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Hybrid Coronary Artery Revascularization: Logistics and Program Development

Guy J. Friedrich,[1] Patricja Jonetzko,[1] Nikos Bonaros,[2] Thomas Schachner,[2] Michael Danzmayr,[2] Ruth Kofler,[1] G. Laufer,[2] O. Pachinger,[1] Johannes Bonatti[2]

Departments of [1]Cardiology and [2]Cardiac Surgery, Innsbruck Medical University, Innsbruck, Austria

ABSTRACT

Planning hybrid coronary artery revascularization—a combination of cardiac surgery with percutaneous procedures—requires, at first sight, a very complex logistical setup. Technical and equipment related details should be defined as early as possible in order to have time for training of all OR personnel involved. The most challenging aspect in OR-located hybrid coronary revascularization remains a very close cooperation of cardiac surgeons and interventional cardiologists. This teamwork does include indication findings and subsequent referral of multivessel coronary artery disease patients to hybrid procedures, as well as high individual flexibility of interventionalists and surgeons. The major prerequisite for this cooperation is a mutual acceptance of different revascularization approaches and the intent to combine their most striking advantages. Intraoperative graft angiography during coronary artery bypass grafting (CABG) procedures is one important step toward simultaneous hybrid coronary revascularization procedures. We describe our experience with on table angiography using a mobile C-arm for intraoperative imaging. This fluoroscopy system can in selected cases be used for simultaneous hybrid procedures.

INTRODUCTION

As known from many catheter-based interventional procedures in cardiology, diagnostic approaches are mandatory as an optimal prerequisite for therapeutic interventions. Building up logistics for hybrid coronary revascularization in a cardiac surgery operating room therefore has to be planned via a diagnostic procedure. Only in cases where safe diagnostic coronary angiography combined with good image quality is feasible, further steps like complete coronary revascularization, combining surgical and interventional revascularization approaches, is possible.

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 MIDCAB plus PTCA to totally endoscopic CABG procedures plus PTCA and drug eluting stenting [Angelini 1996, Friedrich 1997, Riess 1998, Wittwer 1999, Cisowski 2002, Stahl 2002, Bonatti 2005]. Logistic problems are the main reason why hybrid coronary artery revascularization has not reached wide application. Nevertheless, the feasibility of simultaneous procedures has been demonstrated [Angelini 1996].

THE RATIONALE FOR HYBRID CORONARY REVASCULARIZATION

The concept of hybrid coronary revascularization may be based on 3 major rationales:

1) According to the literature and despite the recent developments in interventional cardiology (drug eluting stents), the left internal mammary artery graft probably remains the best revascularization for the LAD concerning reintervention rates as well as major adverse cardiac and cerebral events (MACCE) [Boylan 1994, Tatoulis 2004].

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

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

INTRAOPERATIVE ANGIOGRAPHY AS A PREREQUISITE FOR SIMULTANEOUS HYBRID PROCEDURES

While introducing innovative cardiac surgery procedures, especially minimal invasive techniques, quality control has to be very robust in order to compete with standard operating techniques. We therefore developed an early intraoperative coronary angiographic program to have diagnostic gold standards during transition of surgical learning curves.

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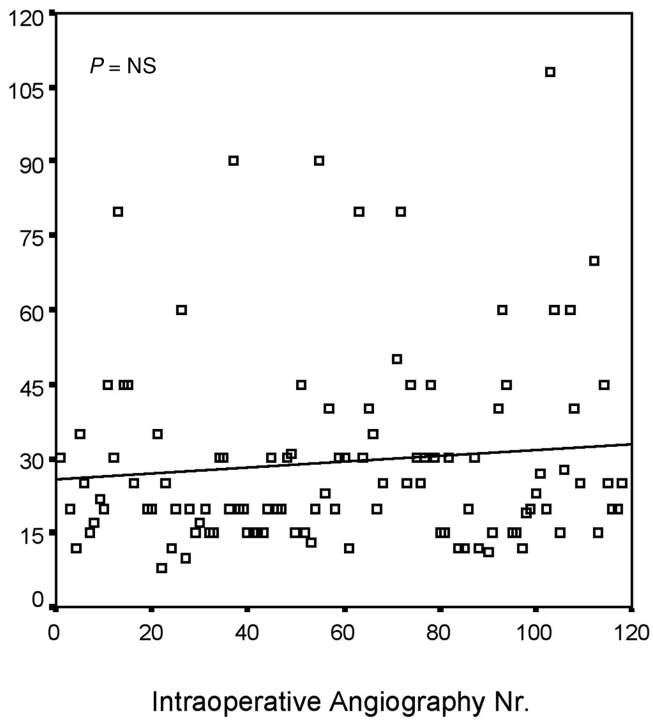
Address correspondence and reprint request to: Guy J. Friedrich, MD, Department of Cardiology, Internal Medicine, Innsbruck Medical University, Anichstrasse 35, A-6020 Innsbruck, Austria; 43-512-504-23255; fax: 43-512-504-22767 (e-mail: guy.friedrich@uklibk.ac.at).



Time requirements for intraoperative angiography in innovative coronary artery bypass grafting procedures (MIDCAB, OPCAB, TECAB, robotic anastomotic suturing during conventional CABG). Note that the majority of procedures can be performed in a 20 to 30 minute range. Outliers represent examinations which led to therapeutic consequences and in which another angiography was carried out in order to check the revision result.

Technical equipment was selected to allow intraoperative coronary angiography with adequate image quality and without causing major operating time delays. This program requires a very intensive cooperation of cardiac surgeons and cardiologists due to the important point of personnel flexibility to guarantee coverage of intraoperative angiography by a cardiologist in the OR, often not situated adjacent to the cath lab setting.

This situation implements a precise scheduling of surgery procedures requiring intraoperative coronary angiography and sometimes more than a good intention of cardiologists and surgeons! Furthermore, cooperation with anaesthesiology and OR staff has to be carefully planned and discussed, especially at the beginning of the program where time delays may not be avoided.

In our experience, the first 10 to 20 diagnostic coronary angiographic investigations were showing in which direction the program should be differently designed. A lot of convincing arguments was necessary to reach general acceptance of a procedure requiring sometimes not more than 30 minutes, but avoiding severe peri- and postoperative complications and subsequently far greater time-consuming surgical revision procedures.

TECHNIQUE OF INTRAOPERATIVE ANGIOGRAPHY

Beginning with MIDCAB and OPCAB procedures [Bonatti 2003] and finally entering the field of TECAB surgery, diagnostic coronary angiography has been performed in more than 100 patients. Using a 7 French femoral access coronary angiography was performed following the Judkins technique. Parallel to operative steps, preparation of angiography was carried out. To perform adequate angiographic views three periprocedural components are essential:

1) an operating table suitable for the use of a mobile C-arm—a must for different angulated angiographic views—(in our program a Maquet 1150.10D0, Maquet(c), Rastatt, Germany);

2) a mobile C-arm allowing good image quality and sufficient fluoroscopy time without a high frequency of examination breaks due to engine cooling (in our program a GE(c) OEC 9800); and

3) a high-quality contrast agent providing good image quality without severe nephrotoxic effects (in our program Visipaque(c), GE).

The video (Video 1) shows how an intraoperative angiographic study is carried out through the exposed femoral artery in an arrested heart TECAB operation.

CURRENT EXPERIENCE

In the following, a summary of our experience in the first 118 patients may provide a first glance on safety and feasibility aspects of intraoperative coronary angiography. As can be seen from Table 1, patients with normal kidney function were selected for intraoperative imaging studies.

Operating nurse, OR technicians, and perfusionists were trained to assist the angiographic examination. Examination times and radiation exposure were within the ranges of conventional diagnostic coronary angiography. Throughout the current experience, the examination time of approximately 25 minutes for 1 to 2 grafts did not decrease or increase significantly. Invasive angiography for quality control is often regarded as too time consuming for CABG but we think that the achieved time frame is well acceptable.

Table 1. Angiography Related Data*

Age	60 (30-70)
BUN	35 (14-331)
Cr	1.06 (.68-7.30)
Allergic to contrast agent	6 (5%)
Contrast agent, mL	150 (20-500)
Examination time, min	23 (8-108)
Fluoroscopy time, s	440 (6-2282)
Radiation dose, mGy	41419 (10260-272119)
Arterial access problems	0 (0%)
Significant arrhythmia	0 (0%)
Hemodynamic problems	0 (0%)

*BUN indicates blood urea nitrogen; Cr, serum creatinine.

Table 2. Grafts Investigated by Intraoperative Angiography*

Patients	118
Grafts investigated	133
Anastomoses on the beating heart:	
MIDCAB	12
OPCAB	42
TECAB (beating heart)	6
Anastomoses on the arrested heart:	
Robotically sutured anastomoses	
Through sternotomy	24
Arrested heart TECAB	49

*MIDCAB indicates minimally invasive direct coronary artery bypass grafting; OPCAB, Off-pump coronary artery bypass grafting; TECAB, totally endoscopic coronary artery bypass grafting.

No angiography-related complications such as femoral access problems or hemodynamic disturbance occurred. Intraoperative imaging studies were primarily carried out in innovative CABG operations such as MIDCAB, OPCAB, and robotic TECAB (Table 2). 95% of our grafts could be adequately visualized using the current equipment (Table 3). Drawback was mainly the inability to selectively intubate the grafts. A high rate of target vessel spasm was noted. Target vessel spasm occurred more often than graft spasm but responded well to intraluminal application of nitroglycerine in the majority of cases. Our graft revision rate of 10% is well in accordance with revision rates reported by other groups who use invasive intraoperative graft imaging [Goldstein 1998, Izzat 1999, Mack 1999]. It needs to be stressed that only innovative coronary revascularization procedures were evaluated.

In one case of TECAB (LIMA to LAD) performed on the arrested heart, acute occlusion of the right coronary artery after reversal of heparin could be demonstrated by intraoperative angiography. As the logistics had already been adequately set up, the problem could be solved by catheter-based intervention (PTCA/stenting) of this acute lesion. The intervention was performed in the cardiac surgery operating room in addition to angiographic study of the LIMA to LAD graft [Bonatti 2005]. After this simultaneous hybrid case that was carried out on an emergency basis, a current prospective protocol, the COMBINATION pilot study, is conducted at our institution in order to show the feasibility of robotic TECAB (LIMA to LAD) combined with drug eluting stent placement to non-LAD targets. The first cases have already been successfully carried out.

WHY A SIMULTANEOUS APPROACH FOR HYBRID PROCEDURES?

Considering these findings, the interest in combined revascularization procedures is constantly rising. As shown in the last year's experiences, several hybrid procedure approaches were evaluated and are displayed in the following. Staged procedures in coronary hybrid revascularization exhibit advantages and disadvantages. As can be read from Table 4, a simultaneous approach would be an intriguing concept, as it represents a single procedure that offers complete potentially long-lasting revascularization without sternotomy.

Table 3. Results of Intraoperative Angiography

Grafts adequately visualized	126/133 (95%)
Graft spasm	24/126 (19%)
Target vessel spasm	54/126 (42%)
Anastomotic patency	124/126 (98%)
Graft occlusion anastomotic toe	3/126 (2%)
Graft occlusion anastomotic heel	5/126 (4%)
Graft bleeding	1/126 (1%)
Anastomotic bleeding	1/126 (1%)
Graft revision	12/126 (10%)

CONCLUSION

An integration of percutaneous coronary interventional techniques in the cardiac surgery OR is an intriguing concept. Due to recent developments in cardiac surgery including several less invasive techniques, hybrid coronary artery revascularization is currently undergoing renewed interest despite the fact that probably few cases are really suitable. However, logistics of intraoperative coronary angiography with possibilities of ad hoc angioplasty or surgical revision may help to improve cardiac surgery results (independently of the technical approach) by diagnostic gold standard. In addition, an interdisciplinary platform is created allowing conduct of simultaneous revascularization procedures that include limited access coronary surgery and catheter-based coronary intervention. Furthermore, new horizons of immediate therapeutic options

Table 4. Hybrid Coronary Revascularization—Timing of the Procedure

Strategy A: Surgery before PTCA/Stent:
1) Angiographic control of the LIMA bypass with subsequent catheter-based intervention
2) Catheter-based intervention with "protected" anterior wall (patient even suitable for left main PTCA/stenting)
3) Very low PTCA/stent failure rate with need for emergency bypass

Strategy B: PTCA/Stent before Surgery:
1) No protected anterior wall
2) Possible delay of surgery due to PTCA/Stent related medical treatment (platelet inhibitors, aspirine, clopidogrel, Gp IIb/IIIa antagonists)
3) No short-term angiographic control of LIMA bypass

Vision/Strategy C: PTCA/Stent combined with surgery
1) One single procedure
2) Potential complications resolved in one setting (switch to CABG or vice versa)
3) Excellent backup of cardio-anesthesia with sophisticated monitoring, patient under general anesthesia
4) New horizons for both catheter-based coronary intervention and coronary surgery
5) Challenges: how do new stents react in the intra- and perioperative setting; stents that require no platelet inhibitor would be ideal

may be considered and help to intensify cooperation between surgeons and cardiac interventionalists.

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