CLINICAL RESEARCH STUDY

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Smoking Cessation Reduces Postoperative Complications: A Systematic Review and Meta-analysis

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ABSTRACT

OBJECTIVE: We aimed to review randomized trials and observational evidence to establish the effect of preoperative smoking cessation on postoperative complications and to determine if there is an optimal cessation period before surgery.

METHODS: We conducted a systematic review of all randomized trials evaluating the effect of smoking cessation on postoperative complications and all observational studies evaluating the risk of complications among past smokers compared with current smokers. We searched independently, in duplicate, 10 electronic databases and the bibliographies of relevant reviews. We conducted a meta-analysis of randomized trials using a random effects model and performed a meta-regression to examine the impact of time, in weeks, on the magnitude of effect. For observational studies, we pooled proportions of past smokers in comparison with current smokers.

RESULTS: We included 6 randomized trials and 15 observational studies. We pooled the 6 randomized trials and demonstrated a relative risk reduction of 41% (95% confidence interval [CI], 15-59, $P = .01$) for prevention of postoperative complications. We found that each week of cessation increases the magnitude of effect by 19%. Trials of at least 4 weeks' smoking cessation had a significantly larger treatment effect than shorter trials ($P = .04$). Observational studies demonstrated important effects of smoking cessation on decreasing total complications (relative risk [RR] 0.76, 95% CI, 0.69-0.84, $P < .0001$, $I^2 = 15\%$). This also was observed for reduced wound healing complications (RR 0.73, 95% CI, 0.61-0.87, $P = .0006$, $I^2 = 0\%$) and pulmonary complications (RR 0.81, 95% CI, 0.70-0.93, $P = .003$, $I^2 = 7\%$). Observational studies examining duration of cessation demonstrated that longer periods of cessation, compared with shorter periods, had an average reduction in total complications of 20% (RR 0.80, 95% CI, 3-33, $P = .02$, $I^2 = 68\%$).

CONCLUSION: Longer periods of smoking cessation decrease the incidence of postoperative complications.

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KEYWORDS: Meta-analysis; Perioperative; Smoking cessation; Systematic review

Tobacco smoking remains the leading cause of preventable death in the world.[1] Smoking cessation is associated with important benefits at individual and societal levels. Given the prevalence of smoking, considerable efforts have been directed toward developing interventions to assist smokers in quitting.[2] The role of smoking cessation benefits within

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specific disease classifications is becoming increasingly clear, with, for example, decreased morbidity and mortality among recent former smokers compared with continuing smokers with cardiovascular diseases.[3]

There has been a recent emerging body of evidence showing the benefit of preoperative and long-term postoperative smoking cessation.[4,5] In the United States, an estimated 53.3 million surgical and nonsurgical procedures are performed annually.[6] Approximately 8 to 10 million procedures requiring surgery and anesthesia are performed on cigarette smokers.[7,8] Smokers may be at a greater risk of postoperative complications than nonsmokers, including delayed wound healing, pulmonary complications, and mortality.[9] Preoperative smoking cessation seems to offer important benefits in reducing complications, although the duration of cessation required and the success of different interventions are not understood.[10] Clinical trials have evaluated smoking-cessation interventions at varying times before surgery and found clinically meaningful reductions in complications.[1-3] Trials also have evaluated both longer-[3] and shorter-term cessation,[4,11] including as late as the day of surgery.[4] We aimed to determine the strength of evidence supporting the role of smoking cessation and the duration of cessation required in preventing postoperative complications by undertaking a systematic review and meta-analysis of observational studies and randomized trials.

CLINICAL SIGNIFICANCE

- Smoking cessation before any type of surgery reduced risks of complications, including wound healing and pulmonary complications.
- Longer periods of smoking cessation before surgery demonstrated a significantly larger reduction in complications.
- Meta-analysis of randomized trials showed a relative risk reduction of 41% (95% confidence interval, 15-59, $P = .01$) for prevention of postoperative complications. This was supported with observational data examining total complications, wound healing, and pulmonary complications.

MATERIALS AND METHODS

Eligibility Criteria

We included both observational studies and randomized trials that evaluated the incidence of postoperative complications among populations who achieved smoking abstinence at a defined time point before surgery. We included any classification of cessation and any surgical populations. Studies had to report the proportion of clinical complications of past smokers and current smokers.

Study End Points

Our primary study outcome was postoperative complications defined as total complications. Secondary outcomes included any wound healing complications, pulmonary or respiratory complications, all-cause mortality, and all-cause length of hospital stay. When a primary complication was distinct and total complications were not reported (eg, wound healing), we did not combine them as a composite.

Search Strategy

In consultation with a medical librarian, we established a search strategy. We searched independently, in duplicate, the following 10 databases (from inception to September 2009): MEDLINE, EMBASE, Cochrane CENTRAL, AMED, CINAHL, TOXNET, Development and Reproductive Toxicology, Hazardous Substances Databank, PsycINFO, and Web of Science. Given that observational studies are poorly indexed in many databases, we also searched databases that include the full text of journals (*ScienceDirect,* and *Ingenta*, including articles in full text from ~1700 journals since 1993).[12] In addition, we searched the bibliographies of published relevant reviews and health technology assessments.[4,13-15] Searches were not limited by language, sex, or age.

Study Selection

Two investigators working independently, in duplicate, scanned all abstracts and obtained the full-text reports of records indicating that the study is an original research article evaluating the impact of smoking cessation on the outcomes of interest. After obtaining full reports of candidate studies (in full peer-reviewed publication or media article), the same reviewers independently assessed eligibility from full-text papers.

Data Collection

Two reviewers conducted data extraction independently using a standardized pre-piloted form (available from the authors on request). Reviewers collected information about the smoking intervention tested, the population studied (age, sex, underlying conditions, and types of surgery), the treatment dosages and dosing schedules, the relative effectiveness of treatments begun at any time points before surgery, the specific measurement of abstinence (sustained or point-prevalence), and the biochemical confirmation of smoking status. Study evaluation assessed risk of bias per a modified Cochrane risk-of-bias tool and included general methodological quality features specific to randomized trials, including allocation concealment, sequence generation, blinding status, intention-to-treat, sources of funding, and appropriate descriptions of loss to follow-up.[16] In addition, for nonrandomized evaluations, we applied the Newcastle-Ottawa Scale to evaluate the reporting rigor of observational studies.[17] The Newcastle-Ottawa Scale is a scoring checklist addressing issues of design and implementation of a

cohort or case-control, including issues of selection of participants, comparability of cases and controls, exposure, and outcomes. We entered the data into an electronic database, such that duplicate entries existed for each study; when the 2 entries did not match, differences were resolved through discussion and third-party arbitration.

Data Analysis

To assess inter-rater reliability on inclusion of articles, we calculated the *Phi* statistic, which provides a measure of interobserver agreement independent of chance.[18] We calculated the relative risk (RR) and appropriate 95% confidence intervals (CIs) of outcomes according to the number of complications reported in the original studies or substudies. Relative risks are typically a more clinically understood effect measure than odds ratios but cannot be used with some observational designs (eg, case-control studies). In circumstances of zero outcome events in one arm of a trial, we planned to apply the Haldane approach and add 0.5 to each arm, as suggested by Sheehe.[19] We applied the modified intent-to-treat principal, whereby a patient must receive at least 1 dose of the study intervention, in this case, surgery. We first pooled all randomized trials. We used the DerSimonian–Laird random effects method to pool studies,[20] which recognizes and anchors studies as a sample of all potential studies, and incorporates an additional between-study component to the estimate of variability.[21] We also calculated the I^2 statistic for each analysis as a measure of the proportion of the overall variation that is attributable to between-study heterogeneity.[22] We performed a sensitivity analysis to examine shorter-term (<4 weeks) and longer-term (>4 weeks) effects, and to examine intensive versus passive interventions, as defined by Thomsen et al.[4] We performed a meta-regression to examine the impact of time, in weeks, on log RR effect size. We display forest plots for our primary analysis, showing individual study effect measures with 95% CIs, and the overall DerSimonian–Laird pooled estimate and the regression plot with circle size conferring study sample size. For observational studies reporting total complications, we pooled the proportions of past smokers and current smokers by stabilizing the variances of the raw proportions (r/n) using a Freeman-Tukey type arcsine square root transformation and applying a random effects model.[23,24] Although several methods of pooling proportions exist,[25] the Freeman–Tukey method works well with both fixed and random effects meta-analysis and truncates at zero (because it is impossible to have less than zero events).[26] Where appropriate, we pooled using random effects RR. All P values are exact to $< .001$. We considered $P < .05$ as significant. Analyses were conducted using StatsDirect (version 2.5.2, www.statsdirect.com) and Comprehensive Meta-analysis (version 2, www.meta-analysis.com).

RESULTS

Results of the Literature Search

We reviewed 847 abstracts that met our search criteria. During the initial title and abstract selection process, we excluded 772 abstracts for reasons identified in Figure 1. The search was sensitive and not initially specific. Of those excluded, 139 abstracts were either non-human studies or non-English abstracts, 399 abstracts did not address the review topic, and a further 234 were review articles. We then obtained the full-text papers of the remaining 75 abstracts, and these proceeded to the full-text review stage. After rigorous screening of the 75 full-text articles, 30 of them satisfied the study inclusion criteria and were included in the initial review (Phi > 0.8). We then excluded 9 observational studies because of errors in the reporting of relevant outcome data per arm[27] and failing to report differences between past and current smokers on the outcomes of interest to the review.[28-35] Our review thus includes 6 randomized trials[4,11,36-39] and 15 observational studies.[40-54]

Characteristics of Included Studies

The majority of the studies were conducted in the United States.[40-42,45,48,50-53] Four studies were performed in Denmark,[49,55-57] 2 studies were performed in Australia,[36,46] 3 studies were performed in Japan,[43,47,54] 1 study was performed in Israel,[44] and 1 study was performed in Sweden.[58] Of the 21 included studies, 6 were randomized trials,[4,36,55-58] and the remaining were observational studies.[40-54] Of the observational studies, 10 were prospective comparisons[40-42,44-47,49,50,54] and 5 were retrospective analyses of patients with complications.[43,48,51-53] The included studies involved a heterogeneous array of surgical procedures, including lung,[40,45,47,51] orthopedic/bone and abdominal,[44,55] breast,[42,48] head/neck,[43] heart,[52,53] and various elective surgeries,[41,46,49,50,54,56-58] and reported on postsurgical complications among study participants. Time of study follow-up ranged from 1 day to 57 months.

Methodological Quality of Included Studies

Table 1 shows the risk of bias characteristics of the randomized trials. In general, studies were well reported with a low risk of bias. Table 2 shows the Newcastle-Ottawa Scale risk of bias for observational studies. One of the observational studies did not clearly define the length of time that smokers/past smokers ceased smoking before the surgery was performed.[49] Seven studies did not specify the follow-up period.[41-43,45,47,48,50]

Meta-analysis of Effectiveness

We pooled 6 randomized trials evaluating varied smoking interventions on total complications (Tables 3 and 4).[4,11,36-39] We found a pooled RR of 0.59 (95% CI, 0.41-0.85, $P = .01$, $I^2 = 14\%$; Figure 2). Our meta-regression analysis found that each week of cessation resulted in a larger effect size (B coefficient −0.191, 95% CI, −0.368 to

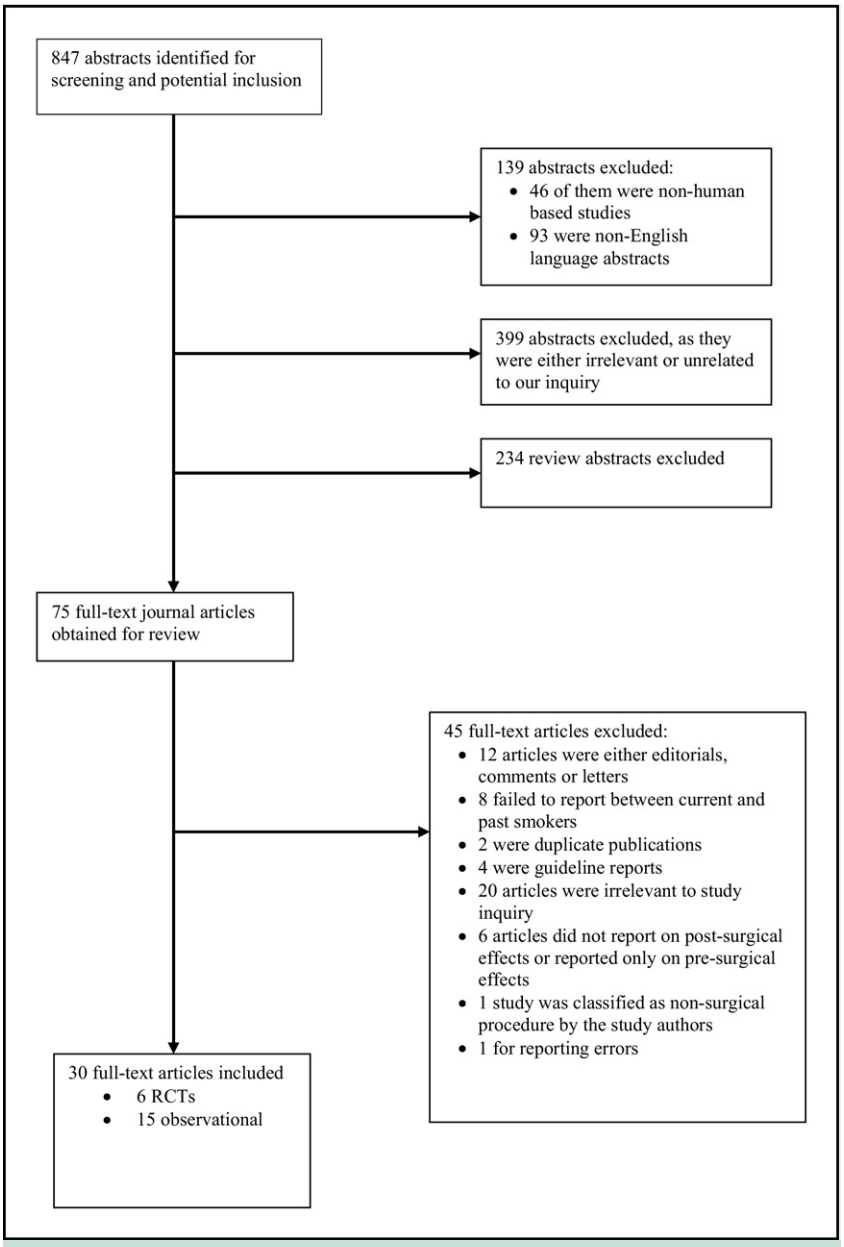

Figure 1 Flow diagram of study selection process. RCT = randomized clinical trial.

−0.014, $P = .03$; Figure 3). We performed a sensitivity analysis evaluating short-term studies (<4 weeks)[4,11] (RR 0.92, 0.53-1.60, $P = .78$) versus longer cessation (RR 0.45, 95% CI, 0.30-0.68, $P < .001$, $I^2 = 0\%$) (P value for difference .041). We also examined the use of intensive[11,37,39] (RR 0.55, 95% CI, 0.31-0.98, $P = .04$, $I^2 = 61\%$) versus less intensive (RR 0.78, 95% CI, 0.34-1.80, $P = .56$, $I^2 = 0\%$) interventions (P value for difference .49).

Observational Studies

Risk of Total Postoperative Complications. Tables 5 and 6 (available online) show the characteristics and outcomes of the 15 observational studies. Thirteen observational studies[40-44,46-49,52-54] provided sufficient details of general complications occurring between past smokers and current smokers. We were able to pool data from 12 of these studies.[40-44,46-48,52-54] (One study presented data only as adjusted odds and was excluded.)[49] There was a statistically significant reduction in the risk of total complications in former smokers compared with current smokers, with an average 22% (95% CI, 13-34) of former smokers experiencing an event compared with 32% (95% CI, 19-47) of current smokers (RR 0.76, 95% CI, 0.69-0.84, $P < .0001$, $I^2 = 15\%$).

Risk of Pulmonary Complications. Seven studies reported on the occurrence of pulmonary complications.[41,45-47,52-54]

Table 1 Risk of Bias Assessment: Randomized Clinical Trials

First Author, Year	Report Method of Sequence Generation	Report Efforts to Conceal Allocation	Report Blinding Status of Groups or Researchers	Refusal Rate of Eligible Participants	Intent-to-Treat Analysis	Free of Selective Reporting	Lost to Follow-Up > 20%	Study Funding Source(s)
Lindstrom 2008	+	+	+	39%	+	+	−	Public, industry provided drug
Moller 2002	+	−	−	28%	+	+	−	Public, industry provided drug
Myles 2004	+	+	+	−	+	+	+	Hospital, industry provided drug
Sorensen 2003	−	+	+	25%	+	+	−	Public, industry provided drug
Sorensen 2007	−	+	+	9%	+	+	−	Public, industry
Warner 2005	+	_	+	4%	+	+	−	Public, industry provided drug

+ = clear; − = unclear or negative.

Data were available to test for differences from all trials. We found differences between past (pooled incidence 15%, 95% CI, 6-28) and current (20%, 95% CI, 8-26%) smokers, which indicated a statistically significant decrease in pulmonary complications (RR 0.81, 95% CI, 0.70-0.93, $P = 0.003$, $I^2 = 7\%$) for the former. There was no statistically significant difference between early and late quitters on this outcome (RR 0.88, 95% CI, 0.28-2.71, $P = 0.81$, $I^2 = 94\%$), possibly because of low power (9%).[51-53]

Risk of Wound-Healing Complications. Five studies provided data on wound healing.[42,43,46,48,50] We found a statistically significant reduction in wound healing complications associated with former smokers compared with current smokers (RR 0.73, 95% CI, 0.61-0.87, $P = .0006$, $I^2 = 0\%$).

Length of Hospital Stay. Two studies reported on the average length of hospital stay.[40,50] One study reported the mean duration of hospital stay as 8 days in past smokers and 9 days in current smokers.[40] The other study found identical duration of stay after nephrectomy.[50]

Mortality. Only 2 studies reported on mortality.[41,45] Both studies had low event rates and found no difference between past and current smokers (RR 1.00, 95% CI, 0.64-1.55, $P = .98$).

Duration of Cessation Period. Seven studies provided adequate details on early versus late quitting and total complications.[40,43,45,47,51-53] We found that shorter-term (<4 weeks) cessation compared with longer-term cessation (>4 weeks) resulted in a relative risk decrease of 20% (RR 0.80, 95% CI, 3-33, $P = .02$, $I^2 = 68\%$) in total complication rates. The residual heterogeneity found in this estimate is from Warner et al,[53] who reported only on early quitters (>8 weeks cessation) versus late quitters (≤8 weeks cessation) before surgery instead of > 4 weeks compared with < 4 weeks cessation. The removal of this study reduced the I^2 value to 0%, but the effect size was no longer statistically significant ($P = .52$).

DISCUSSION

Our review demonstrates a clear benefit of smoking cessation to prevent postoperative complications compared with continued smoking. We found that randomized trials that successfully introduced a smoking cessation intervention and attained abstinence had significantly decreased rates of complications. This effect was magnified with longer durations of cessation. This finding is in agreement with the evidence from observational studies that smoking cessation reduces total postoperative complications, pulmonary complications, and complications of wound healing. From our analyses of both randomized trials and observational studies, longer cessation periods provide greater reductions in clinical complications.

There are both strengths and limitations to consider in our analysis. Strengths include our extensive searching, data abstraction in duplicate, and inclusion of both randomized and observational evidence that provides similar inferences. Our regression analysis shows that the length of time from smoking cessation is directly associated with the magnitude of subsequent complications. We found a larger treatment effect in randomized trials than in the observational studies. This may be due to the smaller sample size of the pooled randomized trials or may be a true therapeutic effect. The populations examined in the randomized trials were more homogenous than those in the cohort studies. Limitations of our analysis are predominantly related to the heterogeneous reporting of outcomes, inconsistent definitions of past smoking status, and differences in study designs across the observational studies. Although this has necessarily led to some study exclusions from the pooled analyses because of lack of relevant data on the key outcomes of interest, our observational study analyses indicated a significant decrease

Table 2 Risk of Bias Tables: Observational Studies*,†

First Author, Year	Adequate Case/ Control/Group Definition?	Potential for Bias in Case/Group Representation	Presence of Controls/Comparison Group?	Comparability among Groups	Ascertainment of Exposure	Cessation Validation Method	Non-Response Rates	Assessment of Outcome	Sufficient Follow-Up for Outcome Occurrence?	Adequacy of Follow-Up (Rates)
Barrera 2005	Yes	Yes	Yes	PQ were significantly older than NS.	Self-report	Self-report via questionnaire	Not applicable	Independent	Yes	>80%
Bluman 1998	Yes	Yes	Yes	CS were significantly younger than PS or NS.	Self-report	Self-report via questionnaire	Not applicable	Independent (medical records)	Yes	>80%
Chang 2000	Yes	Yes	Yes	No significant difference among groups.	Not specified	Medical records	Not applicable	Independent (medical records)	Unclear	>80%
Goodwin 2005	Yes	Yes	Yes	No major significant demographic differences except for the higher proportion of NS with stage 0 disease.	Self-report	Self-report	Not applicable	Independent (medical records)	Yes	>80%
Kuri 2005	Yes	Yes	Yes	NS were more likely to be female, and LQ were significantly younger than EQ.	Self-report	Comparison of 3 self-reports	Not applicable	Independent (medical records), self-reports	Unclear	Unclear
Levin 2004	Yes	Yes	Yes; groups were undefined by their percentages relative to sample size	No significant difference among groups in terms of age and gender.	Medical records	Medical records	Not applicable	Independent (medical records)	Yes	>80%
Mason 2009	Yes	Yes	Yes	NS were more likely to be female.	Medical records	Medical records	Not applicable	Independent (medical records)	Unclear	>80%
Myles 2002	Yes	Yes	Yes	CS were younger than PS or NS.	Self-report	Exhaled air CO	Not applicable	Independent (medical records), self-reports	No	>80%
Nakagawa 2001	Yes	Yes	Yes	Similar demographics among groups.	Self-report	Medical records, Self-report	Not applicable	Independent (medical records), self-report	Unclear	>80%
Padubidri 2001	Yes	Yes	Yes	TRAM flap surgery was used more in NS, and tissue expander method was used more often in smokers.	Medical records	Medical records	Not applicable	Independent (medical records)	Unclear	>80%
Sorensen 2005	Yes	Yes	Yes	Baseline demographics among groups were unreported.	Self-report	Medical records, validated by a second self-report during follow-up	Not applicable	Independent (medical records)	Yes	>80%
Taber 2009	Yes	Yes	Yes	CS had 1 y less of education and more alcohol use than other groups.	Self-report	Self-report	Not applicable	Independent (medical records)	Unclear	>80%
Vaporciyan 2002	Yes	Yes	Yes	Groups differed significantly in age, sex, and disease type.	Medical records	Medical records	Not applicable	Independent (medical records)	Yes	>80%

Table 2 Continued

First Author, Year	Adequate Case/Control/Group Definition?	Potential for Bias in Case/Group Representation	Presence of Controls/Comparison Group?	Comparability among Groups	Ascertainment of Exposure	Cessation Validation Method	Non-Response Rates	Assessment of Outcome	Sufficient Follow-Up for Outcome Occurrence?	Adequacy of Follow-Up (Rates)
Warner 1984	Yes	Yes	Yes	Baseline demographics among groups were unreported.	Self-reports, medical records	Medical records	Not applicable	Independent (medical records)	Yes	>80%
Warner 1989	Yes	Yes	Yes	Baseline demographics among groups were unreported.	Self-report, medical records	Urinary cotinine analysis	Not applicable	Independent (medical records)	Yes	>80%
Yamashita 2004	Yes	Yes	Yes	CS were younger than PS or NS.	Self-report	Self-report	Not applicable	Independent	Yes	>80%

CO = carbon monoxide; CS = current smoker; EQ = early quitters; LQ = late quitters; NS = nonsmoker; PS = past smoker; TRAM = transverse rectus abdominis myocutaneous.
Note: The Newcastle-Ottawa Scale was used to assess observational studies.
*Definition requires classification according to studied groups.
†Versus NS.

in complications for total, pulmonary, and wound healing complications. However, other analyses, such as those examining hospital stay and mortality, may be affected by low power. It is possible that if more trials reported specific outcomes, the results would be more precise.[25]

Ours is not the first systematic review to examine smoking cessation with postsurgical outcomes. A meta-analysis by Thomsen et al[4] examined complication rates in 6 randomized trials and came to a similar effect estimate as that reported in our review. They also examined smoking cessation and demonstrated sustained cessation using a narrative review. Another narrative review by Theadom and Cropley[14] included 12 observational studies examining postsurgical complications using inclusion criteria similar to ours. They did not pool studies but concluded that longer periods of cessation seem to be associated with decreased rates of complications. Our analysis includes 3 additional studies and pooled total complications to demonstrate that smoking cessation in observational studies is associated with a statistically significant reduction in total postsurgical complications, in accordance with the pooled randomized trials evidence, and significant reductions in pulmonary and wound-healing complications. Furthermore, our analysis demonstrated that increasing cessation periods results in a clinically important and statistically significant reduction in complications. The 2004 Surgeon General's Report on smoking concluded that there was sufficient evidence to infer a causal relationship between smoking and increased risks for adverse surgical outcomes related to wound healing and respiratory complications. However, the report relied on observational studies, did not examine the magnitude of risks or time periods of increased risk, and reported findings as a narrative review.[59]

A proof of concept randomized study by Sorensen et al[60] deliberately randomized smokers to receive an incision or not after several weeks of smoking cessation therapy. In an effort to determine the duration of cessation required, study subjects were evaluated at 1, 4, 8, and 12 weeks postcessation, with incisions administered at each evaluation period. The largest and most sustained treatment effects were observed with 4 weeks cessation.

The trials included in our randomized trials meta-analysis provided a variety of interventions that we classified as intensive or less intensive, ranging from the use of bupropion therapy and intensive counseling (intensive) to nicotine replacement therapy patch and brief counseling services (less intensive), as suggested by Thomsen et al.[4] More intensive interventions for cessation of smoking before surgery are therefore relevant for postoperative risk reduction. Pharmacotherapies available to surgery populations include nicotine replacement therapy, bupropion, and varenicline. A recent meta-analysis we conducted examined the short-term (~4 weeks) cessation rates of these pharmacotherapies. Our study demonstrated consistent benefits from each intervention with varenicline, bupropion, and nicotine replacement therapy offering a cascade of relative benefit. The benefits

Table 3 Characteristics of Included Randomized Trials

First Author, Year	Type of Study	Types of Surgery	Intervention and Control Interventions	Sample Size	Male (%)	Mean Age (y)	Cessation Period Defined Clearly?	Cessation Validation Method	Pre-surgery Smoking Cessation Period	Cessation Intervention (and Period Pre-surgery)	Follow-up Period Postsurgery
Lindstrom 2008	RCT	Hernia repair, laparoscopic cholecystectomy, hip/knee prosthesis	IG = 47%; smokers who received an intervention to keep them smoke-free from 4 wk preoperatively to 4 wk postoperatively CG = 53%; smokers who did not receive any such intervention for smoking cessation pre-surgery In per protocol analysis, smokers were grouped as: 1. Smokers who quit ≥ 3 wk preoperatively and 4 wk postoperatively 2. Smokers who quit 1-2 wk preoperatively and 4 wk postoperatively 3. Smokers who continued smoking or only reduced smoking	102	53	55	Yes	Self-report and CO	IG: smoke-free from 4 wk preoperatively to 4 wk postoperatively In per-protocol analysis groups: group 1, ≥3 wk preoperatively and 4 wk postoperatively; group 2, 1-2 wk preoperatively and 4 wk postoperatively; group 3, cessation period undefined	Yes; individual counseling, telephone hotline, and free nicotine substitution (nicotine replacement therapy) for 4 wk pre-surgery	30 d
Moller 2002	RCT	Hip or knee replacement	IG = 52%; defined as smokers who received an intervention to keep them smoke-free or help reduce smoking by 50% from 6-8 wk preoperatively CG = 48%; defined as smokers who did not receive any such intervention for smoking cessation pre-surgery	108	42.6	65	Yes	Exhaled air CO	6-8 wk pre-surgery and 10 d postsurgery	Yes; information and weekly counseling for 6-8 wk pre-surgery	4 wk
Sorensen 2003	RCT	Colorectal surgery	IG: 47%; defined as smokers who received an intervention to keep them smoke-free or reduce their smoking 2-3 wk pre-surgery and until sutures were removed CG: 53%; defined as smokers who did not receive any such intervention and were asked to maintain their daily smoking habits	57	65	65.5 (median)	Yes	Self-report, exhaled air CO; salivary cotinine	IG: advised to be smoke-free or reduced smoking from 2-3 wk pre-surgery	Yes; counseling and nicotine replacement therapy	30 d
Sorensen 2007	RCT	Elective open incisional or inguinal herniotomy	IG: 70%; defined as smokers who received an intervention by means of an advice and reminder to stop smoking at least 1 mo pre-surgery and until sutures were removed CG: 30%; defined as smokers who did not receive any such intervention	213	84.5	54.6 (median)	Yes	Self-report, exhaled air CO; salivary cotinine	IG: advised to stop smoking at least 1 mo pre-surgery	Yes; 3 levels: advice only, advice and telephone reminder, advice and reminder and outpatient nicotine substitution demonstration	3 mo
Myles 2004	RCT	General, orthopedic, urologic, ear, nose, throat, faciomaxillary	IG: Bupropion 7 wk before expected surgery (150 mg bid) + 1 telephone counseling. CG: placebo + 1 telephone counseling	47	66	45	Yes	Exhaled air CO	Both groups 7 wk pre-surgery	Bupropion (150 mg bid)	6 mo
Warner 2005	RCT	Orthopaedic, intra-abdominal, spinal, genitourinary, otorhinolaryngologic, gynecologic, other	IG: nicotine patch applied on day of surgery CG: placebo patch	121	48	47	Yes	Exhaled air CO	Both groups, day of surgery	Nicotine patch applied on day of surgery	1 mo

RCT = randomized clinical trial; IG = intervention group; CG = control group; CO = carbon monoxide.

Table 4 Effects of Randomized Trials on Perioperative Complications

First Author, Year	Intensity of Preoperative Smoking Intervention	Definition of Perioperative Complication	Relative Risk (95% CI) for Perioperative Complications
Lindstrom 2008	Intensive	Events causing additional medical or surgical treatment or investigation, prolonged hospital stay, unscheduled postoperative checkups within 30 d	0.51 (0.27-0.97)
		Any wound complication	0.49 (0.20-1.16)
Moller 2002	Intensive	Death or postoperative morbidity requiring treatment within 30 d	0.34 (0.19-0.64)
		Wound healing complications	0.17 (0.05-0.56)
Myles 2004	Less intensive	Postoperative wound infections	0.82 (0.06-11.33)
Sorensen 2003	Intensive	Adverse events within 30 d requiring medical or surgical intervention	0.94 (0.51-1.73)
Sorensen 2007	Less intense	Postoperative wound infection with swollen or infected wound or medical intervention required at suture removal	0.71 (0.21-2.41)
Warner 2005	Less intensive	Serious postoperative adverse events	0.86 (0.24-3.03)

CI = confidence interval.

of these short-term cessation interventions also seem to extend into longer periods of cessation (<6 months).[2,26]

CONCLUSIONS

In the United States, approximately 8 to 10 million procedures requiring surgery and anesthesia are performed on cigarette smokers.[8] To interpret the possible impact of smoking cessation on population-wide complications, we conservatively estimate that, if all patients were offered a smoking-cessation intervention before surgery, and assuming a 25% cessation rate, this could result in 2 million (95% CI, 1,769,600-2,248,800) complications avoided, resulting in large savings for both patients and health services. The review finding that each additional week of smoking cessation has a significant impact on the reduction of postoperative complications highlights the importance of designing an appropriate secondary care smoking-cessation service. A service designed around early assessment of the smoking

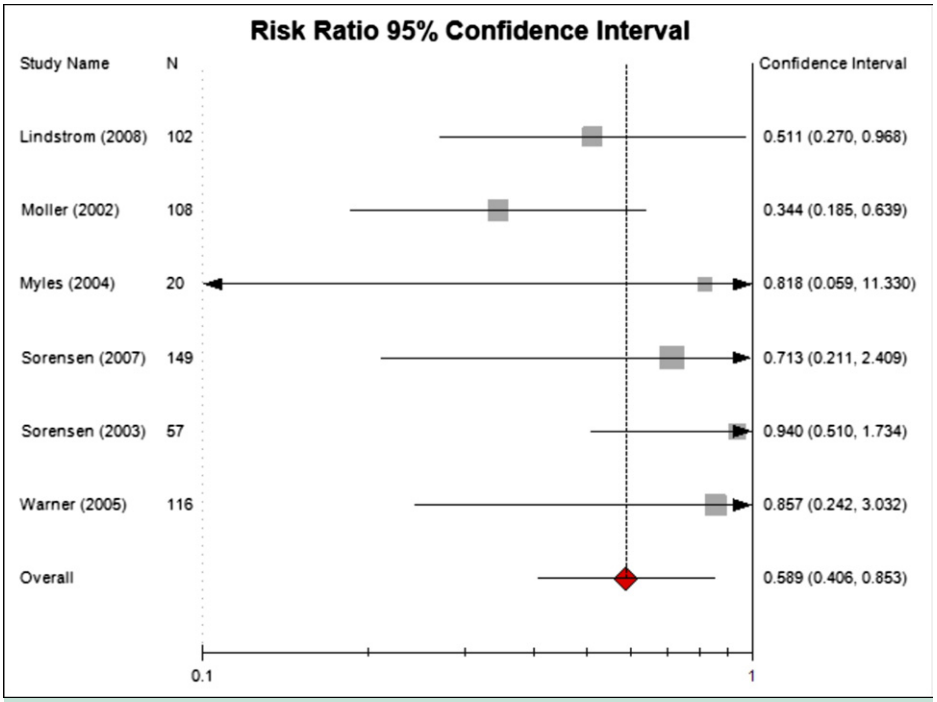

Figure 2 Forst plot of randomized clinical trials on total complications.

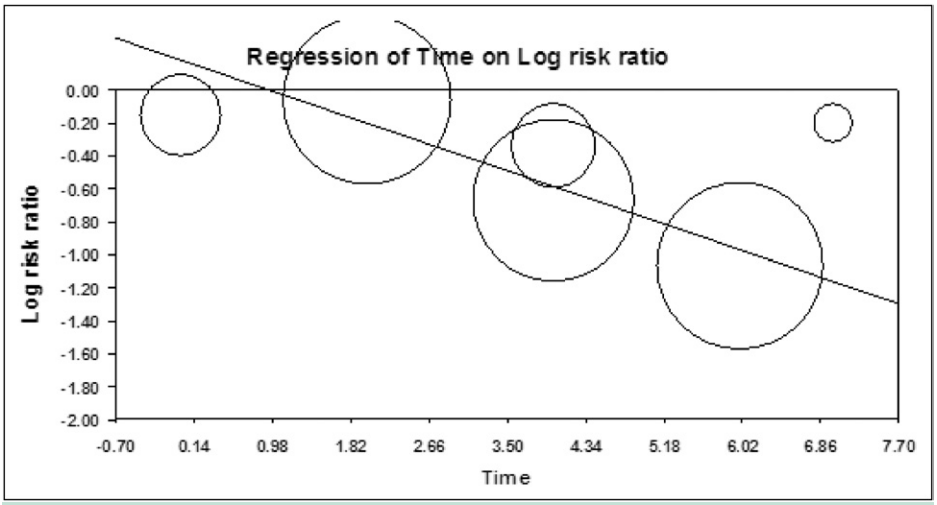

Figure 3 Meta-regression plot, effect of time of cessation on complications.

status of surgery patients and rapid referral to a smoking-cessation program could maximize the cessation period before surgery, resulting in greater reductions in postoperative complications in the secondary care setting.

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Table 5 Characteristics of Included Observational Studies*,†

First Author	Type of Study	Primary Surgery Type	Studied Group According to Smoking Status	Sample Size	Male (%)	Mean Age (y)	Cessation Period Defined Clearly?*	Cessation Validation Method	Pre-surgery Smoking Cessation Period	Cessation Intervention (and Period Pre-surgery)	Follow-up Period Postsurgery
Barrera 2005	Cohort	Lung tumor resection/thoracotomy	NS = 21% PS = EQ: defined as those who quit smoking > 2 mo pre-surgery = 62% LQ: defined as those who quit smoking ≤ 2 mo, but > 1 wk pre-surgery = 13% CS = 4%	300	48	64 ± 12	Yes	Self-report via questionnaire	EQ quit smoking for > 2 mo pre-surgery LQ quit smoking for ≤ 2 mo, but > 1 wk pre-surgery	No	30 d
Bluman 1998	Cohort	General, orthopedic, urologic or cardiovascular elective surgery	NS = 20% PS = 46%; defined as those who smoked > 2 wk pre-surgery CS = 34%; defined as those who smoked ≤ 2 wk pre-surgery	410	97	59.5	Yes	Self-report via questionnaire	PS: >2 wk pre-surgery CS: ≤2 wk pre-surgery	No	NR
Chang 2000	Cohort	Breast reconstruction with TRAM flaps	NS: 67% PS: defined as those who quit smoking at least 4 wk pre-surgery = 21% CS = 13%	718	NR	Not specified	Yes	Medical records	PS: quit smoking at least 4 wk pre-surgery	No	NR
Goodwin 2005	Cohort	Tissue expander/implant breast reconstruction	NS = 74% PS = 15%; defined as those who quit smoking > 4 wk pre-surgery CS = 11%; defined as having continued or stopped smoking < 4 wk pre-surgery	515	0	47	Yes	Self-report	PS = stopped smoking > 4 wk pre-surgery CS = continued or stopped smoking < 4 wk pre-surgery	No	20 mo
Kuri 2005	Cohort	Reconstructive head and neck surgery	NS = 21% PS = LQ = 18%; defined as smoking within 8-21 d pre-surgery IQ = 11%; defined as smoking within 22-42 d pre-surgery EQ = 35%; defined as smoking within ≥ 43 d pre-surgery CS = 15%; defined as smoking within 7 d pre-surgery	188	79.8	59	Yes	Comparison of 3 self-reports	LQ: smoking within 8-21 d pre-surgery IQ: smoking within 22-42 d pre-surgery EQ: smoking within 43 d or longer pre-surgery CS = smoking within 7 d pre-surgery	No	NR
Levin 2004	Cohort	Onlay bone graft, sinus lift	PS: patients who quit smoking for ≥ 6 mo pre-surgery MS: CS smoking < 10 cigarettes/d and smoking history < 10 y HS: CS smoking > 10 cigarettes/d and smoking history > 10 y Groups were undefined by their percentages relative to sample size	128	33.6	NR	Yes	Medical records	PS: quit smoking for ≥ 6 mo pre-surgery	No	≥6 mo postsurgery

Table 5 Continued

First Author	Type of Study	Primary Surgery Type	Studied Group According to Smoking Status	Sample Size	Male (%)	Mean Age (y)	Cessation Period Defined Clearly?*	Cessation Validation Method	Pre-surgery Smoking Cessation Period	Cessation Intervention (and Period Pre-surgery)	Follow-up Period Postsurgery
Mason 2009	Cohort	Lung resections	NS = 21%; defined as never smokers or those who smoked < 100 cigarettes in their lifetime PS: LQ = 5.1%; defined as those who quit smoking for > 14 d to 1 mo pre-surgery IQ = 12%; defined as those who quit 1-12 mo pre-surgery EQ = 50%; defined as those who quit smoking > 12 mo pre-surgery CS = 20%; defined as smoking within 14 d pre-surgery	7990	48.3	66	Yes	Medical records	PS = LQ: quit smoking for > 14 d to 1 mo pre-surgery IQ: quit smoking 1-12 mo pre-surgery EQ: quit smoking > 12 mo pre-surgery CS = smoking within 14 d pre-surgery	No	NR
Myles 2002	Cohort	Ambulatory surgery	NS = 35%; defined as never smokers with a CO_{exp} of ≤ 10 ppm PS = 24%; defined as those who quit smoking for > 28 d pre-surgery CS = 41%; defined as CS or with CO_{exp} of > 10 ppm	489	38	39	Yes	Self-report and CO analysis	PS = quit smoking for > 28 d pre-surgery	No	7 d
Nakagawa 2001	Cohort	Pulmonary surgery	NS = 41% PS = RS = 5%; defined as those who quit smoking 2-4 wk pre-surgery ES = 42%; defined as those who quit smoking for > 4 wk pre-surgery CS = 13%; defined as those who smoked within 2 wk pre-surgery	288	58	61.5	Yes	Medical records, self-report	PS = RS = 2-4 wk pre-surgery ES = >4 wk pre-surgery CS = within 2 wk pre-surgery	No	NR
Padubidri 2001	Cohort	Postmastectomy breast reconstruction	NS = 69%; defined as those who had never smoked PS = 10%; defined as previous smokers who quit smoking ≥ 3 wk pre-surgery CS = 21%; defined as those who were still smoking at the time of surgery	748	0	49.2	Yes	Medical records	PS: quit smoking ≥ 3 wk pre-surgery	Yes; quitting smoking was advised during enrolment at clinic	NR
Sorensen 2005	Cohort	Elective and emergency laparotomies	NS = 29% PS = 29%; defined as those who previously smoked but quit sometime pre-surgery CS = 42%; defined as those who smoked at time of surgery and at follow-up	310	45.5	64.6 (median)	No	Medical records, validated by a second self-report during follow-up	Not specified	No	33-57 mo
Taber 2009	Cohort	Laparoscopic donor nephrectomy	NS = 63%; defined as never smokers PS = 18%; defined as those who previously smoked but quit at least 2 wk pre-surgery CS = 19%; defined as those who smoked up to the surgery day	221	45	39	Yes	Self-report	PS: quit at least 2 wk pre-surgery	No	NR

Table 5 Continued

First Author	Type of Study	Primary Surgery Type	Studied Group According to Smoking Status	Sample Size	Male (%)	Mean Age (y)	Cessation Period Defined Clearly?*	Cessation Validation Method	Pre-surgery Smoking Cessation Period	Cessation Intervention (and Period Pre-surgery)	Follow-up Period Postsurgery
Vaporciyan 2002	Cohort	Pneumonectomy	NS = 13% S = LQ = 23%; defined as persons who quit smoking < 1 mo pre-surgery EQ = 63%; defined as those who quit smoking ≥ 1 mo pre-surgery	257	69.6	60 ± 10 (median)	Yes	Medical records	LQ: quit < 1 mo pre-surgery EQ: quit ≥ 1 mo pre-surgery	No	30 d
Warner 1984	Cohort	Coronary artery bypass grafting	NS = 9% CS = 25%; defined as those who never stopped smoking pre-surgery Stopped smoking < 2 wk pre-surgery = 17% Stopped smoking 2-4 wk pre-surgery = 9% Stopped smoking 4-8 wk pre-surgery = 6% Stopped smoking > 8 wk pre-surgery = 35%	500	77	58.2	Yes	Medical records	Group 1: smokers who stopped < 2 wk pre-surgery Group 2: smokers who stopped 2-4 wk pre-surgery Group 3: smokers who stopped 4-8 wk pre-surgery Group 4: smokers who stopped > 8 wk pre-surgery	No	30 d
Warner 1989	Cohort	Coronary artery bypass grafting	NS = 22%; defined as those who had never smoked and assigned a smoke-free day of 150 PS = 69%; defined as previous smokers who quit smoking sometime in the past, and this group includes LQ = 11%, defined as those who quit ≤ 8 wk pre-surgery, EQ = 58%, defined as those who quit > 8 wk pre-surgery, and CS = 9%, defined as those with cotinine levels > 0.5 μg/mL and assigned a smoke-free day of −1	192	83	64	Yes	Urinary cotinine analysis	Among PS, LQ: quit ≤ 8 wk pre-surgery EQ: quit > 8 wk pre-surgery	No	1 y (via correspondence)
Yamashita 2004	Cohort	Elective minor surgeries	NS = 48%; defined as those who had never smoked PS = 37%; defined as smokers who quit smoking < 2 d pre-surgery CS = 16%; defined as smokers who smoked until 1 d pre-surgery	1008	52.6	53	Yes	Self-report via interview	PS: quit smoking < 2 d pre-surgery CS: quit smoking > 1 d pre-surgery	No	30 d or until discharge

CO = carbon monoxide; CS = current smoker; EQ = early quitters; ES = ex-smoker; HS = heavy smoker; IQ = intermediate quitters; LQ = late quitters; MS = mild smoker; NR = not reported; NS = nonsmoker; ppm = packs per month; PS = past smoker; RR = relative risk; RS = recent smoker; TRAM = transverse rectus abdominis myocutaneous; β = group numbers presented do not sum up to total N.

*Definition requires classification according to studied groups.

†Versus NS.

Table 6 Effects of Smoking Cessation in Observational Studies*,†

First Author	Studied Group According to Smoking Status	Sample Size	Male (%)	Complication Risk/Percentage Risk/Relative Risk/Odds Ratio	Important Findings
Barrera 2005	NS = 21% PS = EQ: defined as those who quit smoking > 2 mo pre-surgery = 62% LQ: defined as those who quit smoking ≤ 2 mo but > 1 wk pre-surgery = 13% CS = 4%	300	48	% Overall complications and 95% CI NS = 8% (1.24-14.38) PS = 19% (14.1-24.46) CS = 23% (0.18-45.98) % Pneumonia and 95% CI NS = 3% (−1.14 to 7.4) PS = 11% (6.69-14.83) CS = 23% (0.18-45.98) % Atelectasis and 95% CI NS = 0% PS = 5% (2.09-7.77) CS = 0% Mean hospital length of stay (d) NS = 6 PS = 8 CS = 9	Overall pulmonary complications and pneumonia incidence were higher among CS compared with PS and NS. CS had longer hospital stays than PS and NS. PQ (>2 mo quit time) had fewer complications compared with recent quitters (≤2 mo, >1 wk quit time).
Bluman 1998	NS = 20% PS = 46%; defined as smoking > 2 wk pre-surgery CS = 34%; defined as smoking ≤ 2 wk pre-surgery	410	97	% Any complications and 95% CI NS = 5% (0.22-9.54) PS = 13% (8.04-17.62) CS = 22% (15.15-28.83) % Pulmonary infections and 95% CI NS = 0% PS = 1% (−0.4 to 2.54) CS = 3% (0.1-5.58) % Atelectasis and 95% CI NS = 4% (−0.4 to 7.72) PS = 7% (3.72-11.26) CS = 8% (3.37-12.23) % Hospital readmission for pneumonia and 95% CI NS = 1% (−1.16 to 3.6) PS = 0 CS = 1% (−0.68 to 2.1) % Mortality due to pulmonary disease and 95% CI NS = 0 PS = 1% CS = 1% (−0.51 to 1.57)	Postsurgical pulmonary complication risk was 6× higher in CS compared with NS (OR 5.5, CI, 1.9-16.2). CS who reduced smoking pre-surgery were 7× more likely to develop postsurgical pulmonary complications compared with those who did not reduce smoking. Among those reducing cigarette smoking ≤ 1 mo pre-surgery, those who reduced closest to surgery were at greatest risk of developing complications.
Chang 2000	NS: 67% PS: defined as persons who quit smoking at least 4 wk pre-surgery = 21% CS = 13%	718	NR	% Overall flap necrosis and 95% CI NS: 22.6% (18.8-26.3) PS: 25.3% (18.4-32.3) CS: 31.1% (21.6-40.7) % Mastectomy skin flap necrosis and 95% CI NS: 9% (6.4-11.6) PS: 10% (5.2-14.8) CS: 18.9% (10.8-27.0) % Flap fat necrosis and 95% CI NS: 6.5% (4.3-8.7) PS: 8.7% (4.2-13.2) CS: 7.8% (2.3-13.3)	PS who quit smoking at least 4 wk pre-surgery have reduced postsurgical complications compared with CS. Smokers with a smoking history of > 10 pack-y were at an increased risk of perioperative complications compared with those with < 10 pack-y. CS were at a higher risk of mastectomy skin flap necrosis than NS.

Table 6 Continued

First Author	Studied Group According to Smoking Status	Sample Size	Male (%)	Complication Risk/Percentage Risk/Relative Risk/Odds Ratio	Important Findings
Goodwin 2005	NS = 74% PS = 15%; defined as having stopped smoking > 4 wk pre-surgery CS = 11%; defined as having continued or stopped smoking < 4 wk pre-surgery	515	0	Comparison is between NS and smokers (CS + PS) % Total complications and 95% CI NS = 15.1% (11.6-18.7) CS = 37.9% (29.6-46.16) % Reconstructive failure and 95% CI NS = 1.6% (0.34-2.86) CS = 5.3% (1.48-9.12) % Skin flap necrosis and 95% CI NS = 6.5% (4.03-8.97) CS = 16.7% (10.31-23.03) % Infection and 95% CI NS = 2.9% (1.22-4.58) CS = 9.1% (4.19-14.01)	Because there was no difference in the overall complication rates in PS and CS (39.7% vs 36.5%), PS were therefore considered as part of CS in the comparisons. In comparison with NS, smokers were 3× more likely to experience a complication postsurgery. A positive relationship was observed between cigarette ppd and overall complications (OR 1.80; 95% CI, 1.00-3.34). A similar relationship also was seen between duration of smoking history and overall complications.
Kuri 2005	NS = 21% PS = LQ = 18%; defined as smoking within 8-21 d pre-surgery IQ = 11%; defined as smoking within 22-42 d pre-surgery EQ = 35%; defined as smoking within ≥ 43 d pre-surgery CS = 15%; defined as smoking within 7 d pre-surgery	188	79.8	% Incidence of impaired wound healing and 95% CI NS: 47.5% (32-63) PS: LQ = 67.6% (52-83) IQ = 55.0% (33-77) EQ = 59.1% (47-71) CS: 85.7% (73-97) Risk of impaired wound healing development (OR and 95% CI) among study groups NS: 0.11 (0.03-0.51) PS: LQ = 0.31 (0.08-1.24) IQ = 0.17 (0.04-0.75) EQ = 0.17 (0.05-0.60)	This study suggests that a 3-wk smoke-free period pre-surgery can reduce the incidence of impaired wound healing among patients undergoing reconstructive head and neck surgery. The data suggest that smoking cessation for ≥ 3 wk before reconstructive head and neck surgery can provide benefits for smokers, regardless of the level of cigarette consumption.
Levin 2004	PS: patients who quit smoking for ≥ 6 mo pre-surgery MS: CS smoking < 10 cigarettes/d and smoking history < 10 y HS: CS smoking > 10 cigarettes/d and smoking history > 10 y Groups were undefined by their percentages relative to sample size	128	33.6	% Total complications and 95% CI (patients with onlay graft) PS: 23.1% (11.63-34.53) CS: 50% (21.71-78.29) % Total complications and 95% CI (patients with sinus lift) PS: 63.3% (49.77-76.77) CS: 66.7% (49.8-83.54)	Compared with PS who had quit smoking for > 6 mo, CS were more likely to experience postoperative complications after onlay graft surgeries. Smoking cessation for > 6 mo can reduce complication risk to similar levels as those of NS.

Table 6 Continued

First Author	Studied Group According to Smoking Status	Sample Size	Male (%)	Complication Risk/Percentage Risk/Relative Risk/Odds Ratio	Important Findings
Mason 2009	NS = 21%; defined as never smokers or smoked < 100 cigarettes in their lifetime PS = LQ = 5.1%; defined as persons who quit smoking for > 14 d to 1 mo pre-surgery IQ = 12%; defined as persons who quit 1-12 mo pre-surgery EQ = 50%; defined as persons who quit smoking > 12 mo pre-surgery CS = 20%; defined as smoking within 14 d pre-surgery	7990	48.3	Hospital mortality rate (OR and 95% CI) NS: 0.39% PS: LQ = 1.7% (4.6 [1.2-18])† IQ = 1.3% (2.6 [0.65-11])† EQ = 1.5% (2.5 [0.82-7.6])† CS: 1.5% (3.5 [1.1-11])† Pulmonary complications (OR and 95% CI) NS: 2.6 PS: LQ = 6.2 (1.6 [0.85-3.1])† IQ = 6.4 (1.5 [0.81-2.8])† EQ = 5.8 (1.3 [0.77-2.2])† CS = 6.9 (1.8 [1.05-3.1])†	Any smoking, past or current, was clearly associated with increased hospital mortality and pulmonary complications. Therefore, surgeons should counsel smokers that risk remains elevated regardless of timing of cessation, but that quitting holds a benefit that improves over time. Smoking seemed to have less of an effect on pulmonary complications compared with mortality. The longer the cessation period, the greater the risk reduction in pulmonary complications. During this study, the authors were unable to identify an optimal interval of smoking cessation.
Myles 2002	NS = 35%; defined as never smokers and with a CO_{exp} of ≤ 10 ppm PS = 24%; defined as patients who quit smoking for > 28 d pre-surgery CS = 41%; defined as CS or with CO_{exp} of > 10 ppm	489	38	% Any respiratory complication and 95% CI NS: 25.9% (19.47-32.55) PS: 34.5% (25.83-43.13) CS: 33.5% (26.96-40.04) CS vs NS: (adjusted OR 1.71, 95% CI, 1.03-2.84) % wound infections and 95% CI NS: 0.6% (−0.55 to 1.71) PS: 2.6% (−0.3 to 5.48) CS: 3.7% (1.08-6.32) CS vs NS: (adjusted OR: 16.3, 95% CI, 1.58-1.75)	Smokers (PS + CS) had a significantly increased risk of respiratory complication compared with NS. Adjusted OR 1.66 (95% CI, 1.07-2.57)
Nakagawa 2001	NS = 41% PS = RS = 5%; defined as patients who quit smoking 2-4 wk pre-surgery ES = 42%; defined as patients who quit smoking for > 4 wk pre-surgery CS = 13%; defined as patients who smoked within 2 wk pre-surgery	288	58	% Overall incidence of postoperative pulmonary complications and 95% CI NS: 23.9% (16.2-31.66) PS: RS = 53.8% (26.75-80.95) ES = 34.7% (26.23-43.19) CS: 43.2% (27.28-59.2) Adjusted OR and 95% CI CS vs NS: 2.09 (0.83-5.25) RS vs NS: 2.44 (0.67-8.89) ES vs NS: 1.03 (0.47-2.26)	For patients undergoing pulmonary surgery, smoking cessation of at least 4 wk pre-surgery can lower the risk of postoperative pulmonary complications.
Padubidri 2001	NS = 69%; defined as persons who had never smoked PS = 10%; defined as previous smokers who quit smoking ≥ 3 wk pre-surgery CS = 21%; defined as those who were still smoking at the time of surgery	748	0	% Overall complication and 95% CI NS: 25.9% (22.14-29.7) PS: 25% (15.26-34.74) CS: 39.4% (31.66-47.04) % Mastectomy flap necrosis and 95% CI NS: 1.5% (0.49-2.61) PS: 2.6% (−0.97 to 6.23) CS: 7.7% (3.53-11.95)	Patients who are scheduled to undergo breast reconstructions should quit smoking for at least 3 wk pre-surgery. Quitting in this time frame or earlier can lower the complications rate to that observed among NS.
Sorenson 2005	NS = 29% PS = 29%; defined as those who previously smoked but quit sometime pre-surgery CS = 42%; defined as those who smoked at time of surgery and at follow-up	310	45.5	Association of smoking status with incisional hernia (adjusted OR and 95% CI) NS: 1 PS: 1.57 (0.81-3.64) CS: 3.93 (1.82-8.49)	CS are 4× at greater risk of incisional hernia than NS.

Table 6 Continued

First Author	Studied Group According to Smoking Status	Sample Size	Male (%)	Complication Risk/Percentage Risk/Relative Risk/Odds Ratio	Important Findings
Taber 2009	NS = 63%; defined as never smokers PS = 18%; defined as those who previously smoked but quit at least 2 wk pre-surgery CS = 19%; defined as those who smoked up to the surgery day	221	45	Mean hospital length of stay (days ±SD) NS: 2 ± 1 PS: 2 ± 1 CS: 2 ± 1 % Postoperative infection and 95% CI NS: 3% (0.1-5.62) PS: 8% (−0.67-16.05) CS: 5% (−1.68-11.2)	Among patients receiving laparoscopic donor nephrectomies, postoperative outcomes were similar among CS, PS who quit at least 2 wk pre-surgery, and NS.
Vaporciyan 2002	NS = 13% S = LQ = 23%; defined as persons who quit smoking < 1 mo pre-surgery EQ = 63%; defined as persons who quit smoking ≥ 1 mo pre-surgery	257	69.6	% Incidence of major pulmonary events and 95% CI LQ: 21.7% (11.25-32.09) EQ: 9.2% (4.76-13.64) Risk of developing major pulmonary events (OR and 95% CI) LQ vs EQ = 2.70 (1.18-6.17)	Timing of smoking cessation was a predictor of developing major pulmonary events. Smoking within 1 mo of pneumonectomy was strongly associated with the development of major pulmonary events. Patients who quit smoking late (ie, smoked within 1 mo pre-surgery) were 2.7× more likely to develop major pulmonary events compared with those who quit smoking for periods ≥ 1 mo.
Warner 1984	NS = 9% CS = 25%; defined as persons who never stopped smoking pre-surgery Stopped smoking < 2 wk pre-surgery = 17% Stopped smoking 2-4 wk pre-surgery = 9% Stopped smoking 4-8 wk pre-surgery = 6% Stopped smoking > 8 wk pre-surgery = 35%	500	77	% Overall pulmonary problems (NS vs smokers) and 95% CI NS = 11.4% (1.98-20.74) Smokers: 39% (34.56-43.52) % Estimate of incidence of pulmonary complications and 95% CI NS = 11.4% (1.98-20.74) Stopped > 8 wk pre-surgery = 17% (11.45-22.55) Stopped 4-8 wk pre-surgery = 46% (27.54-64.46) Stopped 2-4 wk pre-surgery = 62% (47.66-76.34) Stopped < 2 wk pre-surgery = 57% (46.56-67.72) CS = 48.4% (39.59-57.19)	Among patients undergoing coronary artery bypass grafting, clinical benefit due to smoking cessation was observed only in patients who quit smoking for > 8 wk pre-surgery. Smoking cessation in this period can lower the incidence of postoperative complications to levels comparable to those of NS. Preoperative smoking cessation for < 8 wk does not lower postoperative pulmonary complications.
Warner 1989	NS = 22%; defined as persons who never smoked and assigned a smoke-free day of 150 PS = 69%; defined as previous smokers who quit smoking sometime in the past, and this group includes: LQ = 11%; defined as persons who quit smoking ≤ 8 wk pre-surgery EQ = 58%; defined as persons who quit smoking > 8 wk pre-surgery CS = 9%; defined as persons with cotinine levels > 0.5 μg/mL and assigned a smoke-free day of −1	192	83	% Incidence of postoperative pulmonary complications and 95% CI NS: 11.9% (2.11-21.69) >6 mo: 11.1% EQ (>8 wk): 14.5% (7.88-20.94) LQ (≤8 wk): 57.1% (35.97-78.31) CS: 33% (11.55-55.11)	Among patients undergoing coronary artery bypass grafting, smoking cessation < 2 mo pre-surgery does not seem to reduce the incidence of postoperative pulmonary complications below that observed in CS. Patients who quit smoking ≤ 2 mo pre-surgery were ~4× more at risk of developing postoperative pulmonary complications (57.1% vs 14.5%). Smokers who quit > 6 mo pre-surgery had comparable complication rates as NS (11.1% vs 11.9%).

Table 6 Continued

First Author	Studied Group According to Smoking Status	Sample Size	Male (%)	Complication Risk/Percentage Risk/Relative Risk/Odds Ratio	Important Findings
Yamashita 2004	NS = 48%; defined as persons who had never smoked PS = 37%; defined as smokers who quit smoking < 2 d pre-surgery CS = 16%; defined as smokers who smoked until 1 d pre-surgery	1008	52.6	% Intraoperative sputum volume increase and 95% CI NS: 9.4% (6.77-11.99) PS: 17.9% (13.98-21.8) CS: 18.2% (12.24-24.24) Smoke-free period and risk of intraoperative sputum volume increase (RR and 95% CI) Quit < 2 mo pre-surgery PS/CS vs NS: 2.0 (0.9-4.3) Quit < 2 wk pre-surgery PS/CS vs NS: 2.4 (1.2-4.8) % Total postoperative pulmonary complications and 95% CI NS: 1.7% (0.52-2.82) PS: 1.4% (0.18-2.54) CS: 1.9% (−0.23 to 4.01)	In minor surgical patients undergoing general anesthesia, PS and CS were ~2× more likely to have an increased intraoperative sputum volume than NS. Smoking cessation ≥ 2 mo pre-surgery can lower the risk of intraoperative sputum volume increase.

AS = acute smoker; CG = control group; CI = confidence interval; CO = carbon monoxide; CS = current smoker; EQ = early quitters; ES = ex-smoker; HS = heavy smoker; IG = intervention group; IQ = intermediate quitters; LQ = late quitters; MS = mild smoker; N = sample size; NA = not applicable; NR = not reported; NS = nonsmoker; OR = odds ratio; ppd = packs per day; ppm = packs per month; PS = past smoker; PQ = past quitter; RR = relative risk; RS = recent smoker; SD = standard deviation; β = group numbers presented do not sum up to total N.

*Definition requires classification according to studied groups.

†Versus NS.