Coronary Artery Revascularization in the Elderly: Percutaneous Coronary Angioplasty or Bypass Grafting?

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Over the past 20 years the definition of "the elderly" individuals was gradually shifted from persons older than 65 years to those older than or equal to 80 years[1]. Despite the lack of consensus about what defines elderly, coronary revascularization procedures' postoperative mortality rises sharply in those older than 75 years[2].

In western Countries the elderly compose the fastest growing segment of the population[3]. In the United States 12% of the population are over 65 years of age. In addition, the number of people in the above-mentioned age group rises in a 2.5-fold rate in comparison with the number of people aged less than 65 years[4]. Translating this in numbers, 31 million people in the United States are over the age of 65 years, one out of 30 people is older than 80 years and it is expected that in 2050 one out of 20 people will be more than 80 years old[5,6].

The physiologic changes brought upon the myocardium by old age are both functional and anatomical. The functional changes consist of a prolongation in contraction, a prolongation of the action potential, a decrease in contraction velocity as well as in the β-adrenregic contractile response and, finally, an increase of the myocardial stiffness[7,8]. The main anatomical changes consist of an increase in the size and a decrease in the number of myocardial cells with a simultaneous increase of the connective tissue matrix[7,8]. In addition to the aforementioned changes, the large vessels become dilated, less distensible and a weakening in the baroreceptor response occurs[8]. As a result of the above "physiological" changes that take place in the cardiovascular system with advancing age, left ventricular hypertrophy occurs (mainly due to an increase in the size of myocardial cells), the prevalence of hypertension rises, left ventricular ejection fraction slightly decreases, and heart rate at rest and during effort decreases as well[7,8].

The prevalence of cardiovascular diseases increases in a steady linear way with advancing age[7]. Therefore, the aforementioned demographic changes result in a dramatic increase in the number of elderly patients presenting with symptomatic coronary artery disease. Both the prevalence and the severity of coronary atheromatosis increase dramatically with advancing age, so that over 50% of the number of deaths in patients older than 65 years are due to coronary artery disease. In addition, about 75% of the number of deaths due to coronary artery disease involve elderly patients[9]. It is important to point out that symptomatic coronary artery disease constitutes only the "tip of the iceberg", since it accounts for only the 1/3 to 1/2 of the overall cases detected post mortem by autopsy[7] In the United States, in people over 75 years old, the prevalence of cardiovascular disease is estimated to be approximately

70% in men and 79% in women and the number of symptomatic patients is expected to increase by 65% in the following 30 years[5,8].

With regard to myocardial infarction, the database analysis of the TIMI II trial has shown that both mortality and complicated course increase in the elderly[10]. This is attributed to the fact that elderly patients are less likely to undergo thrombolytic therapy (either because of contraindications or because of delayed referral) and to the higher incidence of severe complications (such as strokes) following thrombolytic therapy[7]. Moreover, prognosis is further compromised by the commonly occurring comorbid conditions[11].

Concerning revascularization procedures, in comparison with younger patients, octogenarians subjected to either percutaneous transluminal coronary angioplasty (PTCA) or coronary artery bypass grafting (CABG) are more likely to be women, have multivessel disease, more calcified lesions, unstable angina, a prior myocardial infarction, more comorbid conditions and a lower ejection fraction[12].

A. Percutaneous transluminal coronary angioplasty in the elderly

After reviewing the literature, we were able to come across reports of PTCA in patients even up to 96 years of age![13]

Although PTCA does not seem to contribute to the prolongation of life, in patients older than 70 years suffering from myocardial ischemia and angina attacks it undoubtedly contributes to an improved quality of life[8]. However, since in the elderly, especially the very elderly (i.e. those older than 80 years of age), coronary artery stenoses tend to be more calcified, there is a higher rate of post-procedural complications and a higher rate of residual stenosis (and therefore, a higher rate of restenosis). Recently, with the widespread use of intracoronary stents, a definite shift towards improved PTCA outcomes seems to occur[14,15].

In the following part we are going to look at the outcome of PTCA outcome in the elderly population, as this becomes evident from various trials performed in recent years and database analysis. A related database was provided by the Northern New England Cardiovascular Disease Study Group, which included 12.172 patients who underwent PTCA from 1987 to 1993[12]. Among them 507 (i.e. 4%) were older than 80 years. In this database, octogenarians undergoing PTCA were more likely to be women, have multivessel disease, high-grade stenosis and complex lesions. On the other hand, in comparison with younger patients, octogenarians were less likely to have hypercholesterolemia, a history of smoking, or have been subjected to a previous PTCA. The major clinical indication for PTCA in elderly patients was unstable angina. Advancing age was strongly associated with acute myocardial infarction and in-hospital mortality. Indeed, while in younger patients (less than 60 years of age), the postprocedural myocardial infarction and the mortality rate were 2.05% and 0.36% respectively, the corresponding rates in patients 80 years of age and over were 3.35% and 3.16% respectively.

In the recent PTCA guidelines of the AHA/ACC, the committee pointed out that the age over 75 years was one of the most important variables associated with an increased rate of adverse postprocedural outcomes[16]. It was specified, however, that in the era of coronary artery stenting, both the initial procedural success and the short-term outcome of PTCA in octogenarians tend to be similar to those of younger age groups. Consequently, with the exception of primary PTCA in patients older than 75 years presenting with cardiogenic shock (where both in-hospital and long-term outcomes are definitely disappointing) no specific guidelines regarding octogenarians were edited by the committee[13,17].

Data concerning both short-term and long-term post-PTCA outcomes (30-days and 1-year unadjusted mortality rates respectively) result from the Medicare Provider Analysis and Review (MEDPAR) database[18]. In the aforementioned registry 225.915 consecutive patients who had undergone PTCA from 1987 to 1990 were included. In the above database 93.077 patients aged 65-69 years, 71.389 patients aged 70-74 years old, 42.246 patients aged 75-79 years old and 19.203 patients aged over 80 years old were included. The rate of PTCA in 1990 increased by 55% compared to that of 1987. There was a decline in 30-days mortality rate by 25%, while the one-year mortality rate decreased by 10% as well. Improved procedure related outcomes may have resulted from the increasing experience in performing PTCA in the elderly population, from the improvement in antithrombotic and anticoagulant and, finally, from the technological advances. After adjustment

for changes in patient characteristics, postprocedural thirty-day and one-year mortality rates decreased by 37% and 22% respectively. However, the short-term and long-term mortality rates resulting from this database were significantly higher in the subgroup of octogenarians (7.8% and 17.3% respectively) in comparison with the younger patients' subgroup (aged 65-69 years) where the rates were 2.1% and 5.2% respectively. In the intermediate age groups in-between mortality rates were also intermediate. In patients 70-74 years of age the 30-days mortality rate was 3%, while the one-year mortality rate was 7.3%. The corresponding rates for patients aged 75-79 years were 4.6% and 10.9% respectively. From the MEDPAR database analysis it became evident that the post-PTCA short-term and long-term mortality increases with advancing age in a linear manner.

Thompson et al have looked into the shift in in-hospital post-PTCA mortality, as well as 6-month and 1-year mortality rates, in patients 65 years and over, in the years 1980-1989 and 1990-1992[19]. In the years 1980-1989, 982 patients underwent a scheduled PTCA (group A), while 768 patients underwent a PTCA procedure in the years 1990-1992 (group B). The patients in group A, compared to those in group B, had a lower initial PTCA success (88.1% vs. 93.5%, $p<0.001$) and higher rates of in-hospital mortality 3.3% vs. 1.4%, $p=0.014$), emergency CABG (5.5% vs. 0.65%, $p<0.001$) and combined in-hospital death-myocardial infarction rate (6.3% vs. 3.4%, $p<0.005$). At 6 months the combined death- myocardial infarction rate was 4.7% in group A and 7.1% in group B ($p<0.05$), while at 1-year the rates were 10.3% vs. 9.9% respectively (p=NS). The one-year survival free from myocardial infarction, CABG, repeated PTCA and severe unstable angina was 66.7% in group A and 54.8% in group B ($p<0.001$). The conclusion of this trial was that improvements in initial PTCA success rates resulted in a decrease in short-term post-procedural complications but, unfortunately, this improvement does not apply to the long-term cardiovascular events as well.

PTCA outcome in the very elderly was studied in a trial carried out by seven centers in which revascularization procedures were performed in 26 patients older than 90 years[23]. PTCA was successful in the 65% of patients, while 6 in-hospital deaths were recorded, 4 of which were PTCA related.

Percutaneous transluminal coronary angioplasty with stent implantation

Coronary stenting is one of the most important technological advances in the field of PTCA, well known to have contributed to the decrease in the rate of restenosis (which is the major limitation of the procedure). The contribution of coronary stenting to the improvement of early and late outcome of percutaneous angioplasty has been already shown from the first randomized trials which compared conventional balloon angioplasty with angioplasty with stent implantation. Indeed, in the STRESS and BENESTENT trials stent implantation improved both, the early outcome of angioplasty and the rate of restenosis 6 months after the procedure (from 42 to 31% in the first trial - $p=0.04$, and from 32 to 22% in the second one - $p=0.02$)[21,22]. Concerning specifically the elderly population De Gregorio et al sought to compare the short- and long-term outcomes of elderly patients undergoing coronary artery stenting with those of younger patients and to determine the long-term clinical outcome and survival of elderly patients post stent implantation[23]. In this study, from 1993 to 1997, 137 patients older than 75 years who underwent coronary artery stenting were compared with 2.551 younger patients (less than 75 years old) who underwent PTCA with stent implantation during the same time period. In comparison to younger patients, the incidence of post-procedural myocardial infarction in the elderly ones was similar (2.9% vs. 1.7%, p=NS). On the contrary, elderly patients had a higher rate of emergency CABG (3.7% vs. 1.4%, $p=0.04$) and death (2.2% vs. 0.12%, $p=0.0001$). Angiographic follow-up, obtained in both groups, demonstrated significantly higher restenosis rates in the elderly as compared with younger patients (47% vs. 28%, $p=0.0007$). Overall survival in the elderly population 12 months post-coronary artery stenting was 91% whereas the event-free survival rate was 54%. Analysis of the subgroup of elderly patients who died showed a significantly higher incidence of combined unstable angina, prior MI, lower ejection fraction (<50%), multivessel disease and complex lesions.

Further data on the contemporary outcome trends in the elderly undergoing percutaneous coronary interventions in the era of coronary stenting derive from Batchelor et al who compared the clinical characteristics and in-hospital outcomes of 7.472 octogenarians (mean age 83 years) with

those of 102.236 younger patients (mean age 62 years) who underwent percutaneous coronary interventions at 22 hospitals from 1994 through 1997[24]. Concerning clinical characteristics octogenarians had more comorbidities, more extensive coronary disease and a two- to fourfold increased risk of complications, including death (3.8% vs.. 1.1%), Q wave myocardial infarction (1.9% vs.. 1.3%), stroke (0.58% vs. 0.23%), renal failure (3.2% vs. 1.0%) and vascular complications (6.7% vs. 3.3%) ($p < 0.001$ for all comparisons). Independent predictors of procedural mortality in octogenarians included shock [odds ratio (OR) 5.4], acute myocardial infarction (OR 3.2), left ventricular ejection fraction <35% (OR 2.9), renal insufficiency (OR 2.8), first percutaneous coronary intervention (OR 2.3), age >85 years (OR 2.1) and diabetes mellitus (OR 1.5). For elective procedures, octogenarian mortality varied nearly 10-fold. It is noteworthy that outcomes in octogenarians improved significantly over the four years of observation (OR of 0.61 for death/ myocardial infarction/stroke in 1997 vs. 1994). The authors concluded that the higher risks found in octogenarians compared with younger patients are strongly influenced by comorbidities and have decreased in the stent era.

Percutaneous transluminal coronary angioplasty in cases of multivessel coronary artery disease

The continuously evolving technology in the setting of coronary angioplasty resulted, in recent years, in a widened field of its applications. As a result angioplasty is increasingly applied for the treatment of multivessel coronary artery disease where traditionally, bypass surgery was the treatment of choice. The outcome of PTCA in elderly patients with multivessel disease (2 or 3 vessels) was studied by Bedotto et al between 1981 and 1990 in 1.373 patients aged greater than or equal to 65 years (mean 71)[25]. A mean of 3.5 lesions were dilated per patient and complete revascularization was achieved in 52%. A total of 52 patients (3.2%) had a major in-hospital complication: 27 patients (1.6%) died, 24 (1.4%) had a Q-wave myocardial infarction, and 14 (0.8%) underwent emergent CABG. Stepwise logistic regression analysis identified as independent predictors of mortality an ejection fraction less than or equal to 40% ($p< 0.001$), the three-vessel disease ($p<0.01$), the female gender ($p<0.02$), and PTCA accomplishment from 1981 to 1985 ($p<0.05$). In the follow-up period which included 1023 out of 1373 patients for a period longer than one year (mean follow-up period 32.5 months) 156 late deaths (15.2%), 81 myocardial infarctions (7.9%), 162 CABG (15.8%), and 471 repeat PTCA due to recurrent angina (36.3%) were observed. The overall survival rate upon discharge was 92% at 1 year, 86% at 2 years and 78% at 5 years.

The accumulation of experience in the treatment of multivessel coronary artery disease with angioplasty and the improvement of the early and late outcomes of the procedure in the era of stents, lead to randomized comparisons between percutaneous coronary revascularization employing stent implantation to conventional coronary artery bypass surgery in symptomatic patients with multivessel coronary artery disease. Indeed, several ongoing randomized controlled trials such as, ERACI II, ARTS and SoS are designed to compare coronary artery bypass with coronary angioplasty and primary stent implantation in patients with multivessel coronary artery disease[26-28]. Preliminary results of the aforementioned trials, regarding the early outcome of the randomized patients, have already been notified whereas those concerning the late outcome are expected with great interest. In the ERACI II study 38% of the patients included were older than 65 years[26]. At follow-up of 18 ± 6 months angioplasty with stent implantation showed better survival and freedom from myocardial infarction than did conventional surgery while repeat revascularization procedures were higher in the angioplasty group. In multivariate analysis age >65 years resulted an independent predictor of 30-day major adverse events (death, myocardial infarction, repeat revascularization procedures and stroke) only in the male population (OR: 2.22). The ARTS trial showed no difference in mortality between the two strategies whereas the SoS trial demonstrated increased mortality in the stent arm. From the above preliminary data it is clear that no definite conclusions can be extracted. The final results of the ongoing trials, their meta-analysis, as well as the analysis of subgroups of patients (such as the subgroup of elderly patients which is in our interest), are going to establish the ideal treatment for the multivessel coronary artery disease both, in the general population and in the elderly in the near future[26-28].

The impact of the newer pharmaceutical agents on the outcome of coronary angioplasty

Apart from the impact of the technological improvements on the outcome of coronary angioplasty, the contribution of the newer pharmacological agents such as, ticlopidine and clopidogrel must also be emphasized, on the reduction of the percentages of acute and subacute stent thrombosis, as well as incremental benefit of the intravenously administered Platelet Glycoprotein IIb/IIIa inhibitors on the procedure's outcome[30, 31]. For the latter agents in particular, the results of recent studies showed that their administration before coronary angioplasty with stent implantation in patients with acute ischemic syndromes (unstable angina and non Q wave myocardial infarction) lead to a substantial reduction of the early complications and to a better outcome of the procedure[32-35]. Although the data regarding the subgroup of elderly patients are not sufficient, it must be stressed that in the large scale trials that compared early invasive with conservative strategy in the treatment of acute ischemic syndromes, the sample of the elderly patients was representative (for example ~44% in the TACTICS-TIMI 18 trial)[33]. The use of GP IIb/IIIa inhibitors has even more pronounced effects in diabetic patients, in patients with multivessel disease, and finally as a rule, in all patients at high risk for thrombotic complications[29]. The use of GP IIb/IIIa inhibitors is considered safe for the elderly patients and as a result, also in the aforementioned subgroup of patients, their administration is indicated for the treatment of acute ischemic syndromes in combination with aspirin and heparin[36].

Cost-effective relation of percutaneous angioplasty in the elderly

In the study of Kahler et al the cost-effective relation of PTCA in patients with a mean age of approximately 83 years with symptomatic coronary heart disease, was compared to that of younger patients with a mean age of 62 years[37]. Although the initial procedural success was lower in older patients (88% vs. 97%), there was a post-procedural increase in the patients' activities as well as an improvement in their symptoms. The effect of PTCA in the above-mentioned parameters was more obvious in the elderly then in younger patients. The procedural cost did not differ significantly between the two groups of patients. In addition, in the study Seto et al 6 months after coronary angioplasty physical health had improved in 51% of elderly patients (aged > 75 years) and mental health had improved in 29% of them[38]. The above improvements were similar to those in younger patients.

Coronary angioplasty in the setting of acute myocardial infarction (primary angioplasty)

Concerning primary angioplasty results in elderly patients Antoniucci et al reported the outcome in 55 patients with a mean age of 84 years, who underwent primary PTCA between 1995 and 1998[39]. The initial success rate was 95%. Coronary artery stenting was carried out in 60% of patients. Recurrent ischemia was observed in 13% of cases whereas the overall 30-days mortality was 16%. Database analysis revealed that in patients presenting with cardiogenic shock the mortality was 70% versus 4% in those presenting without hemodynamic compromise. The overall one-year survival rate was 77%. Cardiogenic shock on admission and the final, post-procedural, angiographic result (with better survival rate in TIMI III flows) were identified as independent risk factors in the multivariate analysis. This study showed that the well-established benefits of primary PTCA also apply to the elderly patients who constitute a subgroup of patients at high risk of adverse outcome.

The same issue (i.e. primary angioplasty) was considered in the meta-analysis of DeGeare et al[40]. The study included 452 patients aged >75 years and 2.580 patients aged <75 years. Older patients had a lower number of risk factors for coronary artery disease but more comorbidity. Acute catheterization demonstrated more frequently three-vessel coronary artery disease and lower left ventricular ejection fraction. Elderly patients had a lower procedural success rate and lower rates of final TIMI 3 flow. On the contrary, older patients were more likely to have post-procedural complications and in-hospital mortality (10.2% vs. 1.8% in the younger patients, p = 0.001). Multivariate analysis revealed that the strongest predictors of death were age >/=75 years, lower left ventricular ejection fraction, higher Killip class, need for an intra-aortic balloon pump, and post-procedural stroke, transient ischemic attack, or significant arrhythmia.

B. Outcome of coronary bypass graft surgery in the elderly

Elderly people undergoing bypass surgery constitute a high-risk population due to the increased preva-

lence of associated comorbid conditions[8]. Perioperative mortality in the elderly varies from 2% to 10%[41]. Although age is not the most powerful independent predictor of perioperative mortality, it is an independent predictor of mortality[42]. This is probably due to the other parameters associated with older age contributing to an increase in mortality rates. Apart from mortality, perioperative morbidity is also increased in the elderly with higher rates of perioperative low cardiac output syndrome, strokes, gastrointestinal complications, wound infections and postoperative atrial fibrillation[43]. Specifically, atrial fibrillation constitutes the most common complication of bypass surgery in the elderly with an incidence of approximately 40% in the first postoperative days[44-46].

In recent years, several trials and database analyses enable us to draw safe conclusions concerning CABG outcome in the elderly. Among the aforementioned registries the New York State Cardiac Surgery Reporting Center (CSRC), provided interesting data regarding the in-hospital mortality of each age group of patients undergoing CABG in the period of 1991-1992[47]. The above database included 2.448 patients aged 40-49 years, 6.118 patients aged 50-59 years, 5.352 patients aged 60-64 years, 6.268 patients aged 65-69 years, 5.563 patients aged 70-74 years, 3.561 patients aged 75-79 years and, finally, 1.372 patients aged greater than or equal to 80 years. The in-hospital mortality rates in the above-mentioned groups of ages were 1.1%, 1.7%, 2.2%, 2.8%, 3.4%, 5.3%, and 8.3% respectively. The older cohorts included more females, emergency surgery, unstable angina, previous CABG, renal failure, ejection fraction less than 20%, previous stroke and peripheral vascular disease.

Particularly interesting are the observations resulting from the MEDPAR database (referred to in the PTCA section as well)[18]. In this database 357.885 patients undergoing bypass surgery were included, and 30-days and 1-year mortality rates were studied. The study sample was divided in 4 groups of age. In the first group 142.080 patients aged 65-69 years were included, in the second group 121.323 patients aged 70-74 years, in the third 70.861 patients aged 75-79 years and, finally, in the last one 23.620 patients aged greater than or equal to 80 years. The CABG rate in 1990 increased by 18% compared to 1987. The unadjusted 30-days and 1-year postoperative mortality rates decreased by 12% and 8% respectively, whereas after adjustment for changes in patient characteristics the above rates decreased by 18% and 19% respectively. The significant increase in survival rates was attributed to the important technical improvements and technological advances in bypass surgery, which gained widespread use during the late 1990's, including refinements in cardioplegia techniques, improvements in anesthesia and increased used of mammary artery grafts (which increased by 45% between the years 1987 and 1990). The relative risk of death in patients who received mammary artery grafts, compared to those who received saphenous vein grafts, was 0.46 at 30-days and 0.51 at 1-year. The short and long-term mortality rates resulting from database analysis were higher in patients older than 80 years (10.6% at 30-days and 19.5% at 1-year) in comparison with patients aged 65-69 years who had mortality rates of 4.3% and 8% respectively. In the in-between ages (as was the case of PTCA outcomes as well), the mortality rates were intermediate i.e. 5.7% and 10.9 in the second group and 7.4% and 14.2% in the third group respectively. The above results indicate a linear increase of both, short-term and long-term post-CABG mortality with advancing of age.

In the study of Peterson et al, where the same database was used (MEDPAR, 1987-1990), the trends in the use and outcomes of the bypass surgery in the very elderly were examined[6]. The authors found that the use of bypass surgery in octogenarians increased by 67% during the period of study. In comparison with patients aged 65-70 years, those aged 80 years and over had longer hospital stay (14.3 vs. 10.4 days), higher in-hospital mortality rate (11.5% vs. 4.4%), higher 1-year mortality rate (19.3% vs. 7.9%) and 3-years mortality rate (28.8% vs. 13.1%) and, finally, higher charges (mean $27.200 vs. $21.700). Although the initial surgical risk in octogenarians was high, their long-term survival rate was comparable to that of aged-matched population.

Ivanov et al examined the trends in risk-severity and operative mortality in 3.330 consecutive patients aged 70 years and older who underwent isolated CABG between 1982 and 1996[1]. During this period the number of bypass surgeries in patients older than 75 years at the time of surgery rose significantly and actually tripled in the period of 1992-1996, compared with those in the period of 1982-1986 ($p<0.001$). Crude operative mortality in the population studied was 7.2% in the period of 1982-1986, fell to 4.4% in the period of 1987 to 1991, but did not improve further thereafter. Independent predictors of ope-

rative mortality among elderly patients in this study were poor ventricular function (for ejection fraction between 20-39%, odds ratio 2.6 while for ejection fraction less than 20%, odds ratio 10.7%), previous CABG (odds ratio 3.7), female gender (odds ratio 1.8), peripheral vascular disease (odds ratio 1.8), and diabetes mellitus (odds ratio 1.7). On the contrary, previous angioplasty was found to be protective (odds ratio 0.3%). According to the number of the existing risk factors predicting the operative mortality, the patients in this trial were divided into 3 subgroups of low, middle and high risk respectively. In the years 1982-1986 the rate of high-risk elderly patients undergoing CABG was 16.2%, whereas in 1987-1992 and 1992-1996 the corresponding rates were increased to 19.5% and 26.9% respectively (p=0.001). The rates of operative mortality in high-risk patients in the above-mentioned periods were 17 2%, 9.1% and 8.9% respectively.

Finally, the CASS (Coronary Artery Bypass Surgery) trial investigated the effect of clinical, angio and demographic traits on late survival.[48] In this study the 10 and 15-year survival rates in patients with age 75 years at operation were 59% and 33% respectively (i.e. surprisingly higher than survival rates expected for the apparently healthy age matched population).

Comparison of bypass surgery with coronary angioplasty in patients with multivessel coronary artery disease

In the multicenter BARI trial, the impact of age in the revascularization procedure outcome was studied in 1829 patients with symptomatic coronary artery disease[49]. The patients enrolled were randomly selected to undergo one of the revascularization procedures (either PTCA or CABG). Among them 709 (39%) were 65-80 years old (group A) and the rest (1120 patients) were younger than 65 years (group B). The 30-days mortality rate in group A was 1.7% for both revascularization procedures. In group B post-PTCA mortality rate was 0.7% whereas the post-CABG mortality was 1.1% (p=NS). There was a higher incidence of stroke in group A after CABG surgery (1.7% vs. 0.2% in group B, p=0.015). Heart failure or pulmonary edema, on the other hand, had a higher incidence after PTCA (4.0% vs. 1.3%, p=0.011). In both groups, bypass surgery controlled patients' symptoms more effectively and was followed by a lower rate of ravascularization procedures. Survival at 5 years after the revascularization procedure in the elderly patients' group was 85.7% following CABG surgery and 81.4% following PTCA. Cardiac mortality at 5 years in patients assigned to the PTCA group was greater than in those assigned to the CABG group. However, mortality did not differ significantly between the two groups when diabetic patients were excluded from the database analysis.

Complications of coronary bypass surgery in the elderly

Regarding the CABG complications in the elderly patients, it must be emphasized that, compared to younger ones, they have a significantly higher risk of stroke, pneumonia, acute respiratory failure, acute renal failure and various arrhythmias[8]. In certain cases, such as in patients older then 75 years suffering from chronic obstructive pulmonary disease requiring treatment with steroids, the operative risk is extremely high reaching a rate of approximately 50%[50].

Off-pump coronary artery bypass grafting

As we have already mentioned in the section of coronary angioplasty, in recent years, important technological improvements have also occurred in the field of coronary artery bypass grafting. Among them, the emergence of the off-pump coronary artery bypass technique and the bilateral internal thoracic artery operations appear the most important.

Off-pump coronary artery bypass grafting, could be applied as a valid alternative to the cardiopulmonary bypass in high-risk patients as those with extracardiac comorbid conditions. Elderly patients, as a subgroup at increased risk due to the high prevalence of comorbidities, constitute a population that could benefit from the above technique. The benefit of the off-pump coronary artery bypass grafting in patients at high risk has been stressed in the study of Kihara et al that applied the off-pump technique in 30 high-risk patients (with a history of previous bypass surgery, cerebrovascular disease, and renal failure)[51]. The authors found no differences in graft patency, stroke, or mortality between in the off-pump group as compared with 127 patients with a lower prevalence of extracardiac risk factors who underwent conventional (on-pump) bypass surgery. Specifically in the elderly the outcome of the off-pump technique was investigated by Hirose et al[52]. The study was carried out between 1997 and

2000 and included 175 patients aged 75 years or more. Among them 104 underwent off-pump coronary artery bypass grafting whereas in the rest cardiopulmonary bypass was applied. The study revealed that Intubation time (8.4 versus 18.4 hours) and postoperative stay (13.8 versus 20.0 days) were significantly shorter in the off-pump group than in the on-pump group ($p<0.05$ for both comparisons). The frequency of the occurrence of major complications was significantly lower in the off-pump group than the on-pump group, especially in regard to postoperative stroke and respiratory failure ($p < 0.05$). On the contrary, cardiac event-free and survival rates did not differ significantly between the two subgroups. The conclusion was that off-pump CABG is safe for the elderly patient, reduces the incidence of postoperative complications, and successfully facilitates early recovery.

Bilateral internal thoracic artery operations in the elderly

Recent reports support that bilateral internal thoracic artery revascularization is associated with a better late outcome without any significant increase of the in-hospital complications. The outcome of elderly patients undergoing bypass surgery with use of bilateral internal thoracic arteries has been investigated by Jones et al[53]. The study was conducted during a ten-year period (from 1986 to 1996 and included, 673 patients older than 65 years divided into three groups: 163 patients (Group A) had saphenous vein used for all bypasses; 338 patients had a single internal thoracic arterial graft with supplemental vein grafts (Group B); and 172 patients (Group C) had bilateral internal thoracic arterial grafts with additional vein grafts as needed. Postoperative complications and late outcome were recorded for a mean follow up period of 5±3 years. A multivariate analysis showed that placement of both internal thoracic arteries in older patients independently improved long-term survival ($p=0.03$). To realize improved long-term survival rates, however, both internal thoracic arteries grafts must be grafted to the left coronary artery branches Regarding early outcome, despite the length or complexity of the bilateral internal thoracic artery revascularization, the procedure does not have greater operative morbidity or mortality in the elderly. The safety of the aforementioned surgical procedure was also studied in other large series, such as Ioannidis et al, where bilateral internal thoracic artery revascularization was not associated with any increase of in-hospital mortality and prolonged hospital stay, due to complications compared with single internal thoracic artery revascularization[54]. In multivariate modeling bilateral internal thoracic artery grafts increased the risk of deep sternal wound infections only in emergency cases and in older patients (>70 years old).

Redo coronary bypass surgery

Before concluding our review concerning coronary artery bypass grafting in the elderly, a brief report on redo bypass surgeries is indispensable, given the increasing number of elderly patients requiring another bypass. Nowadays the rate of re-operations is at least 10% while in certain institutions the above rate is approximately 20%[55]. The second operation is related to a higher morbidity and a 2-3 fold mortality compared with the first operation[56]. The mortality rate of re-operations varies from 2 to 11.4%[57]. The high mortality of redo surgeries is mainly due to the impaired systolic function of the patients requiring re-operation[57]. On this issue, Yamamuro et al conducted a retrospective analysis of risk factors for in-hospital and late outcome in patients aged 70 and who underwent a second coronary artery bypass graft operation between 1983 and 1993[58]. The study included 739 patients aged 74±3 years. The mean interval after primary operation was 130 +/- 55 months and the in-hospital mortality detected was 7.6%. Preoperative factors associated with increased in-hospital mortality were preoperative creatinine greater than 1.6 mg/dL ($p<0.001$), emergency operation ($p < 0.001$), female sex ($p = 0.012$), moderate or severe left ventricular dysfunction ($p = 0.049$) and left main coronary disease ($p= 0.045$). Survival was 75% at 5 years and 49% at 10 years. Cardiac event-free survival was 60% at 5 years and 27% at 10 years. The factors independently associated with increased late mortality were hematocrit ($p= 0.046$), diabetes ($p=0.011$), peripheral vascular disease ($p<0.001$), left ventricular function ($p<0.001$), history of cancer ($p=0.016$), preoperative non-sinus rhythm ($p=0.003$), anticoagulation therapy ($p=0.018$), postoperative encephalopathy ($p = 0.001$) and postoperative stroke ($p = 0.014$). The conclusion of this study was that reoperation can have excellent results for many elderly patients However, before reoperation is decided, note should be made that it should be kept

in mind that mortality is markedly higher when elderly patients have certain risk factors and co-morbidity. In these patients, preliminary data support that the off-pump technique provides better morbidity and mortality rates, and in the future (if the preliminary data are confirmed by large randomized studies) the aforementioned technique may be established as a valid alternative in certain subgroups of patients.

Conclusion

It is well established that morbidity and mortality rates after both revascularization procedures (PTCA and CABG) increase linearly with advancing age. This is apparently due to the higher incidence in the elderly of multivessel disease, calcified-complex coronary artery stenoses, low ejection fraction, history of myocardial infarction and, finally, due to the presence of associated comorbid conditions, such as peripheral and cerebrovascular disease[59]. However, when the symptoms of coronary artery disease are not sufficiently relieved with medical treatment, clinicians should consider revascularization procedures despite the advanced age[5].

Concerning long-term survival both revascularization procedures achieve similar rates[5,7,60,61]. However, each one of them has specific advantages and disadvantages compared to the other. Indeed, PTCA is preferable (provided coronary anatomy is suitable and the procedure technically feasible) in patients with severe angina and low life expectancy because of comobid conditions such as malignancies, severe hepatic failure, etc. In these patients, taking into account that perioperative mortality rate is extremely high, the goal is not a prolongation of life but an acceptable quality of life. Advantages of PTCA also include short hospital stays and lower morbidity rates when "heavy volume institutions" are considered[5,7,12]. PTCA disadvantages include a higher rate of recurrent angina and need for repeat revascularization. In the EAST trial, during a 3-year follow-up period after CABG surgery, 13% of the patients had to undergo a second revascularization procedure (either CABG or PTCA)[62]. During the same period of time, 54% of patients subjected to PTCA had to undergo a second revascularization procedure. The frequent need for a further revascularization reduces the initial advantage of PTCA over CABG in terms of procedural cost[63]. However, the final results of the ongoing trials, where the recently developed drug eluting stents are tested, are expected with great interest given the lower restenosis rate preliminarily reported.

Bypass surgery on the other hand offer the possibility of complete revascularization and seems to be the procedure of choice for elderly patients with angina poorly controlled with medical therapy, whose coronary anatomy is not suitable for PTCA. In addition, CABG surgery is recommended in patients with left main or 3-vessel disease (especially with left ventricular dysfunction and/or diabetes mellitus)[5,7].

In the near future, the final results of the ongoing trials where the recent techniques of revascularization are applied and evaluated are expected to re-establish the indications and the cost-effective relation of each procedure. For the time being, the choice of revascularization procedure in the elderly depends on the individual patient. When both revascularization procedures are feasible, the clinician should consider the patient's desire, provided a detailed analysis of the advantages and disadvantages each procedure's has been offered. In any case, PTCA and CABG surgery should be regarded as complementary procedures and not as competitive ones.

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