Myocardial “hybrid” revascularisation with minimally invasive direct coronary artery bypass grafting combined with coronary angioplasty: preliminary results of a multicentre study

T Wittwer, J Cremer, P Boonstra, J Grandjean, M Mariani, A Mügge, H Drexler, P den Heijer, E-R v Leitner, A Hepp, M Wehr, A Haverich

Department of
Cardiothoracic and
Vascular Surgery,
Hannover Medical
School,
Carl-Neuberg-Strasse
1, 30625 Hannover,
Germany
T Wittwer
A Haverich

Department of
Cardiac and Vascular
Surgery, University of
Kiel, Germany
J Cremer

Thorax Center,
University Hospital
Groningen, Groningen,
Netherlands
P Boonstra
J Grandjean
M Mariani

Department of
Cardiology, Hannover
Medical School,
Hannover, Germany
A Mügge
H Drexler

Department of
Cardiology, University
Hospital Groningen
P den Heijer

Department of
Cardiology,
Krankenhaus Siloah,
Hannover, Germany
E-R v Leitner

Department of
Cardiology,
Vinzenzkrankenhaus,
Hannover, Germany
A Hepp

Department of
Cardiology, Augusta-
Kranken-Anstalt,
Bochum, Germany
M Wehr

Correspondence to:
Dr Wittwer
email: Th.Wittwer-MD@
t-online.de

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Abstract

Objective—To expand the benefits of the minimally invasive direct coronary artery bypass (MIDCAB) concept to patients with multivessel disease, a hybrid procedure combining surgical revascularisation of the left anterior descending artery with interventional procedures for additional coronary lesions has recently been introduced. Preliminary results in patients undergoing this hybrid procedure are presented.

Design and patients—Since December 1996, 35 patients (29 male, 6 female, mean (SD) age 56.7 (17) years) underwent a hybrid revascularisation performed as a primary MIDCAB procedure for grafting of the left anterior descending artery with the left internal mammary artery, followed by staged angioplasty and stenting of additional coronary lesions.

Results—After MIDCAB grafting the postoperative course was uneventful in all patients. Coronary reangiography after a median of seven days revealed patent and functioning left internal mammary artery grafts in all patients. Applying subsequent percutaneous transluminal coronary angioplasty and occasional stenting ($n = 14$), a total of 47 lesions were treated successfully. Procedure related complications did not occur. All patients remained free from angina and no stress ECG changes were recorded.

Conclusions—The preliminary results of this hybrid approach to myocardial revascularisation suggest that this is a safe and effective procedure for complete revascularisation in selected patients with multivessel disease. Elderly and reoperative patients with significant comorbidity may benefit especially from such hybrid procedures by avoiding cardiopulmonary bypass and mid sternotomy.

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Revascularisation of multivessel coronary artery disease with the left internal mammary artery (LIMA) and additional vein grafts using cardiopulmonary bypass and cardioplegic arrest currently represents the standard technique in coronary surgery.^{1–2} Despite continuing improvements in equipment and surgical technique, deleterious effects of cardiopulmonary bypass, such as systemic inflammatory reactions, postoperative organ dysfunction, and coagulatory disorders, still pose problems.^{3–5} Aiming for less invasive cardiac surgery, several groups have reported encouraging results of coronary artery bypass grafting without cardiopulmonary bypass through conventional sternotomy or through different minimised incisions.^{6–8} In two larger series, a left anterolateral minithoracotomy was used to harvest the LIMA with subsequent coronary artery grafting of anterior vessels on a beating heart without cardiopulmonary bypass.^{9–10} Because of limited access through this incision, this approach cannot be applied for multivessel revascularisation without additional incisions or use of cardiopulmonary bypass.

To expand the benefits of minimally invasive direct coronary artery bypass (MIDCAB) approaches to patients with multivessel disease, a

“hybrid” procedure combining surgical revascularisation of the left anterior descending artery (LAD) with interventional procedures for additional coronary lesions is considered to be an attractive treatment option for certain coronary patients.^{11–14} We present our preliminary results in 35 consecutive cases undergoing this hybrid procedure, involving initial surgical revascularisation of the LAD followed by subsequent angioplasty of additional coronary lesions. As part of a common educational programme addressing standardisation and technical innovations in MIDCAB procedures, the surgical part was performed in the cardiosurgical departments of either the Hannover Medical School, Germany, or the University Hospital of Groningen, the Netherlands. Subsequent coronary angioplasties were undertaken in the collaborating and referring cardiology departments. This study comprises the largest number of patients undergoing this hybrid procedure to date.

Patients and methods

Since June 1996 hybrid revascularisations were performed in 35 patients (29 men, six women, mean (SD) age 56.7 (17) years). Twenty one patients had two vessel disease, another 10 patients had three vessel disease, and only four

Table 1 Patient characteristics and cardiac performance

Mean (SD) age (years)	56.7 (17)
Sex (male/female)	29/6
Unstable angina	12
Previous myocardial infarction	16
Left ventricular ejection fraction 30–50%	5
Left ventricular ejection fraction < 30%	3
Previous PTCA/stenting	3
One vessel disease	4
Two vessel disease	21
Three vessel disease	10
Proximal LAD stenosis/occlusion	27/8

Values are number of patients (expect for age).

patients exhibited single vessel disease of the LAD with additional stenosis of large diagonal branches (table 1). Twelve patients presented with unstable angina. Left ventricular function was moderately impaired in five patients (left ventricular ejection fraction < 50%) and severely depressed in three patients (ejection fraction < 30%). History of previous myocardial infarction was present in 16 patients. Except for eight patients with a proximal LAD occlusion, significant proximal LAD stenosis unsuitable for percutaneous transluminal coronary angioplasty (PTCA) combined with various lesions in other locations were the major findings on preoperative angiographic evaluation (fig 1). Two patients had developed LAD restenosis after previous PTCA. Comorbidities included chronic obstructive pulmonary disease with peak flow < 4 litres/s and/or forced expiratory volume in one second (FEV₁) < 65%, insulin dependent diabetes mellitus, chronic end stage renal failure (dialysis), recent history of cerebrovascular accident, hyperthyroidism, extensive mediastinal shift following previous thoracic surgery for active tuberculosis, deep vein thrombosis, and malignant melanoma (table 2).

SURGICAL TECHNIQUE

Under general anaesthesia and with use of a left main bronchus blocker, the patient was placed in a 30° right lateral decubitus position. With continuous haemodynamic monitoring by use

Table 2 Patient comorbidity

Disease	n
Diabetes mellitus (insulin dependent)	8
Chronic obstructive pulmonary disease	3
Cerebrovascular accident	2
Hyperthyroidism	2
Chronic renal failure (dialysis)	1
Pulmonary tuberculosis (old)	1
Myocardial aneurysm	1
Deep vein thrombosis	1
Peripheral arterial occlusive disease	1
Malignant melanoma	1
Severe obesity	2

of a thermodilation catheter, the left hemithorax was entered via an 8–10 cm anterior submammary incision through the fourth or fifth intercostal space. Following insertion of specially designed retractors for optimal visualisation (IMA-Retractor, CardioThoracic Systems, Portola Valley, California, USA), the LIMA was dissected in a pedicled fashion for a length of 8–14 cm to allow for a tension free course to the LAD. Side branches were controlled by use of electrocautery or haemoclips. Following systemic heparinisation with 100 IU/kg bodyweight and topically applied papaverine, large haemostatic clips were applied to the distal internal mammary artery. After pericardial incision a “horseshoe” cardiac stabiliser (Stabilizer, CardioThoracic Systems) was placed on the epicardium under moderate pressure to facilitate a motionless field for LAD preparation without haemodynamic compromise. The LAD was encircled by two 4/0 polypropylene tourniquet sutures approximately 2 cm apart and was incised without preceding ischaemic preconditioning if ST segments,

Table 3 Peak concentrations of troponin T and CK-MB postoperatively

Patient	Troponin T (normal < 0.5) (µg/l)	CK-MB (normal < 10) (U/l)
1	0.03	4
2	0.02	5
3	NM	11
4	0.03	6
5	NM	7
6	0.03	5
7	0.01	6
8	NM	9
9	0.01	5
10	0.02	7
11	NM	7
12	0.09	8
13	0.1	10
14	0.08	7
15	0.03	6
16	0.04	6
17	0.02	5
18	0.06	6
19	0.05	5
20	NM	4
21	0.07	4
22	NM	4
23	0.02	3
24	NM	4
25	NM	5
26	0.01	7
27	NM	NM
28	NM	NM
29	NM	NM
30	NM	NM
31	NM	NM
32	NM	NM
33	NM	NM
34	NM	NM
35	NM	NM

NM, not measured.

Figure 1 Proximal stenosis of LAD. (A) Left anterior oblique projection. (B) Right anterior oblique projection.

rhythm, and haemodynamics remained stable during a test period of two minutes. The anastomosis was performed using one running 8/0 polypropylene suture. Thereafter the pedicle was fixed to the epicardium with fibrin glue.

Figure 2 Patent LIMA graft to LAD in different projections (A, B, C).

Table 4 Angiographic results after LIMA to LAD MIDCAB procedures

LIMA	n	Anastomosis	n	Native LAD	n
Course with tension	1	Stenosis	0	Proximal stenosis (new) < 50%	2
Kinking	0	Malinsertion to D2	1	Distal stenosis (new) < 50%	1
Dissection	0				
Intraluminal thrombi	0				
Intramural haematoma	0				
Narrowing	0				
Competitive flow	0				
Occlusion	0				
Fixation to chest wall	2				

D2, second diagonal branch.

Figure 3 Concomitant stenosis of right coronary artery in right anterior oblique projection. (A) Native vessel. (B) During balloon inflation. (C) After successful PTCA.

Protamine was administered as an antagonist for the heparin.

Compared to our conventional coronary artery bypass procedures, the anaesthetic regimen was not modified and all patients remained ventilated in the intensive care unit for about 4–6 hours postoperatively. Concentrations of troponin T and isoenzyme of creatine kinase MB (CK-MB) were routinely checked in a subgroup of patients postoperatively.

INTERVENTIONAL PROCEDURE

After a median of seven days postoperatively, patients were transferred to the cardiology department for coronary angiography. With use of a transfemoral arterial approach (8F sheets), the LIMA graft was selectively catheterised first (6F Cordis (Haan, Germany) diagnostic internal mammary artery catheter). After confirmation of a well functioning anastomosis (no obstruction and with good run off), a left or right guiding catheter (7 or 8F Cordis (Haan, Germany), with sideholes) was placed in order to perform a PTCA of the target lesion. For anticoagulation, 15 000 units of heparin were administered intra-arterially. Patients took 500 mg of aspirin orally 24 hours and one hour before cardiac catheterisation, with an additional dose of 250 mg ticlopidine in case of stenting. A 0.014 inch floppy guiding wire (Galeo F; Biotronics, Berlin, Germany) was placed distal to the target lesion and stenoses were dilated with either Viva (Boston Scientific, Hilden, Germany) or Worldpass (Cordis) balloons. In the event of dissections or in the presence of residual stenosis > 35%, stents (9 mm or 16 mm length, Sitomed, Unterschleissheim, Germany) were implanted with 10–14 atmospheres. After removal of the balloon and guiding wire a final coronary angiogram was performed to document successful PTCA/stent intervention.

Results

Following initial surgical revascularisation all patients had an uneventful postoperative course without myocardial infarction, major intrathoracic bleeding requiring reintervention, or wound healing complications. The mean (SD) postoperative ventilation time was 9.0 (4.4) hours. None of the patients required postoperative inotropic support. In addition no further deterioration of organ function occurred in patients with pre-existing dysfunction of the lungs, kidneys, or central nervous system. Troponin T and CK-MB concentrations, which were routinely checked in a subgroup of patients, were within normal limits after surgery (table 3). With a liberal perioperative anticoagulation management using intravenous heparin, postoperative blood drainage averaged 588 (673) ml and transfusion of packed red blood cells was necessary only in one patient with end stage renal failure caused by a pre-existing anaemic status. Mean postoperative hospital stay was 7.5 (4.1) days. Coronary angiography was performed within 10.0 (11.5) days (median seven days) and revealed patent LIMA to LAD grafts with

Figure 4 Concomitant stenosis of right coronary artery in left anterior oblique projection. (A) After successful PTCA. (B) Native vessel.

adequate graft function in all patients (fig 2). No anastomotic stenoses or LIMA narrowing occurred, but in three patients new wall irregularities of the native LAD without significant stenosis (< 50%) were seen close to the LIMA-LAD anastomosis (table 4). Subsequent PTCA of different coronary artery lesions (figs 3 and 4), with stent implantation in case of dissections or residual stenoses > 35%, was performed during the same investigational period (table 5). All four patients with one ves-

sel disease (patients 3, 5, 13, and 23 from table 5) were included in this hybrid approach; they underwent additional PTCA of large diagonal branches to avoid potential ischaemia in those areas owing to progression of native coronary disease.

After this combined procedure with successful interventional revascularisation, all patients remained free from angina and stress ECG changes in the revascularised areas during their hospital stay.

The long time interval between surgery and PTCA in patients 9 and 12 resulted from their transfer to an affiliate hospital where they were scheduled for PTCA after 41 days and 54 days postoperatively.

Discussion

Following the initial experience of Calafiore and colleagues⁹ and Subramanian and colleagues,¹⁰ performing minimally invasive direct coronary artery surgery via an anterolateral thoracotomy, the interest for this approach has rapidly expanded worldwide. By avoiding extracorporeal circulation, with its potential adverse effects and median sternotomy, major advantages should be expected, especially for elderly and comorbid patients.¹⁵

In our series comorbid factors included severe chronic obstructive pulmonary disease, cerebral deficits after stroke, end stage renal failure requiring haemodialysis, malignant melanoma, severe obesity, and post-tuberculosis scarring with mediastinal shift (table 2). In part these associated diseases have been proven to correlate with increased peri-operative risk.¹⁵ However, none of our patients

Table 5 Coronary status and postoperative interventional procedures

Patient	Coronary artery disease	LAD stenosis (%)	LIMA graft	Function of graft	PTCA of	Stenting of	Post-operative day
1	2	80	LAD	Adequate	D1/RCA	D1	1
2	2	95	LAD	Adequate	RCA	None	9
3	1	100	LAD	Adequate	D1	D1	8
4	3	90	LAD	Adequate	RCA	None	6
5	1	90	LAD	Adequate	D1	D1	4
6	3	94	LAD	Adequate	PLA2	None	7
7	3	100	LAD	Adequate	D1/RCA	D1/RCA	9
8	3	60	LAD	Adequate	CX/PLA1	CX	7
9	2	80	D2	Adequate	RCA	None	41
10	2	100	LAD	Adequate	RCA	RCA	2
11	2	80	LAD	Adequate	CX	None	10
12	3	80	LAD	Adequate	CX	None	54
13	1	80	LAD	Adequate	D2	None	11
14	2	90	LAD	Adequate	RCA	None	6
15	2	75	LAD	Adequate	CX	None	11
16	3	99	LAD	Adequate	RIM	None	24
17	2	95	LAD	Adequate	PLA1	None	5
18	3	100	LAD	Adequate	PLA1/PLA2	None	7
19	2	90	LAD	Adequate	RPDA	None	12
20	2	90	LAD	Adequate	D1	D1	28
21	3	70	LAD	Adequate	PLA2	None	11
22	2	70	LAD	Adequate	PLA1	None	3
23	1	90	LAD	Adequate	D1	None	2
24	2	95	LAD	Adequate	RCA	None	10
25	2	90	LAD	Adequate	PLA2	None	2
26	2	100	LAD	Adequate	RIM	RIM	9
27	2	100	LAD	Adequate	RCA	RCA	7
28	2	100	LAD	Adequate	CX	CX	7
29	3	95	LAD	Adequate	RCA/CX	CX	7
30	2	90	LAD	Adequate	RCA	None	7
31	2	99	LAD	Adequate	CX	None	6
32	2	100	LAD	Adequate	RCA	RCA	5
33	2	90	LAD	Adequate	RCA	RCA	6
34	3	90	LAD	Adequate	RCA/CX	RCA/CX	5
35	2	99	LAD	Adequate	CX	None	6

CX, circumflex artery; D1, first diagonal branch; D2, second diagonal branch; LAD, left anterior descending artery; PLA, posterolateral branch; RCA, right coronary artery; RIM, intermediate branch; RPDA, right posterior descending artery.

developed further deterioration of organ dysfunction. In addition, cerebral disorders or other specific neurologic deficits frequently related to cardiopulmonary bypass techniques were completely absent.¹⁶

Currently, revascularisation of anterior coronary arteries is the most common MIDCAB approach whereas grafting of posterolateral and posterior vessels requires either cardiopulmonary bypass assistance or a beating heart procedure via a median sternotomy. The question therefore arises whether there are particular patients with multivessel disease who may benefit more from MIDCAB grafting than from conventional surgery or interventional treatment. Thus, for patients with a specific increased risk related to cardiopulmonary bypass, exclusive MIDCAB treatment of LAD culprit lesions not amenable to interventional techniques may be a valuable option. However, the conceptual disadvantage of incomplete myocardial revascularisation by means of isolated treatment of culprit lesions has already been evaluated in interventional cardiology.¹⁷⁻¹⁸ In this context, complete interventional or surgical revascularisation has been assessed to reduce the rate of subsequent major events such as myocardial infarction, repeated interventions, and redo surgical treatment.¹⁷⁻¹⁹ Therefore, these facts would strongly argue for completeness of revascularisation even in patients with interventionally untreatable LAD lesions and apparently increased risk for cardiopulmonary bypass application. To utilise the principal advantage of MIDCAB grafting in terms of avoidance of sternotomy and cardiopulmonary bypass, hybrid approaches may represent a very attractive treatment option for this particular group of patients with coronary artery disease.

It may be speculated that the overall acceptance of a hybrid concept depends primarily on the functional success of the MIDCAB LIMA-LAD graft and the long term efficacy of interventional techniques which should be part of randomised trials. Considering the preliminary results of pioneering groups,⁹⁻¹⁰ it may be anticipated that MIDCAB surgery for LAD culprit lesions can be as effective as conventional coronary artery bypass grafting using the internal mammary artery, which has been shown to be more effective than interventional treatment with respect to event free survival and relief of ischaemic symptoms.²⁰⁻²¹ In addition, interventional treatment of coronary lesions of the circumflex system or the right coronary artery appears to be less frequently associated with subsequent restenosis than treatment of LAD lesions.¹⁷⁻²²⁻²⁵ The still significant rate of LAD restenosis of around 20% within the first year, even in the era of stenting,²⁶ could be avoided provided MIDCAB grafting proves to result in superior long term effects. These aspects would support the assumption that hybrid procedures comprise the more successful applications of surgical and interventional techniques, and would extend the benefits of MIDCAB grafting of anterior vessels to multivessel coronary artery disease in a particular group of patients.^{11-14 27}

In addition to patients with multivessel disease and extensive comorbidity, such hybrid approaches may also be reasonable in patients with two vessel disease presenting with LAD type C lesions, which are considered to represent suboptimal indications for interventional treatment.¹⁷ Expecting further progression of coronary artery disease in these patients, primary MIDCAB grafting as the surgical part of a hybrid procedure may prevent complications associated with reoperation through a mid sternotomy occurring later on. In cases of an unacceptable high risk for conventional coronary surgery a hybrid procedure can even be used for revascularisation of a left main stem stenosis, with subsequent intervention being performed under myocardial protection by a functioning LIMA graft to the LAD.¹⁴

In discussing the applicability of a hybrid concept the sequence of the procedures is also important. Currently, some authors tend to perform PTCA first, with the option that in case of any interventional complication surgery will effectively treat the underlying coronary disease as well as the interventional complication in one procedure.¹²⁻²⁸ Additionally, certain PTCA complications such as intimal disruption, thrombus formation or embolisation, and even stenting could require extensive anticoagulation,¹⁷ with increased risk of bleeding complications if performed after MIDCAB surgery. On the other hand, failure of PTCA with need for emergency bypass surgery is rare with decreasing incidence,²⁹⁻³⁰ and primary PTCA with complications requiring pharmacotherapy such as aspirin, ticlopidine, or glycoprotein IIb/IIIa inhibitors³¹⁻³² might delay the following MIDCAB procedure unnecessarily. Consequently, many groups prefer the primary revascularisation of the LAD as the most significant lesion by means of MIDCAB followed by PTCA several days later.¹¹⁻¹³⁻¹⁴ Another major advantage of this sequence is the verification of the LIMA to LAD graft patency at the time of reangiography. The following PTCA can then be performed with a reduced risk as the LAD is already protected by the functioning LIMA graft. In order to reduce further total hospital stay some groups even perform angiography and PTCA immediately after surgery while the patient is still anaesthetised. However, this procedure was not feasible in our institution for technical and organisational reasons. Generally, the sequence with primary MIDCAB grafting would represent the common practice in interventional cardiology to treat the culprit lesion first.¹⁷

CONCLUSION

In our experience the hybrid approach of myocardial revascularisation by means of a LIMA to LAD MIDCAB procedure, followed by additional interventional treatment, appears to be safe and effective in complete coronary revascularisation, particular in patients with two or three vessel disease. Patients who might experience special benefit from this new approach include the very elderly with an intensive degree of comorbidity and a high risk

constellation for cardiopulmonary bypass with mid sternotomy. Also younger and otherwise healthy patients with two vessel disease who are not optimal candidates for exclusive interventional procedures may benefit from a hybrid procedure.

Detailed evaluation of this combined procedure in larger randomised multicentre studies is warranted to document long term effectiveness compared to conventional coronary artery bypass grafting or interventional treatment alone. Follow up information on the described patient group, including serial coronary reangiography, is currently being collected.

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