustments were used to make the intervention and usual care control patients more statistically similar, the medication costs were still higher than expected for usual care control group patients.

Limitations of the study

Although this quasi-experimental design more accurately reflects the reality of how hospital-level

Fig. 2 | Unweighted and weighted cost-effectiveness acceptability curves.

interventions are actually implemented, lack of randomization at the patient level means that despite statistical adjustment, variables inadvertently omitted from our statistical models may lead to bias in our cost-effectiveness results. Because utility data were not systematically collected, quality-adjusted life years or other measures of effectiveness commonly used in CEAs of smoking cessation interventions could not be calculated. Finally, although most insurers cover the cost of medication, it is possible that a subset of patients incurred a certain proportion of these costs. We would expect that if medications were entirely free to the patient, medication use would be higher. This could lead to bias if either group is differentially affected, which we believe is unlikely.

CONCLUSIONS

The Tobacco Tactics intervention is cost-effective relative to usual care smoking cessation care provided to hospitalized patients. The intervention had an incremental cost-effectiveness ratio of \$1,325 per quit. This is within the range of cost-effectiveness found for other smoking cessation interventions, indicating that the Tobacco Tactics intervention is a cost-effective use of health care resources.

Compliance with Ethical Standards

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Ethical Approval: For this type of study, formal consent is not required. This article does not contain any studies with human participants.

Informed Consent: This study does not involve human participants and informed consent was therefore not required.

Welfare of Animals: This article does not contain any studies with animals performed by any of the authors.

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