

INTERVENTIONAL CARDIOLOGY AND SURGERY

Continued improvement of clinical outcome and cost effectiveness following intravascular ultrasound guided PCI: insights from a prospective, randomised study

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Objective: To investigate in a prospective randomised study both long term clinical effects and cost effectiveness of percutaneous coronary interventions (PCI) with or without intravascular ultrasound (IVUS) guidance.

Methods: 108 male patients with stable angina referred for PCI of a significant coronary lesion were randomly assigned to IVUS guided PCI or conventional PCI. Individual accumulated costs of the entire follow up period were calculated and compared in the randomisation groups. Effectiveness of treatment was measured by freedom from major adverse cardiac events.

Results: Cost effectiveness of IVUS guided PCI that was noted at six months was maintained and even accentuated at long term follow up (median 2.5 years). The cumulated cost level was found to be lower for the IVUS guided group, with a cumulated cost of £163 672 in the IVUS guided group versus £313 706 in the coronary angiography group ($p = 0.01$). Throughout the study, mean cost per day was lower in the IVUS guided PCI group (£2.7 v £5.2; $p = 0.01$). In the IVUS group, 78% were free from major adverse cardiac events versus 59% in the coronary angiography group ($p = 0.04$) with an odds ratio of 2.5 in favour of IVUS guidance.

Conclusion: IVUS guidance results in continued improvement of long term clinical outcome and cost effectiveness. The results of this study suggest that IVUS guidance may be used more liberally in PCI.

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Intravascular ultrasound (IVUS) offers the unique opportunity of direct inspection of the coronary vessel wall, while angiography shows the lumen only.¹⁻⁷ In fact, IVUS imaging has shown that angiography underestimates the presence and extent of atherosclerosis.⁶⁻⁹ Moreover, stent underexpansion can frequently be observed with IVUS despite a good angiographic result.¹⁰⁻¹¹ The use of IVUS during percutaneous coronary intervention (PCI) may therefore help to optimise the results of PCI and particularly of stent implantation. In addition, IVUS provides the operator with more correct information on the real vessel size, which facilitates device selection.¹² The approach of IVUS guided PCI has previously been investigated, generally with a much shorter period of follow up,¹³⁻¹⁷ but only a few cost effectiveness analyses on IVUS guidance have been published.¹⁸⁻²¹ Most previous studies on IVUS guidance, however, have been performed in high volume centres for PCI.

In the present study, we assessed the major adverse cardiac event (MACE) rate and cost effectiveness of IVUS guidance at five years after inclusion of the first patient in a relatively low volume centre for PCI. A hospital perspective was applied. Our cost effectiveness analysis addressed the cumulative costs related to the initial interventional procedure, hospitalisation, and outpatient treatment. The cost of documentary IVUS in the coronary angiography (CAG) guided group was not included.

METHODS

Study design and inclusion criteria

The study was performed as a prospective randomised clinical trial. Male patients suffering from stable angina pectoris with de novo lesions in native coronary arteries who where scheduled for PCI according to the standard referral system of Odense University Hospital were included. The standard

referral criterion for PCI was the visually determined significance of one or two coronary artery lesions by > 50% in symptomatic patients. In case of equivocal significance of the lesion, the patient was first assessed by non-invasive tests according to our hospital routine. This is a widespread clinical approach to PCI referral, in both Europe and the USA, which allows transferring the results of this study to many patients.

Immediately before the procedure, the patients were randomly assigned to PCI guided by IVUS or to angiography only. Randomisation was performed by drawing lots from sealed opaque envelopes. Patients randomised to angiographically guided intervention had so-called "documentary IVUS" before PCI and after completion of the intervention.

The interventional cardiologist was blinded to the results of the IVUS investigation, as the IVUS screen was turned away and the entire pullback remained uncommented on. Nevertheless, all IVUS data were stored and analysed off line to compare the IVUS data of the two groups. Accordingly, we could determine how many patients in both groups achieved the so-called MUSIC (multicenter ultrasound stenting in coronaries) criteria.²²

Patients randomised to IVUS guided PCI had a pre-PCI IVUS examination. Predilatation with an undersized balloon was performed if the operator was unable to cross the lesion with the IVUS catheter. Device size was chosen based on the

Abbreviations: AMI, acute myocardial infarction; AVID, antiarrhythmics versus implantable defibrillators; CABG, coronary artery bypass grafting; CAG, coronary angiography; CSA, cross sectional area; CRUISE, can routine ultrasound influence stent expansion; IVUS, intravascular ultrasound; MACE, major adverse cardiac event; MUSIC, multicenter ultrasound stenting in coronaries; OPTICUS, optimization with ICUS to reduce stent restenosis; PCI, percutaneous coronary intervention; RESIST, restenosis after IVUS guided stenting; TVR, target vessel revascularisation

information afforded by the IVUS pullback and was optimised until a satisfactory result was obtained or further optimisation seemed to be unsafe. Intracoronary Doppler investigation was carried out before PCI and at completion of the procedure.

Clinical information was obtained by a physician not related to the study. Five years after inclusion of the first patient, patient records were reviewed and the following data were recorded: rehospitalisation rate; length of stay for angina, Q wave acute myocardial infarction (AMI), coronary artery bypass grafting (CABG), death, or target vessel PCI; and the number of outpatient visits in the department of cardiology.

Patient population

The following patients were not considered for this study: firstly, patients with an AMI less than three months before scheduled PCI; secondly, patients who had suffered from unstable angina within a month before the procedure; thirdly, patients with a left bundle branch block; and lastly, patients with atrial fibrillation and those with increased serum creatinine concentration ($> 200 \mu\text{mol/l}$). Patients in whom PCI proved impossible because of a total occlusion that could not be crossed with a guide wire were subsequently excluded ($n = 6$), as were patients in whom no IVUS pullback could be performed ($n = 3$). The number of excluded patients was considered to be a measure of IVUS guidance applicability. No patient was excluded because of a suboptimal result or unobtainable initial IVUS pullback. The local medical ethics committee approved the study and patients gave informed consent.

IVUS guidance

After routine preinterventional CAG and the administration of 0.2 mg intracoronary glyceryl trinitrate, IVUS was performed using a 2.9 French UltraCross IVUS catheter (CVIS, Sunnyvale, California, USA) in conjunction with a Sonos IVUS imaging system (Hewlett Packard, Andover, Massachusetts, USA). Motorised pullbacks were performed at a speed of 0.5 mm/s, starting from a point at least 10 mm distal to the study lesion up to the ostium of the study vessel. In the IVUS guided group, the choice of the initial balloon size was based on the mean of the distal and proximal reference lumen diameters, which were determined from the cross sectional areas (CSA) using the mathematical formula $\text{area} = \pi \times \frac{1}{2} \text{diameter}^2$. This was to avoid the error of measuring a diameter of an irregular lumen. If the result did not comply with the IVUS criteria for optimal stent implantation or plain balloon angioplasty, the device was upsized. Reference segments were chosen as the healthiest segments proximal and distal to the lesion (maximum distance 10 mm from the target lesion site without major side branches).

The IVUS criteria used to describe optimal stent implantation were adapted from the MUSIC study²² and consisted of the following requirements:

- complete apposition of the stent against the vessel wall
- minimal in-stent lumen CSA of 90% or more of the averaged reference lumen CSA or 100% of the smaller reference lumen CSA; in stents with a minimum lumen CSA of more than 9 mm^2 , this parameter had to be 80% or more of the averaged reference lumen CSA or 90% or more of the smaller reference lumen CSA
- lumen CSA at the proximal stent entrance $> 90\%$ of the proximal reference lumen CSA.

For optimal plain balloon angioplasty; the minimum cross sectional lumen area had to be 90% or more of the average reference lumen CSA or larger than the smaller reference lumen CSA. In case of a minimum lumen CSA of $> 9.0 \text{ mm}^2$, this parameter had to be 80% or more of the average reference lumen CSA or 90% or more of the smallest reference lumen CSA.

Optimisation was continued until the IVUS criteria were met or further increase in balloon size or pressure seemed unsafe. IVUS images were analysed on line for intervention guidance and offline for further lesion characterisation and reevaluation of procedural success according to the abovementioned criteria.

Angiographic guidance

Before the intervention, CAG was performed immediately after an intracoronary injection of glyceryl trinitrate (0.2 mg). Three angiographic views were recorded for the right coronary artery and four views for the left coronary artery. Balloon size was calculated as the mean of the reference lumen diameters (healthiest looking segments proximal and distal to the lesion) in at least two orthogonal projections. Lumen dimensions were measured on line with an electronic calliper measuring system (Siemens, Erlangen, Germany). Angioplasty was considered successful with the accomplishment of a 30% residual stenosis or less in the absence of emergency CABG or the occlusion of major side branches. There was no protocol requirement to implant a stent or, in the case of stenting, to implant a specific type of stent. Provisional stenting was permitted at the operator's discretion.

Quantitative coronary analysis

Quantitative coronary angiography was performed off line on the preinterventional and postinterventional CAG at the core laboratory of the Thoraxcenter, Rotterdam, the Netherlands, using the CAAS II system (PieMedical, Maastricht, the Netherlands), as previously described in detail.²³ On the preinterventional CAG, the lesion was graded according to the modified American Heart Association/American College of Cardiology classification.²⁴ All angiographic data presented in this paper are the results of this (offline) quantitative coronary angiography analysis.

Cost effectiveness analysis

A cost effectiveness analysis measures the effect of an intervention in natural units. The incremental cost and incremental effectiveness of one intervention are determined and compared with one another.²⁵

Activity based costing

The costs of the two approaches (IVUS guided PCI and conventional PCI) were determined by the use of activity based costing. Activity based costing measures the cost of a particular procedure or type of hospitalisation by determining the activities involved and adding the cost of each.²⁵⁻²⁷ The cost of a given activity is composed of costs that are easily related to that particular activity (direct cost) such as utensils used or work time and costs that have to be allocated between several activities (indirect cost), such as shared equipment, administration, and building maintenance.

Cost data compilation

The incremental cost of the initial IVUS guided PCI compared with the CAG guided PCI were calculated by summing for each group the cost of all utensils used in the case of varied use (that is, number of balloons and stents), a cost estimate of time consumption according to profession, and a cost estimate of extra hospitalisation days, based on a calculation of the per day hospitalisation price from a parallel activity based costing study.^{28, 29}

For calculation of the cost of reintervention in the form of elective PCI or CABG, cost data from a parallel study using activity based cost estimates for PCI and CABG hospitalisations, as well as outpatient visits,^{28, 29} were used as given numbers.

All costs were calculated as a full cost figure—that is, containing all cost categories covered by the department involved, including a share of all central initial expenses,

Table 1 Patient demographics

	CAG guided group (n=54)	IVUS guided group (n=54)	p Value
Clinical data			
Age (years)	57 (33–78)	57 (40–73)	NS
Prior CABG (%)	4	7	NS
Prior PCI (%)	15	6	NS
Prior MI (%)	44	54	NS
Diabetes (%)	11	4	NS
Current smoker (%)	15	30	NS
History of hypertension (%)	24	20	NS
Hypercholesterolaemia (%)	93	96	NS
Angiographic data			
Number of diseased vessels			NS
1	48	46	
2	43	41	
3	9	13	
Lesion artery location (%)			NS
Left anterior descending	46	48	
Circumflex	26	24	
Right coronary	28	28	
Lesion classification (%)*			NS
A	24	30	
B ₁	30	24	
B ₂	13	28	
C	33	19	
Lesion length by QCA (mm)	13.3 (9.2)	13.4 (11.7)	NS
Size of reference vessel by QCA (mm)	2.8 (0.5)	2.8 (0.5)	NS
LVEF by ventriculography (%)	69 (12)	65 (12)	NS
IVUS data			
Lesion length by IVUS (mm)	24.2 (15.1)	23.0 (15.6)	NS
Size of reference vessel by IVUS (mm)	3.6 (0.4)	3.6 (0.5)	NS
Calcified plaque (%)†	25	25	NS

*Modified American Heart Association/American College of Cardiology classification.

†Calcium present in an arc >90°.

Continuous data are mean (SD).

CABG, coronary artery bypass grafting; CAG, coronary angiography; IVUS, intravascular ultrasound; LVEF, left ventricular ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; QCA, quantitative coronary angiography.

depreciation of equipment, and administration. Data were collected from 1997 at the time of inclusion in the randomised trial of IVUS guided PCI versus non-IVUS guided PCI.

Statistical analysis and data presentation

We studied two different types of outcome: firstly, the effect measure, defined as freedom from the occurrence of MACE (defined as the occurrence of death, Q wave AMI, or revascularisation procedures); and secondly, the cost measure “coronary artery disease related” costs during follow up—that is, readmittance for stable or unstable angina pectoris or AMI, revascularisation, and outpatient visits—summarised from the study PCI. The occurrence of MACE in each randomisation group over time was depicted by Kaplan-Meier survival curves. The difference in freedom from MACE between the two groups in the entire follow up period was tested using logistic regression.

Individual accumulated costs during follow up were compared using the Mann-Whitney test. For each randomisation group a cumulated cost curve was calculated by summation over time of the cost of occurring activities.

Continuous variables are presented as mean (SD) and were compared using the Mann-Whitney test. Categorical variables are presented as percentages and were compared using Fisher's exact test. Ranked categorical variables were tested with the Mann-Whitney test. In case of a difference, individual ranks were tested with Fisher's exact test. A probability value of $p < 0.05$ was considered significant.

RESULTS

Baseline characteristics

The study comprised 108 lesions in 108 male patients included from May 1996 until December 1998. A total of 54 patients

were randomised to PCI based on CAG guidance only and 54 were randomised to IVUS guided PCI. All patient records were available for the assessment of the event rate follow up.

There was no significant difference in patient demographics between the two randomisation groups with regard to baseline risk factors, extent of coronary artery disease, and target lesion characteristics (table 1). The existing non-significant difference in the occurrence of some risk factors did not challenge the conclusion, as the prevalence was small compared with the influence of the risk factor. For instance, six patients in the CAG guided group and two patients in the IVUS guided group had diabetes.

Procedural results

One hundred and eight procedures were performed. The difference in procedure time between the IVUS guided group and the CAG guided group (corrected for IVUS documentary pullback in the non-IVUS guided group) was 23 minutes. Four patients (three patients in the IVUS guided group and one patient in the CAG guided group) did not receive any coronary intervention, based on reassessment of the lesion (using the CAG results for the CAG guided group and CAG combined with IVUS data in the IVUS guided group). The data from these patients were analysed according to randomisation group. Table 2 presents procedural results. Table 3 presents technical preinterventional and postinterventional data.

Follow up

Median follow up time was two and a half years (0.6–3.8 years, 25th and 75th centiles). The occurrence and time of occurrence of hospitalisation and outpatient visits were noted, along with the amount and type of activity involved in each contact.

Table 2 Procedural results

	CAG guided group (n=54)	IVUS guided group (n=54)	p Value
Procedure type (%)			NS
No intervention	2	6	
Plain old balloon angioplasty	13	7	
Stent	85	87	
Operator time, gloves on to gloves off (minutes)	100 (37)	113 (38)	NS
Success rate (%)*	98	92	NS
MUSIC criteria reached (%)	16	64	<0.01
Final balloon size (mm)	3.5 (0.5)	3.9 (0.5)	<0.05
Inflation pressure (atm)	11 (2)	13 (3)	<0.05
Number of balloons used	1.6 (0.9)	1.9 (1.0)	NS
Number of stents used	1.2 (0.8)	1.4 (0.9)	NS
Acute gain by IVUS (mm)	1.3 (0.8)	1.6 (0.8)	<0.05
Relative acute gain by IVUS (mm)	0.3 (0.2)	0.5 (0.2)	<0.05
Death, Q wave MI, CVA, bleeding at puncture site requiring transfusion, or subacute stent thrombosis (%)	0	0	NS
Femoral aneurysm (%)	2	2	NS
Emergency CABG (%)	0	2	NS
Use of abciximab (%)	6	4	NS

*Residual stenosis of 35% or less by QCA in the absence of emergency CABG, closure of a major side branch, or flow limiting dissection.

CVA, cerebrovascular accident; MUSIC, multicenter ultrasound stenting in coronaries.

Table 3 QCA and IVUS results before and after intervention

	Preintervention			Postintervention		
	CAG guided (n=54)	IVUS guided (n=54)	p Value	CAG guided (n=54)	IVUS guided (n=54)	p Value
QCA data						
Diameter stenosis (%)	64 (18)	60 (17)	NS	26 (14)	27 (10)	NS
MLD (mm)	1.0 (0.5)	1.1 (0.6)	NS	2.2 (0.5)	2.3 (0.4)	NS
IVUS data						
Diameter stenosis (%)	54 (19)	51 (19)	NS	19 (11)	7 (12)	<0.001
Area stenosis (%)	68 (11)	68 (11)	NS	33 (18)	12 (22)	<0.001
MLD (mm)	1.5 (0.9)	1.6 (0.9)	NS	2.9 (0.4)	3.3 (0.5)	<0.001
MLA (mm ²)	2.5 (1.8)	2.7 (2.0)	NS	6.9 (2.1)	8.7 (2.5)	<0.05

Data are mean (SD).

MLA, minimum lumen cross sectional area; MLD, minimum lumen diameter.

Freedom from MACE results

Figure 1 presents the Kaplan-Meier survival curves of freedom from MACE. Significantly fewer patients in the IVUS guided group reached the combined end point of Q wave AMI, repeat PCI, CABG, or death ($p = 0.04$). In the IVUS guided group, 78% of the patients remained completely event-free versus 59% in the CAG guided group, which corresponds to an odds ratio of 2.5 in favour of IVUS guidance ($p = 0.04$). Table 4 presents the number of individual events in each randomisation group. The person time (that is, population at risk) for the first MACE was 122 patient years for the CAG guided group and 145 patient years for the IVUS guided group.

Cost effectiveness results

Table 5 presents central activities costs. Amount and length of hospitalisation, procedure expenses, and number of outpatient visits were considered. In the CAG guided group, more patients had longer in-hospital stays with more expensive activities (that is, CAG, PCI, or CABG). A total of 18.5% had no further costs after CAG guided PCI versus 46.3% of the IVUS guided PCI patients ($p = 0.004$).

The cumulated costs were lower in the IVUS guided group at \$163 672 versus \$313 706 in the CAG group ($p = 0.01$; fig 2). This was the result not only of a lower frequency of expensive activities such as coronary revascularisation but also of a lower rate of hospitalisation due to angina and fewer outpatient visits. Hence, an increase in effect was noted along with a decrease in cost in the IVUS guided group, and IVUS guidance was thus the dominant treatment. As patient inclu-

sion was evenly spaced in both groups, differences in time under study did not influence the results. Studying individual average daily cost in fact yielded the same results as individual accumulated cost. It was found that the average cost per day during the entire length of follow up was \$5.2 for the CAG guided PCI patients and \$2.7 for patients in the IVUS guided group ($p = 0.01$).

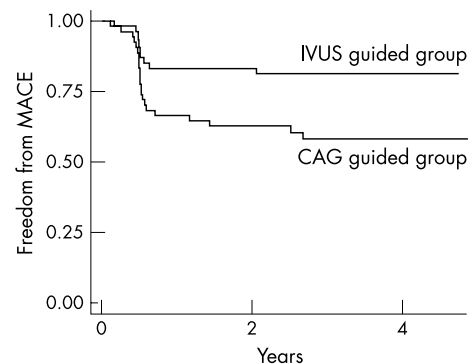


Figure 1 Number of patients meeting a major adverse cardiac event (MACE) end point is significantly lower in the intravascular ultrasound (IVUS) guided group than in the coronary angiography (CAG) group, mainly because there were fewer repeat percutaneous coronary interventions in this group. The difference increases during the first two years, after which it appears to stabilise.

Table 4 Occurrence of major adverse cardiac events (MACE) during follow up

MACE	CAG guided group (n=54)	IVUS guided group (n=54)	p Value
Repeat PCI (%)	61	31	0.004
CABG (%)	17	11	NS
Q wave AMI (%)	0	2	NS
Death (%)	4	0	NS

The person time (that is, population at risk) for the first postintervention cost was 174 patient years for the CAG guided group and 176 patient years for the IVUS guided group.

DISCUSSION

IVUS guidance of PCI is rarely practised on a routine basis, apart from certain high volume centres. Potential arguments against the routine use of IVUS are the increase in time required, the need for supplementary training, and a subjective feeling that "I do not need this extra information to perform a good coronary intervention". Nevertheless, the results of the present study cast much doubt on such points of view and suggest more use of IVUS for guidance of coronary interventions would be beneficial.

Present study

Our data show that the use of IVUS guided PCI results in a long term reduction of MACE. Though initial costs were higher for patients who received IVUS guided PCI, cumulated costs over time were less than half the costs for patients who received conventional angiographically guided PCI. Mean and median cost per day after PCI was significantly lower in the IVUS guided group ($p = 0.01$). The differences in both MACE and cost even seem to increase over time (figs 1 and 2). In the present study, IVUS guided PCI was found to be cost effective because fewer rehospitalisations, reinterventions, and outpatient visits clearly outweighed the initial extra expenses.

Nevertheless, patients with greater or lesser benefit of IVUS guidance could not be identified because of the limited sample size. In the AVID (antiarrhythmics versus implantable defibrillators) trial,¹³ high grade lesions (> 70%) had a very low restenosis rate (4%) following IVUS guided PCI and this may support a general assumption that IVUS guidance may be less beneficial in mild lesions than in more advanced lesions.

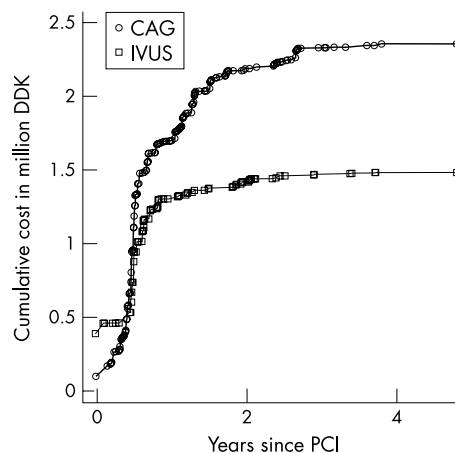


Figure 2 IVUS guidance is seen to be an incremental cost. This is because of the use of IVUS catheters and extra procedure staff and time. IVUS guided PCI results in a lower target vessel revascularisation rate and because of this patients guided by IVUS have a lower cumulated cost than patients guided by CAG alone. This is most apparent at one and a half to two years after PCI, after which the difference in cost is stable.

Previous studies

A few randomised studies have previously shown that IVUS guidance reduces the clinically driven target vessel revascularisation (TVR) rate during follow up^{14,30} and may reduce angiographic restenosis rate.¹⁵ However, some studies have shown no benefit of IVUS guidance.^{16,17} The results of the present study are in concordance with those of the CRUISE (can routine ultrasound influence stent expansion) study, where follow up at nine months showed lower TVR rates in the IVUS guided arm,¹⁴ and with the SIPS (strategy for intravascular ultrasound guided PTCA and stenting) trial,³⁰ where a significant difference in TVR rates was noted after two years of follow up.

In contrast to our study, the RESIST (restenosis after IVUS guided stenting),¹⁷ OPTICUS (optimization with ICUS to reduce stent restenosis),³¹ and AVID¹³ studies found no overall benefit of IVUS guided PCI. However, there are several differences between those trials and ours, notably a difference in end points, study population, and design.

We did not study the end point of angiographic restenosis, as angiographic restenosis, specifically angiographic restenosis of 40–60%, may or may not be clinically significant and lead to TVR and, as a result, it is difficult to compare our study with

Table 5 Cost of individual activities according to the activity based costing system in Danish, US, and European currencies

Activity	Cost		
	Kr	\$	€
PCI procedure	44188.07	5260.5	6028.40
CAG procedure	4891.76	581.67	667.21
Admission to cardiology department	2843.97	338.17	387.90
Basic bed-day, cardiology department	1794.48	213.38	244.76
Discharge from cardiology department	1204.22	143.19	164.25
Outpatient visit to cardiology department	756.48	89.95	103.18
CABG procedure	39354.37	4679.53	5367.70
Admission to thoracic surgery department	2813.31	334.52	383.72
Basic bed-day, thoracic surgery department	1671.42	198.74	227.97
Discharge from thoracic surgery department	217.97	25.92	29.73
Admission to intensive care, thoracic surgery or cardiology department	523.22	62.21	71.36
Basic bed-day, intensive care, thoracic surgery or cardiology department	12908.36	1534.90	1760.62
Discharge from intensive care, thoracic surgery or cardiology department	217.97	25.92	29.65
Myocardial perfusion imaging	3400.00	404.29	463.74

Corresponding costs in US dollars and euros were calculated from currency exchange rates of March 2002. Nuanced costs were calculated by summing up individual relevant activities.

the RESIST trial,¹⁷ which studied this end point. In the RESIST trial, which was powered to a degree of 40%, no difference in angiographic restenosis was discernable at six months' follow up. In the OPTICUS trial there was no difference in angiographic restenosis at six months or in MACE at six and 12 months.

Also, a difference in study population, as well as a difference in the number of PCIs performed every year at the study centres, between our study and the RESIST¹⁷ and OPTICUS³¹ studies may explain the difference in outcome. Our patients were all referred for elective PCI, whereas the other studies also included patients with unstable angina.

Our study design was different, with an event oriented follow up of five years following inclusion of the first patient, as opposed to a mandatory six month invasive follow up and a clinical 12 month follow up in the OPTICUS trial. Another difference is that our patients were randomised before initiation of the intervention as opposed to randomisation of patients with a satisfactory angiographic result; thus, our study also comprised unsuccessful PCIs and thus presumably more challenging procedures. Also, our study was carried out at a low volume centre with only 500 PCIs performed yearly. This may indicate that the greatest value of IVUS guided PCI is in patients with stable angina and possibly in low volume centres, where one would assume that operator expertise would be more limited than in high volume centres.

Only few cost effectiveness analyses on IVUS guidance have previously been published. In the RESIST trial¹⁸ the overall cost induced by the use of IVUS was not fully offset during follow up (six months). At six months' follow up of the present study population IVUS guidance was cost effective.¹⁹ This was in accordance with the findings of the SIPPIS trial at two years' follow up.²⁰ In a review of a mixture of study types, randomised as well as non-randomised, with immediate follow up²¹ an improved effect of IVUS guided PCI at an increased cost was found. Our estimate of incremental cost of IVUS guidance in PCI (Kr5370 or £470) was comparable with the one reached in this review (£412). Our follow up time was considerably longer.

In the analysis of the patients in the present study¹⁹ at six months' follow up an insignificant cost difference of Kr152 223 in favour of IVUS guidance was found with a significant difference in combined end points of angina, flow reduction, and angiographic restenosis in favour of IVUS guidance. Although no significant difference in TVR rates was shown, a trend existed.¹⁹ In this study of long time follow up in the same patients, the cost difference was further increased to significance, implying that cost effectiveness, although not immediately present, can be anticipated in this subset of patients in the long run.

Applicability of the present study's result

Patients were included before any intervention and there were no angiographic exclusion criteria or protocol requirements to implant a stent. The intention in selecting the patient sample was for it to be representative of the routine patient referred for elective PCI. Participation was proposed to all patients prospectively matching the inclusion criteria and all of those who agreed to take part were included. The intention of the inclusion criteria was to match an everyday population of elective PCI patients, as well as patients with a presumed suboptimal PCI result. As the applied referral procedure is comparable with routine clinical practice in Europe and the USA, the results may relate to a large number of patients.

Conclusions

The data of this prospective, randomised, single centre study showed that IVUS guidance resulted in continued improvement of long term clinical outcome and cost effectiveness. The data support a more liberal use of IVUS guidance of coronary

interventions, particularly in procedures performed on patients with stable angina.

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IMAGES IN CARDIOLOGY

Intermittent opening of a mitral valve tilting disc prosthesis 23 years after implantation caused by circumferential pannus

A 58 year old woman was admitted with a short history of presyncope and orthopnoea. Mitral valve (MV) replacement had been performed 23 years earlier. Transthoracic echocardiogram showed the mitral prosthesis was well seated but appeared to open on alternate cardiac cycles only. M mode examination of the aortic valve revealed cyclical variation of the ejection time and transmitral Doppler showed antegrade flow through the valve on alternate cardiac cycles only (below left, arrows mark intermittent absence of transmitral flow). Transoesophageal echo showed no evidence of thrombus or vegetation. At left and right heart catheterisation, the pulmonary wedge pressure (PCW) showed cyclical variation, rising to a crescendo every second cycle before MV opening. Simultaneous PCW and left ventricle (LV) pressure monitoring revealed a peak MV gradient of 24 mm Hg, falling to 2 mm Hg

during opening (below right). Correspondingly, LV and aortic pressure traces showed an alternating rise and fall, which was exaggerated by deep inspiration.

The patient was referred for urgent valve surgery. At operation no evidence of strut fracture, thrombus or vegetation was found. On the ventricular aspect a florid pannus was seen, spanning 360° of the valve impinging on the free margin of the disc. During ventricular systole the valve closed normally, but during diastole would only open when atrial pressure reached a level sufficient to overcome the frictional resistance imparted by the pannus. The valve was replaced with a 25 mm Sorin bileaflet valve and she was discharged without complication.

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