Coronary Artery Bypass Grafting Surgery for Atherosclerotic Cardiac Disease

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Edited by

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TABLE OF CONTENTS

PREFACE

Coronary artery bypass surgery has been performed for more than fifty years, and it is fair to claim that it is one of the most effective treatment modalities in medical history. Considering the long-term results of multivessel coronary artery disease, there is not such an effective alternative therapeutic modality yet. The reason is probably that it is a biological solution using autologous grafts.

The profile of patients referred for coronary bypass surgery has changed over time. Today, even high-risk patients can be operated on with better surgical results. For example, patients with chronic renal insufficiency, octogenarians and nonagenarians are more frequently operated on. In fact, the incidence of coronary reoperations has decreased because of percutaneous interventions, and surgeons are more reluctant to perform coronary endarterectomy.

All cardiovascular surgeons participating in this monograph tried to interpret the actual practice of coronary bypass surgery, with the help of their experience and recent literature. Our primary aim was to provide our colleagues a practical and realistic perspective on the topic. One of the most important and compelling issues was to discuss the topics without being either too detailed or too shallow. My participating colleagues and I trust that each section in this monograph reflects our rigorous effort to achieve this goal. Appraisal belongs to our readers.

With Regards,

Mehmet Erdem Toker, MD
Associate Professor of Cardiovascular Surgery
Istanbul, 2020

LIST OF ABBREVIATIONS

ACS	Acute Coronary Syndrome
ACT	Activated Clotting Time
AKI	Acute Kidney Injury
ALCAPA	Anomalous Coronary Artery Originating from Pulmonary Artery
ASO	Arterial Switch Operation
BMI	Body Mass Index
BITA	Bilateral Internal Thoracic Artery
CABG	Coronary Artery Bypass Graft
CAD	Coronary Artery Disease
CCB	Calcium Channel Blocker
CKD	Chronic Kidney Disease
CKF	Chronic Kidney Failure
CLL	Chronic Lymphocytic Leukemia
CML	Chronic Myeloid Leukemia
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular Disease
Cx	Circumflex Artery
CPB	Cardiopulmonary Bypass
CRT	Cardiac Resynchronization Therapy
DM	Diabetes Mellitus
ECMO	Extracorporeal Membrane Oxygenation
ERO	Effective Regurgitant Orifice
EVH	Endoscopic Vein Harvesting
FHC	Familial Hypercholesterolemia
GEA	Gastroepiploic Artery
GFR	Glomerular Filtration Rate
ICU	Intensive Care Unit
IEA	Inferior Epigastric Artery
INR	International Normalized Ratio
IMR	Ischemic Mitral Regurgitation
ITA	Internal Thoracic Artery
KD	Kawasaki Disease
LAD	Left Anterior Descending Artery
LDL	Low-Density Lipoprotein
LIMA	Left Internal Mammary Artery
LM	Left Main Coronary Artery

LMWH	Low Molecular Weight Heparin
LV	Left Ventricle
LVD	Left Ventricular Dysfunction
MACCE	Major Adverse Cardiac and Cerebrovascular Events
MDS	Myelodysplastic Syndromes
MI	Myocardial Infarction
MICS-CABG	Minimally Invasive Cardiac Surgery Coronary Artery Bypass Grafting
NSCLC	Non–Small Cell Lung Carcinoma
OPCAB	Off-Pump Coronary Artery Bypass Grafting
PCABG	Pediatric Coronary Artery Bypass Grafting
PCI	Percutaneous Coronary Intervention
PTCRA	Percutaneous Transluminal Coronary Rotational Ablation
RA	Radial Artery
RAST	Right Anterior Small Thoracotomy
RBBB	Right Bundle Branch Block
RCA	Right Coronary Artery
RCPD	Right Coronary Posterior Descending
RCPL	Right Coronary Posterolateral
RIMA	Right Internal Mammary Artery
RITA	Right Internal Thoracic Artery
RRT	Renal Replacement Therapy
RV	Right Ventricle
SVC	Superior Vena Cava
SVG	Saphenous Vein Graft
SMR	Secondary Mitral Regurgitation
TEE	Transesophageal Echocardiography
TGA	Transposition of the Great Arteries
TIA	Transient Ischemic Attack
VC	Vena Contracta
VWF	Von Willebrand Factor

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CHAPTER ONE
EVOLUTION OF THE PATIENT PROFILE AND CABG: DOES THE RISK INCREASE?

MEHMET ERDEM TOKER

Introduction

Coronary artery bypass surgery (CABG) has been performed for 50 years (Head et al. 2013), but the patient profile has changed over time. Today, CABG is more common in high-risk patients who had less chance of undergoing surgery in the past. The proportion of patients with well-known risk factors such as peripheral arterial disease, chronic renal failure, and diabetes has increased over time (Song et al. 2009). The CABG rate for octogenarians has increased, and nonagenarians have a higher chance of surgical treatment now than in previous years. Isolated CABG can be performed in patients whose body mass index is between 40 and 50 (Choi et al. 2012; Villavicencio et al. 2007). Patients with active or previous cancer are more likely to undergo CABG. The definition of cardio-oncology and its specialists allows a closer evaluation of cancer and heart disease (Hermann et al. 2014; Al-Kindi et al. 2016).

Although the number of high-risk patients with comorbid conditions has increased, outcomes have also improved, and early mortality and morbidity rates have decreased (Song et al. 2009; Abramov et al. 2000; Ferguson et al. 2002; El Bardissi et al. 2012; Estafanous et al. 1998; McNeely et al. 2016) because of the increase in the number of experienced staff and centers, improvement in intensive care monitoring, and technological progress. There has also been a reduction in the number of repeat CABG operations over time (Algarni et al. 2012; Ghanta Kavi et al. 2013). Similarly, revascularization rates in shock or emergency conditions have decreased. In contrast, the number of patients who have undergone one or more percutaneous interventions has increased over time.

The risk increases if there is a mismatch between the physiological requirements of a procedure and the functional reserve of the patient (Lobdell et al. 2016). Often, more than one risk factor may be intertwined (Pan et al. 2006).

Here, we discuss the major risk factors that affect early outcomes in isolated CABG.

CABG in octogenarians and nonagenarians

The world population and average age are both increasing (Wan et al. 2006). In the United States, the population aged 80 and over increased from 8.1 million in 1995 to 12.1 million in 2015 (Miller et al. 2018). In 2050, this figure is projected to be approximately 30 million (Ortman et al. 2014). Advanced age alone is not considered a rejection criterion for a curative operation. However, the decrease in the physiological reserves of organs with age is a risk factor for this age group (Wan et al. 2006). Frailty is a more important problem for this age group than for younger age groups, increasing the duration of postoperative rehabilitation for older patients.

Standard treatment algorithms may cause more complications than expected in the postoperative period. For example, sternotomy may require longer rehabilitation in octogenarians and nonagenarians than in younger patients (Yanagawa et al. 2016). In pharmacological treatment for arrhythmia, liver enzymes may increase abnormally and multi-organ failure may develop because the pharmacokinetics of drugs is different for those over 80 years old. Blood transfusions can lead to lung problems. Therefore, patient-based evaluation is important to ensure early and long-term benefits from treatment.

Coronary angiography, percutaneous intervention, and CABG numbers and rates have increased over time in many nonagenarian and octogenarian patient populations (Sawant et al. 2017; Rajani et al. 2011; Maganti et al. 2009; Habib et al. 2018; Likovsky et al. 2008). The increase in the elderly population; the high rates of cardiovascular disease in this group; improvements in the catheter laboratory, surgical techniques, and intensive care units; and increased cumulative experience have improved treatment options and outcomes for older age groups. Advances and developments in the treatment of diseases other than life-threatening cardiovascular ones play a role in this increase (Bridges et al. 2003).

CABG in octogenarians

CABG for patients in their 80s is an accepted reality with its early (Luc et al. 2017; Nicolini et al. 2015) and long-term (Dacey et al. 2007; Kurlansky et al. 2011) results. Publications on the comparison of any revascularization procedures with medical therapy alone in octogenarians have been increasing since the early 2000s (Pfisterer et al. 2003; Graham et al. 2002). Although similar results were found in the early postoperative period (Pfisterer et al. 2003), surgery was superior in the long term (Graham et al. 2002). Over the years, octogenarian patients have undergone CABG operations in increasing numbers (Maganti et al. 2009; Habib et al. 2018) and proportions (Likovsky et al. 2008).

The prevalence of cardiovascular diseases increases with age. The prevalence of cardiovascular disease in those over 80 years of age is 21.7% in women and 30.6% in men (Benjamin et al. 2017). These values are lower in the 60-79 age range and younger age ranges. In an autopsy study involving octogenarians and nonagenarians, 300 of 490 cadavers (61%) had narrowing of more than 75% in at least one major coronary artery (Roberts et al. 1998). When the patient profile is examined, female patients, three-vessel disease, and left main coronary artery (LMCA) lesion rates are higher in those 80 years and older than in younger patients (Likovsky et al. 2008; Graham et al. 2002; Saxena et al. 2011).

Performing complete revascularization provides a survival advantage over incomplete revascularization (Melby et al. 2016; Aziz et al. 2009). The operations are mainly performed with cardiopulmonary bypass. However, off-pump coronary artery bypass (OPCAB), which is performed on a beating heart, may be a reliable alternative (LaPar et al. 2011). Left internal mammary artery (LIMA) use ranges from 41.5% to 95% (Kurlansky et al. 2011; Melby et al. 2016; Sen et al. 2012; Nissinen et al. 2018). However, the use of LIMA grafts has increased over time (Maganti et al. 2009; Kurlansky et al. 2011), which has contributed to a decrease in mortality (Kurlansky et al. 2011).

The 30-day mortality rate is between 2% and 9.7% (Maganti et al. 2009; Luc et al. 2017; Kurlansky et al. 2011; Saxena et al. 2011; Sen et al. 2012; Nissinen et al. 2018). It has been stated that the early mortality rate in CABG patients has decreased over time (Maganti et al. 2009; Kurlansky et al. 2011; Habib et al. 2018).

Prolonged ventilation, reintubation, and neurological events are more common in octogenarians than in younger patients (Sen et al. 2012). Over time, stroke, low cardiac output, intra-aortic balloon pump (IABP) requirement, ventilator requirement, intensive care unit stay time, and postoperative stay time have decreased (Maganti et al. 2009). The one-year survival rate is 90.8% (Nissinen et al. 2018), 5-year survival is 73.2%

-76.6% (34.39), and 7-year survival is 42% (Kurlansky et al. 2011). The results of CABG performed on octogenarians are similar, if not better, in the long-term compared with age-adjusted populations (Saxena et al. 2011). Comparisons with percutaneous interventions emphasize that early outcomes are better in percutaneous coronary intervention (PCI) (Dacey et al. 2007; Sheridan et al. 2010), but CABG is significantly advantageous over time (Nicolini et al. 2015; Dacey et al. 2007; Sheridan et al. 2010). In a 14-year cross-sectional study, the 2600 patients in the 80-84 age group who underwent CABG had a mean life span of 7.4 years, and the 586 patients over 85 years had a mean life span of 5.8 years (Likovsky et al. 2008).

Therefore, the benefit and necessity of CABG is evident in complex conditions such as three-vessel disease and LMCA lesions for patients 80 years and older. Early mortality rates are at acceptable levels. Recent results point to further improvement. Quality of life and survival are comparable to those of the same age group in the general population (Kurlansky et al. 2011). This improvement over time is related to increases in general experience, improved surgical practice, improvement of perioperative care and patient selection, and perhaps avoidance of emergency surgery in this group of patients (Habib et al. 2018).

CABG in nonagenarians

Worldwide, the population over the age of 90 is increasing. The nonagenarian population, which was about 4.76 million in 1990, increased to 15.7 million in 2015 (United Nations, Department of Economic and Social Affiars, Population Division 2019). These results are related to progress in medicine and hygiene, public health campaigns, and improved living conditions (Rivoirard et al. 2014). It is well known that chronological and biological age may not be comparable in elderly patients. With advanced age, changes occur in economic, physical, mental, daily life, and social environments (Randal et al. 2011). Open-heart operations for patients aged 90 years and older have been performed since the 1990s (Samuels et al. 1996). Although a relatively small series of patients was initially reported, larger series of patients with CABG and valve surgery have since been published (Assman et al. 2013; Caceres et al. 2013; Praschker et al. 2006).

The rate of female patients, renal dysfunction, emergent and urgent cases, and patients with LMCA disease are higher in nonagenarians than in younger age groups (Caceres et al. 2013; Bridges et al. 2003). The rate of female patients is between 37% and 46% (Caceres et al. 2013; Bridges et al. 2003), which can be explained by the higher life expectancy among women compared to men. On the other hand, other well-known risk factors such as diabetes, obesity, and chronic lung disease are less prevalent in nonagenarians than in younger age groups (Bridges et al. 2003; Praschker et al. 2006). Patient selection criteria are important in CABG decisions. Generally, bedridden patients without family support do not receive operations (Speziale et al. 2010).

Reported morbidity and mortality rates are acceptable in most studies of elective cases for nonagenarians. In a multicenter retrospective study based on the Society of Thoracic Surgeons (STS) database, the rate of operative mortality was 11.8%, prolonged ventilation was 12.2%, and renal insufficiency was 9.2% for patients with isolated CABG, including 663 patients over 90 years of age (Bridges et al. 2003). In another study, which included the results of 127 procedures in nonagenarian patients, 33.4% of which were nonelective and 49 of which were isolated CABG operations, operative mortality was 13.4% for all patients (Speziale et al. 2010). In urgent or emergency operations and those in patients with a preoperative IABP, the rate of early mortality may exceed 20% (Bridges et al. 2003). Often, a long stay in intensive care is also a problem for this age group. In a study of patients who underwent isolated CABG that included nonagenarians with a mean age of 91.4 ± 1.9, mean survival was 4.1 years, which is close to age-adjusted life expectancy (Caceres et al. 2013).

As a result, CABG can be performed with acceptable results in nonagenarian patients. In the selection of patients, three factors should be considered: social and functional status (DASI score); indicators of operative risk, especially myocardial, renal, pulmonary, and hepatic function; and the patient's motivation regarding the operation (Speziale et al. 2010). Patients who do not have emergency conditions or hemodynamic problems, don't have preoperative support, and do not carry significant, severe peripheral vascular disease (PVD) or cardiovascular disease (CVD) are good candidates for CABG (Bridges et al. 2003).

CABG in cardiogenic shock

In the case of cardiogenic shock after myocardial infarction, emergency CABG may be necessary. Cardiogenic shock occurs when systolic blood pressure falls below 90 mm Hg for 30 minutes, vasopressor requirement to increase blood pressure above 90 mm Hg, pulmonary congestion or high filling pressures, altered mental status, cold wet skin, oliguria, and increased lactate levels (Joseph et al. 2016). The cardiac index is less than 1.8 L/min/m^2 without mechanical or inotropic support or less than 2 L/min/m^2 with mechanical or inotropic support (Acharya D and Gulack BC et al. 2016).

Neurological status is unclear in some patients (Santarpino et al. 2015; Davierwala et al. 2016). External cardiac massage may be required before or during surgery (Acharya D and Gulack BC et al. 2016; Santarpino et al. 2015; Davierwala et al. 2016; Axelson et al. 2016; Lee et al. 2016). Percutaneous intervention may have been performed or tried before bypass (Santarpino et al. 2015). Patients may require preoperative IABP, extracorporeal membrane oxygenation (ECMO), or other short-term mechanical circulatory support (Acharya D and Gulack BC et al. 2016; Davierwala et al. 2016; Demondion et al. 2014). In some patients, revascularization alone is not sufficient to regulate the damaged ventricle and to restore systemic function in multiorgan failure. Implanting a permanent ventricular assist device (VAD) may be necessary after temporary mechanical circulatory support (Acharya D and Loyaga-Rendon et al. 2016).

In cardiogenic shock, 77.8-88.7% of operations are performed under cardioplegic arrest or cardiopulmonary bypass (CPB) on a beating heart (Acharya D and Gulack BC et al. 2016; Davierwala et al. 2016). Complete revascularization is essential in myocardial revascularization. However, OPCAB as well as CABG may be preferred for patients with cardiogenic shock, depending on the number of occluded vessels, the extent of the disease, the patient's hemodynamic stability, and surgeon experience and preference (Gaudino et al. 2016). It is essential to apply CPB to all patients undergoing external cardiac massage (Santarpino et al. 2015). The use of LIMA grafting is desirable, as well. However, especially in rescue patients who undergo surgery with external cardiac massage, the rate of LIMA use remains low (Santarpino et al. 2015; Axelson et al. 2016).

In CABG operations performed for cardiogenic shock, the early mortality rate varies between 14% and 33.7% (Acharya D, Gulack BC et al. 2016 Davierwala et al. 2016; Gaudino et al. 2016). This rate can be as high as 35.3-41% (Santarpino et al. 2015; Axelson TA et al. 2016) in patients who undergo direct external cardiac massage, and up to 58.4% (Acharya D and Gulack BC et al. 2016) in patients with intraoperative or postoperative mechanical support. Long-term postoperative survival rates are reportedly 49.8% (Santarpino et al. 2015) at 3 years, 40.9% (Santarpino et al. 2015) and 42.6% (Davierwala et al. 2016) at 5 years, and 33.4% (Davierwala et al. 2016) at 10 years.

In summary, CABG has high early mortality in patients with cardiogenic shock. In recent years, the number and rate of CABG in patients with shock have decreased, probably because of increased percutaneous intervention rates and potentially long reperfusion periods after surgery. However, the number of studies related to these two treatment modalities is limited (Gaudino et al. 2016). In shock, CABG is a well-established intervention (Acharya D and Gulack BC et al. 2016), and this active intervention should be used when necessary (Gaudino et al. 2016). Of course, whichever intervention modality is applied, it is important to make patient-based decisions in these patients for whom the risk is high in the early postoperative period.

CABG in chronic kidney disease

The proportion of CABG patients with chronic kidney disease (CKD), including end-stage dialysis patients, is continuously increasing (Song et al. 2009; Ferguson et al. 2002; El Bardissi et al. 2012; McNeely et al. 2016; Kindo et al. 2017; Abramov et al. 2000). It is appropriate to consider this proportional increase together with the increase in the prevalence of CKD in the general population (Benjamin et al. 2017; Caresh et al. 2007). Other important reasons for the increase in CABG patients with CKD may be improved perioperative management for the patients with CKD and reduced reluctance on the part of surgeons. Decreases in the exclusion of patients with CKD from clinical trials (Coca et al. 2006) also help to explain this increase.

CKD is a well-known risk factor for coronary artery disease (Kestenbaum et al. 2009). Atherosclerotic plaque in CKD patients is different from that in patients without renal failure., containing more necrotic core and dense calcium content and less fibrous tissue (Baber et al. 2012). In addition, the pathophysiology of CKD is related to other comorbid diseases and conditions. For example, the obesity rate in the adult population is 30% in the United States (Go et al. 2014). Diabetes mellitus is becoming more prevalent, especially in developed countries (Shaw et al. 2010; Wild et al. 2004). Therefore, the increase in CKD rates in the general population and CABG series should be evaluated together with other comorbid factors.

Surgery can be performed with CABG and CPB or by OPCAB on a beating heart. The difficulty of CABG with CPB for patients with CKD can be summarized as difficulties in maintaining fluid electrolyte balance, maintaining adequate hemoglobin levels, and restoring hemostasis (Dewy et al. 2006). Preoperative low-potassium dialysis, intraoperative hemofiltration, postoperative intermittent dialysis, and postoperative venovenous hemodialysis in patients with hemodynamic problems are examples of management techniques for CABG patients dependent on renal replacement therapy (Takami et al. 2012).

These perioperative problems might be less in OPCAB. The average number of grafts is higher in CABG than in OPCAB (Dewy et al. 2006; Shroff et al. 2010). Although there is an early survival advantage for OPCAB, it does not persist in the long term (Dewy et al. 2006; Shroff et al. 2010; Takami et al. 2012). In a study with 13,085 patients (Shroff et al. 2010), hospital mortality was similar for the 2335 patients with OPCAB (9.7%) and the 10750 with CABG (11%; $p = 0.06$). A review of 10 studies emphasized that OPCAB was not superior and that conventional CABG should not be avoided to avoid early postoperative problems (Lim et al. 2015).

Comparisons of CABG and PCI in CKD have been performed for approximately 20 years (Herzog et al. 1999). In the long term, CABG is superior to PCI (Hemmelgarn et al. 2004; Bangalore et al. 2015; Kumada et al. 2014; Chan et al. 2015). As noted, this long-term superiority becomes more pronounced at the expense of increased early risk in CKD patients on dialysis (Shroff et al. 2016). Indeed, early mortality is higher in dialysis-dependent CABG patients, but rates of 1-year mortality, acute myocardial infarction, combined major adverse cardiovascular and cerebral events (MACCE), bleeding complications, and recurrent revascularization are significantly lower after CABG (Möckel et al. 2016). Nonetheless, patients should receive individualized treatment. PCI may be more appropriate in stable elderly patients without frailty (Osaka et al. 2010). CABG may be preferred to PCI in patients with CKD but without acute coronary syndrome (ACS) because of its lower early mortality (Shroff et al. 2016).

CABG in female patients

Introduction

Life expectancy is longer in women than in men. However, early mortality rates in women after CABG are 2.3-5.6%, which is higher than in men (Saxena et al. 2012; Ter Woost et al. 2019; Filardo et al. 2016; Bukkapatnam et al. 2010; Alam et al. 2013). This higher mortality rate may be related to some preoperative and operative differences between the sexes.

In the CABG population, the rates of diabetes (Saxena et al. 2012; Ter Woost et al. 2019; Filardo et al. 2016; Bukkapatnam et al. 2010; Alam et al. 2013; Vaccarino et al. 2003; Ahmed et al. 2011), obesity (Saxena et al. 2012; Ter Woost et al. 2019; Bukkapatnam et al. 2010; Vaccarino et al. 2003), and low-weight patients (Ter Woost et al. 2019; Bukkapatnam et al. 2010; Vaccarino et al. 2003) are higher in women than in men. The mean age (Ter Woost et al. 2019; Vaccarino et al. 2003) and percentage of elderly patients (Saxena et al. 2012; Bukkapatnam et al. 2010) are also higher. However, in most cases, left ventricular function is better preserved in women than in men, and fewer women than men have diffuse vascular disease or low ejection fraction.

Biological differences between the sexes lead to variations in the occurrence and prevalence of cardiovascular diseases. Also, diagnosis of acute and chronic ischemic heart disease is often delayed in women. Many women at risk of related complications do not receive specific preventive diagnosis and treatment (Garcia et al. 2016). Today, it is emphasized that sex-specific algorithms should be developed in the treatment of cardiovascular diseases (Aziz et al. 2017).

Operative findings

Many publications report differences in operative characteristics between men and women. Rates of emergency and urgent surgery are higher in women than in men (Saxena et al. 2012; Ter Woost et al. 2019; Filardo et al. 2016; Alam et al. 2013; Vaccarino et al. 2003). This higher rate may be related to the later referral of women to surgery. Furthermore, LIMA use is often lower in women than in men (Bukkapatnam et al. 2010; Vaccarino et al. 2003; Ahmed et al. 2011). More generally, the average number of grafts in CABG is lower in women than in men, as diffuse vascular disease is often more frequent in men (Saxena et al. 2012; Ter Woost et al. 2019; Vaccarino et al. 2003). In addition, women's rate of admission to hospital after postoperative discharge is higher than that of men (Vaccarino et al. 2003; McNeely et al. 2017; Hannan et al. 2011). Therefore, both preoperative and operative characteristics and differences may lead to differences in early outcomes between the sexes.

Conclusion

Men form the basis of many diagnostic and therapeutic strategies in atherosclerotic diseases of the epicardial coronary arteries (Wengeer et al. 2012). Among symptomatic patients, fewer angiographies and CABG operations are performed in women (Johnston et al. 2011). On the other hand, microvascular dysfunction occurs in approximately half of women with chest pain who do not have obstructive coronary artery disease (Reis et al. 2001), which exceeds the rate in men (Aziz et al. 2017). When considered together, these findings suggest that it is necessary to minimize the possible loss of time for diagnosis and effective treatment in patients who may require surgery because the symptomatology and clinical findings of female patients are different.

Less use of LIMA grafts may be a factor for early morbidity and mortality. Higher rates of non-elective CABG may be associated with less use of LIMA. In general, although the benefits of LIMA grafting in atherosclerotic heart diseases is well-known, it is important to consider why the use of at least one IMA in elective CABG operations is less frequent in female patients than in male patients.

In summary, referral to surgery without any delay in cases with appropriate indications and the use of at least one IMA will undoubtedly benefit early outcomes in female patients, as in male patients.

CABG and Obesity

Introduction

The rate of obesity has increased and reached epidemic rates around the world (Bastien et al. 2014). The prevalence of obesity in the adult population in the United States is over 30% (Flegal et al. 2016; Hales et al. 2018). The pathophysiological process of the relationship among atherosclerosis, cardiovascular disease, and obesity is clearly based on a chronic inflammatory condition (Bastien et al. 2014).

Performing CABG in obese patients is often a necessity (Terada et al. 2016; Engel et al. 2009; Sun et al. 2009; Benedetto et al. 2014). The rate of obese patients has doubled in the last 30 years. As the obesity epidemic increases, the number of obese and morbidly obese patients referred to CABG will increase, as well (Choi et al. 2012).

Obesity occurs when BMI reaches or exceeds 30 kg/m². Above this value, obesity is classified into subgroups of Grade I (BMI 30-34.9), Grade II (35-39.9), and Grade III (>40) (Bastien et al. 2014). In CABG publications, subgroups of obese patients with BMI over 30 kg/m² can be identified according to these ranges (Terada et al. 2016). Cut-off values for morbid obesity can be selected as BMI ≥34.9 (van Straten et al. 2010) or BMI ≥40 (Engel et al. 2009).

Preoperative features

Obesity is often intertwined with other comorbid conditions. As shown in CABG studies, the prevalence of diabetes is higher in obese and morbidly obese patients than in normal-weight and overweight patients (Terada et al. 2016; Engel et al. 2009; van Straten et al. 2010). In addition, among obese CABG patients, the proportion of female patients is higher and the average age is younger (Engel et al. 2009; Yap et al. 2007). Generally, obese patients have decreased pulmonary functional residual capacity and significantly decreased expiratory reserve volume (Poirier et al. 2009). Obese patients have diastolic dysfunction, lower total peripheral resistance, and higher cardiac output than normal-weight patients (Poirier et al. 2009).

Surgery

Technically, exploration may be more difficult in obese patients in CABG. Specifically, heart and LIMA exploration and saphenous vein removal may be difficult (Yap et al. 2007). The risk of sternal complications due to LIMA harvesting may be higher. In CABG operations for those with BMI >50, a bariatric operating table, lateral extensions to prevent damage to the upper extremities of the patient, and special retractors for IMA removal are used (Villaciencio et al. 2007). OPCAB is recommended for patients whose BMI is over 50 (Sun et al. 2009).

Obese and morbidly obese patients do not have greater early mortality after CABG than patients with a normal BMI (Terada et al. 2016; Engel et al. 2009, Wang et al. 2013). Early mortality is 2-2.4% in obese patients (Poirier et al. 2009) and 1-2.9% in morbidly obese patients (Engel et al. 2009; Poirier et al. 2009; Wang et al. 2013). In CABG patients with BMI >50, early mortality is 5% (Sun et al. 2009) to 7% (Villaciencio et al. 2007). However, postoperative morbidity is generally more frequent. This group of patients has a prolonged stay in the operating room, intensive care unit, and hospital compared to non-obese patients (Choi et al. 2012; Terada et al. 2016). Morbidity in diabetic obese patients is high (Pan et al. 2006). In addition, rates of prolonged ventilation and respiratory failure (Engel et al. 2009; Alam et al. 2011), sternal wound infection (Baylor et al. 2011), and postoperative renal failure (Baylor et al. 2011) are higher in obese patients than in normal-BMI patients.

In conclusion, many publications show that early mortality after CABG is not greater in obese patients. Rather, CABG can be performed with acceptable mortality even in morbidly obese patients. Therefore, obese patients, including elderly obese patients (Le-Bert et al. 2011), should not be deprived of CABG.

Changing patient profiles: other reasons

CABG is a standard treatment for complex multivessel disease (Mohr et al. 2013; Head et al. 2014). In 77% of the comparative studies of CABG and PCI published during the past 15 years, CABG is associated with superior survival (Doenst et al. 2019). Patients who benefit from this survival advantage include those with multivessel disease, those without diabetes (Chang et al. 2016), and those with LMCA disease (Mäkikallio et al. 2016; Lee et al. 2016). Most of the late deaths are due to new myocardial infarction, and the superiority of surgical treatment is related to its being not only curative but also protective (Doenst et al. 2019). Thus, cardiologists and cardiovascular surgeons should make decisions by common consensus, considering early risk and long-term efficacy in choosing the most effective treatment.

Public reporting affects both cardiologists' and cardiovascular surgeons' preference for accepting patients at risk. Risk aversion is a concept that has been expressed for a long time (Lobdell et al. 2016). This is particularly important for critically ill patients, such as those in shock (Bangalore et al. 2016). These patients' high risk makes some physicians wary of performing coronary angiography, percutaneous intervention, and subsequent CABG in these patients (Bangalore et al. 2016). Experienced centers and experienced physicians should admit these patients, who have a chance of success and survival even though they are high-risk.

The concept of 'failure to rescue' should be considered as a metric along with morbidity and mortality for postoperative outcomes in open-heart surgery (Edwards et al. 2016). For example, rates of cardiac arrest, dialysis, pneumonia, prolonged ventilation, and other major complications may vary from center to center (Reddy et al. 2013). For this reason, a given center's ability to overcome certain complications can affect its the postoperative results after open-heart surgery.

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