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The Cost-Effectiveness of Smoking Cessation Programs for Prevention of Wound Complications Following Total Ankle Arthroplasty: A Break-Even Analysis

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Abstract

Background: Tobacco use significantly increases the rate of wound complications in patients undergoing total ankle arthroplasty (TAA). Preoperative optimization through smoking cessation programs significantly minimizes the rate of infection and improves wound healing in arthroplasty procedures. Despite its utility, minimal research has examined the cost-effectiveness of preoperative smoking cessation programs to reduce the need for extracapsular irrigation and debridement (I&D) due to wound complications following TAA.

Methods: The cost of an I&D procedure was obtained from our institution's purchasing records. Baseline wound complication rates among tobacco users who have undergone TAA and smoking cessation program cost were obtained from literature. A break-even economic analysis was performed to determine the absolute risk reduction (ARR) to economically justify the implementation of preoperative smoking cessation programs. Different smoking cessation program and I&D costs were tested to account for variations in each factor. ARR was then used to calculate the number needed to treat (NNT) to prevent a single I&D while remaining cost-effective.

Results: Smoking cessation programs were determined to be economically justified if it prevents 1 I&D surgery out of 8 TAAs among tobacco users (ARR = 12.66%) in the early postoperative period (<30 days). ARR was the same at the literature high (27.3%) and weighted literature average (13.3%) complication rates when using the cost of I&D surgery at our institution ($1757.13) and the literature value for a smoking cessation program ($222.45). Cost-effectiveness was maintained with higher I&D surgery costs and lower costs of smoking cessation treatment.

Conclusion: Our model's input data suggest that the routine use of smoking cessation programs among tobacco users undergoing TAA is cost-effective for risk reduction of I&D surgery in the early postoperative period. This intervention was also found to be economically warranted with higher I&D costs and lower smoking cessation program costs than those found in the literature and at our institution.

Level of Evidence: Level III, economic and decision analysis.

Keywords: wound complications, total ankle arthroplasty, break-even analysis, smoking cessation, cost-effectiveness

Introduction

Superficial wound infections are a common complication following orthopaedic surgery, with previous literature reporting rates between 2.3% and 9.1%.[4,7,17] Following elective orthopaedic foot and ankle surgery, however, the overall wound complication rate was found to be as high as

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$$S_{total} \times C_i \times IR_i = (S_{total} \times C_s) + (S_{total} \times C_i \times IR_f)$$

Solving for IR_f yields:

$$IR_f = ((IR_i \times C_i) - C_s)/C_i$$

Figure 1. Equation used to calculate the break-even wound complication rate (adapted from Hatch et al).[12] C_i, cost of I&D surgery; C_s, cost of smoking cessation program; IR_i, initial wound complication rate; IR_f, break-even wound complication rate; S_{total}, total annual surgeries.

16.9%.[33] These infections significantly prolong hospital length of stay[1,30] and nearly double rehospitalization rates.[32] If left untreated, superficial wound complications can progress to periprosthetic joint infections, resulting in revision arthroplasty, conversion to arthrodesis, or potentially below-the-knee amputation.[2]

In the United States, surgical site infections (SSIs) alone account for approximately $3.5 billion of annual health care costs,[24,34] with more than 150 000 new cases annually.[27] Given the 16.4% compound annual growth rate in TAA utilization,[16] the 136.1% volume increase in the number of TAAs being performed from 2009 to 2019 in the United States,[13] and expanding indications for TAA,[11] it is reasonable to expect a considerable increase in the total number of wound complications among patients undergoing TAA.

Smoking and tobacco use have been well documented as significant predictors of postoperative complications. Although they have also been found to be a risk factor for delayed wound healing following TAA,[9] it is important to understand that tobacco use is just one of the many contributory factors for wound complications. Although Møller et al[19] have shown the potential benefits of preoperative smoking interventions in reducing postoperative morbidity and complications, literature regarding the cost-effectiveness of smoking cessation programs in preventing wound complications following TAA is sparse. The aim of this study was to determine the economic viability of implementing routine smoking cessation programs preoperatively to prevent the need for irrigation and debridement (I&D) surgery due to wound breakdown following TAA using break-even economic modeling.

Materials and Methods

Study Design

A break-even analysis, adapted from Hatch et al,[12] was performed to determine the cost-effectiveness of smoking cessation in preventing wound complications following TAA. The primary goal of this analysis was to determine the absolute risk reduction (ARR) necessary for the cost of smoking cessation programs in patients undergoing TAA to equal the cost of extracapsular I&D surgery for treatment of wound breakdown. This methodology has been previously used in orthopaedic studies to economically justify the utility of a preoperative intervention to prevent postoperative infection.[6,14,21-23] The equation in Figure 1 was used to calculate the break-even wound complication rate (IR_f) following utilization of a smoking cessation program using the initial wound complication rate in those who did not use a smoking cessation program (IR_i), the cost of I&D surgery (C_i), and the cost of a smoking cessation program (C_s). The ARR was calculated as the difference between IR_i and IR_f. The number needed to treat (NNT) was defined as the number of patients needed to treat with a smoking cessation program to prevent a single I&D surgery while remaining cost-effective. NNT was calculated as the inverse of ARR or 1/ARR.

Study Variables

The variable values used in this study were obtained from the literature and our institution. Two studies have evaluated the need for I&D due to wound complications in smokers following TAA, with rates of 8.8%[15] and 27.3%.[9] These values were assigned as the literature low and high rates of wound complication, respectively. The weighted average (13.3%) was also calculated and used as a third wound complication rate for comparison in our analysis.

Boylan et al[5] conducted an analysis examining the cost-effectiveness of preoperative smoking cessation programs in the prevention of periprosthetic joint infection in total joint arthroplasty. They used a base cost of $187.00 for a smoking cessation intervention, consisting of 2 extended counseling sessions, 2 abbreviated counseling sessions, and a 6-week supply of nicotine replacement therapy. Counseling services cost a total of $86.00 and were calculated using the 2017 Centers for Medicare & Medicaid Services (CMS) fee schedule. The cost of nicotine replacement therapy was $101.00 and was calculated using the National Average Drug Acquisition cost database. When adjusting values for inflation using the Consumer Price Index, the 2023 cost for a smoking cessation program is $222.45. Lastly, for the cost of an extracapsular I&D, our institutional value of $1757.13 was used. This was determined by using *Current Procedural Terminology* (*CPT*) code 27610 (under incision procedures on the leg [tibia and fibula] and ankle joint) to identify

Table 1. Cost-Effectiveness of Smoking Cessation Programs in the Prevention of Irrigation and Debridement in Tobacco Users Undergoing Total Ankle Arthroplasty.[a]

Cost of Smoking Cessation Program, USD	Initial Wound Complication Rate, %	Break-Even Wound Complication Rate, %	Absolute Risk Reduction, %	Number Needed to Treat
222.45	8.8[b]	–3.86	12.66	8
222.45	13.3[c]	0.64	12.66	8
222.45	27.3[d]	14.64	12.66	8

Abbreviation: USD, US dollar.
[a]Presumes irrigation and debridement surgery cost of $1757.13.
[b]Literature low complication rate.
[c]Weighted literature complication rate.
[d]Literature high complication rate.

Table 2. Cost-Effectiveness of Smoking Cessation Programs While Varying Intervention Cost.[a]

Cost of Smoking Cessation Program, USD	Initial Wound Complication Rate, %	Break-Even Wound Complication Rate, %	Absolute Risk Reduction, %	Number Needed to Treat
110.00	8.8[b]	2.54	6.26	16
222.45	8.8[b]	–3.86	12.66	8
500.00	8.8[b]	–19.66	28.46	4
110.00	13.3[c]	7.04	6.26	16
222.45	13.3[c]	0.64	12.66	8
500.00	13.3[c]	–15.16	28.46	4
110.00	27.3[d]	21.04	6.26	16
222.45	27.3[d]	14.64	12.66	8
500.00	27.3[d]	–1.16	28.46	4

Abbreviation: USD, US dollar.
[a]Presumes irrigation and debridement surgery cost of $1757.13.
[b]Literature low complication rate.
[c]Weighted literature complication rate.
[d]Literature high complication rate.

hospital account records with the associated *CPT* code. Records with additional *CPT* codes were excluded. Our institution's purchasing records were then used to identify itemized charges for each account record, which were then totaled and averaged to represent our institutional value for extracapsular I&D.

Sensitivity Analysis

Because variable values obtained from the literature and the cost for I&D at our institution will vary across hospital and health care systems, a sensitivity analysis was conducted to vary the cost of the smoking cessation program (C_s) and cost of I&D surgery (C_i) to account for these differences. These costs were examined using all 3 wound complication rates in our analysis.

Results

With a cost of $222.45 for a smoking cessation program and a cost of $1757.13 for I&D, implementation of preoperative smoking cessation programs is economically justified if it prevented 1 I&D surgery due to wound complication out of 8 TAAs among tobacco users (ARR = 12.66%) with baseline wound complication rates of 13.3% and 27.3% (Table 1). Cost-effectiveness was not maintained with a wound complication rate of 8.8%, as the final break-even rate exceeded the baseline complication rate given an ARR of 12.66%.

Given that each tobacco treatment clinic uses different regimens and therapies in their smoking cessation programs, variable treatment costs were analyzed for wound complication rates of 8.8%, 13.3%, and 27.3% while keeping the cost of I&D surgery ($1757.13) constant (Table 2). Reducing the cost of treatment to half of its literature value required an ARR of 6.26% (NNT = 16) and demonstrated economic viability across each wound complication rate. Approximately doubling the cost of treatment ($500.00) resulted in a loss of cost-effectiveness, regardless of baseline wound complication rate.

The cost of I&D surgery is highly variable across institutions. A range of I&D surgery costs ($900-$5000) were

Table 3. Cost-Effectiveness of Smoking Cessation Programs While Varying Cost of Irrigation and Debridement.[a]

Cost of I&D, USD	Initial Wound Complication Rate, %	Break-Even Wound Complication Rate, %	Absolute Risk Reduction, %	Number Needed to Treat
900.00	8.8[b]	–15.92	24.72	5
1300.00	8.8[b]	–8.31	17.11	6
1757.13[e]	8.8[b]	–3.86	12.66	8
3500.00	8.8[b]	2.44	6.36	16
5000.00	8.8[b]	4.35	4.45	23
900.00	13.3[c]	–11.42	24.72	5
1300.00	13.3[c]	–3.81	17.11	6
1757.13[e]	13.3[c]	0.64	12.66	8
3500.00	13.3[c]	6.94	6.36	16
5000.00	13.3[c]	8.85	4.45	23
900.00	27.3[d]	2.58	24.72	5
1300.00	27.3[d]	10.19	17.11	6
1757.13[e]	27.3[d]	14.64	12.66	8
3500.00	27.3[d]	20.94	6.36	16
5000.00	27.3[d]	22.85	4.45	23

Abbreviations: I&D, Irrigation and Debridement; USD, US dollar.
[a]Presumes smoking cessation program cost of $222.45.
[b]Literature low complication rate.
[c]Weighted literature complication rate.
[d]Literature high complication rate.
[e]Institutional value for irrigation and debridement.

economically assessed while keeping the cost for smoking cessation program ($222.45) constant (Table 3). For each complication rate, with I&D surgery costs of $3500.00 and $5000.00, cost-effectiveness improved with ARRs of 6.36% (NNT = 16) and 4.45% (NNT = 23), respectively. With costs of I&D surgery lower than our institutional value ($1757.13), economic viability was only observed with baseline wound complication rates of 13.3% and 27.3%.

Discussion

This study demonstrates that routine smoking cessation programs are economically justified for wound complication prevention following total ankle arthroplasties in the early postoperative period (<30 days) if 1 I&D is prevented out of 8 TAAs. Improved economic viability was observed with lower smoking cessation program costs ($110.00) and higher I&D surgery costs ($3500.00 and $5000.00). Although our study found that smoking cessation programs are not cost-effective at the literature low wound complication rate of 8.8%,[15] the institutional costs for *CPT* code 27610 only takes into account perioperative care, with additional inpatient and outpatient care likely to drive total costs to break-even range.

Literature examining smoking cessation programs and TAA has primarily investigated its utility with regard to wound healing. Numerous studies have found that wound complication rates are significantly greater among TAA patients who were former smokers compared to patients without a history of smoking.[9,15,31] Although the impact of smoking on wound healing is well documented in various medical specialties,[8,20,25,26] these studies specifically highlight that former smokers had lower wound complication rates than active smokers.[9,15] Additionally, Tischler et al[28] observed that in total joint arthroplasty patients, active smokers are more likely to undergo reoperation than nonsmokers (odds ratio = 1.82), with former smokers having no significantly increased risk of reoperation than nonsmokers (odds ratio = 1.1), further emphasizing the potential utility of smoking cessation programs.

Despite the limited number of studies examining the value of preoperative optimization prior to TAA,[10] such interventions have been found to be efficacious for total joint arthroplasty. Boylan et al[5] found that the average 90-day cost for patients enrolled in a mandatory smoking cessation program was $32.00 less than for patients not enrolled. Additionally, preoperative smoking interventions were found to reduce overall complication rates by 3 times that for those who did not receive an intervention.[19] Although there is no standardized timeline with regard to preoperative smoking cessation initiation, Lindström et al[18] found that such programs remained beneficial even if introduced as late as 4 weeks preoperatively. Although the mechanism underlying smoking cessation's effect on infection rate and wound healing remains undefined, it has been theorized to be a result of nicotine's effect on vasoconstriction, reduced oxygenation of peripheral tissues, and elevated white blood cell count.[18,19] Given the compound annual

growth in TAA utilization,[16] preoperative optimization with smoking cessation programs has significant cost-saving potential and implications in the future.

Our break-even analysis has several limitations. First, the study variables used in our analysis were taken from the literature and our own institution, which impacts the generalizability of our results. To account for this lack of external validity, a sensitivity analysis was performed for various costs of smoking cessation programs and I&D surgery. Second, our break-even model does not account for patient-specific factors such as race, ethnicity, sex, comorbidities, or differences in smoking cessation regimens, covariates that may impact the true break-even point. This study also identifies the threshold at which smoking cessation programs become cost-effective, rather than if the intervention itself is economically viable. Additionally, this study examines cost-effectiveness for preventing I&D in the early postoperative period (<30 days). Although *CPT* codes 27703 and 27704 (repair, revision, and/or reconstruction procedures on the leg [tibia and fibula] and ankle joint) could be analyzed to determine cost-effectiveness in the late postoperative period (>90 days), considerable variability in complexity and procedures performed precludes a single cost estimate from accounting for all long-term complications. This study also investigates how smoking cessation programs can address one of the many risk factors associated with wound complications, without considering how the interplay among various factors is likely contributory to the need for I&D. Finally, the findings of this study are limited in its ability to be feasibly implemented in a health system. Although such a proposition is resource intensive, orthopaedic surgeons can use telephone hotlines, online resources, coordinate care with a patient's primary care practitioner or cessation specialist, or code nicotine dependence as an *International Classification of Diseases, Tenth Revision* (*ICD-10*), code for insurance coverage of smoking cessation counseling to minimize burden of care and optimize smoking-cessation efforts.[3,29]

Despite these limitations, this is the first study to determine the cost-effectiveness and break-even wound complication rate of smoking cessation programs in preventing the need for I&D in total ankle arthroplasty patients. Our study shows that smoking cessation programs are economically justified with the given literature and institutional values if it prevented 1 I&D out of 8 TAAs in the early postoperative period (<30 days) with baseline infection rates of 13.3% and 27.3% (ARR = 12.66%). Break-even economics affords surgeons the opportunity to determine if smoking cessation programs are cost-effective within the scope of their practice using their own institutional values.

Conclusion

Our model's input data suggest that the routine utilization of smoking cessation programs among tobacco users prior to TAA is economically justifiable if it prevents 1 I&D surgery due to wound complication out of 8 TAAs in the early postoperative period. Cost-effectiveness was validated at lower smoking cessation program costs, higher baseline wound complication rates, and higher costs of I&D surgery. Surgeons at high-volume ankle arthroplasty centers should consider routinely optimizing patients with current tobacco use undergoing TAA with smoking cessation programs as a means of minimizing the costs associated with wound complications.

Ethical Approval

Ethical approval was not sought for the present study because the study used publicly available cost data.

Declaration of Conflicting Interests

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