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## The impact of coronary revascularisation on endothelial and platelet function
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# Chapter 9
# Continued cigarette smoking after coronary artery bypass surgery reduces endothelium-dependent vasodilatation in internal thoracic artery grafts

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## ABSTRACT

Cigarette smoking is known to promote endothelial dysfunction, thus it can be responsible for an impaired endothelium-dependent vasomotility in arterial grafts late after coronary surgery.

**Methods and results**
20 consecutive patients (mean age 64.5 yrs.), previously submitted to coronary bypass surgery with the internal thoracic artery, underwent quantitative angiography of the implanted graft at long-term follow-up (mean time 2.5 yrs.). To assess both endothelium-dependent and -independent vasomotility, angiograms were acquired before and after selective infusions of acetylcholine ($10^{-6}$ mmol/ml) and nitroglycerine (500 mg). The predictive value of risk factors, including previous and continued smoking, for an impairment in endothelium-dependent vasomotility was assessed.

Continued smoking (p=0.038), but not a previous history of smoking (p=0.55) was the only predictor of a reduced endothelium-dependent vasodilation. While previous smokers and non-smokers showed a similar response to acetylcholine, current smokers showed a reduced endothelium-dependent vasodilation vs. non-smokers (94.8±2.6% vs. 99.6±2.3% of the maximal vasodilative capacity, p=0.001).

**Conclusions**
Although maintained, the vasodilative response to acetylcholine appear reduced in internal thoracic artery grafts of patients who continued smoking long-term after coronary bypass surgery. Whether this could affect the long term outcome of these patients has to be further investigated.

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## INTRODUCTION

Cigarette smoking has a deleterious effect on coronary arteries since it is responsible for atherosclerosis, thrombogenicity, and vasoconstriction [1]. Cigarette smoking also worsens the outcome of patients after coronary surgery (CABG) by jeopardising the integrity of venous grafts [2]. Currently, there is a tendency to use the internal thoracic artery (ITA) as a first-choice conduit for CABG. The ITA shows an excellent angiographic patency, providing a good long-term event-free survival [3]. To investigate the effect of previous and/or continued cigarette smoking on this graft, we studied ITA's vasomotor response to acetylcholine, an endothelium-dependent vasodilator, by means of quantitative angiography.

**List of abbreviations:**

CABG: coronary artery bypass surgery
ITA: internal thoracic artery
LVEF: left ventricle ejection fraction
ECG: electrocardiogram
ACE: angiotensin converting enzyme
MI: myocardial infarction

## METHODS

Twenty consecutive patients (mean age: 64.5±7.5 yrs), with no evidences of angina and good left ventricular function (LVEF>40%) were submitted to an angiographic follow-up (mean time: 2.5±0.9 yrs) after CABG with pedicled ITA. Patients gave informed consent and the protocol was approved by the Institutional Review Board. Among the study group, 10/20 patients (previous smokers) had a history of smoking before CABG: six of them (current smokers) were continuing to smoke at the time of follow-up. No patient started smoking after CABG.

Baseline angiograms of the ITA graft were acquired in a fixed radiological view, then acetylcholine was injected in the ITA in three increasing dosages ($10^{-8}$, $10^{-7}$ and $10^{-6}$ mmol/ml x 3 minutes each) under ECG and blood pressure monitoring. Angiograms were repeated within 1 minute after each infusion and after a subsequent administration of nitroglycerine (500 µg). End-diastolic frames were chosen and the mean diameter of the proximal part of the ITA was calculated by quantitative analysis (Quantocor QCA 3.0, Pie Medical Imaging, Maastricht, The Netherlands) for baseline, post-acetylcholine (highest dose achieved) and post-nitroglycerine sequences.

As nitrates are considered an endothelium-independent vasodilative agent, post-nitroglycerine mean diameter was taken as the maximal vasodilative capacity of the ITA: the endothelial contribution to vasodilation was then calculated for each patient as the ratio (in percentage) between post-acetylcholine (highest dose achieved) and post-nitroglycerine mean diameters, normalised for baseline diameters.

Statistical analysis was performed by means of the Statistical Package for the Social Science version 8.0 for Windows (SPSS Inc., Carey, NC). Descriptive statistics are expressed as mean values ± SD or as percentages. Univariate regression analysis was performed to evaluate the influence of clinical features, medications, or risk factors on endothelium-dependent vasodilation, included as a continuous variable. Variables with a probability value of less than 0.20 were selected for multivariable regression analysis. Analysis of variance was performed for assessing statistical differences between groups (previous and current, smokers and non-smokers).

## RESULTS

All patients tolerated the highest acetylcholine dose ($10^{-6}$ mmol/mL) without significant side effects.

At univariate analysis, continued smoking (p=0.038), but not a previous history of smoking before surgery (p=0.55) was the only predictor of an endothelium-dependent vasodilation impairment, thus a multivariable analysis was not performed. Smokers and non-smokers showed similar characteristics regarding clinical features, medications or risk factors (Table I).

Previous smokers vs. non-smokers showed comparable baseline values and maximal vasodilative capacity of the ITA and the endothelium-dependent vasodilation was not significantly different between the two groups (97.0±3.9 % vs. 98.9±2.2 % of the maximal vasodilative capacity; p:0.20). Current smokers vs. non-smokers

**Table I.** *Clinical features, medications and other risk factors for previous and current, smokers and non-smokers.*

| | Previous | | Current | |
| --- | --- | --- | --- | --- |
| | **Smokers (n=10)** | **Non-smokers (n=10)** | **Smokers (n=6)** | **Non-smokers (n=14)** |
| Age (years) | 64.4±5.8 | 64.5±9 | 64.5±7.3 | 64.5±7.8 |
| Follow-up (months) | 25.1±18.3 | 35.4±19.8 | 21.8±17.7 | 34.5±19.3 |
| Sequential anastomosis | 3 (30%) | 4 (40%) | 3 (50%) | 4 (29%) |
| LVEF (%) | 51.5±9.2 | 51.9±9.5 | 51.4±8.9 | 52.1±9.7 |
| ACE inhibitors use | 3 (30%) | 4 (40%) | 3 (50%) | 4 (29%) |
| Statins use | 3 (30%) | 5 (50%) | 2 (33%) | 6 (43%) |
| History of: | | | | |
| Hypercholesterolemia | 3 (30%) | 6 (60%) | 2 (33%) | 7 (50%) |
| Systemic hypertension | 3 (30%) | 3 (30%) | 2 (33%) | 4 (29%) |
| Diabetes mellitus | 2 (20%) | 0 | 1 (16%) | 1 (7%) |
| MI in the grafted area | 2 (20%) | 2 (20%) | 1 (16%) | 3 (21%) |

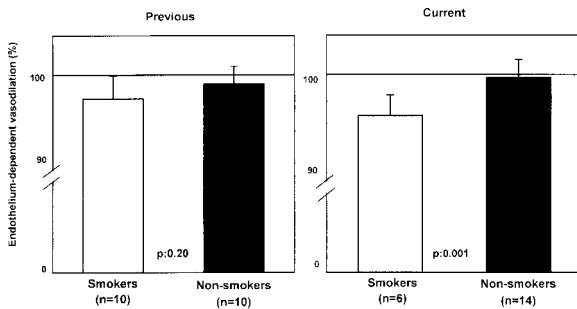*Legend: LVEF: left ventricular ejection fraction; MI: myocardial infarction.*

**Figure 1.**
*Endothelium-dependent vasodilation (as percentage of the maximal vasodilative capacity) of ITA grafts in smokers and non-smokers.*

showed also comparable baseline values and maximal vasodilative capacity of the ITA, but the endothelium-dependent vasodilation was significantly lower in current smokers than in non-smokers (94.8±2.6 % vs. 99.6±2.3 %; p:0.001 "95% CI: -7.1 to -2.1") (Figure 1).

## DISCUSSION

This study demonstrates that, though ITAs maintain a vasodilative response to acetylcholine infusion in the presence of coronary atherosclerosis and after CABG, continued smoking, but not a previous history of smoking before surgery, predicts a reduction in endothelium-dependent vasodilatation of the arterial graft.

Cigarette smoking is known to reduce the production of nitric oxide, alter the rheology at the endothelial surface and upregulate the expression of leukocyte adhesion molecules. Smoking can enhance the oxidation of circulating low-density lipoproteins, thus leading to the development of atherosclerosis. It is also able to promote thrombosis onto the dysfunctional endothelium. In the clinical setting this translates as an increased incidence of cardiac adverse events [4].

Previous studies have reported that smokers have a worse outcome after CABG, due to an increased hazard for perioperative complications, graft occlusion and re-intervention [2]. Referring to the unfavourable results and hypothesising a waste of health care resources, some authors have even suggested not offering CABG to smokers [5].

Although smoking can be held responsible for myocardial and coronary damages occurring before surgery, a previous history of smoking before CABG does not seem a mayor determinant for a future impairment of the arterial graft integrity. In a previous study we found that both endothelium-dependent and independent vasomotility of arterial conduits are correlated with the age of the patient but do not deteriorate over time after surgery [6]. Even in the presence of diffuse atherosclerosis, and differently from coronary arteries, which show an aberrant vasoconstrictive response to acetylcholine, ITAs vasodilate regardless of any risk factor, including smoking habit before surgery.

However, in patients who continued smoking after surgery the endothelium-dependent vasodilatation is mildly but significantly impaired: whether this finding might negatively influence the long-term outcome in those patients receiving arterial grafts is questionable, also due to the small dimensions of our study group. Nevertheless, an effort should be made in convincing patients who undergo CABG of the beneficial effect of quitting smoking with the aim of preserving the integrity of the implanted grafts.

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