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Hybrid Coronary Artery Revascularization—Review and Update 2007

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ABSTRACT

Hybrid coronary revascularization is a combination of minimally invasive coronary artery bypass grafting and percutaneous coronary intervention in patients with multivessel coronary artery disease. The concept is now 10 years old. Implementation was slow, but major developments have taken place. The surgical part of the procedure can be performed in a totally endoscopic fashion instead of by a mini-incision approach and catheter-based intervention includes the use of drug-eluting stents. Whereas during early development staged approaches were taken, simultaneous interventions have become feasible. Hybrid procedures are an attractive option for high-risk patients or for patients who seek a less traumatic revascularization option.

INTRODUCTION AND DEFINITION

Hybrid coronary artery revascularization is a combination of minimally invasive left internal mammary artery (LIMA) bypass grafting to the left anterior descending artery (LAD) combined with a catheter-based intervention to other coronary arteries. Over the last 10 years, this procedure has been developed from minimally invasive direct coronary artery bypass grafting (MIDCAB) plus percutaneous transluminal coronary angioplasty (PTCA) to totally endoscopic coronary artery bypass grafting (TECAB) procedures plus PTCA and drug-eluting stenting. Table 1 shows publications on hybrid coronary revascularization.

In the following report, we want to update the status of hybrid coronary revascularization in the light of new studies as well as discuss again the rationale and the approach to a hybrid concept seen as part of an integrated interventional process.

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RATIONALE AND BACKGROUND

Reviewing the most recent literature, "hybrid" techniques and approaches in cardiac patients are described in different settings. Most investigating groups are publishing data about coronary revascularization combining surgery with percutaneous coronary intervention (PCI), where operating techniques and the order and delay of selected procedures are changing [Kiaii 2005; Katz 2006; Us 2006]. Other colleagues define the "hybrid" approach as PCI combined with operative valve placement [Brinster 2000].

We want to focus on pure coronary interventions; because of recent publications, the indication and the timing and sequence of the procedures may be discussed in a very intriguing fashion. Furthermore, we think that combined interventional and surgical coronary revascularization procedures have to be evaluated in the light of the specific cardiac surgery technique applied. Therefore, we have to recapitulate a few milestone studies published in this field.

HISTORY AND DEVELOPMENT

Beginning with Angelini et al in 1996 using minithoracotomy procedures, mostly MIDCAB surgery was applied in integrated revascularization [Friedrich 1997; Riess 1998; Witwer 1999; Cisowski 2002], and because of the fact that this technique is very challenging, a broad use of the hybrid approach was prevented. Despite the study of Diegeler et al showing a superiority of MIDCAB operations with LIMA to LAD compared with bare-metal stenting in proximal target vessel lesions, the abovementioned technical problems combined with elevated reintervention rates were turning surgeons away from hybrid approaches.

A new aspect for cardiac surgeons, cardiologists, and patients was introduced with the technique of TECAB. This approach, for the first time, was really accepted as *the* minimally invasive procedure that had been expected for a long time.

Based on the first encouraging clinical results of endoscopic bypass procedures [Falk 2000; Kappert 2000; Dogan 2002] in single-vessel disease, complete coronary revascularization in multivessel disease began to be embedded in the idea of a hybrid minimally invasive procedure combining LIMA grafting to LAD, which should present a lesion not suitable for PCI, and stenting of non-LAD lesions.

Table 1. Data from Previous Studies*

Report	Patients	Mortality	LIMA Stenosis 6 mo, %	PTCA/Stent Restenosis 6 mo, %
[Angelini 1996]	6	0	n.a.	n.a.
[Friedrich 1997]	2	0	n.a.	n.a.
[Mack 1997]	1	0	n.a.	n.a.
[Zenati 1999]	31	0	0	10
[Wittwer 2000]	35	0	0	7
[Farhat 2000]	1	0	n.a.	n.a.
[De Canniere 2001]	20	0	0	5
[Presbiterio 2001]	42	2	10	n.a.
[Riess 2002]	57	0	3	24
[Cisowski 2002]	50	0	2	10
[Stahl 2002]	54	0	n.a.	n.a.
[Bonatti 2005]	1	0	n.a.	n.a.
[Kiaii 2005]	1	0	n.a.	n.a.
[Bonatti 2005]	1	0	0	0
[Davida Vicius 2005]	20	0	0	0
[Katz 2006]	27	0	4	33
[Hulusi 2006]	17	0	0	18
[Srivastava 2006]	1	0	n.a.	n.a.
Total	367	0	2%	12%

*LIMA indicate left internal mammary artery; PTCA, percutaneous transluminal coronary angioplasty; n.a., not applicable.

The Position of LIMA to LAD in Hybrid Procedures

In this context, we have to consider the literature-based background for integrated revascularization procedures combining cardiac surgery and PCI.

The LIMA graft probably remains the best revascularization for the LAD concerning reintervention rates as well as major adverse cardiac and cerebral events [Boylan 1994; Tatoulis 2004].

Catheter-based interventional procedures on non-LAD lesions may reach similar long-term patency rates as surgicalrocedures using either arterial or venous grafts, especially if drug-eluting stents (DES) are used [Hirshfeld 1991; Moses 2003].

After LIMA grafting of the LAD, the protection of the left anterior myocardial wall allows safer approach of a second coronary lesion affecting the posterior wall segment or even the left main coronary artery [Mack 1997].

Other valuable factors favoring integrated or hybrid coronary revascularization approaches are the morbidity and mortality rates of conventional bypass surgery in higher risk patients. In particular, the use of cardiopulmonary bypass led to a bad outcome in these patients and fueled the broad use of stenting techniques in multivessel diseased patients [Serruys 2004].

If considering lesion morphology, even interventional cardiologists have to admit that left main adjacent or emerging LAD stenoses, long chronically occluded LAD lesions, or other type C classified LAD morphology are not very attractive for percutaneous revascularization. Therefore the statement "LIMA grafting is the best choice for a complex LAD lesion" should not be contradicted in the light of long-term follow-up [Moses 2003; Tatoulis 2004]. Moreover, the safety of LIMA grafting appears to be very high, with mortality rates near zero percent [Ovrum 1997].

The Position of DES in Hybrid Procedures

In terms of safety issues, the latest controversies concerning DES have completely changed the interventional cardiologist's world. The first published data of DES reducing significantly the restenosis rate have contributed to an extended off- and on-label use of these stents [Moses 2003; Fajadet 2005; Tschuchida 2007]. Since 2006, however, bigger concerns about DES use and elevated mortality rates compared to bare-metal stents appeared [Camenzind 2006, 2007; Nordmann 2006]. Since then, a very polarized debate with new meta-analyzed data and retrospective registry evaluations appearing monthly have created doubts about the risks and benefits of DES use.

The newest data from a Swedish registry [Lagerqvist 2007] are outweighed by other meta-analyses [Stone 2007], leaving the real-world cardiologist with a large variety of information but without a clear take-home message.

We think that these discussions will help stimulate cooperative resolutions between cardiac surgeons and cardiologists, where the best therapeutic options from both sides should be combined to achieve the optimal revascularization result.

LATEST INFORMATION

Reviewing the latest publications on hybrid coronary revascularization, 2 studies were conducted with a more representative patient cohort. In the first study, off-pump CABG was combined with PCI. Immediate postoperative outcome and long-term angiographic results were investigated. Delay between PCI and off-pump CABG in a high-risk defined

Table 2. Strategies*

Strategy A: Surgery before PTCA
- Angiographic control of LIMA bypass with subsequent PTCA
- PTCA possible with "protected" anterior myocardial wall (patient even suitable for left main PTCA?)
- Very low PTCA failure rate with need for emergency bypass
- No major time delay for complete revascularization

Strategy B: PTCA before Surgery
- No protected anterior wall
- Possible delay of surgery due to PTCA/stent–related medical treatment (aspirin, clopidogrel, GP IIB/IIIA antagonists)
- No mid-term angiographic control of LIMA bypass
- Rescue CABG technically easier

Strategy C: PTCA with Surgery
- ONE procedure (intraoperative CABG and PTCA)
- Complications resolved in one setting (switch to CABG or vice versa)
- Excellent back up of cardioanesthesia with ECG, vital parameters and TEE
- New PTCA horizons with use of coated stents (sirolimus, NO, paclitaxel) and/or carbon stents (less platelet aggregation inhibitors required?)

*PTCA indicates percutaneous transluminal coronary angioplasty; LIMA, left internal mammary artery; CABG, coronary artery bypass grafting; ECG, electrocardiography; TEE, transesophageal echocardiography.

Table 3. Hybrid Revascularization with Use of Robotic Technique*

MIDCAB (LIMA endoscopically)	2	5%
AH-TECAB (LIMA-LAD)	28	79%
BH-TECAB (LIMA-LAD)	4	11%
AH-TECAB (RIMA-LAD/LIMA-Cx)	2	5%
LIMA first	26	72%
PCI first	2	6%
Simultaneous intervention	8	22%

*MIDCAB indicates minimally invasive direct coronary artery bypass grafting; LIMA, left internal mammary artery; AH-TECAB, arrested-heart totally endoscopic coronary artery bypass grafting; LAD, left anterior descending artery; BH-TECAB, beating-heart totally endoscopic coronary artery bypass grafting; RIMA, right internal mammary artery; Cx, circumflex artery; PCI, percutaneous coronary intervention.

population was only 3 hours. The study shows an uneventful postoperative outcome, a 100% patency of LIMA grafts after one year, and a 17.6% restenosis rate in dilated segments. There was no specification about the use of bare-metal or drug-eluting stents [Us 2006].

The second study [Katz 2006], a multicenter trial, combined PCI with robotic TECAB. There are 2 major issues in this trial: first, the discussion about variation of timing and sequence of the procedures selected; second, the endpoints concerning safety, feasibility, and long-term results. As shown in Table 2, the pros and cons of procedure timing are debated controversially.

The reintervention issue in this publication may not be representative because of the rather small patient cohort, but reflects very well the "real world" in a multicenter trial not comparable to the selected patients in randomized "bare-metal stents versus DES" studies. In this study, there was not only a high percentage of diabetic patients but also a large variety of PCI target lesion morphology. Safety and feasibility aspects of integrated revascularization were demonstrated to be positive in this study, but the reintervention issue has to be investigated in larger patient cohorts.

The concept of integrated revascularization combining robotic TECAB with PCI in one simultaneous session is very intriguing. The prerequisites for this challenging approach are

Table 4. Hybrid Revascularization with Use of Robotic Technique*

PTCA + bare metal stent	5	14%
PTCA + DES	10	28%
SVG (conversion)	4	11%
Not feasible (severely calcified target)	1	3%
Not performed (pat. asymptomatic after LIMA-LAD) or to be performed (if symptomatic)	15	41%

*PTCA indicates percutaneous transluminal coronary angioplasty; DES, drug-eluting stents; SVG, saphenous vein graft; LIMA, left internal mammary artery; LAD, left anterior descending artery.

Table 5. Hybrid Revascularization with Use of Robotic Technique

Mortality	0%
Freedom from angina at 3 years postop	89%
Target vessel reintervention	
LIMA 3 (periop)	10%
0 (after discharge)	0%
PCI target 1 (3 months)	4%

*LIMA indicates left internal mammary artery; PCI, percutaneous coronary intervention.

a very close cooperation between cardiac surgeons, cardiologists, anesthesiologists, and perfusionists as well as a specially designed operating theatre with facilities for both TECAB surgery and PCI. Bob Kiaii et al in 2005 described an enhanced operative suite allowing integrated revascularization procedures. In the same publication, the authors address a very crucial benefit of hybrid approaches: the potential for cost reduction resulting from a more efficient and multipurpose use of hospital room facilities combined with a shorter hospital stay of a patient with a more rapid return to full physical activity and social environment.

From our experience beginning with staged hybrid interventions in 1995 [Friedrich 1997] and based on logistics of intraoperative diagnostic angiography [Friedrich 2005], we introduced a simultaneous integrated revascularization program [Bonatti 2005, 2007]. We have learned from this experience that combined interventions in one session are feasible and reproducible and that it is possible to operate under full aspirin and clopidogrel loading.

We considered feasibility, safety, and reintervention rates as major endpoints (Tables 3-5). For this purpose, a specifically tailored preoperative, intraoperative, and postoperative quality control program with the use of invasive and noninvasive imaging modalities is mandatory at our institution (Table 6) [Schachner 2007].

As shown in the publications in Table 1, hybrid coronary intervention results according to the literature are very attractive. Despite the fact that high-risk patients were included in many series peri-interventional mortality was only 0.5%. In the studies that performed follow-up angiography, LIMA patency rates were found to be in the 98% range and restenosis rates in the PCI part of the procedure are in an attractive 12% range.

Furthermore, this "hybrid thinking" approach is highly intensifying surgeons and cardiologist's cooperation because of the extensive common evaluation of coronary angiograms and possible triage to hybrid procedures.

Table 6. Follow-up Standard in Coronary Hybrid Revascularization

(1) Noninvasive computed tomography angiography
(2) Invasive coronary angiography (intraoperatively; 3 or 6 months)
(3) Clinical evaluation 3 or 6 months and 12 months with stress testing

CONCLUSION

Based on an intense cooperation program between cardiac surgeons and cardiologists, a "closed chest" minimally invasive coronary revascularization program for patients with multivessel coronary artery disease is feasible, safe, and may be a very attractive therapeutic option in well-selected patients. The indications for "hybrid strategies" in cardiac patients will certainly increase because of the fact that more individually tailored therapies are warranted in patients at high risk for complications in conventional procedures or patients searching for a less traumatic intervention that allows for a faster physical and social rehabilitation process.

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