

Outcomes of coronary artery bypass graft surgery

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Abstract: This review article summarizes the major studies that have investigated the outcomes of coronary artery bypass graft surgery (CABG). The article includes a review of the literature in the areas of: history of CABG; indications for CABG; and measurement of quality of life following CABG, including prolongation of life, physical functioning (ie, relief from angina and dyspnea, physical activity, as well as complications of surgery and re-hospitalization), psychological functioning, and social functioning. Overall, the literature demonstrates that the outcomes of CABG have historically been measured in terms of mortality and morbidity; however, it has now been well recognized that adjustment to CABG is a multidimensional phenomenon that is not fully explained by medical factors. Therefore, in addition to studying mortality and morbidity outcomes following CABG, many recent studies have identified that it is important to investigate various physical, psychological, and social variables that have a significant impact on post-operative adjustment to CABG.

Keywords: coronary artery bypass graft surgery, outcomes, quality of life, recovery.

Methodology

Electronic databases were searched, without language restriction, from January 1966 to January 2006. The databases used included the Cochrane Database of Systematic Reviews, MEDLINE(R), CINAHL, and PsychINFO. Key search terms included: revascularization; coronary artery bypass graft surgery; CABGS; CABG; coronary bypass surgery; percutaneous transluminal coronary angioplasty; PTCA; percutaneous coronary intervention; PCI; mortality; morbidity; quality of life; angina; dyspnea; physical activity; complications; rehospitalization; vocational status; physical functioning; psychological functioning; social functioning; and outcomes.

History of coronary artery bypass graft surgery (CABG)

In 1962, a cardiac surgeon by the name of Sabiston conducted the first unsuccessful saphenous vein graft from the ascending aorta to the distal right coronary artery and the patient died 3 days later. The technique was then pioneered by Argentinian René Favaloro and others at the Cleveland Clinic in the late 1960s. The next major development was in 1970, when the internal mammary artery was used as a bypass conduit to the coronary arteries. By the mid 1970s, many centers in the United States, Australasia, and Europe were performing CABG with low peri-procedural mortality, and a high rate of pain relief (Pollick 1993).

In 1989, the number of procedures performed per 100 000 people was: 26.6 in the United Kingdom, 62.9 in Australia, and 141.8 in the United States (Wise and Graham-Clarke 1994). In Australia, following a tentative start in 1969, CABG is now one of the most common major elective surgical procedures. In 1994, the national cardiac surgery rate in Australia had risen to 108 procedures/100 000 people, with a mortality rate of 2.8%

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(Senes-Ferrari 1999). However, more recently in Australia, the rates of CABG have fallen to 90–100 procedures/100 000 in 1999 (comparable with the Netherlands, New Zealand, and Finland), and 70–80 procedures/100 000 in 2001 (AIHW and NHFA 2004). In comparison, in 1999 the United States had the highest rates of CABG of 16 OECD countries and their age-standardized procedure rates were twice those of Australia (AIHW and NHFA 2004).

The CABG operation has become the most completely studied operation in the history of surgery. It has been shown to be highly effective for the relief of severe angina, and to have prolonged life in subsets of patients. Nonetheless, the role of CABG is being re-evaluated as a consequence of new technologies, both in coronary surgery and in percutaneous coronary intervention (Kirklin et al 1991; Caines et al 2004).

Indications for CABG

The CABG procedure is indicated for the relief of symptoms (primarily angina) unresponsive to medical treatment or percutaneous transluminal coronary angioplasty (PTCA), particularly when it is likely that this operation will delay unfavorable events (death, myocardial infarction, angina recurrence) longer than other forms of treatment. For angina relief, surgery has often succeeded where medical or interventional therapy has failed or is not recommended. For survival, the situation is more complex. There is general agreement that CABG improves prognosis in the early post-surgical years in those patients with symptomatic left main coronary artery stenosis or stenosis of the three main coronary vessels, although this advantage is not thought to be significant after 10–12 years (Cundiff 2002; Hlatky et al 2004). However, for the majority of patients with less severe pathology, the prognosis is good without surgery (Kirklin et al 1991; Caines et al 2004). Furthermore, cardiac surgery has advanced to a point where mortality rates have declined dramatically (Ferguson et al 2002). Thus, with such low death rates, selection among alternative courses of cardiac therapy is increasingly being based on measures of quality of life (QOL), including minimization of pain and disability.

Measurement of quality of life following CABG

The measurement of treatment outcome or QOL for the patient is the keystone of modern scientific medicine. The importance of treatment outcome is recognized throughout clinical practice, particularly when innovative, invasive or costly treatments are evaluated, and the mortality rate is too low to

affect decision making (Caine et al 1991). However, there is no universal agreement of the meaning of QOL or how it should be measured (Wenger et al 1995).

Following cardiac intervention, outcomes have been evaluated in terms of mortality, and complications or recurrence of symptoms, as they are easy to measure (Caine et al 1991; Wenger et al 1995; Chocron et al 1996). However, these measures do not provide a complete assessment of an individual's capabilities at home, at work, or in the community (McCarthy et al 1995). Hence, the study of outcomes of cardiac intervention has been characterized by changes in the questions asked in evaluation, changes in the technologies used to answer these questions, and changes in the sources of assessment information. Outcomes of CABG can be grouped into categories that reflect the expected goals of CABG such as: prolongation of life, reduction of symptoms, improvement in physical, psychological and social functioning, and improvement in vocational status (Duits et al 1997).

Prolongation of life

Prolongation of life as an outcome of CABG was initially addressed in three major randomized clinical trials that compared CABG with medical therapy. They include the Veterans Administration Study (VAS), (Grover et al 1990) the European Coronary Artery Surgery Study (ECASS), (European Coronary Surgery Study Group 1982) and the Coronary Artery Surgery Study (CASS) (CASS PI 1983; Serruys et al 2005).

The VAS recruited 1015 patients from 13 centers between 1970 and 1974. Patients were randomly allocated to medical or surgical treatment. The study revealed no significant difference in mortality 4 years after CABG in patients with one-, two- or three-vessel disease, although a highly significant increase in survival rate was observed in a subset of patients who underwent CABG for left main coronary artery obstruction. The 4-year mortality for CABG patients was 7% (n = 46), compared with 33% for medical treatment (n = 44) (Hampton 1984).

The ECASS recruited 768 men under 65-years between 1973 and 1976. While the participants were randomized to medical or surgical treatment, the main weakness of this trial was that nothing was known about the original population from which the trial patients were drawn. There was significant improvement in survival for the total CABG population, and for patients with three-vessel disease, with stenosis in the proximal third of the left anterior descending artery, or with left main coronary disease. After 5 years of follow up, 30 deaths were reported among the 395 patients treated surgically

(7.6%), and 61 deaths among the 373 patients using medical treatment (16.3%) (European Coronary Surgery Study Group 1982; Hampton 1984).

The CASS followed 780 patients under 65 years allocated to medical or surgical treatment between 1975 and 1979 (90% male). The overall 5-year cumulative survival rates in the medically assigned group (92%) and the surgically assigned group (95%) were similar. No significant differences in survival were found between medically and surgically treated groups at baseline in extent of coronary heart disease (CHD) or in ventricular function. In patients with three-vessel disease and low ejection fractions, a distinct (but not significant) trend for improved 5-year survival was observed in patients treated surgically (90%) compared with those treated medically (80%). This difference persisted and reached statistical significance when the 7-year cumulative survival was 88% in the surgically assigned group and 65% in the medically assigned group (CASS PI 1983; Hampton 1984).

Since these early randomized studies it has become clear that there were a number of methodological issues with these trials. First, there were few females in the early trials, which is concerning as there appears to be a gender difference in outcome following surgery. Second, the types of patients included in these studies represented only 20% of the total coronary artery disease population, and thus results cannot be extrapolated to the entire population (Pollick 1993). Finally, the CABG procedure has advanced significantly over the years to a point where operative mortality is now much lower than reported in the early trials, at less than 3% for routine CABG (Pollick 1993; Senes-Ferrari 1999; Ferguson et al 2002).

One such procedural change in CABG has been routine use of the internal mammary artery as a conduit for revascularizing the coronary arteries, as 10 years after CABG three quarters of vein conduits are blocked or severely diseased (Fitzgibbon et al 1996), whereas more than 90% of internal thoracic artery grafts are patent and disease free (Pollick 1993; Damgaard et al 2005). Vein graft failure leads to reduced survival, recurrent angina, late myocardial infarction, and the need for further intervention (Eagle et al 1999), so that by 10–15 years after the initial operation up to 40% of patients may require redo CABG at increased risk and cost (Weintraub et al 1994; Kaul et al 1995; Lytle et al 1999). Thus, recent studies suggest that the use of the left internal thoracic artery to the left anterior descending coronary artery is the most important factor for survival and reduction of late cardiac events after CABG (Loop et al 1986; Yusuf et al 1994; Cameron et al 1996).

Furthermore, while there have been no randomized trials of total arterial revascularization compared with conventional surgery, several large studies have reported that multiple arterial revascularization offers survival advantages over a single internal thoracic artery graft (Pick et al 1997; Schmidt et al 1997; Buxton et al 1998; Lytle et al 1999; Calafiore et al 2000; Dion et al 2000). In a meta-analysis of almost 16 000 patients comprising 11 269 single and 4693 bilateral internal thoracic artery patients matched for age, gender, left ventricular function, and diabetes, the bilateral internal thoracic artery group had significantly better survival (hazard ratio for death 0.81, 95% confidence interval 0.70–0.94) (Taggart et al 2001).

More recently, up to 25% of CABG operations are being performed without the use of a heart-lung pump—“off-pump CABG”. A number of non-randomized studies have shown off-pump CABG is as safe as on-pump surgery, and in experienced hands offers less early complications, particularly in those patients with significant comorbidity. In high-risk groups, particularly those with renal impairment, off-pump surgery makes the need for postoperative renal support less likely, and in groups over 70 years of age, there is a reduction in the incidence of cerebral injury when an off-pump technique is employed. However, randomized trials have not yet revealed a significant reduction in morbidity or mortality (Pepper 2005).

In parallel with the progress of the revascularization techniques for patients with stable angina, several randomized trials have also been performed comparing: medical management with surgery; medical management with PTCA or percutaneous coronary intervention (PCI); and PCI with surgery (Spargias and Cokkinos 2004; Bakhai et al 2005). In a review of seven trials, survival was greater in high risk patients following CABG compared with medical therapy, where patient risk was defined by severity of ischemia, number of diseased vessels, and left ventricular dysfunction. In low-risk patients, a strategy of initial medical therapy has been shown to be effective (Solomon and Gersh 1998). Despite the difficulty of drawing conclusions from trials comparing outperformed treatments, a recent article attempts to outline the comparative efficacy of the available treatment strategies and we refer the reader to that publication for more information (Spargias and Cokkinos 2004).

Overall, the three early major randomized trials and more recent studies indicate that patients with narrowing of the left main coronary artery, or triple-vessel disease and subnormal

left ventricular functioning have a particularly poor prognosis when treated medically, and benefit from CABG. Recent studies suggest that the use of the left internal thoracic artery to the left anterior descending coronary artery, and potentially multiple arterial revascularization, improves survival and reduces late cardiac events after CABG (Loop et al 1986; Yusuf et al 1994; Cameron et al 1996). Furthermore, off-pump CABG may offer fewer early complications, particularly in those patients with significant comorbidity (Pepper 2005). Data are less clear for patients with single- or double-vessel disease, or with normal left ventricular functioning. For these patients, many other variables must be taken into account when assessing the benefits of surgery including the patient's level of physical functioning, psychological functioning, social functioning, and vocational status (Allen 1990).

Physical functioning

Improved functional status and return to pre-morbid lifestyle is a major goal for most patients undergoing CABG. Relief of angina and dyspnea, level of physical activity, complications of surgery, and re-hospitalization have been investigated when assessing physical functioning (Jenkins et al 1983; Herlitz et al 2001).

Relief from angina and dyspnea

Incapacitating angina is the most common indication for CABG. Results of observational studies and randomized controlled trials of medical versus surgical treatment have demonstrated that in patients with disabling angina pectoris, surgery results in relief from symptoms and decreased need for anti-anginal medication (Herlitz et al 2001). A review of 14 controlled clinical trials demonstrated that the likelihood of becoming angina-free was approximately 40% greater in the surgical than the medical group (Wortman and Yeaton 1985). A more recent study found that 80% of CABG patients were angina-free up to 5 years after surgery (Fihn et al 2001).

Breathlessness, or dyspnea, following CABG has also been investigated (Jenkins et al 1983; Mayou and Bryant 1987; Sjoland et al 1997b; Herlitz et al 2001). In a study in which 60% of patients experienced dyspnea before CABG, 54% of these were completely relieved of dyspnea, 22% reported some improvement, and 18% had no improvement 6 months following surgery. Nine percent of the total patient group reported more dyspnea following surgery, with more than 50% of these reports being from patients without dyspnea pre-surgery (Jenkins et al 1983). Another study found that 71% of

patients experienced dyspnea before surgery whilst 39% reported it 12 months post-surgery (Mayou and Bryant 1987). In a later study, 63% of CABG patients complained of dyspnea pre-surgery, with the proportion falling to 30% at three months and 33% at 12 months. The level of exertion at which these symptoms developed was also greater after surgery (Caine et al 1991). More recently, symptoms of chest pain and dyspnea were significantly reduced in both male and female patients following CABG (Sjoland et al 1997b; Herlitz et al 2001). Thus in general, an improvement in angina and dyspnea has been observed following CABG.

Physical activity

Increased maximal exercise performance after CABG has been reported in a number of studies (Jenkins et al 1983; Caine et al 1991; Chocron et al 1996; Sjoland et al 1997a; Herlitz et al 2001). One study found that 6 months after CABG, usual daily physical activity had increased, with a sharp reduction in the number of days participants were unable to carry out usual activities, or were confined to bed, due to their heart condition (Jenkins et al 1983). An investigation of usual activity levels at home, at leisure, and socially, found that these were improved 1 year following surgery (Caine et al 1991). An assessment of QOL before and 3 months after heart surgery found that physical mobility was improved in 77% of patients (Chocron et al 1996). One study developed a physical activity score containing six questions for the self-estimation of physical abilities and limitations. The score improved over time, with the major improvement observed at 3 months, and further slight improvement at 2 years (Sjoland et al 1997a).

In contrast, other researchers have found no change, or a decrease, in physical functioning following CABG. One study found that 17% of previously active CABG patients reported a significant decrease in leisure and social activities up to 2 years after surgery (Wilson-Barnett 1981). Investigators in the CASS found that 68% of patients had a moderate activity level pre-surgery with no change in activity during the 5-year follow-up period (CASS PI 1983). More recently, an investigation of exercise behavior at 6 and 24 months post-surgery found that 67% of CABG patients had become long-term regular exercisers by 2 years post-surgery (Jue and Cunningham 1998). These results support the view of Allen (1990) that physical functioning improves for some patients following CABG, while pre-operative inactivity continues or physical activity levels deteriorate following surgery for other patients (Allen 1990).

Complications of surgery and re-hospitalization

Some surgical complications and medical problems have resulted in hospitalization following CABG. In an early study, 23% of CABG patients were re-hospitalized in the first 6 months following surgery. Cardiac problems were responsible for 32% of these hospitalizations, complications of surgery (including cardiac complications) for 14%, gastrointestinal difficulties for 9%, and a wide variety of problems in other organ systems for 45% of hospitalizations (Jenkins et al 1983). More recently, 33% of CABG patients were re-hospitalized in the first 2 years after surgery, with the most common reasons for re-admission being acute myocardial infarction, arrhythmia or angina (Geissler and Aggestrup 2002). Risk factors for re-hospitalization include: length of stay in intensive care; severe non-cardiac complications; duration and severity of pre-operative cardiac symptoms; intra-aortic balloon insertion; pre-operative resting angina; female gender; age; diabetes; and surgical procedure (patients with left internal mammary artery graft or multiple arterial grafts are less likely to be re-hospitalized) (Jenkins et al 1983; Stanton et al 1985; Fasken et al 2001; Damgaard et al 2005). Thus, a significant number of patients are re-hospitalized following CABG, although this high rate of readmission may reflect a greater likelihood that physicians will hospitalize patients if there is a recent history of cardiac surgery.

Psychological functioning

The reported rates of psychological difficulties following CABG vary widely (Tienari et al 1982; Raja et al 2004). Studies assessing anxiety levels of CABG patients have generally shown that anxiety levels are raised prior to surgery but drop rapidly post-surgery (Jenkins et al 1983; Gardner and Worwood 1997; Boudrez and Backer 2001). One study found that the anxiety of CABG patients pre-operatively was more severe than the reference population of general medical and surgical patients, although anxiety levels significantly improved post-surgery. It has been suggested that such rises in anxiety levels may reflect anticipation of the forthcoming procedure (Jenkins et al 1983). However, some patients appear to suffer severe anxiety for extended periods of time after surgery, which is often associated with substantial depression (Gardner and Worwood 1997).

Research indicates that a number of CABG patients are depressed immediately following surgery, with a return to pre-operative levels at discharge. One study found that 50% of patients were significantly depressed 8 days post-surgery,

but this declined substantially with time to 24% 8 weeks post-surgery, and 22% at 12 months (Timberlake et al 1997).

There are a number of reported reasons for depression following CABG. First, the post-operative period involves substantial discomfort and pain, with patients being isolated from family, friends, and the familiarity of home, which may produce depression (Timberlake et al 1997). Second, pre-operative mood appears to contribute to the prediction of depressive symptoms post-surgery (Jenkins et al 1983; Timberlake et al 1997; Boudrez and Backer 2001). Early studies found that patients with an inability to cope with stressful events, or those with neurotic personality traits, could be identified pre-surgery and were more likely to have poor psychological outcomes following surgery (Magni et al 1987; Timberlake et al 1997). Pre-operative depression scores were shown to account for 34% of the variation in depressed mood post-operatively (Magni et al 1987). More recently, pre-operative levels of depression were shown to be the best predictors of depression at 8 days, 8 weeks and 12 months post-surgery (Timberlake et al 1997). These results emphasize the value of examining patients' levels of anxiety and depression prior to surgery.

Third, there is increasing recognition that CABG may be a risk factor for subtle cognitive decline or psychological abnormalities (Raja et al 2004; Phillips-Bute et al 2006). Neurological complications following CABG include: stroke (5%–6% of patients); and ophthalmologic abnormalities such as retinal infarction, retinal embolization and reduction in visual acuity (13%–29% of patients) (Van Dijk et al 2002). Cognitive decline may present as short-term memory loss, psychomotor slowing, or executive dysfunction. Proposed mechanisms include surgical-related trauma, microembolization, genetic susceptibility (eg, apolipoprotein E4 allele), other vascular or ischemic changes, and temperature during surgery. Thus the etiology for cognitive decline is most likely multifactorial and includes a synergistic effect of microemboli, hypo-perfusion, and other variables associated with major surgery. Non-pharmacologic (eg, emboli reduction, temperature, or glucose management) and strategies to prevent post-CABG cognitive deficits are currently under investigation (Raja et al 2004).

Therefore, studies have shown that a significant proportion of CABG patients experience psychological difficulties post surgery, and there appears to be a range of possible reasons for these difficulties.

Social functioning

The emphasis on treating patients as social beings who live in a complex social context has permeated many branches of medicine. This approach holds that the ultimate aim of medical care should be to reintegrate the individual into a normal, productive life in society, rather than merely to treat their medical symptoms (McDowell and Newell 1996). Many studies have highlighted the importance of social support in attenuating the effects of stressful events and thereby reducing the incidence of disease, although there is substantial variability in the manner in which social support has been conceptualized and measured (Orth-Gomer et al 1998; Lett et al 2005). Social support is generally defined in terms of the availability of trusted, reliable people who make the individual feel cared for and valued. The emphasis in related sociomedical indices lies with assessing the quality, rather than the number or type, of relationships (McDowell and Newell 1996; Lett et al 2005).

Some studies of social functioning following CABG have shown little change in social activities (CASS PI 1983; Jenkins et al 1983), while others have reported an increase in social interaction (Mayou and Bryant 1987; Ross and Ostrow 2001). An investigation of social interactions of CABG patients found a stable level of interaction for 48% of patients, an increase for 28%, and a decrease for 24% of patients 6 months after surgery (Jenkins et al 1983). Another study reported a general increase in leisure activities, social activities, and satisfaction post-surgery (Mayou and Bryant 1987). However, only a minority of patients appear to take advantage of angina relief post-surgery by undertaking more energetic pastimes. Thus, it seems that CABG patients are able to perform their usual undemanding activities more comfortably following surgery, but may have little desire to dramatically change the pattern of their lives (Mayou and Bryant 1987; Pollick 1993).

Vocational status

An important goal of CABG is the resumption of gainful employment in employment-eligible patients (Allen 1990). In a review of 15 studies, 80% of patients were less likely to be employed after CABG, while for 20% there was no change or an improvement. The percentage of patients employed after CABG ranged from 38% to 81% (average 62%) (Allen 1990). In the CASS study, a consistent annual decline in employment was observed, with 76% employed at baseline and 52% at 5 years (CASS PI 1983). A more recent study found that employment rates pre-surgery, 6 and 12 months

post-surgery were 36%, 34%, and 21% respectively, although these results were not controlled for age (Skinner et al 1999). Patients may also experience a decline in income post-surgery as a result of employment changes (Jenkins et al 1983).

Some variables consistently appear to predict employment after CABG, although investigators have used different CABG populations, employment definitions, end points, and follow-up times. There have also been methodological limitations. The major predictor of post-operative employment is pre-operative work status, which accounts for more than 40% of the total variance in post-operative employment (Hlatky et al 1998; Geissler and Aggestrup 2002). Patients who expect to return to work post-surgery are also more likely to do so (Allen 1990; Skinner et al 1999). Predictors of failure to return to work have included: older age; more severe CHD; more chronic medical conditions; persistent angina; female gender; co-morbidities; pre-operative fatigue; blue-collar workers; higher income; and negative communications from physicians and family regarding return to work (Allen 1990; Mittag and Schwarzer 1993; Hlatky et al 1998; Skinner et al 1999). Other variables influencing return to work are: prolonged waiting time for surgery; the economic environment; the availability of disability payments; and the increasing age of the population (Skinner et al 1999).

Conclusion

Coronary artery bypass surgery remains an established form of treatment for coronary artery disease, and the majority of coronary surgical procedures are performed for multiple vessel disease. Overall, the mortality rate of coronary artery surgery is low, at around 2%–3% (Keogh and Kinsman 2004), although this benefit is offset by a complication rate of 20%–30%. Furthermore, post-surgical neurocognitive impairment is of concern (Wolman et al 1999; Newman et al 2001). PCI has had a dramatic effect on CABG, arresting the dramatic growth of surgery in the 1980s and shifting the attention of surgeons to patients with more advanced coronary disease and extensive coexisting conditions. This has motivated surgeons to refine coronary revascularization techniques in order to maximize clinical effectiveness, limit costs, and reduce invasiveness.

Outcomes of CABG have historically been measured in terms of mortality and morbidity; however adjustment to CABG is a multidimensional phenomenon that is not fully explained by medical factors. When investigating post-operative adjustment to CABG, it is important to assess various physical, psychological and social variables as well, which is increasingly being recognized in recent studies.

Abbreviations

CABG, coronary artery bypass graft surgery; QOL, quality of life; VAS, veterans administration study; ECASS, European coronary artery surgery study; CASS, coronary artery surgery study; CHD, coronary heart disease; PTCA, percutaneous transluminal coronary angioplasty; PCI, percutaneous coronary intervention.

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