Therapeutics and Clinical Risk Management

Dovepress
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ORIGINAL RESEARCH

Validity of subjective smoking status in orthopedic patients

This article was published in the following Dove Press journal:
Therapeutics and Clinical Risk Management
27 August 2015
Number of times this article has been viewed

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Purpose: In this level 1 diagnostic study, we analyzed the validity of subjective smoking status and, as secondary research question, the smoking cessation adherence in orthopedic patients during a routine hospital stay of nonunion patients by measuring serum cotinine.

Methods: We included patients undergoing revision surgery due to nonunion of long bones. Patients were interviewed about their smoking status. Blood samples were taken from all the patients prior to surgery and for an additional 6 weeks following surgery. Serum levels of cotinine were measured, and coherence between subjective smoking status and objective cotinine analysis was evaluated.

Results: Between March 2012 and August 2014, we enrolled 136 patients. Six of the 26 "previous smokers" (23%) and four of the 65 "nonsmokers" (6%) had serum cotinine above cutoff levels. In self-labeled smokers, serum cotinine levels averaged at 2,367.4±14,885.9 ng/mL (with a median of 100 ng/mL), whereas in previous smokers the levels averaged at 4,270±19,619.4 ng/mL (with a median of 0 ng/mL) and in the nonsmokers group the levels averaged at 12±53.9 ng/mL (with a median of 0.03 ng/mL). Overall, the subjective smoking status matched serum cotinine testing in 88% of the cases. Sensitivity was 79.6% and specificity was 93.1%. Ninety-one percent of the patients with preoperative positive serum values were still positive at follow-up.

Conclusion: In this study, we could show that subjective smoking status in orthopedic patients is predominantly reliable as validated by objective cotinine measurements; however, patients who declare themselves as "previous smokers" are at elevated risk for underreporting continued smoking and patients who smoked preoperatively are at high risk for continuing their habit. In the future, caregivers should consider introducing effective treatments for smoking cessation to smokers and furthermore offer effective treatments to maintain smoking cessation in previous smokers during their routine consultation prior to orthopedic and trauma surgery.

Keywords: smoking, cotinine, nonunion, smoking behavior, smoking cessation, risk evaluation

Introduction

Smoking is one of the most important risk factors to fracture healing.[1,2] In the past years, there has been a multitude of clinical studies emphasizing the negative impact smoking has on fracture healing;[3,4] furthermore, we could show that serum transforming growth factor beta, an important marker of fracture healing, was significantly decreased in fracture patients who were smokers.[5] Recently, we published the results of a study on 85 tibia shaft fracture patients where we showed that both current and previous smokers displayed a significantly increased risk for delayed union or nonunion, increased time required for fracture healing, and a markedly increased time out of work.[6] In a 2005 study, Castillo et al investigated 268 fracture patients and found that current

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and previous smokers are challenged by an elevated risk for nonunion compared to nonsmokers.[4] In both studies, not only current but also previous smokers suffered from an elevated risk of insufficient bone healing. In particular, the results from these studies suggest that the negative impact that smoking has on fracture healing may last longer than expected or, in fact, may even be irreversible.[4] The major problem of these studies is that they assessed smoking by subjective patient status. Recently, many antismoking campaigns and laws have been introduced all over the world, making smoking a more and more socially unwanted behavior. Hence, subjective patient smoking status is highly questioned, since patients, especially previous smokers, might conceal nicotine consumption. For example, Kang et al showed that 56% of the Korean females questioned provided inaccurate information about their smoking habits.[7] This also puts the results of orthopedic studies in question.

In clinical surgery, insight into the validity of subjective patient smoking status will also become important. In the past years, risk scores for nonunions have been developed, with many of them including smoking status. For example, Calori et al proposed the Nonunion Scoring System (NUSS) with a higher score indicating an increased risk for nonunion. Ten out of 100 points are given if the patient smokes.[8] We developed a scoring system in which 15 of the 65 maximal achievable points are given if the patient is a current smoker and five points are given to previous smokers (a higher score indicating an increased risk for nonunion).[6] To use these tests, surgeons must be aware about the validity of the information that their patients provide.

As in all surgical procedures, smoking cessation is highly recommended in nonunion patients, but no satisfactory data exist about the adherence of orthopedic and trauma patients to this recommendation that caregivers commonly provide during the preoperative consultation. We performed this study to assess if orthopedic patients provide correct answers about their subjective smoking status and if they adhere to smoking cessation.

Materials and methods

Patient recruitment

We included all patients 18 years of age and above undergoing revision surgery due to nonunion of long bones (humerus, radius, ulna, femur, tibia, fibula, clavicula), subsequent to the approval by the ethical committee of the Ruprechts-Karls-University of Heidelberg (S-636/2011). Exclusion criteria were intake of corticosteroids (excluding hormonal contraception) or chemotherapy. All patients gave informed consent. Prior to surgery, all patients were informed about the risks of smoking to fracture healing, and were advised to quit smoking.

There are several methods of objectively asserting patient smoking status.[9] Nicotine itself has a plasma half-life of approximately 2 hours, whereas its main metabolite cotinine has a half-life of approximately 18 hours.[10] It can be measured in serum, urine, or saliva. Other methods such as carbon monoxide measurement in exhaled air or thiocyanate in serum or urine are less common. For our study, we chose cotinine measurement in serum, because it delivers acceptable test values (sensitivity 96%, specificity 100%) and drawing of blood samples can be easily performed within our clinical and scientific routine.

Sample acquisition and measuring of serum cotinine

Venous blood samples from all the patients were taken 1 day prior to surgery. Serum was separated and stored at −80°C. Serum samples were thawed and equilibrated to room temperature for at least 2 hours before analysis. Serum cotinine levels were measured according to the manufacturer's instructions. According to the findings of Benowitz et al,[10] serum cotinine cut-point was defined as 3.08 ng/mL. Serum values above this point were defined as "positive", while the values below this point were defined as "negative". To investigate cessation behavior, a second blood sample was drawn at a follow-up consultation 6 weeks after surgery.

Questionnaire

All the patients taking part in the study were interviewed according to a standard questionnaire. They were asked about their smoking status giving three possible categories: "nonsmoker", "previous smoker", and "current smoker". Current and previous smokers were asked about the beginning of their smoking life and their amount of pack-years, defined as smoking 20 cigarettes (1 pack) per day for 1 year. Previous smokers were also asked about the time their smoking life ended. The questionnaire further included an open question about the use of "other recreational drugs". If they answered "yes", they were asked to specify about the kind of substance consumed.

Statistical analysis

Data entry was performed using MS Excel, and statistical analysis was performed on SPSS Statistics version 2.0 (SPSS Inc., Chicago IL, USA). For comparison of serum cotinine levels between smokers and nonsmokers, Mood's median test and Kruskal–Wallis test were used. For comparison of

preoperative and follow-up serum cotinine levels, the Wilcoxon signed-rank test was used. To detect risk factors for underreporting, we conducted logistic regression analysis. *P* was set at 0.05.

Results

Between March 2012 and August 2014, 136 patients were included in our study (Table 1). There were 74 men and 62 women in our collective and median age was 51 years. Incidence as measured by subjective status was as follows: 45 patients (33%) labeled themselves as "smokers", 26 (19%) as "previous smokers", and 65 (48%) as "nonsmokers" (Table 2). As measured by cotinine assessment, incidence of smoking was 49 in 136 patients (36%, Table 3). In self-labeled smokers, serum cotinine levels ranged between 0 and 100,000 ng/mL with a mean of 2,367.4±14,885.9 ng/mL (median of 100 ng/mL), and in 39 patients (87%) were above cutoff value. In previous smokers, serum cotinine levels ranged between 0 and 100,000 ng/mL with a mean of 4,270±19,619.4 ng/mL (median of 0 ng/mL), and in six patients (23%) were above cutoff value. In the nonsmokers group, serum cotinine levels ranged between 0 and 260 ng/mL with a mean of 12±53.9 ng/mL (median of 0.03 ng/mL), and in four patients (6%) were above cutoff value (Figure 1). Overall, subjective statuses matched with serum measurements in 120 cases (88%). Sensitivity (rate of cotinine-positive patients admitting to smoke) was 79.6%, and specificity (rate of cotinine-negative patients claiming not to smoke) was 93.1% (Table 3). We conducted a statistical analysis: patients with negative and positive serum cotinine values did not show significant differences between sex or age categories. Patients with positive serum cotinine concentrations were more likely to report to smoking when they also reported drug abuse, and the risk of underreporting (self-labeling as "nonsmoker" or "previous smoker" alongside with positive cotinine values) increased with the amount of pack-years smoked.

Blood samples could not be obtained at the follow-up for four of the 49 patients initially positive for cotinine. In the remaining 45 patients, 41 (91%) still had positive serum cotinine values at the follow-up. Two other patients, who had had negative serum cotinine values prior to surgery, had positive values at the follow-up. These two patients had initially described themselves as "smokers". At follow-up, no significant change regarding median serum cotinine levels was found, regardless of any subjective smoking status (Figure 1).

Discussion

In this study, we analyzed the validity of subjective smoking status and, subsidiarily, smoking cessation adherence in orthopedic patients during a routine hospital stay. Subjective patient reporting matched serum findings in 88% of the patients, although 6.2% of nonsmokers and 23.1% of previous smokers were positive for serum cotinine. Sensitivity of subjective smoking status was 79%. Furthermore, we found that smoking cessation rate was 8%. Strengths of the study are the prospective design, its clear inclusion and exclusion criteria, and blinding (despite consent in serum studies, patients were not aware that their smoking status was verified).

Among our patients, 33% admitted to smoking, while 48% identified themselves as nonsmokers, and 19% as previous smokers. In a 2013 health survey conducted by the German Federal Statistical Office on 69,996 individuals, 79% provided information concerning their smoking status:[11] 24.5% labeled themselves as smokers, while 56.2% said they were life-long nonsmokers, and 19.3% said they were previous smokers. In our study, the percentage of smokers was higher, probably due to selection bias (all of our patients suffered from failed fracture healing, for which smoking is an important risk factor). The reason for the higher reporting values in our study (only one patient declined to give information [0.7%]) may be that our patients were more motivated to give information than the responders to an epidemiological inquiry.

In our study, six patients had cotinine levels below 3.08 ng/mL, but still described themselves as "smokers".

Table 1 Patients' characteristics

	Sex		Age (years)	BMI (kg/m²)	Location					Serum cotinine		Total
	M	F	Median (min, max)		Humerus	Forearm	Femur	Lower leg	Other	Negative	Positive	
Subjective												
NS	28	37	53 (20, 89)	28 (18, 42)	9	1	23	31	1	61 (92.8%)	4 (6.2%)	65 (48%)
PS	17	9	51 (22, 84)	28 (21, 52)	3	2	8	12	1	20 (76.9%)	6 (23.1%)	26 (19%)
CS	29	16	50 (23, 78)	27 (19, 35)	2	3	16	23	1	6 (13.3%)	39 (79.6%)	45 (33%)
Total	74	62	51 (20, 89)	28 (18, 52)	14	6	47	66	3	87 (64%)	49 (36%)	136 (100%)

Notes: Negative, serum level below cut-point; positive, serum level above cut-point.
Abbreviations: M, male; F, female; BMI, body mass index; NS, nonsmoker; PS, previous smoker; CS, currect smoker.

Table 2 Prevalence of smoking as measured by subjective status and serum cotinine testing

	Subjective status			Serum testing		Total
	NS	PS	CS	Negative	Positive	
Male	28	17	29	42	32	74
Of all male patients (%)	37.8	23.0	39.2	56.8	43.2	100
Female	37	9	16	45	17	62
Of all female patients (%)	59.7	14.5	25.8	72.6	27.4	100
Total	65	26	45	87	49	136
Of all patients (%)	47.8	19.1	33.1	64.0	36.0	100

Notes: Percentages indicate prevalence within sexes and within general population; negative, serum level below cut-point; positive, serum level above cut-point.
Abbreviations: NS, nonsmoker; PS, previous smoker; CS, currect smoker.

This group consisted of three men and three women, aged between 41 and 60 years with a median age of 51 years. Due to the small number, we were not able to perform further statistical analysis. Remarkably, two of these patients had positive serum cotinine levels at follow-up. It is implausible to suggest these six patients did not tell the truth, since this would mean they would have wrongly admitted to a socially unwanted behavior. It is far more plausible to consider these patients as occasional smokers, meaning they consume cigarettes, but in low doses and/or infrequently. Little is known about the impact of this behavior on fracture healing: most clinical studies regarding the impact of smoking on fracture healing did not account for the amount of cigarettes smoked or the frequency of smoking. Hence, it can be assumed that these studies also included occasional smokers. There is no evidence for bone-save smoking, and in other medical fields, any pattern of smoking has been rated hazardous. Therefore, any concession of smoking – at least in adults – must be taken seriously. These considerations also have consequences on our calculations: if these six patients are excluded from calculation, the rate of correct answers rises up to almost 92%.

There have been several studies about the validity of subjective smoking status with a wide range of results. In a systematic review, Connor et al determined sensitivities of subjective smoking status to be between 0% and 98% in 19 studies.[12] Cotinine concentration cut-points differed, but had no impact on sensitivity. In a Canadian epidemiological study by Wong et al, 18.8% of the 4,223 participants reported smoking and 19.1% were positive for urinary cotinine.[13] The higher percentage of smokers in our study (33% by reporting, 36% by cotinine testing) may be attributed to the aforementioned selection bias. There was no group of previous smokers in the Wong et al study, but 74.7% of the patients with positive urinary cotinine despite denial of smoking labeled themselves as such. In a 2005 survey of 627 Chicago residents, Fendrich et al found the sensitivity to be 78.3%, falling close to our result.[14] Furthermore in that study, underreporting of marijuana abuse was associated with underreporting of tobacco abuse. We did not perform tests

Table 3 Test quality of subjective smoking status

Subjective status	Serum testing	
	Positive	Negative
Current smokers	39	6
Patients above cut-point (%)	79.6	6.9
Nonsmokers and previous smokers	10	81
Patients above cut-point (%)	20.4	93.1
Total	49	87

Notes: Negative, serum level below cut-point; positive, serum level above cut-point.

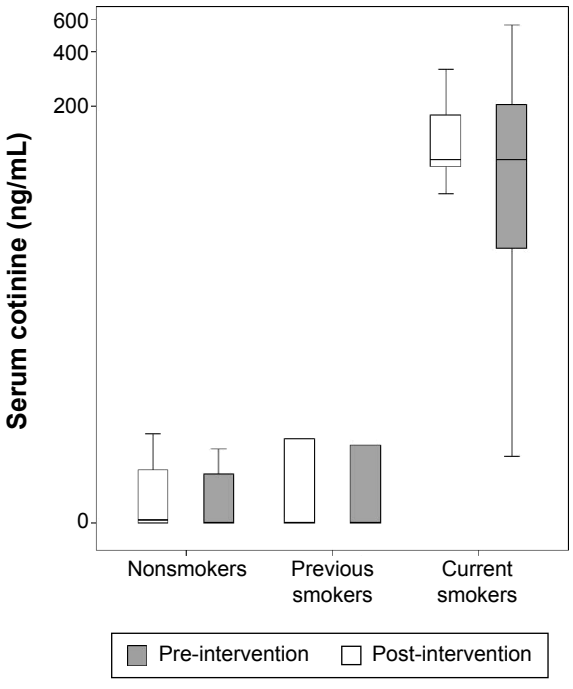

Figure 1 Serum cotinine levels.
Notes: White boxes: levels at preoperation; gray boxes: levels at follow-up. Black lines indicate medium; bottom and top of the boxes indicate the first and third quartile, respectively. Whiskers indicate the lowest and highest values within 1.5 interquartile range. Outliners above and beyond extremes are not shown.

for other drugs except for cotinine but asked patients about the use of other drugs: five patients reported consumption of marijuana and one of heroin. Analysis showed reporting of other drugs was associated with nicotine reporting. It can be assumed that, due to the illegality, use of these substances is socially even more unwanted than smoking and that patients admitting to it are unlikely to deny smoking. Due to the small number, this result must be viewed carefully.

On summarizing the results, our study showed that the validity of subjective smoking status in orthopedic and trauma patients can be considered reliable. However, caregivers should be aware of an increased risk of incorrect answers among the previous smokers, and therefore should consider intensifying preoperative consultations regarding the negative impact smoking has on fracture healing and, subsequently, the outcome of long bone surgery. Furthermore, patients who are at risk for underreporting smoking as well as smokers should be offered antismoking interventions such as individual or group counseling and medication, such as nicotine replacement or bupropion.[15]

In another study on reporting as well as on smoking cessation adherence in a clinical setting, Coon et al investigated patients before elective plastic surgeries: 33.5% of the 415 patients stated they had quit smoking, while 9.4% reported to have continued.[16] These results fall close to ours. Urinary cotinine samples revealed that of all the patients tested, 4.1% were positive for cotinine despite claiming to have quit smoking. In our study, this rate was 7.3%. A possible explanation of this higher value might be that these patients were informed of being tested. As in our study, patients who stated they had quit smoking were more likely to be deceitful than those who had stated they never smoked.

Despite common knowledge that smoking deteriorates healing of bones and soft tissue and thereby negatively influences outcome of long bone surgery,[6] it is still unclear whether fracture patients undergoing surgery receive sufficient advice and support regarding smoking cessation;[17] furthermore, till this date inpatients are not routinely provided with such advise during their hospital stay.[18,19] It is known that advice from a physician has a positive impact on smoking cessation;[20] therefore in our study, we sought to determine as a subsidiary research question the prevalence of smoking cessation among fracture patients undergoing surgery subsequent to a routine preoperative consultation with an emphasis on the negative impact of smoking on the outcome of surgery.

In our study, 8% of the smoking patients had negative values at the follow-up 16 weeks after the surgery. It can be assumed that patients positive for cotinine at this point had continued regular smoking, since any cigarette in previous smokers is an unyielding predictor of relapse.[21] When we compared median serum cotinine levels preoperative and at follow-up, there was no significant change. Although these data should be carefully viewed, it can be assumed that the majority of patients did not change their habits regarding smoking cessation. The effect of smoking on fracture healing is well known, but little is known about the benefit of smoking cessation for nonunion therapy. Nevertheless, we advised our patients to quit smoking. In a study of 168 smokers undergoing surgery, a nonintervention group was only advised to quit smoking, while patients in the intervention group were provided additional help, such as detailed information, counseling, and transdermal nicotine replacement.[22] In that study, postoperative cessation rate of control patients as measured by carbon monoxide exhalation was 11%, comparable to our results, while 22% of the intervention patients quit smoking. Recent recommendations include individual or group counseling and medication, such as nicotine replacement or bupropion.[15] The benefits of abstinence from smoking may outweigh the pursued but decreased presence of nicotine,[23] but research on this question, especially in orthopedic surgery, is still needed.

Summarizing the results of the current study show that the routine preoperative consultation regarding crucial risk factors influencing the outcome of surgery with an emphasis on smoking, as performed in our study, leads to a smoking cessation rate of only 8%, despite being known to have a positive impact on smoking cessation.[20]

Thereby, the current study indicates that in the future sufficient support and advice regarding antismoking interventions, exceeding the routine consultation, should be provided to enhance the smoking cessation rate among the concerned patients, thereby improving the outcome of nonunion therapy.

Due to the declining social acceptance of smoking, the risk of underreporting smoking may increase. Furthermore, the population of previous smokers is growing and research focus is shifting toward them. The long-term effects of smoking on bone health are still not fully understood; for example, increased risk of fracture persisted until 30 years after smoking cessation in smokers.[24] Some clinical studies about the impact of smoking on fracture healing showed increased risk of nonunion in previous smokers.[25] From our results, it can be assumed that there were latent smokers among these "previous smokers". Further studies about the impact of smoking on fracture healing should consider cotinine testing on these patients.

Limitations

Limitations of our study are the small sample size, possible disturbance by passive smoking and other nicotine sources like snuff and medication, and individual patient factors. Since the values in most of the patients classified as positive were far above cut-points, it is implausible to consider their positive cotinine levels as the result of passive smoking. An additional limitation of our study is the lack of further antismoking interventions. However, in our study, we assessed the smoking cessation rate after a routine preoperative consultation and advice regarding the positive impact of smoking cessation on fracture healing. Hence, the lack of further antismoking interventions had not interfered with the results of our study. Furthermore, in the current study the Fagerström test, a reliable and established tool in the evaluation of the nicotine addiction level,[26] was not used for assessment. We sought to determine the validity of subjective smoking status and the smoking cessation rate during a routine hospital stay of orthopedics and trauma patients in a major center for orthopedics and trauma surgery in Germany. The Fagerström test is a reliable tool for the analysis of nicotine addiction; however, nicotine addiction in previous smokers is not assessable and currently, the assessment by using the the Fagerström test remains an exception in German centers for orthopedic and trauma surgery. Thereby, the findings of our study regarding our research question were not influenced by the exclusion of the Fagerström test.

Conclusion

In this study, we could show that although subjective smoking status was correct in 88% of the patients, the rate of incorrect statuses increased to 23% in "previous smokers", and that only 8% of smokers actually quit smoking postoperatively. The low cessation rate and the high number of latent smokers among the previous smokers can be attributed to the highly addictive nature of smoking. Since smoking is one of the most important risk factors of fracture healing, the number of severely addicted smokers as well as previous smokers may be increased in nonunion patients. These patients may especially be at risk for underreporting and noncompliance. Therefore, orthopedic surgeons should be aware of possible incorrect answers about smoking, in particular among previous smokers. Prospectively, the findings of our study indicate that assessment of subjective smoking status is a reliable tool for trauma surgeons to evaluate smoking status in patients prior to surgery. However, in the future, caregivers should consider introducing effective treatments for smoking cessation to severely addicted smokers (assessed by tobacco dependency tests such as the Fagerström test) and offer effective treatments to maintain smoking cessation in previous smokers. This may help to improve the outcome of orthopedic surgery, thereby enhancing benefits for concerned patients.

Ethical approval

The study was conducted in accordance with the declaration of Helsinki. All individuals accorded with the study protocol. This study was approved by the ethics committee of the Ruprecht-Karls-University of Heidelberg (S-636/2011).

Disclosure

The authors report no conflicts of interest in this work.

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