CARDIOVASCULAR SURGERY

Outcome after redo coronary artery bypass grafting in patients with ischaemic cardiomyopathy and viable myocardium

V Rizzello, D Poldermans, A F L Schinkel, E Biagini, E Boersma, A Elhendy, F B Sozzi, A Palazzuoli, A Maat, F Crea, J J Bax

Heart 2007;93:221–225. doi: 10.1136/hrt.2006.088146

See end of article for authors' affiliations

Correspondence to:
Dr D Poldermans,
Department of Cardiology,
Thorax Center Room Ba
300, Erasmus MC, Dr.
Molewaterplein 40, 3015
GD Rotterdam, The
Netherlands;
d.poldermans@
erasmusmc.nl

Accepted 21 July 2006
Published Online First
11 August 2006

Background: Repeat coronary artery bypass grafting (redo-CABG) in patients with ischaemic cardiomyopathy is associated with high perioperative risk and worse long-term outcome compared with patients undergoing their first CABG.

Objective: To assess whether patients with viable myocardium undergoing redo-CABG have a better outcome.

Methods: 18 patients with ischaemic cardiomyopathy underwent redo-CABG and 34 underwent their first CABG; all had substantial viability ($\geq 25\%$ of the left ventricle) on dobutamine stress echocardiography (DSE). Left ventricular ejection fraction (LVEF) and heart failure symptoms were assessed before and 9–12 months after revascularisation. Cardiac event rate was assessed during the follow-up period (median 4 years, 25–75th centile 2.8–4.9 years).

Results: The extent of viable myocardium on DSE was comparable in the two groups (11.3 (3.9) segments in patients who underwent redo-CABG v 12.8 (3.0) in patients who underwent their first CABG; $p = \text{NS}$). LVEF improved from 32% (9%) to 39% (12%); $p = 0.01$, in patients who underwent redo-CABG and from 30% (7%) to 36% (7%); $p < 0.01$, in those who underwent their first CABG; New York Heart Association class improved from 2.5 (1.1) to 1.9 (0.8); $p = 0.03$, and from 2.7 (1.0) to 1.8 (0.70); $p < 0.01$, respectively. In patients who underwent redo-CABG, the perioperative mortality was 0, post-surgery inotropic support was needed in 11% of the patients and mid-term (4-year) survival was 100%, with a total event rate of 28%. All these variables were not statistically different from patients who underwent their first CABG ($p = 0.50, 0.90, 0.08$ and 0.81 , respectively).

Conclusion: Patients with ischaemic cardiomyopathy and substantial viability undergoing redo-CABG benefit from revascularisation in terms of improvement in LVEF, heart failure symptoms, angina and mid-term prognosis.

Patients with ischaemic cardiomyopathy (ie, chronic left ventricular dysfunction, secondary to coronary artery disease) represent a population exposed to a high risk of cardiac events when treated medically.¹ Despite relevant progress in treatment, prognosis in this population remains poor.¹ Numerous studies, although non-randomised, have shown that patients with ischaemic cardiomyopathy will benefit from revascularisation in terms of improvement in the left ventricular ejection fraction (LVEF), heart failure symptoms and prognosis if viable myocardium is present.^{2–9} Accordingly, viability assessment has become an important component in the decision to perform revascularisation in this subset of patients. Still, coronary revascularisation in patients with severe left ventricular dysfunction represents a high-risk procedure. This risk is even higher in patients who have undergone a coronary artery bypass grafting (redo-CABG) previously than in patients who are undergoing their first CABG.^{10–11} Moreover, patients undergoing redo-CABG seem to have a worse outcome at long-term follow-up,^{10–14} and currently, doctors are reluctant to refer patients with ischaemic cardiomyopathy for redo-CABG. However, in the available reports on the relatively poor outcome of patients undergoing redo-CABG, viability testing was not performed.^{10–14} Given the clinical experience of viability testing in patients undergoing their first CABG,¹⁵ it can be said that outcome in patients undergoing redo-CABG is better when they are selected on the basis of the presence of a substantial viable myocardium. We

report the results and outcomes in patients with viable myocardium who underwent redo-CABG. For comparison, a consecutive group of patients with viable myocardium who underwent their first CABG was also studied.

PATIENTS AND METHODS

Study population

The study population included 18 consecutive patients (15 men, mean age 64 (standard deviation (SD) 8 years) with ischaemic cardiomyopathy who had undergone CABG previously, and 34 consecutive patients (25 men, mean (SD) age 61 (9) years) with ischaemic cardiomyopathy without previous CABG. All patients had moderate to severe left ventricular dysfunction (LVEF $< 40\%$). In 32 (61%) patients, LVEF was $\leq 30\%$. Patients were scheduled for revascularisation (first or redo-CABG) on the basis of clinical presentation, presence of ischaemia or viability. All these patients with decreased LVEF needed to have substantial viability, defined as ≥ 4 viable segments on dobutamine stress echocardiography (DSE). All revascularisation procedures were performed at the Thorax Center, Rotterdam, The Netherlands, by the same team of surgeons between 1998 and 2001. All patients included in the study had

Abbreviations: CCS, Canadian Cardiovascular Society; DSE, dobutamine stress echocardiography; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; redo-CABG, repeat coronary artery bypass grafting

heart failure symptoms (New York Heart Association (NYHA) class 2.6 (SD 1.1)) and 35 (67%) patients had concomitant angina pectoris (Canadian Cardiovascular Society (CCS) class 2.1 (SD 1.1)). In 47 (90%) patients myocardial infarction had occurred ≥ 6 months before the study. Patients with severe (3–4+) mitral regurgitation were not included.

Study protocol

The study protocol was prospectively designed as follows. Before revascularisation, all patients underwent DSE to be evaluated for myocardial viability and ischaemia. Radionuclide ventriculography was performed before and 9–12 months after revascularisation to assess resting LVEF. In addition, heart failure symptoms and angina score were evaluated before and 9–12 months after revascularisation. Cardiac events (cardiac death, myocardial infarction and hospitalisation for heart failure) were evaluated during the follow-up period. The local ethics committee approved the protocol and all patients gave informed consent.

Assessment of myocardial viability

All echocardiograms were taken using commercially available equipment (Sonos-5500, Hewlett-Packard, Philips Medical Systems, Eindhoven, The Netherlands) with second harmonic imaging (1.8–3.6 MHz transducer). Standard parasternal and apical views of the left ventricle were obtained¹⁶ at rest and at the end of each step of dobutamine infusion. Dobutamine was given intravenously as described previously.¹⁷ DSE results were interpreted offline from cine-loops, by two experienced observers blinded to the clinical data. Interobserver and intraobserver agreement for analysis were reported previously (92% and 94%, respectively).¹⁸ According to previous reports, segments showing a sustained improvement of the wall motion or ischaemia (biphasic response or worsening of the wall motion) during DSE were considered viable.^{2 16 18} Segments with unchanged wall motion and those with akinesia becoming dyskinesia were considered to be non-viable (scar) tissue.^{2 17 19} The presence of ≥ 4 viable segments indicated a substantial amount of viable myocardium.

Assessment of LVEF

Before revascularisation and 9–12 months after revascularisation, radionuclide ventriculography was performed to assess improvement in LVEF by an independent technique. This procedure was performed with the patient in the supine position after the administration of 740 MBq of technetium 99m. Images were acquired with a small-field-of-view gamma camera (Orbiter, Siemens Corp, Iselin, New Jersey, USA), oriented in the 45° left anterior oblique position with a 5–10° caudal tilt. LVEF was calculated from the 45° left anterior oblique view by an automated technique. An improvement of $\geq 5\%$ in LVEF after revascularisation was considered to be clinically significant.²

Assessment of functional status and mid-term follow-up

Before and after revascularisation, structured clinical interviews were conducted by an independent doctor blinded to all data, to assess the functional status according to the NYHA class (for symptoms of heart failure) and the CCS criteria (for angina). The mid-term follow-up was performed by chart review and telephone contact. Events included cardiac death, myocardial infarction and hospitalisation for heart failure. Cardiac death was defined as sudden death, death due to acute myocardial infarction or heart failure. Myocardial infarction was defined according to the classic criteria (symptoms, electrocardiographic changes and raised levels of cardiac enzymes).

Table 1 Study population

	Redo-CABG n = 18	First CABG n = 34	p Value
Age in years, mean (SD)	64 (8)	61 (9)	NS
NYHA class, mean (SD)	2.5 (1.1)	2.7 (1.0)	NS
CCS score, mean (SD)	2.06 (1.2)	2.03 (1.1)	NS
Previous myocardial infarction, n (%)	18 (89)	30 (91)	NS
Years from myocardial infarction, mean (SD)	8.8 (71)	7.2 (6.9)	NS
Hypertension, n (%)	13 (72)	27 (81)	NS
Diabetes, n (%)	2 (12)	14 (41)	<0.05
Smoking, n (%)	5 (28)	18 (53)	0.08
Left ventricular ejection fraction (%), mean (SD)	32 (9)	30 (7)	NS
β -Blockers, n (%)	10 (56)	19 (60)	NS
ACE inhibitors, n (%)	9 (50)	23 (68)	NS
Severely dysfunctional segments, n (%)	11.3 (3.9)	12.8 (3.0)	NS
Viable segments, n (%)	7.9 (3.2)	6.9 (2.1)	NS

ACE, angiotensin-converting enzyme; CABG, coronary artery bypass grafting; CCS, Canadian Cardiovascular Society; NYHA, New York Heart Association.

Hospitalisation for heart failure was defined according to the hospital discharge diagnosis.

Statistical analysis

Continuous data are expressed as mean (SD) and dichotomous data as proportions. Continuous data were compared using Student's t test for paired and unpaired samples when appropriate. Proportions were compared using χ^2 analysis with Yates' correction. The cardiac event rate during the 5 years was evaluated using Kaplan–Meier curve analysis. Differences between curves were tested with the log rank χ^2 statistics. For all tests, $p < 0.05$ was considered significant.

RESULTS

Study population

Table 1 summarises the characteristics of patients who underwent redo-CABG and those who underwent their first CABG. Clinical characteristics were comparable between the two groups. Only diabetes was less frequently observed in the patients who underwent redo-CABG. LVEF and the number of severely dysfunctional segments (wall motion score 3–5) were similar in the two groups. On-pump CABG was performed in all patients. All major coronary stenoses were bypassed, with the exception of the right coronary artery in two patients who underwent their first CABG (due to inadequate anatomy). In these two patients, the distribution territory of the right coronary was a scar according to the DSE findings. Thus, all viable regions were revascularised. On average, 3.1 (SD 1.2) grafts were placed; where possible, arterial grafts were used (in 79% of patients). The mean cardiopulmonary bypass time was 90 (SD 15) min and the mean clamp time was 55 (SD 10) min. Aneurysmectomy was performed in 1 (5%) patient who underwent redo-CABG and in 3 (9%) patients who underwent their first CABG ($p = \text{NS}$).

Dobutamine stress echocardiography

Haemodynamic response

During DSE, the mean (SD) heart rate significantly increased from rest to the peak dobutamine infusion both in patients who underwent redo-CABG (from 67 (11) to 122 (27) beats per min (bpm); $p < 0.001$) and in those who underwent their first CABG (from 74 (13) to 130 (13) bpm; $p < 0.001$). In patients who underwent redo-CABG, mean (SD) systolic blood pressure significantly decreased from rest to the peak dobutamine

Figure 1 Change in left ventricular ejection fraction (LVEF) after revascularisation in (A) patients undergoing redo coronary artery bypass grafting (CABG) and (B) those undergoing their first CABG.

infusion (from 130 (22) to 116 (28) mm Hg; $p = 0.01$); also diastolic blood pressure tended to decrease, but the difference was not significant (from 72 (9) to 67 (14) mm Hg; $p = 0.08$). In patients who underwent their first CABG, both systolic and diastolic blood pressure values did not change significantly from rest to the peak dobutamine infusion (from 127 (22) to 131 (21) mm Hg and from 75 (9) to 73 (10) mm Hg, respectively; both $p = \text{NS}$).

Myocardial viability and ischaemia

The results of DSE showed that the extents of ischaemia and viability were comparable between patients who underwent redo-CABG and those who underwent their first CABG. In particular, an ischaemic pattern during DSE (biphasic response or worsening of wall motion) was observed in 5.0 (SD 3.2) segments in the patients who underwent redo-CABG and in 4.1 (SD 2.8) segments in patients who underwent their first CABG ($p = \text{NS}$). A sustained improvement in wall motion was observed in 2.7 (SD 2.3) segments in patients who underwent redo-CABG and in 2.8 (SD 2.3) segments in those who underwent their first CABG ($p = \text{NS}$). The mean (SD) number of dysfunctional segments without a change in wall motion

during DSE (scar segments) was lower in patients who underwent redo-CABG than in those who underwent their first CABG (3.2 (2.7) v 5.7 (2.9); $p < 0.01$).

Improvement in LVEF after revascularisation

LVEF at 9–12 months after revascularisation was not obtained in the three patients who underwent their first CABG and who died in the early post-surgery period. LVEF improved significantly in the patients who underwent redo-CABG (from a mean (SD) of 32% (9%) to 39% (12%); $p = 0.01$) and also in those who underwent their first CABG (from 30% (7%) to 36% (7%); $p < 0.01$; fig 1). In particular, a significant improvement ($\geq 5\%$) in LVEF occurred in 10 of 18 (56%) patients who underwent redo-CABG and in 19 of 31 (61%) patients who underwent their first CABG ($p = \text{NS}$ v patients with redo-CABG).

Improvement in heart failure symptoms and angina after revascularisation

At 9–12 months after surgery, heart failure symptoms and angina score were re-evaluated in all patients except the three patients who had undergone their first CABG and who had died in the early postoperative period. Heart failure symptoms

Figure 2 Kaplan-Meier curves showing all cardiac event rates for patients undergoing redo coronary artery bypass grafting (CABG) and those undergoing their first CABG.

improved significantly after revascularisation, both in the patients who underwent redo-CABG (mean (SD) NYHA class decreased from 2.5 (1.1) to 1.9 (0.8); $p = 0.03$) and in those who underwent their first CABG (from 2.7 (1.0) to 1.8 (0.7); $p < 0.01$). In particular, NYHA class improved at least 1 point in 13 of 18 (72%) patients who underwent redo-CABG and in 21 of 31 (68%, $p = \text{NS}$ v redo-CABG patients) patients who underwent their first CABG. The extent of improvement in heart failure symptoms (defined as the change in NYHA class before and after revascularisation) was comparable in the two groups (1.0 (SD 0.7) v 1.3 (SD 1.6) in patients who underwent redo-CABG and in those who underwent their first CABG, respectively; $p = \text{NS}$). Similarly, the mean (SD) CCS class improved significantly after revascularisation in both groups (from 2.06 (1.2) to 1.2 (0.6); $p < 0.05$, in patients who underwent redo-CABG, and from 2.03 (1.1) to 1.1 (0.4); $p < 0.01$, in patients who underwent their first CABG. The extent of improvement in angina score (defined as the change in CCS class before and after revascularisation) was comparable in the two groups (1.3 (SD 1.2) v 1.2 (SD 1.3) in patients who underwent redo-CABG and in those who underwent their first CABG, respectively; $p = \text{NS}$).

Perioperative results and mid-term outcome

The median follow-up was 4 years (25–75th centile 2.8–4.9 years). Three patients undergoing their first CABG died early (within 30 days) after revascularisation (one patient from sepsis and the other two from heart failure), whereas none of the patients who underwent redo-CABG died in the early postoperative period. The mean (SD) length of stay in the intensive care unit was comparable between the two groups (1.4 (0.6) v 1.6 (0.4) days, in patients who underwent redo-CABG and those who underwent their first CABG, respectively; $p = \text{NS}$). Only 2 (11%) patients who underwent redo-CABG and 2 (6%) patients who underwent first CABG needed inotropic support to maintain adequate haemodynamic status ($p = \text{NS}$); intra-aortic balloon pumping was not needed.

During the 4-year follow-up, cardiac death occurred in 3 (10%) patients who underwent their first CABG, whereas none of the patients who underwent redo-CABG died. One patient with redo-CABG developed a new myocardial infarction. Hospitalisation for heart failure occurred in 4 (22%) patients who underwent redo-CABG and in 4 (13%) patients who underwent their first CABG. Cardiac events (all events) were not significantly different between the two groups (28% in redo-CABG and 21% in first CABG; $p = \text{NS}$; fig 2). Also, death due to cardiac reasons was not significantly different between the two groups (17.7% v 0; $p = 0.08$).

DISCUSSION

Our findings show that patients with ischaemic cardiomyopathy and a substantial amount of viable myocardium undergoing redo-CABG benefit from revascularisation in terms of both improvement in LVEF and heart failure symptoms. These improvements are similar to those observed in patients undergoing their first CABG. In addition, perioperative and mid-term outcome in patients who underwent redo-CABG was also excellent.

Why assess myocardial viability in patients with ischaemic cardiomyopathy?

Assessment of myocardial viability has become part of the diagnostic and prognostic investigation of patients with ischaemic cardiomyopathy. Several non-invasive imaging techniques are available, including nuclear imaging, stress echocardiography and magnetic resonance imaging.²⁰ The findings are needed for clinical decision making, particularly to select

patients who may benefit from revascularisation. Although data from randomised trials are not yet available, numerous studies have clearly shown that only in the presence of a substantial amount of viable myocardium (at least 25% of the left ventricle), the potential benefit of revascularisation outweighs the risk of revascularisation in patients with left ventricular dysfunction.^{2–9} In these “viable” patients, revascularisation may improve LVEF, heart failure symptoms, perioperative outcome and prognosis.^{2–9} In particular, the most complete meta-analysis so far published (including 24 studies with 3088 patients) showed an 80% relative reduction in cardiac death and a 51% reduction in all other events in viable patients who underwent revascularisation compared with viable patients treated medically.¹⁵ Conversely, no benefit of revascularisation was noted in patients without viable myocardium.¹⁵ The currently available data suggest that in the presence of an extensive dysfunctional but viable myocardium, revascularisation should be considered; however, in the presence of predominantly scar tissue, conservative management is indicated.

Role of myocardial viability in patients undergoing redo-CABG

Previous studies

As the population of patients with ischaemic cardiomyopathy is ageing, redo-CABG is needed more often. Despite advances in surgical techniques and optimisation of perioperative metabolic and mechanical support, redo-CABG is still associated with increased cardiac risk compared with first CABG.^{10–14} This risk is even higher in patients with left ventricular dysfunction.²¹ For example, Weintraub *et al*¹⁰ reported a high mortality (up to 16.4%) in patients who underwent a repeat cardiac surgery, and Van Eck *et al*¹¹ reported 13.9% mortality at 6 months after redo-CABG. Also, various studies have shown that patients undergoing redo-CABG have a worse long-term outcome than those undergoing their first CABG.^{12–14} These data highlight the need for careful selection of candidates for redo-CABG. Although assessment of myocardial viability has been shown to accurately identify patients who may benefit from revascularisation,¹⁵ data on the role of viability testing in patients undergoing redo-CABG are lacking.

Findings

In this prospective study on viable patients who underwent redo-CABG, it seemed that revascularisation of viable myocardium was associated with improvement in LVEF (from 32% (SD 9%) to 39% (SD 12%); $p = 0.01$) and heart failure symptoms (mean (SD) NYHA class decreased from 2.5 (1.1) to 1.9 (0.8); $p = 0.03$). Moreover, the extent of improvement in these parameters was comparable to that in patients who underwent their first CABG. These findings are important as LVEF is an important determinant of prognosis,²² and improvement in heart failure symptoms is extremely important in terms of quality of life.

In addition, the perioperative morbidity and mortality were low in patients who underwent redo-CABG, and the need for inotropic support was minimal, with a mean length of stay of 1.4 (SD 0.6) days in the intensive care unit after surgery. Also, mid-term mortality and other event rates were low in patients who underwent redo-CABG. Importantly, all these variables were not different from those of patients who underwent their first CABG. Recently, Haas *et al*²³ has shown that selection of patients for first CABG on the presence of viability resulted in an improved outcome. When selection was based on viability testing, a lower perioperative morbidity and mortality, and favourable long-term survival was seen in patients who underwent their first CABG. In line with these data, our

findings show an excellent outcome in patients with viable myocardium undergoing redo-CABG. These observations are of high clinical importance, considering the general reluctance of patients with ischaemic cardiomyopathy to undergo redo-CABG. Accordingly, the discrepancy between the excellent outcome in patients who underwent redo-CABG in our study and the worse outcome after redo-CABG in previous studies may partly be explained by the selection of patients on the basis of the presence of viable myocardium.

Study limitations

Several limitations of the study need to be considered. Firstly, the sample size of the study population is small, and further studies including a larger population are warranted to confirm our findings. Secondly, coronary angiography was not repeated after revascularisation, and graft closure may have influenced the results. Thirdly, we included no control groups of patients without viable myocardium and therefore the conclusion that viability testing is mandatory to ensure uncomplicated outcome after redo-CABG cannot be fully substantiated. However, the discrepancy between the excellent results in patients who underwent redo-CABG in our study compared with the relatively poor outcome in these patients in the available literature (where selection was not based on viability testing)¹⁰⁻¹⁴ suggests that patient selection based on preoperative viability testing may improve the outcome after redo-CABG. Finally, the lack of a control group of patients treated medically may be a limitation.

CONCLUSION

Patients with ischaemic cardiomyopathy and substantial viability who underwent redo-CABG showed an improvement in LVEF and heart failure symptoms compared with patients with viable myocardium who underwent their first CABG. Also, perioperative and mid-term outcome were excellent in this cohort selected on the basis of viability.

Authors' affiliations

V Rizzello, D Poldermans, A F L Schinkel, E Biagini, E Boersma, A Elhendy, F B Sozzi, A Palazzuoli, A Maat, Department of Cardiology, Thorax Center, Erasmus MC, Rotterdam, The Netherlands
F Crea, The Catholic University of the Sacred Heart, Rome, Italy
J J Bax, The Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands

Competing interests: None declared.

REFERENCES

- 1 **Roger VL**, Weston SA, Redfield MM, *et al*. Trends in heart failure incidence and survival in a community-based population. *JAMA* 2004;**292**:344-50.
- 2 **Bax JJ**, Poldermans D, Elhendy A, *et al*. Improvement of left ventricular ejection fraction, heart failure symptoms and prognosis after revascularization in patients

- with chronic coronary artery disease and viable myocardium detected by dobutamine stress echocardiography. *J Am Coll Cardiol* 1999;**34**:163-9.
- 3 **Ragosta M**, Beller GA, Watson DD, *et al*. Quantitative planar rest-redistribution 201Tl imaging in detection of myocardial viability and prediction of improvement in left ventricular function after coronary bypass surgery in patients with severely depressed left ventricular function. *Circulation* 1993;**87**:1630-41.
- 4 **Vanoverschelde JL**, Gerber BL, D'Hondt AM, *et al*. Preoperative selection of patients with severely impaired left ventricular function for coronary revascularization. Role of low-dose dobutamine echocardiography and exercise-redistribution-reinjection thallium SPECT. *Circulation* 1995;**92**(Suppl):II37-44.
- 5 **Pagano D**, Bonser RS, Townend JN, *et al*. Predictive value of dobutamine echocardiography and positron emission tomography in identifying hibernating myocardium in patients with postischaemic heart failure. *Heart* 1998;**79**:281-8.
- 6 **Di Carli MF**, Asgarzadeh F, Schelbert HR, *et al*. Quantitative relation between myocardial viability and improvement in heart failure symptoms after revascularization in patients with ischemic cardiomyopathy. *Circulation* 1995;**92**:3436-44.
- 7 **Pagley PR**, Beller GA, Watson DD, *et al*. Improved outcome after coronary bypass surgery in patients with ischemic cardiomyopathy and residual myocardial viability. *Circulation* 1997;**96**:793-800.
- 8 **Meluzin J**, Cerny J, Frelich M, *et al*. Prognostic value of the amount of dysfunctional but viable myocardium in revascularized patients with coronary artery disease and left ventricular dysfunction. Investigators of this Multicenter Study. *J Am Coll Cardiol* 1998;**32**:912-20.
- 9 **Lee KS**, Marwick TH, Cook SA, *et al*. Prognosis of patients with left ventricular dysfunction, with and without viable myocardium after myocardial infarction. Relative efficacy of medical therapy and revascularization. *Circulation* 1994;**90**:2687-94.
- 10 **Weintraub WS**, Jones EL, Craver JM, *et al*. In-hospital and long-term outcome after reoperative coronary artery bypass graft surgery. *Circulation* 1995;**92**(Suppl):II50-7.
- 11 **Van Eck FM**, Noyez L, Verheugt FW, *et al*. Analysis of mortality within the first six months after coronary reoperation. *Ann Thorac Surg* 2002;**74**:2106-12.
- 12 **Noyez L**, van Eck FM. Long-term cardiac survival after reoperative coronary artery bypass grafting. *Eur J Cardiothorac Surg* 2004;**25**:59-64.
- 13 **Shapiro I**, Isakov A, Heller I, *et al*. Long-term follow-up after coronary artery bypass grafting reoperation. *Chest* 1999;**115**:1593-7.
- 14 **Di Mauro M**, Iaco AL, Contini M, *et al*. Reoperative coronary artery bypass grafting: analysis of early and late outcomes. *Ann Thorac Surg* 2005;**79**:81-7.
- 15 **Allman KC**, Shaw LJ, Hachamovitch R, *et al*. Myocardial viability testing and impact of revascularization on prognosis in patients with coronary artery disease and left ventricular dysfunction: a meta-analysis. *J Am Coll Cardiol* 2002;**39**:1151-8.
- 16 **Schiller NB**, Shah PM, Crawford M, *et al*. Recommendations for quantitation of the left ventricle by two-dimensional echocardiography. American Society of Echocardiography Committee on Standards, Subcommittee on Quantitation of Two-Dimensional Echocardiograms. *J Am Soc Echocardiogr* 1989;**2**:358-67.
- 17 **Salustri A**, Ciavatti M, Seccareccia F, *et al*. Prediction of cardiac events after uncomplicated acute myocardial infarction by clinical variables and dobutamine stress test. *J Am Coll Cardiol* 1999;**34**:435-40.
- 18 **Arnesen M**, Cornel JH, Salustri A, *et al*. Prediction of improvement of regional left ventricular function after surgical revascularization. A comparison of low-dose dobutamine echocardiography with 201Tl single-photon emission computed tomography. *Circulation* 1995;**91**:2748-52.
- 19 **Afridi I**, Kleiman NS, Raizner AE, *et al*. Dobutamine echocardiography in myocardial hibernation. Optimal dose and accuracy in predicting recovery of ventricular function after coronary angioplasty. *Circulation* 1995;**91**:663-70.
- 20 **Rizzello V**, Bax JJ, Poldermans D. Assessment of myocardial viability in chronic ischemic heart disease: current status. *Q J Nucl Med Mol Imaging* 2005;**49**:81-96.
- 21 **He GW**, Acuff TE, Ryan WH, *et al*. Determinants of operative mortality in reoperative coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 1995;**110**:971-8.
- 22 **Gheorghiade M**, Bonow RO. Chronic heart failure in the United States: a manifestation of coronary artery disease. *Circulation* 1998;**97**:282-9.
- 23 **Haas F**, Haehnel CJ, Picker W, *et al*. Preoperative positron emission tomographic viability assessment and perioperative and postoperative risk in patients with advanced ischemic heart disease. *J Am Coll Cardiol* 1997;**30**:1693-700.