SURGERY FOR ACQUIRED HEART DISEASE

SEVEN-YEAR FOLLOW-UP OF CORONARY ARTERY BYPASSES PERFORMED WITH AND WITHOUT CARDIOPULMONARY BYPASS

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Background: **There has been resurgent interest in coronary revascularization performed on the beating heart. Heretofore, there has been no long-term comparison of this technique to traditional coronary artery bypass with cardioplegia.** ***Objective:*** **The purpose of this study was to provide a comparison of long-term survival and intervention-free outcome between patient groups subjected to coronary bypass accomplished with or without the use of cardiopulmonary bypass.** ***Method:*** **From June 1989 to July 1990, all patients treated for coronary revascularization by three surgeons were considered for coronary revascularization with the heart beating: 107 patients underwent coronary bypass on the beating heart, and 112 patients underwent revascularization with the aid of bypass with cardioplegia. Mean ages (65 ± 10 years) and risk factors were identical. Patients operated on with the heart beating had 2.4 ± 0.9 grafts versus 3.2 ± 1.1 grafts for patients having cardiopulmonary bypass with cardioplegia.** ***Results:*** **At 7-year follow-up, 86 of 107 (80%) patients operated on with the heart beating were alive versus 88 of 112 (79%) patients in whom cardiopulmonary bypass with cardioplegia was used. Cardiac deaths occurred in 13 of 107 (12%) patients in the former group versus 10 of 112 (9%) patients in the latter group. However, 32 of 107 patients operated on with the heart beating (30%) needed catheterization for their symptoms versus 18 of 112 (16%) patients in the bypass with cardioplegia group ($p = 0.01$). This results in 21 of 107 (20%) patients in the beating heart group needing angioplasty or a second coronary bypass versus only 8 of 112 (7%) patients in the bypass with cardioplegia group. No patient in the bypass with cardioplegia group required reoperation. Most of the reinterventions for the beating heart group were percutaneous transluminal coronary angioplasty (15 of 21 [71%] patients).** ***Conclusion:*** **Despite one less graft per patient, survival and cardiac death rates were similar for the two groups. However, twice as many patients in the beating heart group required recatheterization (30% versus 16%), and 20% needed a second intervention. Only 7% of the bypass with cardioplegia group required reintervention. Limited revascularization of the beating heart provides long-term results comparable to full revascularization with cardiopulmonary bypass, but at the cost of a threefold increase in reinterventions. (J Thorac Cardiovasc Surg 1998;115:1273-8)**

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The severity of complications associated with coronary artery bypass grafting (CABG) by cardiopulmonary bypass (CPB) are legion and often reported.[1, 2] Attempts to decrease this morbidity, shorten hospital stay, and hasten recovery time have resulted in renewed interest in revascularizing the beating heart (BH) without CPB via either full or partial sternotomy or anterior thoracotomies.[3] The apparent advantages of eliminating CPB must be weighed against the presumed disadvantages of operating on a moving field and encountering access problems to all areas of the heart, which may limit the number of vessels that can be bypassed. To date, the technical feasibility of BH CABG has been demonstrated by a number of investigators using a myriad of techniques.[1, 3] However, heretofore, there existed no long-term comparison or follow-up on a large cohort of patients who have undergone myocardial revascularization concurrently with either CPB-supported CABG (indicated hereafter as CPB) or without CPB (BH). Beginning in the summer of 1989, emboldened by the training that one of us had received with Frederico Benetti of Argentina, three attending surgeons at Loma Linda University Medical Center considered revascularization with a BH for all patients in need of myocardial revascularization and continued to offer this approach for 1 year. In that year, 107 patients underwent successful operations with BH; 112 patients were deemed unsuitable for this approach and had traditional CPB. Thus, by mere serendipity, two nearly equal groups were available for long-term follow-up.

Patients and methods

All patients seen by the senior author and two other attending surgeons at Loma Linda University Medical Center during the period from June 1989 to July 1990 were offered the opportunity to have their revascularizations performed without CPB. We were encouraged by the return of one of the surgeons from several months of direct training in this technique by Frederico Benetti in Buenos Aires, Argentina. If consent was obtained from the patient, the choice of performing the operation without CPB was left to the operating surgeon and was often decided in the operating room. BH CABG was performed with silicone rubber tapes around the coronary arteries proximal and distal to the anastomosis. Heart rate was slowed with intravenous beta blockage; blood pressure was supported by phenylephrine intravenously. Thermodilution cardiac output for all patients was determined periodically. Anastomosis visualization was aided by either fine suction or continuous warm saline solution irrigation. Proximal anastomoses were usually constructed first. CPB CABG was performed with dual-stage venous cannula drainage, moderate systemic hypothermia, and antegrade and/or retrograde cold blood cardioplegic solution (2:1 dilution). Proximal anastomoses were constructed with a partial occlusion clamp on the ascending aorta.

Table I. *Comparison of initial bypasses*

Vessels bypassed	*Pump (%)*	*Beating heart (%)*
LAD	96 (86)	94 (88)
Internal thoracic artery	15 (13)	14 (18)
1st diagonal	30 (26)	19 (17)
2nd diagonal	16 (14)	12 (11)
1st obtuse marginal branch	45 (40)	33 (31)
2nd obtuse marginal branch	19 (17)	3 (3)
3rd obtuse marginal branch	50 (45)	26 (24)
Posterolateral branch	9 (8)	5 (5)
Posterior descending artery	52 (46)	17 (16)
Right coronary artery	29 (26)	37 (35)
Circumflex artery	1 (1)	0
TOTAL	362*	260†

*112 Patients.
†107 Patients.

Statistical analysis

Comparison between the two groups was accomplished with the χ^2 test with the Casio Statistical Package (Casio Computer Company, Tokyo, Japan). Results are given as mean ± standard deviation.

Results

At the end of 1 year, 107 patients had successfully undergone the operation with BH, and 112 patients had undergone CPB. Mean patient age was identical at 65 ± 10 years. No risk stratification was performed but, in general, patients believed to have more difficult problems, either from anatomic or ejection fraction criteria, were treated with CPB.

A total of 260 vessels in 107 patients were bypassed in the BH group (2.4 ± 0.9 vessels per patient) versus 362 vessels in 112 patients with CPB (3.2 ± 1.1 vessels per patient); the distribution of vessels bypassed can be seen in Table I. Almost all patients had a bypass performed to the left anterior descending coronary artery (LAD; 88% vs 86% with a BH vs CPB, respectively) although 81% versus 96%, respectively, had an internal thoracic artery used ($p = 0.8$). A much higher proportion of obtuse marginal (100% vs 62%) and posterior descending vessels (46% vs 16%) were bypassed in the patients with CPB, reflecting our relative difficulty in approaching these vessels without CPB. In essence, one less vessel per patient was performed in the BH group, primarily in the obtuse marginal and posterior descending distributions. Patients recovered and were followed for the next 6.5 to 7.5 years, with

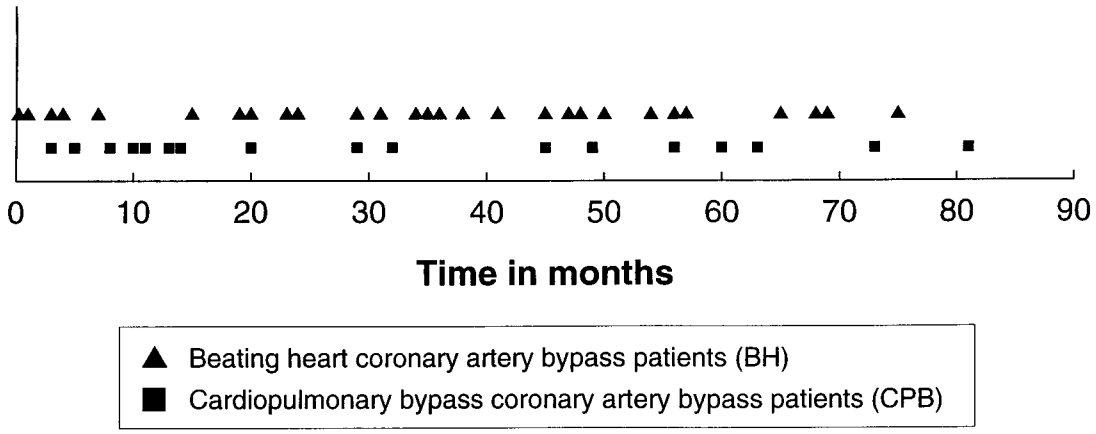

Fig. 1. Time after the operation for catheterization between patients who had BH bypass and who had CPB CABG.

follow-up completed in January 1997. Follow-up data were obtained from patient records; if a patient had not received medical follow-up within 1 month of chart review, a telephone call was made to the patient and/or referring physician. Follow-up was 100% complete. Patients were compared for return for cardiac catheterization both in number and time from operation, deaths, cardiac deaths, additional cardiac procedures (percutaneous transluminal coronary angioplasty [PTCA] and/or stents), redo CABGs, vessels patent or occluded as seen on an angiogram, and current symptomatic status.

At the 7-year follow-up, 86 of the 107 patients who underwent BH bypass are alive (80%) versus 88 of the 112 patients who underwent CABG (79%; $p = 0.8$). Of the 21 BH deaths, 13 (62%) were cardiac related; of the 24 CPB deaths, 10 (42%) were cardiac related ($p = 0.3$).

A total of 30 (30%) patients who had a BH bypass underwent 32 catheterizations during the 7 years; 16 (16%) patients with CPB had 18 catheterizations($p = 0.01$). Time to treatment for catheterization was identical between the two groups (mean, 32 ± 26 months vs 32 ± 23 months, respectively) (Fig. 1), although several patients who had undergone revascularization with BH clustered early after bypass.

A total of 34 catheterizations were available for direct visualization (21 BH and 13 CPB) by the senior author. Patency as determined by the cardiologist and confirmed by the senior author is shown in Table II. Patients who had undergone CPB had 12 of the 13 LAD grafts (92%) versus 7 of the 15 BH grafts (47%); 7 of the 13 patients had right coronary artery or patent ductus arteriosus grafts (54%) versus 3 of the 13 BH grafts (23%) and overall patency of 31 of the 41 (72%) CPB grafts versus 12 of the 35 (34%) BH grafts. Of note, three of the internal thoracic artery/LAD grafts in the patients who had BH bypass had significant stenoses at the site of vessel loops.

Twenty-one of the 107 (20%) patients who had undergone BH bypass required 22 interventions versus 6 (7%) patients who required 8 interventions in the CPB group. Sixteen patients who had undergone BH bypass underwent PTCAs (one repeat); an additional five (5%) patients required redo CABG. The only interventions required in the CPB group were PTCAs. One patient who had undergone CPB required two PTCAs. One patient who had had BH bypass died after redo CABG; one patient who had had CPB died of a pulmonary embolus 5 days after a cardiac catheterization.

Post-CABG PTCAs differed markedly between patients who had undergone BH bypass and who had undergone CPB (Table III). In the patients with BH bypass, 12 PTCAs were performed on a vessel that had been previously bypassed and on only four vessels that had not been bypassed; in the patients who had undergone CPB, only two PTCAs were performed on previously bypassed vessels, and six PTCAs were performed on vessels previously unbypassed.

Comment

CABG on the BH has been used since the inception of coronary revascularization[4, 5] but has rarely been applied on a consistently large enough scale until it was revived by Benetti[6] and Buffolo and coworkers[7] in the mid-1980s. The technique flour-

Table II. *Patency rates of post-CABG of those patients who underwent angiography*

	LAD		*RCA/PDA*		*All grafts*	
	Open (%)	*Closed*	*Open (%)*	*Closed*	*Open (%)*	*Closed*
BH	7 (41)	8	3 (23)	10	12 (34)	23
CPB	12 (92)	1	7 (54)	6	31 (72)	10

RCA, Right coronary artery; *PDA,* posterior descending artery.

ished briefly in the early 1990s in the United States but was largely abandoned. In the past few years, the technique was reapplied via smaller incisions, most notably a left anterior thoracotomy or partial sternotomy, to accomplish bypass to the LAD and/or right coronary artery.[8, 9] Although short-term results appear encouraging, heretofore, no long-term studies were available to compare BH bypass to conventional bypass techniques.

The results of this 7-year follow-up among two patient groups simultaneously receiving either BH bypass or conventional bypass (CPB) reveals that either policy results in similar outcomes in death and cardiac causes of death, although it must be observed that generally patients in less favorable condition were operated on with CPB. This finding occurs despite the use of one less graft per patient in the BH group. Most patients receiving either therapy were asymptomatic at the 7-year follow-up (71% BH vs 84% CPB), implying significant graft patency in both groups. Despite these similarities, significant differences in subsequent therapies emerged between the two treatment modalities. Specifically, approximately one third of the patients who underwent BH bypass required catheterization for renewed anginal symptoms, which resulted in 17 PTCAs and 5 reoperations (20%). In contrast, only 16% of the patients who had CPB experienced anginal symptoms requiring catheterization, resulting in eight PTCAs and no reoperations (7%). In other words, parity between groups was achieved only by using three times as many postbypass interventions in the BH group.

Although the reintervention rate was higher in the BH group, this needs to be compared not only with CPB as primary therapy but also with the results of PTCA as a management strategy for coronary artery disease. In a 10-year follow-up of an initial strategy of PTCA in 856 patients, as described by Ruygrok and coworkers,[10] 220 patients (26%) required subsequent CABG and an additional 221 patients (26%) underwent further angioplasty. Comparing our current study with this, it would

Table III. *Vessels bypassed and subsequent PTCA*

	PTCA same vessel	*PTCA different vessel*
BH (No. of patients)	12	4
CPB (No. of patients)	2	6

appear that BH bypass produces results intermediate between conventional bypass (best) and angioplasty (worst). It further suggests that limited revascularization, by either PTCA or BH bypass, will produce long-term results comparable to full revascularization, but only if one accepts the need for additional procedures later. Interestingly, despite less than full revascularization in the BH group, subsequent PTCAs were usually directed at previously bypassed vessels, rather than nonbypassed targets. This also implies, but does not prove, that an initial strategy of PTCA of those vessels may have been equally effective.

Our study, somewhat surprisingly, also revealed that the time of presentation for renewed symptoms after the procedure was identical between groups at approximately 2.5 years (although several patients who underwent BH bypass clustered early [Fig. 1]). Because all patients had a negative stress test at the time of discharge, early graft patency did not imply late (several year) patency, making a policy of predicting graft behavior on 1-day or 1-month angiography risky.[11]

Several techniques used in our BH group deserve mention and perhaps criticism. Our technique used a full sternotomy; every attempt was made to achieve full revascularization. This must be contrasted against current suggestions that very limited revascularization (i.e., an internal thoracic artery onto an LAD) is sufficient for patients with multivessel disease. Although full sternotomy is useful to access most regions of the heart off bypass, opening of the pericardium allows significant cardiac motion, which may affect the technical quality of the anastomosis. A limited approach may lessen cardiac movement and improve graft patency. Our policy of using soft, cushioned silicone rubber tapes around the coronary arteries should also be questioned. These tapes produce a broad area of contact with the coronary artery and may, therefore, produce more, rather than less, endothelial cell damage.[12] Furthermore, the use of these tapes to aid in vessel stabilization produces significant tension on the coronary arteries and may produce stenoses distal or proximal to the anastamosis. Newer stabilization devices may further enhance anastomotic quality

and improve late patency,[13] but this remains speculative.

The results of our study suggest that multivessel BH CABG has the potential to produce late mortality rates equal to that of conventional bypass operations; but, in exchange, additional procedures may be needed in a number of patients. Thus we advise patients in advance that additional procedures may be needed if BH revascularization is desired. Nevertheless, multivessel BH bypass would appear to be more efficacious than a policy of PTCA alone.

In conclusion, multivessel CABG performed on the BH appears capable of producing equivalent longevity and symptomatic status 7 years after the operation when compared with a similar cohort of patients receiving conventional bypass. However, twice as many patients who had undergone BH bypass required catheterization, and three times as many reinterventions were required to achieve parity with conventional bypass techniques. We recommend that patients be fully informed of these late results before embarking on a course of BH revascularization.

REFERENCES

1. Magovern JA, Mack MJ, Landreneau RJ, Acuff TE, Benckort DH, Hunter TJ, et al. The minimally invasive approach reduces the morbidity of coronary artery bypass [abstract]. Circulation 1996;94(Suppl):I52, 697.
2. Fonger JD, Nicholson CF, Susoman MS, Solomon NW. Cost analysis of current therapies for limited coronary artery revascularization [abstract]. Circulation 1996;94(Suppl):I51, 506.
3. Akna E, Gurboz A, Baikanay M, Yakut C, Ik O, Yakut C. The cost effect of coronary artery surgery on beating heart without pump-oxygenator in patients with no additional risk factor [abstract]. Circulation 1996;94(Suppl):I51, 506.
4. Murray G, Porcheron R, Hilario J, Rosehlau W. Anastomosis of a systemic artery to the coronary. Can Med Assoc J 1954;7:594-8.
5. Sabiston DC Jr. The coronary circulation. Johns Hopkins Med J 1974;134:314-27.
6. Benetti FJ. Direct coronary surgery with saphenous vein bypass without either cardiopulmonary bypass or cardiac arrest. J Cardiovasc Surg 1985;26:217-22.
7. Buffolo E, Andrade JCS, Succi J, Leao LEV, Gallucci C. Direct myocardial revascularization without cardiopulmonary bypass. Thorac Cardiovasc Surg 1985;33:26-9.
8. Greenspan HG, Adourian UA, Fonger JD, Fan JS. Minimally invasive direct coronary artery bypass (MIDCAB): surgical techniques and anesthetic considerations. J Cardiothorac Vasc Anesth 1996;10:507-9.
9. Emery RW, Emery AM, Flavin TF, Nissen MD, Mooney MR, Arom KV. Revascularization using angioplasty and minimally invasive techniques documented by thermal imaging. Ann Thorac Surg 1996;62:591-3.
10. Ruygrok PN, deJaegere PPT, vanDomburg RT, vanden-Brand MJ, Serruys PW, deFeyter PJ. Clinical outcome 10 years after attempted percutaneous transluminal coronary angioplasty in 856 patients. J Am Coll Cardiol 1996;27:1669-77.
11. Subramanian VA, Sani G, Benetti F, Calafiore AM. Minimally invasive coronary artery bypass surgery: a multi-center report on preliminary clinical experience [abstract]. Circulation 1996;94(Suppl):I645.
12. Gundry SR, Jones M, Ishihara J, Ferrans VJ. Optimal preparation techniques for human saphaneous vein grafts. Surgery 1980;88:785-94.
13. Jansen EWL, Grundeman PF, Borst C, Eefting FD, Wesenhagen HH, Diephuis J, et al. Less invasive coronary artery bypass grafting on the beating heart: initial clinical experience with the Utrecht "Octopus" method for regional cardiac wall immobilization. Circulation 1996;94(Suppl):I52, 1646.

Discussion

Dr. Federico J. Benetti *(Buenos Aires, Argentina).* Although the study you present is retrospective and the groups you compare are difficult to match at the time of your analysis, it is clear that the results describe a learning curve in this procedure. I would like to share the following observations:

We began our experience of off-pump bypass with LAD, diagonal, and right bypasses; after a period of time, we moved to the circumflex system. We never performed more than 20% of circumflex grafts in our experience. In our first 400 patients in BH surgery, we achieved 90% survival in 7 years. In this group approximately 12% of the patients underwent recatheterization at around 3.5 to 4 years. Of these cases, approximately one half of them needed other treatment, most of them PTCA. It was interesting for us to find that 91% of the grafts in the LAD were patent. Our experience also reflects a learning curve, yet our patency rate seems much higher in the LAD. Dr. Buffolo of Brazil also has an interesting experience comparing, prospectively, thoracic artery to LAD with pump and without pump. He had similar patency rates to our experience of 93% in both groups.

Although the discrepancy between the authors' experience and our experience seems great, both analyses are weakened by the fact that only a few patients were restudied based on symptoms rather than a more random sample. The analysis is therefore biased based on symptoms. Additionally, the authors state that no preoperative risk stratification was performed; therefore comparison between the two groups is somewhat less reliable for interpretation of outcomes.

The data of the initial cardiothoracic surgery registry in which 508 patients in 34 different groups all over the world with LAD mechanical stabilization systems show a 94% patency rate. This experience includes centers with small experiences in BH surgery and also reflects a learning curve. Additionally, Drs. Calafiore and Subramanian have presented large series of BH surgery in which the patency rate in the LAD has reached more than 97%. It is still early to tell what long-term patency will look like with improved techniques and new technology for coronary

stabilization. Early reports for 1-year follow-up are very encouraging.

Dr. Gundry honestly recognizes that there are a lot of technical issues in this initial series. Dr. Gundry concluded that outcomes of death and symptoms were the same in both groups, although the need for reintervention appeared to be three times greater in the BH group. I believe this is the most important finding of this paper, that the outcome of survival is the same with or without pump support.

We know CPB has morbidities that we would like to avoid, especially in high-risk groups. We also know today that left internal thoracic artery to LAD is the most important predictor of event-free survival. The concern of the paper in terms of reintervention in the BH group can be resolved with improvement in the technique and advancement of the learning curve.

With the results we have today, such as good early angiographic patency, very low incidences of complications, and mortality rates in the minimally invasive left internal thoracic artery to LAD, how many patients need more than that in the different situation of coronary disease?

Thank you again, Dr. Gundry, for highlighting the point that with technical improvements, BH surgery can possibly offer the best option for the patient.

Dr. Marko I. Turina *(Zurich, Switzerland).* What is your impression about the cause of this obstruction? Is it more an anastomosis-related problem, or is it the restraining devices put on the artery to control the backflow?

Dr. Gundry *(Loma Linda, Calif.).* Having reviewed this personally on all the angiograms, there is a fairly even distribution between anastomotic narrowing and narrowing at the site of our vessel occluders.

Now, as I mentioned in the article, we use those vessel occluders to actually help stabilize the anastomosis. I have abandoned that practice on the basis of our angiograms because I think this really does denude a large area of endothelium. That problem may not be noticed for a long period of time because smooth muscle prevalence takes place there. So I think that, with the newer stabilization devices in which snares are not used to actually help stabilize the vessel, I would anticipate that problem would lessen.

Now, can I address Dr. Benetti's comments. Dr. Benetti, it was your leadership that really led us to this provocative study nearly 8 years ago.

Your survival statistics are identical with ours at 7 years of about 90%, and that probably speaks to the consistency and reproducibility of this technique.

I think patency will get better. It certainly did in our learning curve; I believe with the newer stabilization devices, we do construct a better anastomosis.

Your point as to how many vessels one actually needs to maintain reliable long-term myocardial revascularization and relief of angina is the fundamental question that needs to be addressed before any of these techniques are going to be widely adapted. Certainly in our study, one less vessel bypass per patient did not result in long-term harm in terms of cardiac deaths. However, the price we seem to have paid was an increase in PTCAs and recatheterizations. I think it is up to the patient and perhaps the referring cardiologist and perhaps third-party payers to decide whether this penalty is worth the initial price.