Impact of Smoking on Endovascular Abdominal Aortic Aneurysm Surgery Outcome

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Objective. Smoking plays a major role in deficiencies of the vascular system, and seems to have consequences for the treatment of cardiovascular diseases. We hypothesized that smokers have a higher mortality and more complications after endovascular abdominal aortic aneurysm surgery than non-smokers.

Methods. We assessed mortality and complications of 3270 patients who underwent endovascular abdominal aortic aneurysm surgery in Europe between January 1994 and July 2001. Survival and (post) operative complications were assessed by smoking status.

Results. Mortality did not significantly differ between smokers and non-smokers. Smokers had a higher number of intra-operative additional procedures, but a lower number of late endoleaks in comparison to non-smokers. In addition, smokers had a reduced risk of late type II endoleaks in comparison with non-smokers.

Conclusion. There seems to be no significant difference in endovascular abdominal aortic aneurysm surgery outcome between smokers and non-smokers, although there were significant differences in intra-operative additional procedures and late endoleaks.

Key Words: Surgery outcome; Smoking; Abdominal aortic aneurysm.

Introduction

Smoking is a major risk factor for cardiovascular morbidity and mortality. It triples the risk of dying from heart disease among middle-aged men and women.1 Since 1960, the percentage of smokers has decreased from about 90% to 30–35%. Over the past few years, this percentage has not decreased further, while the percentage of juvenile smokers has even shown an increase.23

Smoking plays a major role in deficiencies of the vascular system such as arteriosclerosis of the extremities, arterial embolism, carotid artery disease, thrombophlebitis, and abdominal aortic aneurysm. Particularly, smoking is related to abdominal aortic aneurysm expansion and rupture.4,5 Acute effects, physiological, metabolic, and pathological consequences of smoking are observed.6–19 The beneficial effects of smoking cessation have also been reported.20–22

Treatment of cardiovascular diseases ranges from exercise and medication to vascular and endovascular surgery. Smoking seems to influence treatment outcome. Researchers suggest that the poorer survival of women as compared to men after abdominal aortic aneurysm surgery could be attributed to greater cardiovascular co-morbidity, because evidence from screening studies suggests that women with abdominal aneurysm are more likely to have been smokers than men.23–25 Furthermore, a greater risk of death, Q-wave infarction, and re-operations as well as a lower rate of repeated revascularization after vascular surgery are reported for smokers as compared to non-smokers.26,27 Interestingly, a recently published study found that a lower rate of subsequent revascularization in smokers was partly explained by a reduced sensitivity to re-stenosis in smokers and their greater reluctance to seek medical attention.28

The consequences of smoking on endovascular abdominal aortic aneurysm surgery outcome are unclear. Elevated blood pressure and morphological changes as a consequence of smoking, such as arterial wall changes29 (i.e. thinning or thickening) and increased arterial wall stiffness, are important aspects, especially for endovascular surgery. Since smoking
may lead to changes that are closely related to abdominal aortic aneurysm morphology, smoking may have effects on endovascular aneurysm repair. We hypothesized that smokers have a higher mortality and more complications after endovascular abdominal aortic aneurysm surgery than non-smokers.

**Methods**

**Study population**

Patient data were obtained from the EUROSTAR registry (EUROpean collaborators on Stent-graft Techniques for abdominal aortic Aneurysm Repair). This multi-centre registry comprises 107 collaborating European institutions. The study population included 3270 patients who underwent endovascular abdominal aortic aneurysm surgery between January 1994 and July 2001. The study population was divided into two groups according to the Society for Vascular Surgery/International Society for Cardiovascular Surgery (SVS/ISCVS) smoking risk score at the time of enrolment. The group of non-smokers consisted of patients who did not smoke at the time of enrolment (i.e. both patients who never smoked or who had not smoked in the previous 10 years and patients who smoked in the previous 10 years: SVS-ISCVS risk score-0 or 1). The group of smokers consisted of patients who did smoke at the time of enrolment (i.e. both patients who smoke less than one packet per day and patients who smoke more than one packet per day: SVS-ISCVS risk score-2 or 3). The majority of the data was collected prospectively (91%). The methods have been reported in several other reports.

**Data assessment**

Baseline information collected and documented in the EUROSTAR registry included demographic data, clinical characteristics, vascular morphology, and relevant concomitant diseases according to the SVS/ISCVS guidelines. Operative data included type of endograft, operative technical details and the occurrence of complications. Information collected during follow-up consisted of complications and clinical events determined by physical examination or imaging techniques: CT, angiography, MRI or Duplex. The follow-up protocol included visits at 1, 3, 6, 12, 18 and 24 months after the procedure and yearly thereafter.

**Outcome variables**

The primary outcome variable was mortality. Secondary outcome variables were early and late complications. Early mortality/complications are defined as death or events occurring within the first 30 post-operative days or until discharge in case of prolonged hospital stay. Late mortality/complications are defined as death or events after the first 30 post-operative days and after discharge.

**Statistical analysis**

The results are expressed as mean (SD) or as frequencies (percentages). The differences between groups in early outcome measures were assessed using the $\chi^2$-test or the Fisher exact test for categorical data and continuous data by the t-test, or the rank-test for non-parametric variables. Late outcome (after the first 30-days) measures were analysed using the Kaplan–Meier method. Differences in survival were assessed for significance by means of the log-rank test. Multivariate Cox proportional hazards models were used to examine the relationship of smoking to late events, adjusted for baseline characteristics, including age, gender, morphological data, pre-existing co-morbidity, device, year of operation and operating team experience. A $P$ value of less than 0.01 was considered statistically significant.

**Results**

**Baseline clinical characteristics**

Among the 3270 patients who underwent endovascular abdominal aortic aneurysm surgery, 853 (26%) were smokers (Table 1). Overall, smokers were younger in age ($P < 0.01$), had less baseline cardiac dysfunction ($P < 0.01$), and abnormal pulmonary status ($P < 0.01$). Furthermore, smokers had less often significant angulation of the aneurysm ($P < 0.01$) in comparison to non-smokers. However, regression analysis showed a less significant relationship of smoking to aneurysm angulation ($P < 0.05$) after correction for age. Eight patients were lost to follow-up within the first 30 postoperative days and 16 patients were lost to follow-up after this period.

**Operative data and early outcome**

Early mortality did not significantly differ ($P = 0.558$) between non-smokers (3%) and smokers (2%).
Smoking was associated with more intra-operative additional procedures (39% in smokers versus 32% in non-smokers, \( P < 0.01 \)) (Table 2). The increased number of intra-operative additional procedures consisted mainly of an increased number of PTA or stents for stenosis (19% in smokers versus 15% in non-smokers, \( P < 0.01 \)).

Smokers did not significantly differ from non-smokers in their number of early endoleaks, 33 conversions, ruptures, and other complications.

Late outcome

Median follow-up duration was 12 months for both smokers (range: 0–84) and non-smokers (range: 0–72). Late mortality did not significantly differ between smokers and non-smokers (Table 3, Fig. 1).

Unadjusted analyses (Table 3, Fig. 2) showed fewer late endoleaks among smokers than among non-smokers (15% versus 20%, \( P < 0.01 \)). Additional analysis revealed that the number of late type II endoleaks was significantly lower in smokers compared with non-smokers (7% versus 11%, \( P < 0.01 \)). Adjusted for all baseline variables, smokers had reduced risk for late type II endoleaks than non-smokers (Hazard ratio: 0.64; 95% confidence interval: 0.5 to 0.9). The association between smoking and late type II endoleaks also remained unchanged after correction for preoperative patency of IMA or the hypogastrics and also after operative embolisation of IMA lumbar or hypogastric arteries.
Table 3. Late outcome

<table>
<thead>
<tr>
<th></th>
<th>Non-smokers (n = 2417)</th>
<th>Smokers (n = 853)</th>
<th>Unadjusted P value*</th>
<th>Adjusted P value†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
<td></td>
<td></td>
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<tr>
<td>Secondary</td>
<td>306 (13)</td>
<td>126 (15)</td>
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<td></td>
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<tr>
<td>interventions</td>
<td></td>
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<td></td>
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<tr>
<td>Endoleaks‡</td>
<td></td>
<td></td>
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<tr>
<td>Overall</td>
<td>488 (20)</td>
<td>128 (15)</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Type I proximal</td>
<td>71 (3)</td>
<td>20 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I distal</td>
<td>138 (6)</td>
<td>40 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type II</td>
<td>267 (11)</td>
<td>59 (7)</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Type III</td>
<td>117 (5)</td>
<td>29 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversion</td>
<td>40 (2)</td>
<td>26 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rupture</td>
<td>17 (1)</td>
<td>6 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>185 (8)</td>
<td>62 (7)</td>
<td></td>
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</tr>
</tbody>
</table>

*P value was determined by the Kaplan–Meier analysis and the log-rank test.
†Adjusted for all baseline characteristics (Cox’s proportional hazards model).
‡Endoleaks have been categorized according to the May–White classification.33.

Smoking and AAA Surgery

Fig. 1. Survival in patients who underwent endovascular AAA surgery stratified by smoking status.
There were no significant differences in numbers of late conversions, ruptures and secondary interventions in smokers compared with non-smokers.

Discussion

About a quarter of the patients who underwent elective endovascular aneurysm repair smoked at the time of enrolment. Smokers were more often younger, and had more often normal cardiac and abnormal pulmonary status. The number of intra-operative additional procedures was higher in smokers. A lower prevalence of late endoleaks was observed in smokers compared with non-smokers. Furthermore, no statistically significant differences were found between smokers and non-smokers in mortality, conversion rate and other complications. For ruptures, although a total of 24 ruptures was reported, this number might be too small to detect differences between the groups.

This study was the first large investigation on the impact of smoking on endovascular surgery outcome. Previous studies have investigated the impact of smoking on vascular surgery outcome. One study on the effect of smoking on long-term outcome after successful percutaneous coronary revascularization showed that smokers were at greater risk of Q-wave infarction and death after surgery than non-smokers. In addition, this study reported a higher risk for
non-smokers than for smokers and former smokers to undergo additional percutaneous coronary procedures or coronary bypass surgery. Another study reported that smokers were at greater risk for myocardial infarction and re-operation after coronary bypass surgery than former smokers and non-smokers. In our study no significant differences were found in the number of deaths and re-operations in smokers compared to non-smokers. The relationship between smoking and aneurysm angulation seems to be merely the result of the presentation of smokers at an early age, since regression analysis showed a less significant relationship after correction for age.

We found a higher number of PTA and stents for stenosis during operation in smokers. This is in accordance with the results of previous studies and might be explained by metabolic and pathological changes as a consequence of smoking, such as increased platelet aggregation, consistent changes in serum lipoproteins, arterial wall thickening, and ultrastructural changes in aortic endothelial cells, which are thought to be primary initiating events of atherosclerosis.

Finally, we found a lower prevalence of late endoleaks in smokers compared with non-smokers. This difference did not reflect the number of pre-operative patent IMA, since the association remained unchanged after correction for IMA hypogastric patency. This might be explained by an increased platelet aggregation as a consequence of smoking, by which the thrombotic potential increases and the risk of endoleaks, especially type II endoleaks, may decrease in smokers.

Type II endoleaks occur when there is persistent blood flow from patent lumbar arteries, the inferior mesenteric artery, or other collateral vessels. Early type II endoleaks resolve spontaneously in approximately 50% of patients. If the endoleak does not resolve it may be treated by embolisation of the collateral vessels filling the aneurysm sac or by placement of metal coils in the aneurysm sac. Although type II endoleaks are not innocuous, it does not lead directly to more mortality or life threatening complications.

One limitation of our study was that the self-reported status of smoking was not confirmed by biochemical tests. In the literature it is found that patients tend to underreport their smoking habits. If a substantial proportion of the non-smokers were smokers, this could bias risk estimate for late endoleaks among smokers. One study that used both self-reported smoking status and the serum creatinine level reported a significant association between serum creatinine and postoperative death after elective surgical repair of abdominal aortic aneurysm. No association was found between smoking status and late outcome.

In conclusion, smoking behaviour is found in about a quarter of the patients who underwent endovascular abdominal aortic aneurysm surgery. Smoking is associated with more intra-operative additional procedures and less type II endoleaks after the first 30 postoperative days. Smoking seems to have no consequences for the technical outcome in patients who underwent endovascular abdominal aortic aneurysm surgery. Our conclusion is, however, irrelevant to clinical practice since there can be no vascular surgeon in the world who would recommend that patients under their care should continue to smoke. The risks of smoking are well established. Smoking has an adverse effect on patients in many ways but the technical outcome of endovascular surgery is unlikely to be one of them.

References
13 Gidding SS, Xie X, Liu K, Manolio T, Flack J, Perrins L,


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