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Smoking and Joint Replacement: Resource Consumption and Short Term Outcome

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Smoking has been shown to increase morbidity and mortality in surgical procedures. Microvascular and trauma surgeons have documented the adverse effect of smoking in the healing of skin flaps and increased complication rates in the treatment of nonunions. In addition, spine surgeons have shown the adverse effects of smoking in fusion rates. The objective of this study was to assess the effects of smoking on the incidence of short term complications, resource consumption, and length of hospital stay of patients undergoing arthroplasty of the hip and knee. Two hundred two patients who underwent joint replacement surgery were evaluated. A smoking history was assessed for all patients. The number of packs multiplied by the number of years as a smoker were calculated. Operative and anesthesia time and medical severity of illness were documented on all patients. Short term outcome was assessed using hospital charges, length of stay, inhospital consults, and the presence and number of complications during the acute hospitalization. One hundred forty–one primary and 61 revision procedures were done. The mean age of the patients was 66.07 years. Sixty-one percent of the patients had osteoarthritis, 3.9% had rheumatoid arthritis, 4.9% had osteonecrosis, 28% had a failed total knee or hip arthroplasty and 2% had a periprosthetic fracture. There were 25 patients who smoked and 177 patients who did not smoke. For patients who currently smoke, the mean number of packs of cigarettes smoked per day multiplied by the number of years as a smoker was 28.3. The average length of stay in the hospital was 5.1 days and the average hospital charges were $31,315. Patients who smoked were younger and had fewer comorbidities than patients who did not smoke. However, patients who smoked were found to have statistically longer surgical time and higher charges adjusted for age, procedure, and surgeon than patients who did not smoke. Patients who smoked also had longer anesthesia times. A history of smoking is obtained easily on all patients. Preoperative screening for nicotine use can predict operative time and health resource consumption. The exact reasons why patients who smoked had higher hospital charges remain elusive. Probable reasons include higher degree of operative complexity (orthopaedic severity of illness). In addition patients who smoked previously also had better short term outcome than patients who currently smoke. This indicates the importance of smoking abstinence before joint replacement surgery and other surgical procedures. Regardless of the exact causes, it is more expensive to treat patients who smoke. Contracting for orthopaedic care should include a history of smoking.

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In 1964, the Surgeon General released the first published official recognition that cigarette smoking is a direct cause of cancer and other serious diseases.[24] After that report, many public and private agencies have adopted measures to decrease the use of tobacco products in the general population. Community and school programs on smoking and health, and warnings printed on cigarette packages have been implemented. These antismoking efforts have been successful and the number of people who smoke has dropped almost 50% in the last 34 years. However, despite the adverse effects and consequences of smoking on health, 48 million American adults continue to smoke.[24]

Cigarette smoking is the leading cause of preventable death in people in the United States and results in more than $50 billion in direct medical costs. Furthermore, more than 400,000 Americans die from smoking related problems every year.[24]

In the past, much attention has been focused on the increased risk of smoking in the causal pathogenesis of cancer, cardiovascular, and pulmonary diseases.[21] Recently, the effect of cigarette smoke has gained increased interest among plastic and microvascular surgeons, because patients who smoke have been shown to have increased rate of infection and skin flap necrosis.[10–13,17,19,22] Studies relating the detrimental effect of cigarette smoke to various orthopaedic problems, such as delayed fracture repair, delayed healing after tibial lengthening, increased risk of nonunion, decreased bone density, and increased back pain, have been reported.[1,4,7,9,16–18,20,23,25,26]

To the authors' knowledge, the adverse effects of cigarette smoking on patients undergoing joint replacement surgery have not been reported. The objective of this study was to assess the consequences of smoking on resource consumption and short term outcome in patients undergoing joint replacement surgery.

MATERIALS AND METHODS

Two-hundred three consecutive patients admitted to the authors' hospital for elective unilateral arthroplasty of the hip or knee were included in this study. All surgeries were performed between January 1, 1997 and December 31, 1997 by one of three orthopaedic surgeons.

Data were collected prospectively using a standard questionnaire before admission for surgery or from medical charts. A thorough smoking history was obtained by the anesthesiologist for each patient in every case. The number of cigarettes smoked per day and the number of years as a smoker were recorded for patients who currently smoke and patients who smoked previously, and the time elapsed since cessation of smoking, if applicable. Patients were divided into several groups: patients who never smoked, patients who smoked previously, and patients who currently smoke. An additional grouping was done in which patients were divided into the following groups: patients who currently smoke and patients who currently do not smoke, which included patients who never smoked and patients who smoked previously. All patients who currently smoke had been smoking for at least 6 weeks before surgery. The number of packs per day multiplied by the number of years as a smoker were calculated for patients currently smoking and patients who smoked previously. To verify the information recorded from the medical charts, telephone calls were made to more than 75% of the patients included in the study. All patients who smoked previously and all patients who currently smoke were contacted via telephone.

Medical severity of illness was assessed using the Charlson Comorbidity Index[3] which takes into account the number and the severity of medical diseases present at the time of surgery. Each disease is given a weight score, and the total score for the index is obtained by adding the individual scores. Data on the comorbidity index were grouped into three categories depending on the total score (0, 1, and 2 or more), and analyzed as an ordinal variable. Length of anesthesia and length of the surgical procedure were recorded from the anesthesiologist's surgical record. Standard

preoperative laboratory tests were performed on all patients and the results were included in the database for the present analysis.

Additional short term outcome measures were assessed using hospital charges as a measure of resource consumption, length of stay, number of inhospital consults and the presence of complications during hospitalization. Complications were defined as events that occurred during surgery and intrahospital recovery that could increase resource consumption, lead to a specialist inhospital consult, or increase length of stay. Length of stay was divided into four categories: 0 to 3, 4 to 6, 7 to 9, and greater than 10 days. Likewise, three categories were used for the number of inhospital consults: 0, 1, and 2 or more.

Statistical Method

Before any analysis, the normality of the distribution of the continuous variables was assessed and, if necessary, either the data were transformed or nonparametric methods were used. Independent groups were compared using either the t test or analysis of variance (ANOVA) or the nonparametric counterparts of these tests, the Mann-Whitney or the Kruskall-Wallis test. To assess associations between discrete variables, chi square analyses were used. Multiple linear regression was used to assess, after adjusting for relevant covariates, the effect of smoking on resource consumption and short term outcome measures. A $p < 0.05$ was considered statistically significant. Statistical analysis was performed using SPSS 8.0 software (SPSS Inc, Chicago, IL).

RESULTS

Two hundred three consecutive patients underwent unilateral joint replacement surgery at the authors' institution during the study period. Patients who had a hip fracture were not included in the analysis. Also excluded from the analysis was one patient who smoked previously, had a length of stay of 42 days, six inhospital consults, the longest surgical and anesthesia times in the study, and a total hospital charge of $206,000.00.

The mean age (± standard deviation) for the remaining 202 patients was 66.07 ± 14.01 years (range, 22–93 years; median, 69 years), and 126 of these patients were women (61.9%). Preoperative diagnoses included: osteoarthritis, n = 123 (61%); rheumatoid arthritis, n = 8 (3.9%); osteonecrosis, n = 10 (4.9%); failed total knee or hip replacement, n = 52 (25.7%), infected total knee or hip replacement, n = 5 (2.4%); and periprosthetic fracture, n = 4 (2%). One hundred forty-one primary (72%) and 61 revision (28%) procedures were performed. Three board certified joint replacement surgeons performed all surgeries. One hundred ten procedures (54%) were done on the patient's right side and 92 (46%) were done on the left. One hundred ten (54%) patients had general anesthesia and 92 (46%) patients had epidural anesthesia. The charges for 1 hour of regional or general anesthesia were the same.

The average charge (± standard deviation) for all patients was $31,315 ± 10,764 (range, $15,684–$83,761; median, $28,801), with an average length of stay of 5.2 ± 2.85 days, mean number of inhospital consults of 0.63 ± 0.74, and average anesthesia and surgical times of 196.2 ± 64 and 117.4 ± 65.7 minutes, respectively. (Figs 1, 2) For the 202 patients, the overall complication rate was 21.8% (Table 1). The average number of comorbid diseases was 0.67, and the average comorbidity index score was 0.77.

The mean number of packs of cigarettes smoked per day multiplied by the number of years as a smoker for current smokers was 28.3 and for former smokers was 33.3. The average years since quitting smoking was 17 years. Table 2 compares the patients who never smoked, patients who smoked previously, and patients who currently smoke. Table 3 compares patients who currently smoke with patients who currently do not smoke.

Table 3 shows the age and short term outcome parameters for each of the groups of patients who smoke. There were statistically sig-

TABLE 1. Surgical Complications: Patients Who Currently Do Not Smoke* versus Patients Who Currently Smoke

Complication	Patients Who Currently Smoke (n = 177)	Patients Who Do Not Currently Smoke (n = 25)
Limitation of motion	1 (4.0)	1 (0.56)
Altered mental state	0 —	3 (1.69)
Hemorrhage	1 (4.0)	4 (2.25)
Cardiovascular	0 —	8 (4.50)
Wound infection	0 —	5 (2.80)
Vascular injury	1 (4.0)	0 —
Poor wound healing	0 —	1 (0.56)
Urinary and bladder disorders	0 —	4 (2.25)
Pneumothorax	0 —	1 (0.56)
Deep venous thrombosis	0 —	1 (0.56)
Joint instability	1 (4.0)	1 (0.56)
Fractures	0 —	2 (1.12)
Nerve injury	0 —	2 (1.12)
Patellar problems	0 —	1 (0.56)
Other	0 —	10 (5.60)
Total	4 (16)	44 (24.60)

Values are number of complications. (% within number of patients). Four patients had more than one complication.

*Patients who currently do not smoke include patients who never smoked and patients who smoked previously.

nificant differences with respect to age (p = 0.002), surgical time (p = 0.005) and anesthesia time (p = 0.02), and the comorbidity index (p = 0.003). There was a borderline statistically significant difference in charges among the three groups (p = 0.05). The lack of statistical significance in some of the other variables might be attributable to the small sample size of those patients who currently smoke or patients who previously smoked. When the patients who smoked previously and patients who never smoked are considered together, as shown in Table 2, statistically significant differences are found between patients who currently smoke and patients who do not currently smoke with respect to age, charges, and surgical and anesthesia times. A trend toward an increase in comorbid medical conditions

TABLE 2. Age and Short Term Outcome Parameters by Smoking Group

Variable	Total (n = 202)	Patients Who Currently Smoke (n = 25)	Patients Who Currently Do Not Smoke (n = 177)	p Value
Age (years)	66.07 ± 14	58.31 ± 13.69	66.9 ± 13.55	0.001
Charges ($)	31,315 ± 10,764	35,628 ± 16,899	30,706 ± 9506	0.032
Number of consults	0.63 ± 0.74	0.44 ± 0.77	0.66 ± 0.74	0.13*
Length of stay (days)	5.1 ± 2.8	5.44 ± 3.86	5.16 ± 2.6	.36*
Anesthesia time (minutes)	196.4 ± 64	225.53 ± 84.84	191 ± 60	0.01
Surgical time (minutes)	117 ± 65	156.7 ± 92	111.8 ± 59.5	0.001
Comorbid index	0.77 ± 1.09	0.56 ± 1.4	0.72 ± 0.97	0.09*
Complications (%)	21.8	16	22	0.3

Values are mean ± standard deviation.

*p value by chi square of dichotomized variables.

TABLE 3. Age and Short Term Outcome Parameters by Smoking Group

Variable	Total (n = 202)	Patients Who Never Smoked (n = 135)	Patients Who Smoked Previously (n = 42)	Patients Who Currently Smoke (n = 25)	p Value
Age (years)	66.07 ± 14	66.20 ± 14.56	69.31 ± 9.36	58.31 ± 13.69	0.002
Charges ($)	31,315 ± 10,764	30,210 ± 8756	32,302 ± 11,572	35,628 ± 16,899	0.05
Number of consults	0.63 ± 0.74	0.62 ± 0.73	0.79 ± 0.75	0.44 ± 0.77	0.2*
Length of stay (days)	5.1 ± 2.8	5.10 ± 2.6	5.3 ± 2.7	5.44 ± 3.86	0.4*
Anesthesia time (minutes)	196.4 ± 64	188.73 ± 56.60	201.9 ± 69.71	225.53 ± 84.84	0.02
Surgical time (minutes)	117 ± 65	110.08 ± 55.06	117.6 ± 72.2	156.7 ± 92	0.005
Comorbid index	0.77 ± 1.09	0.65 ± 0.94	1.24 ± 1.2	0.56 ± 1.4	0.003*
Complications (%)	21.8	21.5	26.2	16	0.6

Values are mean ± standard deviation.

*p value is chi square of dichotomized variables.

was observed in the population of patients who did not smoke ($p = 0.09$). Patients who currently smoke also had statistically significantly higher hemoglobin levels (14 ± 1.68 standard deviation versus 12.9 ± 1.56 standard deviation). A trend toward worse short term outcome parameters was seen in the patients who currently smoke, followed by patients who smoked previously.

Multiple stepwise regression analysis was performed using charges and surgical and anesthesia times as the dependent variable and age, gender, body mass index, preoperative diagnosis, surgeon, procedure, comorbid medical conditions, and current smoking as the independent variables. Variables that fit the model were surgeon (β coefficient = −11,434 ± 1168 standard error, $p < 0.001$), procedure (β coefficient = 8475 ± 1244 standard error, $p < 0.001$) and current smoking (three groups) (β coefficient = .111 ± 692 standard error, $p = 0.03$) when charges was the dependent variable. Variables that fit the model when surgical time was used as the dependent variable were surgeon (β coefficient = −85.3 ± 6 standard error, $p < 0.001$), procedure (β coefficient = 52.49 ± 6.2 standard error, $p < 0.001$), smoking (three groups) (β coefficient = 8.355 ± 3.4 standard error, $p = 0.01$) and age (β coefficient = −481 ± 0.2 standard error $p = 0.02$). Current smoking (two groups) also entered the model after surgeon and procedure (Table 4). When anesthesia time was used as the dependent variable, surgeon (β coefficient = −68.9 ± 6.7 standard error, $p < 0.001$), procedure (β coefficient = 55.7 ± 7.2 standard error, $p < 0.001$) and smoking (three groups) (β coefficient = 9.3 ± 4 standard error, $p = 0.02$) entered the model (Table 4).

DISCUSSION

Plastic and microvascular surgeons have used animal models to show that smoking delays wound healing, and increases the incidence of skin flap necrosis.[10,11] Direct damage to red blood cell precursors, macrophages, and fibroblasts and the vasoconstrictive and thrombogenic effects of nicotine have been implicated as possible etiologic factors.[11,10,18,20,21] Collagen production is an important factor in wound repair and also has been found to be decreased in patients who smoke.[12–14] The effects of cigarette smoke components on the immune system and microcirculation could be implicated in wound healing delays and the increased risk of infection observed in healthy young people who smoke.

The consequences of cigarette smoking on bone metabolism and long term outcome after orthopaedic procedures has been studied by numerous investigators.[1,4–9,16–18,20,23,25,26] Spine

TABLE 4. Stepwise Multiple Regression Analysis

Dependent Variable	First Variable	Second Variable	Third Variable	Fourth Variable	Variables Excluded
Charges	Surgeon: β −0.518, p < 0.001	Procedure: β 0.361, p < 0.001	Smoking: β 0.111, p = 0.03	—	Age, gender, body mass index, diagnosis, comorbidity
Operative time	Surgeon: β −0.634, p < 0.001	Procedure: β 0.366, p < 0.001	Smoking: β 0.104, p = 0.01	Age: β −102, p = 0.02	Gender, body mass index, diagnosis comorbidity
Anesthesia time	Surgeon: β −0.631, p < 0.001	Procedure: β 0.365, p < 0.001	Smoking: β 0.129, p = 0.003	—	Age, gender, body mass index, diagnosis, comorbidity

surgeons have reported three to four times higher incidence of nonunions or pseudarthrosis after bony fusions in patients who smoke when compared with patients who do not smoke.[2] Daftari et al[4] proposed an animal model to study the pathophysiologic mechanisms leading to these findings by implanting a cancellous bone graft in the anterior chamber of the eyes of 24 rabbits. Half of the rabbits received placebo and the other 12 received nicotine subcutaneously for 16 to 30 days. Observing the pattern of vessels during revascularization, Daftari et al[4] concluded that the rabbits that received nicotine had delayed revascularization within the graft, decreased area of revascularization, and predisposed to graft necrosis when compared with the rabbits in the control group. Silcox et al,[23] studied the effects of nicotine on the healing of lumbar spinal fusion performed on rabbits. The animals were observed for 35 days and then sacrificed. Biomechanical motion testing was performed and radiographs were taken at this time. Radiographs showed frank nonunion in the rabbits exposed to nicotine or relative bone graft demineralization, whereas in the rabbits in the control group, some spines showed evidence of fusion and early remodeling. A trend toward greater strength and stiffness at the fracture site in the rabbits in the control group was observed when biomechanical testing was performed.

Bolander et al[1] found a 50% delay in healing of open and closed tibial fractures in patients who smoke, when compared with patients who do not smoke. Lau et al,[15] reported a 50% higher incidence of delayed unions in an experimental animal model. The adverse action of cigarette smoking on bone metabolism also has been evaluated in an experimental study of tibial lengthening in rabbits. Ueng et al[25] divided 38 rabbits into two groups (rabbits that received intermittent smoke inhalation and rabbits that did not receive intermittent smoke inhalation). The tibia of each animal was lengthened 5 mm for 5 days. Rabbits were intermittently exposed to cigarette smoke for 8 hours. The animals were sacrificed at 2, 4, 6, or 8 weeks and histologic and biomechanical testing was performed. Histologic evaluation of the regenerating sites showed differences in granulation tissue resorption, and bone formation and remodeling. At 8 weeks, the rabbits that received smoke inhalation had a callus mainly composed of woven bone, whereas the rabbits that did not receive smoke inhalation had lamellar bone surrounding a medullary cavity. Mechanical testing at 4, 6, and 8 weeks postoperatively showed a decrease in torsional strength in the group of rabbits that received intermittent smoke inhalation. The investigators concluded that cigarette smoke inhalation delayed regenerating bone formation.

Carbon monoxide also can contribute to a hypercoagulable state observed in patients who smoke by inducing erythrocytosis. Blood viscosity is elevated because of an increased hematocrit value, red cell volume, and high plasma fibrinogen levels. This also results in decreased blood delivery to tissues.[19] In addition, blood flow in small arteries becomes turbulent and the endothelium increases sensitivity to factors involved in the coagulation cascade. The increased thrombi formation added to the increased erythrocyte volume may increase blood clot formation. In the current study, patients who smoked had higher hemoglobin levels than patients who did not smoke (14 ± 1.68 standard deviation versus 12.9 ± 1.56 standard deviation). In patients who smoked a decreased pulmonary function and oxygen carriage capacity by erythrocytes is compensated by an increase in red cell mass, allowing almost normal oxygen delivery to tissues. No clinically apparent large vessel thrombosis formation was seen in the present cohort of patients.

The time needed to reach physiologic baseline after smoking cessation has been reported to range from 1 to 6 weeks. The clearance of all free oxygen radicals produced by cigarette smoking occurs after 1 week but an adverse effect over macrophages[26] persists for at least 6 weeks. All the patients in the smoking group had been using tobacco during the last 6 weeks before surgery. This leads to a continuous physiologic derangement that persists during hospitalization. As reported above, this acute effect of nicotine did not correlate with an increased incidence of wound infection or delayed wound healing in this patient population. The authors think that other findings (increased resource consumption and surgical and anesthesia time) could be attributable to the chronic effects of cigarette smoking on arthritic joints. The metabolic and cellular effects of nicotine potentially could influence the severity of the underlying disease that lead patients to joint replacement. The orthopaedic severity of illness perhaps could account for the statistically significant increase in surgical time observed in this cohort of patients. Although the authors did not quantitate directly the orthopaedic severity of illness, it is suspected that it might be a contributing cause of increased surgical intervention time and increased consumption of resources in these patients.

The need for smoking abstinence before orthopaedic procedures remains controversial.

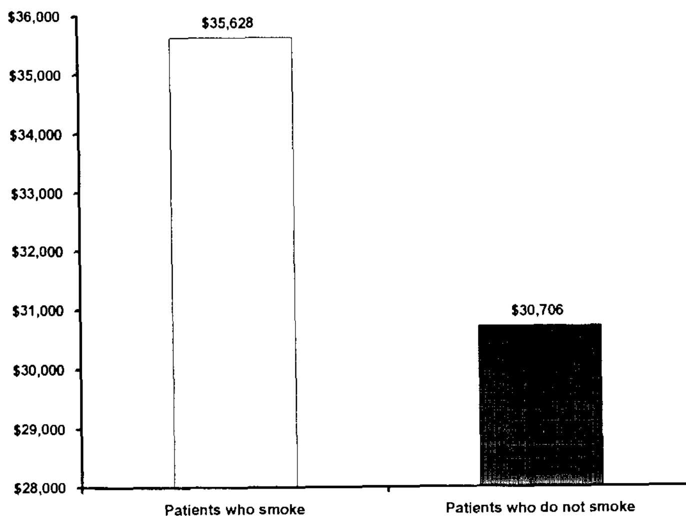

Fig 1. Hospital charges for patients who currently smoke and patients who do not smoke

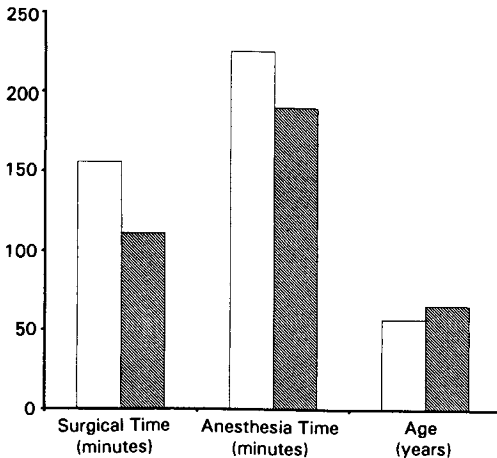

Fig 2. Age and operative times for patients who currently smoke (white bars) and patients who do not smoke (shaded bars).

In light of the results of the present study, the authors recommend a smoking abstinence of at least 6 weeks before surgery to decrease the risk of short term complications.

The current study shows a correlation between cigarette smoking and short term outcome in patients undergoing arthroplasty surgery. Patients who currently smoke who undergo joint replacement surgery consume more health resources and have longer surgical and anesthesia times. Although this group also shows a trend toward worse outcome with longer length of stay and higher number of consults, this difference was not statistically significant. This lack of significance probably could be attributable to the small number of patients who smoked in the study group. Although patients who currently smoke are younger and have less comorbid disease, they consume significantly more fiscal resources and have longer surgical times than patients who do not smoke before undergoing arthroplasty surgery.

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