The Heart Surgery Forum #2005-1004
8 (3), 2005 [Epub May 2005]
doi:10.1532/HSF98.20051004

Online address: http://cardenjennings.metapress.com/link.asp?id=112496

Influence of Body Size on Outcomes of Off-Pump Coronary Artery Bypass Surgery

Alexander Yap, MD,[1] Naoum Baladi, MD,[1] Alex Zapolanski, MD,[1] Michael B. Pliam, MD, PhD,[1] Richard E. Shaw, PhD[2]

[1]Department of Cardiovascular Surgery, Seton Medical Center, San Francisco Heart & Vascular Institute, Daly City, [2]Quality and Education Sutter Pacific Heart Centers, San Francisco, California, USA

ABSTRACT

Objective: Patients of small physical stature may be more likely selected for an on-pump coronary artery surgery (ONCAB) rather than an off-pump procedure (OPCAB). Small patients who do have OPCAB may do poorly. Our hospital demographics afford a unique opportunity to examine a group of small patients.

Methods: Information was available over the past 4 years on 1015 patients who had isolated CABG and a calculable body surface area. Sixty-one patients had a body surface area of less than 1.5 m^2 (SMALL). The 954 remaining patients were classed as larger (LARGER). Patients were compared with respect to preoperative risk factors, operative procedures, and postoperative results.

Results: Among SMALL patients, 59% were Asian, 89% female, averaged slightly older, had higher STS risk scores, lower hematocrits, more severe NYHA class ratings, and less elective surgical status ($P < .05$) than LARGER patients. Fifty-one percent of SMALL patients had OPCAB, 44.3% received blood, 90% had an event-free course, and 4.9% died postop (versus 1.2%, $P < .05$). OPCAB mortality was lower than ONCAB for both SMALL and nonsmall ($P < .05$). Blood use was greater for SMALL than for LARGER (44% versus 20%, $P < .05$) but less for SMALL OPCAB than SMALL ONCAB (27% versus 62%, $P < .05$). No differences were noted in postop MI, CVA, or length of stay, but 30-day readmission was lower for SMALL patients (5.0% versus 7.4%).

Conclusions: Patients with small physical stature can be safely operated upon using off-pump techniques with good revascularization and postop results, despite apparently higher preop STS risk scores.

Presented at the Seventh Annual Meeting of the International Society for Minimally Invasive Cardiothoracic Surgery, London, UK, June 23-26, 2004.

Received February 16, 2005; accepted February 17, 2005.

Address correspondence and reprint requests to: Alexander Yap, MD, Consulting Cardiac Surgeon, San Francisco Heart Institute, Seton Medical Center, 1900 Sullivan Avenue, Daly City, California, 94015, USA; 1-650-992-8200; fax: 1-650-992-8388 (e-mail: AlexanderYap@dochs.org).

INTRODUCTION

Despite the fact that off-pump coronary artery bypass (OPCAB) has increasingly been shown to be superior to on-pump coronary artery bypass (ONCAB) with respect to patient outcomes [Boyd 1999, Hirose 2001, Hoff 2002, Parolari 2003, Plomondon 2001, Puskas 2003, Sabik 2002, Van Dijk 2002], not all coronary surgery patients are candidates for OPCAB [Fisher 1982, O'Conner 1996, Ryan 2000]. In part, this is because OPCAB is a more demanding technique than ONCAB. Thus, small patients with small coronary arteries might be a contraindication to OPCAB. It would be helpful to know whether or not OPCAB can be performed on small patients with results comparable to those seen with ONCAB for small patients. The present study attempts to address this question.

METHODS

Clinical Data

Since the early 1980s, clinical data on patients undergoing surgical revascularization have been systematically abstracted and recorded in a cardiac surgical information registry. Demographic history and physical examination, surgical procedures and outcome data were collected prospectively by clinical nurse specialists and physicians and stored in the Heart Institute cardiac database (HeartBase, SIR Americas, Inc., Chicago, Illinois). All coronary artery bypass surgeries performed at Seton Medical Center from January 1, 2000 to December 31, 2003 were reviewed. There were a total of 1215 consecutive patients who underwent isolated CABG. Information was available over the past 4 years on 1015 patients to allow calculation of body surface area (BSA). BSA was calculated using Dubois formula [DuBois 1916]:

$$\text{BSA (m}^2\text{)} = 0.007184 \times \text{Height (cm)}^{0.725} \times \text{Weight (kg)}^{0.425}$$

Patients with BSA $\leq 1.5 m^2$ were categorized as SMALL and all others as LARGER. Patients were categorized as ONCAB or OPCAB, depending upon whether or not cardiopulmonary bypass was used to perform the operation. No information was available regarding intention to treat or conversion from intended OPCAB to ONCAB. Patients with missing data with respect to BSA, ONCAB, and OPCAB were eliminated from the study.

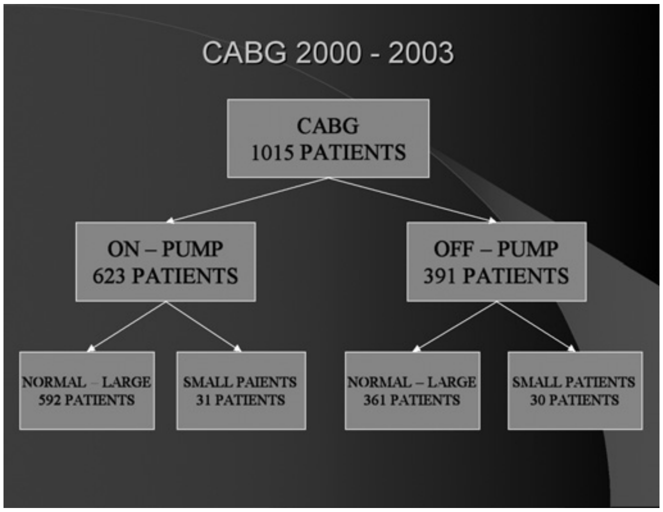

Figure 1. Distribution of Study Patients, 2000 to 2003.

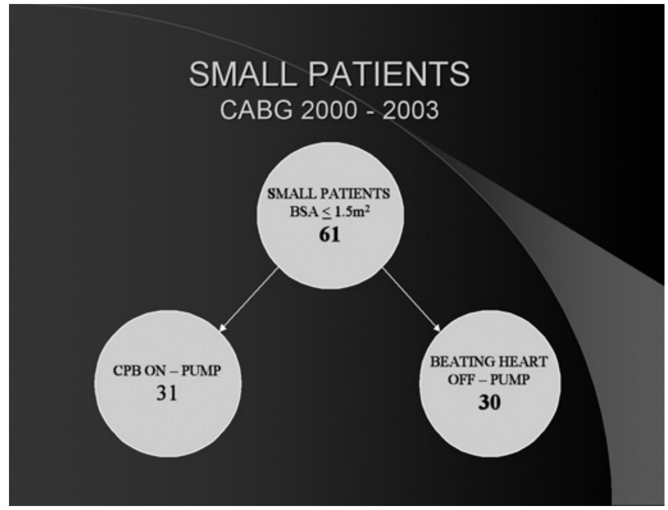

Figure 3. Distribution of Small CABG Patients, 2000 to 2003.

Statistical Analysis

All continuous variables are expressed as the mean value ± standard deviation. Unpaired Student's *t*-tests were used to compare mean values. The Pearson Chi-square statistic was used to compare discrete variable differences. The Society of Thoracic Surgeons (STS) mortality risk model was used to analyze the independent relationship of variables to in-hospital mortality. A *P*-value of 0.05 was used to determine statistical significance. Analyses were performed using the SPSS statistical software package (SPSS, Inc., Chicago, Illinois).

Surgical Technique

The surgical technique for ONCAB, as practiced by one of the surgeons in this study, has been described [Yap 2000]. OPCAB was performed via a standard median sternotomy. Pericardial stitches and moist laparotomy sponges were placed to lift and position the heart. Cardiac immobilization was further achieved using the Genzyme or Guidant stabilizing devices. One-half of the standard heparin dose was given prior to occluding the coronary vessels. Intra-coronary shunts were seldom used. Shed blood was scavenged using a cell saving device and reinfused at the end of the procedure. Activated clotting time levels were monitored throughout the procedure and maintained above 300 seconds. The majority of the proximal anastomosis was performed using a side-biting partial occlusion clamp. When the ascending aorta was seriously calcified, either a "no-touch" technique was used and vein grafts were taken off the mammary artery, or a Novare clamp technique was used to perform the proximal anastomosis to the ascending aorta. Postoperatively, all patients were transferred to the surgical ICU and were treated with the same postoperative protocol.

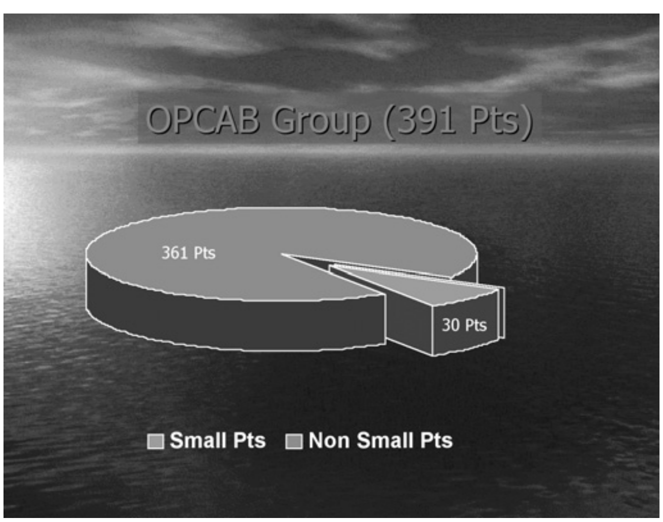

Figure 2. Distribution of Off-Pump CABG Patients, 2000 to 2003.

RESULTS

The distribution of study patients is shown in Figure 1. The distribution of off-pump patients is shown in Figure 2. The proportion of small patients to larger patients is shown in Figure 3.

Preoperative data for all 1015 isolated CABG patients comparing SMALL and LARGER is shown in Table 1. SMALL were significantly older (75 years versus 68 years) and had a significantly higher calculated STS mortality risk (6.6% versus 3.3%), lower hematocrits (37% versus 40%), and were preponderantly female (89% versus 31%). SMALL presented more often with NYHA class III symptoms (21% versus 15%), and were significantly classified as urgent operative status (51% versus 37%). Operative data for all 1015 isolated CABG patients comparing SMALL and LARGER are shown in Table 2. SMALL were significantly more likely to have the pump used (51% versus 62%), somewhat less likely to have an internal mammary artery used (75% versus 81%), less likely to have 4 or more proximal anastomoses, and more than twice as likely to receive blood products (44% versus 20%). Postoperative data for all 1015 isolated CABG patients comparing SMALL and LARGER are shown in Table 3. Operative mortality was significantly higher in SMALL (4.9% versus 1.2%) and 30-day readmission lower (5% versus 7%).

Table 1. Preoperative Data for All 1015 Isolated CABG Patients Comparing Small and Larger Patients

	Small Patients BSA < 1.5 m^2 n = 61	Larger Patients BSA > 1.5 m^2 n = 954	P*
Body surface area, m^2	1.43 ± .06	1.86 ± .21	.00
Age, yrs	75.4 ± 9.2	68.2 ± 10.7	.00
Hematocrit, %	37.4 ± 4.6	39.9 ± 5.2	.00
STS mortality risk, %	6.6 ± 8.8	3.3 ± 3.9	.00
Ejection fraction, %	48.1 ± 10.9	48.8 ± 12.0	ns
Female gender	88.5%	31.0%	.00
NYHA class			
Class I	70.5%	75.6%	.00
Class II	6.6%	6.9%	ns
Class III	21.3%	15.4%	.00
Class IV	1.6%	2.0%	ns
Elective status	47.5%	61.4%	.047
Urgent status	50.8%	37.0%	.047
Emergent status	.0%	1.0%	.047
Diabetes	32.8%	38.5%	ns
Left main disease	34.4%	32.4%	ns
Triple vessel disease	57.4%	62.4%	ns
Prior stent	10.4%	10.5%	ns
Hypertension	90.2%	77.0%	ns
Hyperchol	55.7%	62.5%	ns
CHF history	14.8%	10.2%	ns
COPD	6.6%	9.2%	ns
CVA history	8.2%	8.8%	ns
Renal failure	9.8%	6.6%	ns

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 2. Operative Data for All 1015 Isolated CABG Patients Comparing Small and Larger Patients

	Small Patients BSA < 1.5 m^2 n = 61	Larger Patients BSA > 1.5 m^2 n = 954	P*
Pump used	50.8%	62.1%	.000
Reoperation	1.6%	4.9%	ns
IMA used	75.4%	81.1%	.023
Radial artery used	.0%	3.1%	ns
Total # prox anastomoses			.011
0	3.3%	6.3%	
1	23.0%	15.2%	
2	42.6%	39.2%	
3	29.5%	30.6%	
≥ 4	1.6%	8.6%	
Intra-aortic balloon pump	6.6%	5.1%	ns
Blood products used	44.3%	20.0%	.000

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 3. Postoperative Data for All 1015 Isolated CABG Patients Comparing Small and Larger Patients

	Small Patients BSA < 1.5 m^2 n = 61	Larger Patients BSA > 1.5 m^2 n = 954	P*
Stroke	1.6%	2.4%	ns
Acute renal failure	.0%	1.8%	ns
Atrial fibrillation	16.4%	18.7%	ns
Reop for bleeding	1.6%	2.2%	ns
New Q-wave MI	.0%	.4%	ns
Infection	3.3%	4.4%	ns
Event free	90.2%	94.2%	ns
Postop LOS, days	7.5 ± 4.2	8.0 ± 5.9	ns
≥30-day readmission	5.0%	7.4%	.034
Operative mortality	4.9%	1.2%	.021

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 4. Preoperative Data for 61 Small Isolated CABG Patients Comparing On-Pump and Off-Pump Patients

	On-Pump n = 31	Off-Pump n = 30	P*
Body surface area, m^2	1.43 ± .06	1.43 ± .07	ns
Age, yrs	73.4 ± 8.9	77.5 ± 9.2	ns
Hematocrit, %	38.6 ± 4.2	36.4 ± 4.8	ns
STS mortality risk, %	7.1 ± 11.4	6.0 ± 5.2	ns
Ejection fraction, %	46.7 ± 10.8%	49.6 ± 11.0%	ns
Female gender	87.1%	90.0%	ns
NYHA class			
Class I	77.4%	63.3%	ns
Class II	9.7%	3.3%	ns
Class III	12.9%	30.0%	ns
Class IV	0.0%	3.3%	ns
Elective status	54.8%	40.0%	ns
Urgent status	41.9%	60.0%	ns
Emergent status	3.2%	0.0%	ns
Diabetes	29.0%	36.7%	ns
Left main disease	32.3%	36.7%	ns
Triple vessel disease	58.1%	56.7%	ns
Prior stents	8.7%	12.0%	ns
Hypertension	90.3%	90.0%	ns
Hypercholesterolemia	51.6%	60.0%	ns
CHF history	16.1%	13.3%	ns
COPD	6.5%	6.7%	ns
CVA history	9.7%	6.7%	ns
Renal failure	9.7%	10.0%	ns

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 5. Operative Data for 61 Small Isolated CABG Patients Comparing Off-Pump and On-Pump Surgical Factors

	On-Pump n = 31	Off-Pump n = 30	*P**
Reoperation	0.0%	3.3%	ns
IMA used	77.4%	73.3%	ns
Radial artery used	0.0%	0.0%	ns
Total # prox anastomoses			ns
0	3.20%	3.3%	
1	22.6%	23.3%	
2	48.4%	36.7%	
3	25.8%	33.3%	
≥4	0.0%	3.3%	
Intra-aortic balloon pump	6.5%	6.7%	
Blood products used†	61.3%	26.7%	.007

*Value of $P < .05$ used for significance test.
†Fisher's exact test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Preoperative data for all 61 SMALL patients comparing on-pump (ONCAB) and off-pump (OPCAB) are shown in Table 4. There were no apparent differences in the preoperative characteristics of these two groups. Operative data for all 61 SMALL patients are shown in Table 5. The ONCAB group received significantly more blood products (61% versus 28%) than the OPCAB groups. There was no significant difference in the total number of proximal anastomoses performed. Postoperative data for all 61 SMALL patients are shown in Table 6. There were no significant differences observed between the ONCAB and OPCAB groups, despite the observation that operative mortality was 9.7% for ONCAB and 0% for OPCAB, and the 30-day readmission rate was 10% for ONCAB and 0 for OPCAB.

Preoperative data for all 391 OPCAB patients comparing SMALL and LARGER are shown in Table 7. SMALL were significantly older (78 versus 69 years), with lower hematocrit (36% versus 40%), higher calculated STS mortality risk (6.0%

Table 6. Postoperative Data for 61 Small Isolated CABG Patients Comparing On-Pump with Off-Pump Results

	On-Pump n = 31	Off-Pump n = 30	*P**
Stroke	0.0%	3.3%	ns
Acute renal failure	0.0%	0.0%	ns
Atrial fibrillation	19.4%	13.3%	ns
Reop for bleeding	3.2%	0.0%	ns
New Q-wave MI	0.0%	0.0%	ns
Infection	0.0%	6.7%	ns
Event free	90.3%	90.0%	ns
Postop LOS (days)	6.8 ± 3.6	8.3 ± 4.5	ns
>30-day readmission	10.0%	0.0%	ns
Operative mortality	9.7%	0.0%	ns

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 7. Preoperative Data for 391 Off-Pump Isolated CABG Patients Comparing Small and Larger Patients

	Small Patients BSA < 1.5 m^2 n = 30	Larger Patients BSA > 1.5 m^2 n = 361	*P**
Body surface area, m^2	1.43 ± .07	1.86 ± .21	.000
Age, yrs	77.5 ± 9.2	68.8 ± 10.6	.000
Hematocrit	36.4 ± 4.8	39.7 ± 5.0	.001
STS mortality risk, %	6.0 ± 5.2	3.0 ± 2.9	.000
Ejection fraction, %	49.6 ± 11.0	49.0 ± 11.6	ns
Female gender	90.0%	28.3%	.00
NYHA class			.000
Class I	63.3%	72.9%	
Class II	3.3%	8.9%	
Class III	30.0%	14.7%	
Class IV	3.3%	3.6%	
Elective status	40.0%	62.3%	ns
Urgent status	60.0%	37.1%	ns
Emergent status	0.0%	.6%	ns
Diabetes	36.7%	38.2%	ns
Left main disease	36.7%	33.2%	ns
Triple vessel disease	56.7%	50.4%	ns
Prior stent†	12.0%	13.0%	.023
Hypertension	90.0%	75.3%	ns
Hyperchol	60.0%	62.9%	ns
CHF history	13.3%	8.9%	ns
COPD	6.7%	10.5%	ns
CVA history	6.7%	8.0%	ns
Renal failure	10.0%	7.5%	ns

*Value of $P < .05$ used for significance test.
†4.7% of prior stents were in small versus 62.5% in larger patients.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 8. Operative Data for 391 Off-Pump Isolated CABG Patients Comparing Small and Larger Patients

	Small Patients BSA < 1.5 m^2 n = 30	Larger Patients BSA > 1.5 m^2 n = 361	*P**
Reoperation	3.3%	2.5%	ns
IMA used	73.3%	84.5%	ns
Radial artery used	.0%	3.6%	ns
Total # prox anastomoses			ns
0	3.3%	10.5%	
1	23.3%	20.8%	
2	36.7%	36.8%	
3	33.3%	26.3%	
≥4	3.3%	5.1%	
Intra-aortic balloon pump	6.7%	3.3%	ns
Blood products used	26.7%	8.9%	.005

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

Table 9. Postoperative Data for 391 Off-Pump Isolated CABG Patients Comparing Small and Larger Patients

	Small Patients BSA < 1.5 m^2 n = 30	Larger Patients BSA > 1.5 m^2 n = 361	P*
Stroke	3.3%	1.4%	ns
Acute renal failure	0.0%	1.4%	ns
Atrial fibrillation	13.3%	14.4%	ns
Reop for bleeding	0.0%	1.1%	ns
New Q-wave MI	0.0%	.6%	ns
Infection	6.7%	3.9%	ns
Event free	90.0%	96.4%	ns
Postop LOS (days)	10.1 ± 5.2	10.9 ± 8.7	ns
≥30-day readmission	0.0%	6.6%	ns
Operative mortality	0.0%	0.6%	ns

*Value of $P < .05$ used for significance test.
Rates analyzed using Pearson chi-square statistic.
Continuous variables analyzed using Student's *t*-test.

versus 3.0%), and preponderantly female (90% versus 28%). They also tended to presented with more severe NYHA class III symptoms and were slightly less likely to have had a prior coronary stent placed (12% versus 13%). Operative data for all 391 OPCAB patients are shown in Table 8. SMALL were more likely to receive blood products (27% versus 9%). Postoperative data for all 391 OPCAB patients are shown in Table 9. No significant differences were noted in the postoperative course between the groups compared.

The changing trends that we have experienced in isolated coronary artery surgery from 2000 to 2003 are shown in Table 10. We have seen a diminution in case load associated with higher risk patients. The proportion of on-pump cases has steadily diminished (71% to 33%) whereas that of the off-pump cases has increased (28% to 67%). Our overall adjusted mortality has remained below 1.0%. The percentage of small patients appears to be steadily growing (4.5% to 8.1%).

DISCUSSION

A growing number of studies have shown that OPCAB is safe and significantly reduces postoperative morbidity and cost when compared to ONCAB procedure [Boyd 1999, Hirose 2001, Hoff 2002, Parolari 2003, Plomondon 2001, Puskas 2003, Sabik 2002, Van Dijk 2002]. However, certain subsets of patients represent greater challenges for OPCAB [Fisher 1982, O'Conner 1996, Ryan 2000], and not all of these have been delineated. Patients with small-diameter coronary vessels can pose serious technical difficulties for coronary revascularization regardless of whether a pump is used or not. For example, O'Conner et al in 1996 demonstrated that small mid-LAD diameter is associated with substantially increased risk of in-hospital mortality with CABG. This work tends to corroborate earlier observations of Fisher et al in 1982, who noted that there is a strong association between female gender, physical size, and operative mortality after CABG. Christakis et al in 1995 has made similar observations but argued that the increased risk of CABG in women might be explained, in part, by dramatic differences in preoperative risk factors between men and women. In particular, these authors noted that low-output syndrome was a predictor of operative mortality in women, but not in men. Even very simplified calculations using Poiseuille's law in a laminar flow ideal fluid model reveals a drastic decrease in flow as both driving pressure and vessel diameter decreases (see Figure 4). This is likely the reason that small patients get into trouble more readily when their cardiac output falls. Other factors, which limit OPCAB with respect to small vessels, include the need for better coronary artery stabilization, finer visualization, and more precise instrumentation. In truth, we do not yet know what the actual limitations are on the size of coronary anastomoses.

The present study confirms the observations of others that small patients tend to be older females with less stable preoperative status and higher calculated preoperative risk. In our experience, small patients were less likely to have an off-pump procedure and an internal mammary artery graft than

Table 10. Trends in Isolated CABG Surgery from 2000 to 2003

	Isolated CABG Procedures Year			
	2000	2001	2002	2003
Cases	506	277	223	209
On-pump, %	71.7	64.6	48.4	33.0
Off-pump, %	28.3	35.4	51.6	67.0
STS risk, %	3.4	4.2	3.1	3.1
Mortality rate, %	1.8	1.4	3.1	.0
Adjusted mortality, %	.53	.34	.99	.00
Small (BSA < 1.5 m^2), %	4.5	6.1	1.8*	8.1

*145 cases in 2002 without height and weight data.

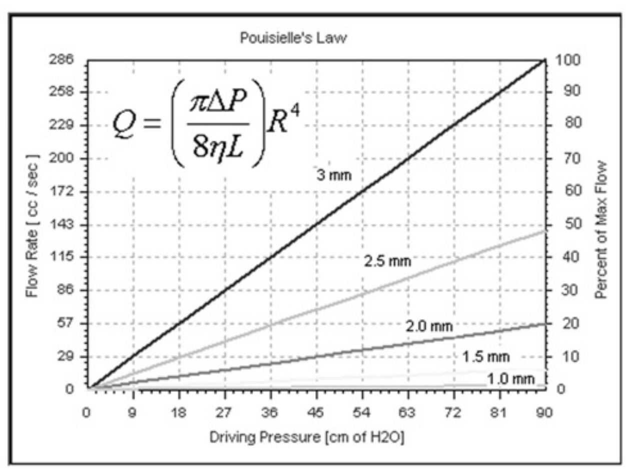

Figure 4. Pouissielle's Law demonstrates the theoretical change in flow rate for various pressure drops across a 1-cm long vessel segment. Note that reducing vessel diameter from 3 mm to 2.5 mm results in 50% decrease in flow rate at the maximum pressure drop. The volume of ideal fluid flowing per unit time is proportional to the pressure difference across the ends of the vessel and the fourth power of its radius.

larger patients. However, this observation is confounded by the fact that participating surgeons were steadily gaining experience throughout the study period. Since no significant differences were observed preoperatively or postoperatively between those small patients who underwent ONCAB and OPCAB (see Tables 4 and 6), one might assume that these subsets were equally matched. But the difference in operative mortality (9.7% versus 0.0%), although not statistically significant, strongly suggests that some selection was probably going on. In fact, we are quite certain that it was. In each case, the surgeon was required to make some decision as to whether or not the patient was a candidate for OPCAB. And the intention to treat with OPCAB has now become almost universal, as can be seen in Table 10.

CONCLUSION

An effective comparison of ONCAB with OPCAB in SMALL patients is affected by patient and procedure selection bias, the duration of follow-up, and the type of events studied. Nevertheless, results of the current study tend to support the view that off-pump coronary revascularization can be performed safely and effectively in small patients. Furthermore, in most circumstances, OPCAB is probably the preferred procedure. Because surgical judgment and self-assessment is so important in determining the feasibility of OPCAB for any given patient, a controlled randomized study, particularly early in the "learning curve," would most probably result in poorer overall outcome for OPCAB [Khan 2004, Loop 1979].

REFERENCES

Boyd DW, Desai ND, Del Rizzo DF, et al. 1999. Off-pump surgery decreases postoperative complications and resource utilization in the elderly. Ann Thorac Surg 68:1490-3.

Christakis GT, Weisel RD, Buth KJ, et al. 1995. Is body size the cause for poor outcomes of coronary artery bypass operations in women? J Thorac Cardiovasc Surg 110:1344-58.

DuBois D, DuBois EF. 1916. A formula to estimate the approximate surface area if height and weight be known. Arch Int Med 17:863-71.

Fisher LD, Kennedy JW, Davis KB, et al. 1982. Association of sex, physical size, and operative mortality after coronary artery bypass in the Coronary Artery Surgery Study (CASS). J Thorac Cardiovasc Surg 84:334-41.

Hirose H, Amano A, Takahashi A. 2001. Off-pump coronary artery bypass grafting for elderly patients. Ann Thorac Surg 72:2013-9.

Hoff SJ, Ball SK, Coltharp WH, et al. 2002. Coronary artery bypass in patients 80 years and over: is off-pump the operation of choice? Ann Thorac Surg 74:S1340-3.

Khan NE, De Souza A, Mister R, et al. 2004. A randomized comparison of off-pump and on-pump multivessel coronary-artery bypass surgery. N Engl J Med 350:21-8.

Loop FD. 1979. A surgeon's view of randomized prospective studies. J Thorac Cardiovas Surg 78:161-5.

O'Conner NJ, Morton JR, Birkmeyer JD, et al. 1996. Effect of coronary artery diameter in patients undergoing coronary bypass surgery. Circulation 93:652-5.

Parolari A, Alamanni F, Cannata A, et al. 2003. Off-pump versus on-pump coronary artery bypass: meta-analysis of currently available randomized trials. Ann Thorac Surg 76;37-40.

Plomondon ME, Cleveland JC, Ludwig ST, et al. 2001. Off-pump coronary artery bypass is associated with improved risk-adjusted outcomes. Ann Thorac Surg 72:114-9.

Puskas JD, Williams WH, Duke PG, et al. 2003. Off-pump coronary artery bypass grafting provides complete revascularization with reduced myocardial injury, transfusion requirements, and length of stay: a prospective randomized comparison of two hundred unselected patients undergoing off-pump versus conventional coronary artery bypass grafting. J Thorac Cardiovasc Surg 125:797-808.

Ryan C, Shaw RE, Zapolanski A, et al. 2000. Risk factors, ethnicity and type of treatment predict need for late repeat revascularization in patients presenting for treatment of coronary artery disease. JACC 35(2):552A.

Sabik JF, Gillinov AM, Blackstone EH, et al. 2002. Does off-pump coronary surgery reduce morbidity and mortality? J Thorac Cardiovasc Surg 124:698-707.

Van Dijk D, Jansen EWL, Hijman R, et al. 2002. Cognitive outcome after off-pump and on-pump coronary artery bypass graft surgery. A randomized trial. JAMA 287:1405-1412.

Yap AG, Baladi N, Allman G, et al. 2000. Coronary artery bypass surgery on small patients. J Invas Cardiol 12:242-6.