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Aortic stent-grafting: successful introduction into the combined procedure for coronary artery bypass grafting and aortic aneurysm repair☆

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Abstract

Objectives: Coronary artery bypass grafting (CABG) and combined stent-grafting (SG) were evaluated to reduce morbidity and mortality of patients with descending or infrarenal aortic aneurysm. **Methods**: CABG and SG (thoracic $n = 6$, infrarenal $n = 36$) were performed during the same hospitalization in 42 patients (mean age of 73 ± 14 years). In 29 patients (mean Euroscore: 9), SG was performed under local anesthesia 9 ± 3 days after coronary surgery (simultaneous) and in 13 patients (mean Euroscore: 7) during the same anesthesia (synchronous). In the latter group, 11 out of 13 patients underwent off-pump CABG. All aneurysms were treated by implantation of commercially available self-expanding grafts. **Results**: CABG was successful in all, but one patient with left internal mammary artery hypoperfusion syndrome, requiring an additional distal saphenous graft to the left anterior descending coronary artery. SG was uneventful in 98% (41/42 patients). Postoperative computerized tomography showed incomplete sealing in seven patients (17%), but only the two attachment endoleaks had to be treated by one proximal and one distal SG extension. Overall hospital stay for the synchronous repair was 12.5 ± 6 days and that of the simultaneous group 17.5 ± 7 days. Thirty-day mortality was 5% (2/42) as one patient of the simultaneous group experienced a lethal cerebral embolism during SG and one patient of the synchronous group developed an untreatable infection. In the follow-up of 4 years, there were two vascular reinterventions but no additional procedure-related morbidity or mortality. **Conclusions**: This experience shows that combined CABG and SG of thoracic or infrarenal aortic aneurysm is a safe and less-invasive alternative to the open graft repair, especially in the older patients or patients with severe comorbidities.

Keywords: Coronary artery bypass grafting; Beating heart; Off-pump; Combined procedure; Aortic aneurysm; Stent-grafting

1. Introduction

Arterosclerosis commonly affects different vascular areas. Abdominal aortic aneurysms (AAA) as well as thoracic descending aortic aneurysms (TAA) are frequently associated with severe coronary artery disease (CAD) [1]. Patients undergoing AAA repair are known to present a 50% incidence of concomitant clinically significant CAD [2]. Therapeutical strategy and management of patients requiring operation for CAD and aortic aneurysm (AA) repair are representing a therapeutic challenge. The optimal timing of aneurysm repair in patients with severe CAD is still a subject of controversial discussions [3].

The two-stage intervention for surgical treatment of CAD and AAA is repeatedly reported to carry enhanced risks arising from the untreated vascular disease. The mortality rate for patients with significant CAD undergoing conventional open AAA repair is noted to be four times higher than for patients without severe CAD [4,5]. Myocardial infarction remains the leading cause of perioperative death following AAA resection [6]. However, even though coronary revascularization prior to AAA repair protects from perioperative myocardial ischemic events, these patients have still to be classified as high-risk cases, due to the significantly increased tendency of aneurysm rupture [3,7,8]. Delayed repair of an AAA following coronary artery bypass grafting (CABG) is associated with a significant increase in mortality (33%) secondary to aneurysm rupture [7].

One-stage procedure for CABG and AAA repair is frequently recommended to avoid severe complications in patients requiring myocardial revascularization and aneurysm repair [9,10]. Reduction in mortality and morbidity rates

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has been achieved with combined CABG/AAA procedure besides reduced length of hospital stay and costs [11,12]. With the rising interest in performing CABG on the beating heart, a limited number of reports have recently been published recommending the combined off-pump CABG and open surgical AAA repair as a further optimized therapeutical strategy [12–14].

With the introduction of commercially manufactured and modular devices, stent-grafting (SG) has been widely established as a therapeutical alternative for treatment of AAs with encouraging results [15,16]. Reports on combined procedure of CABG and SG are only sporadic so far [17,18]. According to an extensive literature review, publications about treatment of CAD and AAA/TAA in combined procedure with off-pump CABG and SG are completely absent at present.

The purpose of the present study was the evaluation of combined treatment for AAs and CAD by simultaneous and synchronous SG and CABG in order to achieve a further reduction of mortality and morbidity rates.

2. Patients and methods

Forty-two patients with combined CABG and SG for AA since May 1998 have been included in a prospective non-randomized study. Because of the experimental nature of aortic SG and the necessity for willing long-term follow-up controls, informed consent was obtained from all patients. Mean age of the 38 male and four female patients was 73 ± 14 years (range: 51–89 years). Ninety percent (38 patients) of all patients aged over 60 years at the time of operation.

2.1. Selection of patients

All patients were suffering either from clinically significant CAD with the presence of an associated AAA or TAA essentially requiring treatment as well, or patients have been referred for treatment of a symptomatic AA and presented a concomitant severe CAD. Main study inclusion criterion was the feasibility of aortic SG. Aortic morphological and pathological conditions were assessed by preoperative angiography and computerized tomography (CT) scanning according to a previously reported method [16].

2.2. Cardiac disease

Most of the patients had typical angina symptoms (New York Heart Association >II). According to preoperative coronary angiography, severity of the CAD was classified in ten patients (24%) as one-vessel disease and in nine patients (21%) as two-vessel disease. Majority of the patients (23 patients, 55%) were suffering from a three-vessel disease. Left ventricular ejection fraction (LVEF) was slightly reduced in 11 out of 42 patients (26%) presenting a LVEF between 40 and 55%. In 4 out of 42 patients (10%), LVEF was lower than 30%. Concomitant cardiac diseases have been valvular heart disease (4/42 patients, 10%) and cardiac arrhythmias (5/42 patients, 12%). Thirteen out of 42 patients (30%) had a history of prior myocardial infarction.

2.3. Aortic disease

Aortic disease (AAA in 17 and TAA in three patients) was the primary indication for operation in 48% of patients (20/42 patients). In this group of patients, aneurysm diameter was within 4.5–6.0 cm in 11 patients and over 6.0 cm in nine patients. Asymptomatic AA was diagnosed for the remaining 22 patients (AAA in 19 and TAA in three) primarily referred for CAD. Distribution of aneurysm diameter in that group was up to 6.0 cm in 19 patients and wider than 6 cm in three patients. The pathology of thoracic aortic disease was atherosclerotic in four and chronic aortic type B dissection in two patients.

2.4. Concomitant non-cardiac diseases

Concomitant non-cardiac diseases with clinical significance have been systemic arterial hypertension (28 patients), diabetes mellitus (five patients), chronic obstructive pulmonary disease (11 patients), chronic renal failure (13 patients), history of cerebrovascular ischemic event (four patients), history of pulmonary embolism (two patients), obesity (13 patients) and cancer in three cases (adrenal cancer, carcinoma of the prostata and carcinoma of the tongue root).

2.5. Timing and management of surgical interventions

Myocardial revascularization and combined aortic SG have been performed in all the 42 patients during the same hospitalization. Simultaneous treatment of both pathologies was performed within a mean interval of 9 ± 3 days in 29 out of 42 patients (mean age 71 years; range: 51–89 years). Preoperative mean Euroscore for this group was 8.79 ± 3.13 and the mean aneurysm diameter was 5.9 ± 1.2 cm (range: 4.1–10). Synchronous procedure, defined as treatment of two different diseases within one anesthesia, was performed in 13 out of 42 patients (mean age 73 years; range: 54–89 years). The mean Euroscore for the synchronous group was 7.0 ± 3.16 and the mean aneurysm diameter in this group of patients was 5.92 ± 1.20 cm (range: 4.5–8.5). Myocardial revascularization was performed under cardiopulmonary bypass, cardioplegic arrest or off-pump technique, respectively, according to general accepted indications. All patients unsuitable for off-pump CABG and with any degree of renal failure had to be treated in a simultaneous strategy to avoid the addition of nephrotoxic effects caused by cardiopulmonary bypass circulation during CABG and application of contrast agent during SG.

2.6. Coronary surgery

Coronary surgery was performed in the simultaneous group under cardiopulmonary support in all of the 29 patients, but cardioplegic arrest was used in only 19 patients. In ten patients, satisfactory and uncomplicated revascularization could be achieved on the unloaded beating heart. In two patients, CABG had to be performed urgently because of unstable lesions. Out of the synchronous group, 84.6% of patients (11/13) underwent coronary surgery in off-pump techniques. No case of conversion to circulatory support has become necessary. For the remaining two patients, CABG procedure has been performed with on-pump technique, but cardioplegic arrest was performed only in one patient. The average number of grafts was 3.5 ± 1.5 grafts per patient in the simultaneous group and 2.1 ± 1.6 grafts per patient in the synchronous group.

2.7. Stent-grafting

Feasibility of SG was assessed by preoperative angiography and CT scanning. SG for TAA (six patients) and AAA (36 patients) was performed according to the previously reported technique [16]. All aneurysms were treated by implantation of commercially available self-expanding grafts. The six TAA were stented with tubular endografts: Talent (Medtronic) $n = 1$/Excluder (Gore and Associates) $n = 5$. Modular type endografts, designed as trunk-ipsilateral components with an attachment site for the contralateral component, were used for treatment of AAA: Talent (Medtronic) $n = 3$, Excluder (Gore and Associates) $n = 22$, Vanguard (Boston scientific) $n = 10$, Zenith (Cook) $n = 1$. Local anesthesia combined with intravenous analgosedation was chosen as an anesthesiologic management for SG procedure in 24 out of 29 patients (89%) of the simultaneous group [16,19]. In five patients, general anesthesia was required to achieve transilliac access.

2.8. Postoperative management

All patients have been transferred to the intensive care unit (ICU) for postoperative recovery after CAD. In the simultaneous group, all of the patients went directly to the normal ward after SG. Control CT scans were performed early postoperatively for assessment of correct SG positioning, aneurysm sealing and exclusion of retroperitoneal hematoma. Follow-up of all patients including CT scans was continued at 6 weeks, 6 months and yearly postoperatively according to well-accepted criteria.

3. Results

One patient of the simultaneous group developed postoperatively, following AAA SG, a severe hypoperfusion syndrome of the left internal mammary artery–left anterior descending coronary artery (LIMA–LAD) graft that required an additional distal saphenous vein bypass grafting to the distal LAD. This procedure could again be preformed with off-pump techniques. Supplementary to inotropic medication, an intraaortic ballon pump (IABP) was inserted intraoperatively. The balloon catheter was introduced into the femoral artery and carefully maneuvered through the SG to its position into the thoracic descending aorta. Throughout the following two postoperative days, the patient's condition required inotropic support and intraaortic balloon counterpulsation. The IABP could be removed at postoperative day (POD) 2. Both the patients were operated at an emergency because unstable coronary lesions have shown an uneventful intra- and postoperative course after synchronous intervention for CAD and AAA. Minor cardiac events have been the postoperative occurrence of atrial fibrillation (seven patients, 17%) and the appearance of premature ventricular contractions in four patients (10%). Reoperations due to mediastinal bleeding have been performed in one patient of the synchronous group and in two patients of the simultaneous group.

Aortic SG showed an immediate success rate of SG with complete sealing of the aneurysm in 83% (35/42 patients), confirmed in postoperative CT scans. In two patients (2/42, 5%), one proximal as well as one distal type-I endoleak have been detected and immediately successfully corrected by SG extension. Reperfusion of the excluded aneurysm originating from the lumbar or mesenteric circulation was treated conservatively in five patients (5/42, 12%).

Two patients needed reintubation and prolonged ventilation due to respiratory failure. In four patients, temporary progression of chronic renal failure occurred (9.5%), however, without progression to terminal renal failure. Further, chest wound infections and groin wound infections occurred in five patients each. All wound infections have been minor-degree infections with unproblematic healing and without a need for surgical intervention or prolonged hospital stay.

Total duration of stay at the ICU was a mean of 3.3 ± 3.9 days for the patients of the synchronous group. These patients have been discharged from hospital after 12.5 ± 6.2 days mean. All patients after simultaneous procedure have been transferred to the ICU for postoperative recovery after CABG and after SG. Total length of stay at the ICU was 2.9 ± 4.7 days (1.8 ± 1.7 days after CABG and 1.01 ± 3.9 days after SG). Mean duration of hospital stay was 17.5 ± 7.3 days in the simultaneous group.

Early procedure-related mortality (30-day mortality) was 2.2% as one patient of the simultaneous group died at POD 3 due to a cerebral embolism following SG procedure. Another patient of the synchronous group developed an untreatable multiple organ failure and died at POD 2 after SG. Therefore, the overall early mortality of the combined procedure was 4.8% (2/42 patients) with a strictly SG-related mortality of 2.4% (1/42 patients).

During the follow-up of 4 years, no additional procedure-related morbidity or mortality occurred. Due to the death of three patients out of the simultaneous group by non-procedure associated diseases (two cases of exacerbation of carcinoma with lethal outcome and one lethal stroke) the overall mortality raised to 10.9% (five patients). However, the procedure-related mortality after completion of 4 years of follow-up remains still at 4.3% (two patients).

4. Discussion

The coexistence of severe CAD and AA is a common phenomenon, especially in the elderly population [1,7]. The incidence of coronary arterosclerosis in patients presenting with an AA can be as high as 80% [2,20]. On the other hand, CAD patients show a high rate of coexistence of major vascular diseases such as AAA or TAA. This frequent coincidence of major vascular and cardiac diseases emphasized the importance of a precise preoperative evaluation of the patient's history to avoid catastrophic events arising from unknown or suspected concomitant disease. In general, patients referred to our institution for cardiac or major vascular procedures undergo, in the presence of symptoms or risk factors for concomitant vascular or cardiac diseases, complete cardiovascular investigations preoperatively. This includes appropriate coronary, aortic and/or peripheral angiography as well as thoracic and/or abdominal CT/magnetic resonance tomography scanning to achieve accurate diagnostic information in order to decide on the therapeutic strategy. Abdominal ultrasonography and/or duplexsonography prior to cardiac surgery has a leading position as a diagnostic tool for exclusion of major abdominal aortic diseases.

Two different surgical options are used in patients requiring treatment of both diseases. A one-stage intervention, where both diseases are corrected synchronously during a single anesthesia, and the two-step staged procedures. Latter strategy, especially when there is a long delay between both procedures, carries an enhanced risk arising from the untreated vascular disease. The increased risk of aneurysm rupture following CABG procedure has been well documented [3,7,8] and can be as high as 30%. The leading cause of aneurysm rupture is probably the inflammatory response, induced by the usage of the cardiopulmonary bypass. The inflammatory reaction triggers the activation of matrix metalloproteinases, increased collagenase and elastase activity [22]. This leads to the destruction of collagen and elastin structures of the aneurysm wall. These changes in structure and composition of the aortic wall lead to aneurysm wall weakening, reduced tensile strength and progression toward aneurysmal rupture [21,22]. On the other hand, myocardial infarction remains the leading cause of perioperative death following AAA resection [6]. The mortality rate for patients with significant CAD undergoing conventional open AAA repair, without prior correction of the CAD, is observed to be four times higher than for patients without severe CAD [4,5].

One-stage procedure for CABG and AAA repair is frequently recommended to avoid such complications [9, 10]. Reduction in mortality and morbidity rates has been achieved with combined one-stage conventional open procedure besides reduced length of hospital stay and costs [11,12]. However, due to rising age of concerned population, the one-stage repair by conventional open surgery might be associated with increased perioperative mortality and morbidity caused by extensive operations and prolonged durations of procedures, as well as by concomitant non-vascular diseases [23].

To further optimize the outcome of combined procedures for CABG and AA repair, especially in the elderly patients with multifocal atherosclerosis and/or reduced organ function, less-invasive techniques are required. For the treatment of CAD, revascularization on the beating heart or with off-pump techniques should be encouraged. Systemic inflammatory response to the cardiopulmonary bypass and cardioplegic arrest can totally be avoided under off-pump technique, which correlates with lower morbidity and mortality rates [24,25]. However, not all patients will be suitable for off-pump CABG. If feasible, myocardial revascularization in these cases should be performed on the beating heart with circulatory support and ventricular unloading by on-pump technique. Avoiding cardioplegic arrest was shown to reduce myocardial damage and to improve postoperative outcome [25].

Abdominal or thoracic aortic SG of isolated aortic pathologies has been proved as safe intervention and less-invasive alternative to conventional open aneurysm repair [15,16]. Aortic SG is performed without laparotomy or thoracotomy, periaortic dissection, aortic cross-clamping and their systemic and/or metabolic complications. If a simultaneous procedure is intended, the choice of anesthetic management opens a further option for modulation of disease management. As previously reported, aortic SG under local anesthesia is a feasible and attractive alternative to avoid disadvantages and risks of repeated general anesthesia [16, 19]. Our series shows that SG applied in the combined treatment of CAD and aneurysm repair has a low procedural complication rate and well acceptable mid-term results in the follow-up. Moreover, recovery period and duration of hospital stay are reduced. However, in contrast to these benefits, key questions on the long-term results of this technique are still unanswered and the evaluation of costs for treatment involving SG is still controversially discussed. Reasons for the reported higher hospital costs following endovascular treatment might be an incomplete learning curve in this rapidly evolving field as well as the markedly higher expense for one endograft compared with a regular vascular graft.

The performance of off-pump CABG and SG in synchronous procedure has proved to us as an optimal novel combination of efficient and less-invasive techniques. However, only a limited number of patients are suitable for this therapeutic strategy. Renal failure must be considered as main contraindication for one-stage treatment in synchronous strategy when CABG cannot be achieved in off-pump technique. Potential addition of nephrotoxic effects caused by cardiopulmonary bypass circulation during CABG and application of contrast agent during SG is likely to deteriorate even a merely slightly reduced renal function. Higher degree of left ventricular failure might require simultaneous treatment of CAD and AA. The risk–benefit assessment between advantages of one-stage repair and prolonged duration of synchronous procedure must be considered carefully from case to case.

In conclusion, aortic SG combined with CABG is a safe and less-invasive approach to concomitant coronary artery and aortic disease. Further improvement can be achieved by coronary artery revascularization performed on the beating heart or with off-pump techniques, as well as the use of local anesthesia for simultaneous SG procedures. Nevertheless, synchronous procedure should be performed only when coronary morphology and ventricular function surely enable to achieve CABG in off-pump technique or when any restriction of renal function definitely has been excluded.

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Appendix A. Conference discussion

Dr F. Maisano (*Milan, Italy*): I see that in your experience all of the OPCAB procedures were simultaneously done with the stent-grafting. Is there any reason for that?

Dr Lachat: Generally we do perform the one-step synchronous procedure only when the coronary revascularisation could be achieved off-pump. We try to avoid a cumulative impairment of the renal function due to the use of the cardiopulmonary bypass and contrast medium, necessary for stent-grafting. So if we have to operate on cardiopulmonary bypass, we will delay the aneurysm repair for a week. Overall, we have had in both groups two patients showing a perioperative decrease of their renal function, but all of the four patients went home with a normalized renal function.