Percutaneous Cardiopulmonary Bypass

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Abstract

We have employed a percutaneous cardiopulmonary bypass (PCPB) system during high risk interventional procedures in the cardiac catheterization laboratory. Eight patients (group 1) were elective and six (group 2) were emergencies. Group 1 (ages 39 - 80 years, mean 56 years) includes seven patients who were high risk percutaneous transluminal coronary angioplasty (PTCA) and one patient who underwent balloon aortic valvuloplasty. Group 2 (ages 54 - 80 years, mean 66 years) were in cardiogenic shock, five of whom had arrested.

All patients were fully heparinized (300 iu•Kg^{-1}) prior to percutaneous insertion of 17 - 19F cannulae. Group 1 patients underwent ilio-femoral angiography prior to cannulae insertion.

Mean bypass time was 103 minutes (range 37 - 231 minutes) in group 1 and 406 minutes (range 40 -1781 minutes) in group 2. Bypass was instituted at a flow of 0.5 l•min^{-1} in group 1, flow was increased if chest pain, ECG changes or hypotension occurred, (maximum flow 0.5 - 2.5 l•min^{-1}, mean flow 1.7 l•min^{-1}) Maximum bypass flow in group 2 was 4 - 5.5 l•min^{-1} (mean 4.5 l•min^{-1}). Mean fluid infusion during PCPB was 200 ml•$hour^{-1}$ in group 1 and 385 ml•$hour^{-1}$ in group 2.

The mortality was four patients, all in group 2. Three patients were unable to support their circulation when weaned from PCPB and one patient had a massive intrathoracic bleed such that PCPB could not be maintained. There were no procedural complications associated with cannulae insertion or perfusion management. Of the survivors two had an unexplained haematuria (normal plasma haemoglobin). Two patients bled from the cannulation site following cannulae removal, haemostasis was achieved without surgical intervention.

Introduction

The growth in both the number and the complexity of interventional procedures performed in the cardiac catheterization laboratory, combined with the risks of acute vessel closure and haemodynamic collapse[1-4], clearly necessitate that some form of circulatory support device be immediately available in case of complications[5-8].

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In some instances the prophylactic use of a support device is indicated[9-10] Intra-aortic balloon counterpulsation (IABC) has been successfully employed to haemodynamically support patients[11-12]. IABC, however, has been of limited value in patients with haemodynamic collapse, as it is capable only of augmentation of ventricular output to increase diastolic coronary perfusion rather than providing circulatory support in the absence of an intrinsic rhythm.

The application of cardiopulmonary bypass (CPB) technology has been recognized for many years as a potential tool for the support of patients in cardiogenic shock[13-14], wether an intrinsic rhythm is present or not. The use of such technology outside the operating room has been limited by the need for surgical access to the patients vascular system. The development of small, percutaneously inserted cannulae, capable of being rapidly introduced, combined with a direct aspiration extracorporeal circulation, has enabled the use of CPB outside the operating room[15-16].

Patient Selection

Patients due to undergo interventional procedures in the cardiac catheterization laboratory were assessed for risk factors and assigned to one of three groups; no support required, "standby," or elective support (Table 1).

In cases where the patient's risk score does not indicate PCPB support a decision may be made to perform PTCA as a "standby." In such circumstances the PCPB equipment is set-up and primed in the cardiac catheterization laboratory, a perfusionist is in attendance and access to the femoral vessels with small sheaths is gained. Cannulae insertion and PCPB initiation can then be rapidly performed. To minimize the cost implications of a "standby" an elective case would be placed on the list following the "standby."

Materials and Methods

We have utilized two PCPB systems during interventional procedures in the cardiac catheterization laboratory. System 1[a] consisted of a Bio-Console 540[b], TX40 flow transducer[b], Normotherm heater system[a] and an external battery back-up[a], all located on a transportable cart together with an oxygen cylinder and flow meter. The disposable patient circuit consisted of a BP80 constrained vortex pump head[b], DP38 flow probe[b], HF4000 membrane oxygenator bundle[a] and a CPS System heat exchanger[a] connected with 3/8 inch PVC tubing. The circuit was

primed with 1300 ml of Hartmann's Solution, 100 ml of 10% human albumin, 10,000 iu of sodium heparin and 40 mMol of sodium bicarbonate.

System 2[c] consisted of a Bio-Console 540[b], 540T external drive unit[b], TX40 flow transducer[b], Bio-Cal 370 heater/cooler[b], and an air/oxygen blender with dual flow meters[d], all located on a transportable cart together with air and oxygen cylinders and wall outlet air and oxygen hoses. The disposable patient circuit consisted of a BP80 constrained vortex pump head[b], DP38 flow probe[b], and a Maxima membrane oxygenator[c] connected with 3/8 inch PVC tubing. The circuit was primed with 800 ml of Hartmann's Solution, 100 ml of 10% human albumin, 10,000 iu of sodium heparin and 30 mMol of sodium bicarbonate.

Prior to PCPB circuit preparation and cannulae insertion ilio-femoral angiography was performed to assess the suitability of the femoral vessels for cannulae placement.

During circuit priming and de-bubbling patients were heparinized (300 iu Kg^{-1}) and cannulae placement with either 18F[a], 17F[b] or 19F[b] cannulae performed using a modified Seldinger technique employing a stepped dilation method.

Bypass was initiated at a flow rate of 0.5 $l \cdot min^{-1}$, flow being increased if chest pain, ECG changes or hypotension occurred. Activated clotting time (ACT) was monitored throughout the procedure and sodium heparin administered to maintain the ACT > 450 seconds.

Following the interventional procedure the patient was weaned from PCPB and transferred to the high dependency unit with the cannulae still in place. In instances where extended support was required the patient was transferred to the Intensive Care Unit while on PCPB and supportive bypass continued. Following bypass the ACT was allowed to fall to 200 seconds, a sodium heparin infusion was then started to maintain the ACT at 200 seconds and cannulae removal performed. Haemostasis was achieved initially by digitally applied pressure for twenty minutes and subsequently by the use of a C-clamp compressor system[e].

We have also used PCPB systems in the emergency situation for patients in cardiogenic shock and cardiac arrest, both in the cardiac catheterization laboratory and in the general ward areas. In such circumstances PCPB was initiated without prior ilio-femoral angiography and flow rates of up to 5.5 $l \cdot min^{-1}$ were employed.

Results

Eight patients (group 1) were elective and six patients (group 2) emergencies. Group 1 (Table 2) includes seven patients who were high risk PTCA and one patient who underwent balloon aortic valvuloplasty. Mean bypass time was 103 minutes (Table 3), mean bypass flow was 1.4 $l \cdot min^{-1}$, mean fluid infusion during bypass was 200 $ml \cdot hour^{-1}$ and mean urine output was 163 $ml \cdot hour^{-1}$.

Group 2 patients were in cardiogenic shock five of whom had arrested (Table 4). Mean bypass time was 406 minutes (Table 5), mean bypass flow was 3.5 $l \cdot min^{-1}$, and mean fluid infusion during bypass was 385 $ml \cdot hour^{-1}$.

The one patient who underwent balloon aortic valvuloplasty had a trans-aortic gradient reduced from 100 mm Hg to 60 mm Hg. Fourteen patients underwent PTCA for one or more vessels (Tables 6 & 7). There were 29 diseased vessels in the 12 patients (12 total occlusions and 17 stenosis), PTCA was attempted in 25 of these vessels. Anangiographically successful result was achieved in 21 vessels (84%).

The mortality was 4 patients, all in the emergency group. Three patients were unable to support their circulation when weaned from PCPB. One patient had a massive intra-thoracic bleed such that PCPB could not be maintained, this was attributed to a torn subclavian vein as a consequence of external cardiac compression in a patient with marked Kyphosis resulting from Ankylosing Spondylitis.

There were no procedural complications associated with cannulae insertion or perfusion management. Of the survivors, two had an unexplained haematuria (normal plasma haemoglobin). Two patients bled from the cannulation site following cannulae removal (haemostasis was achieved without surgical intervention).

Discussion

PCPB has proved to be a useful procedure to support patients undergoing high risk interventional procedures. Cannulae placement has been uncomplicated and perfusion management straightforward. The outcome of PCPB for emergency resuscitation appears to be related to the time delay in deciding to initiate PCPB and the effectiveness of external cardiac compression. The need to maintain a good cardiac output via external cardiac compression whilst the PCPB equipment is being assembled and the cannulae placed cannot be over-stressed. Alerting the PCPB team to the possibility of a patient requiring PCPB support at the first sign of deterioration in a patient's status, will ensure rapid institution of PCPB should the patient further deteriorate.

References

1. Scheidt S, Ascheim R, Killip T. Shock after acute myocardial infarction: a clinical and haemodynamic profile. Am J Cardiol 1970; 26; 556-564
2. Cowley MJ, Dorros G, Kelsey SF, Van Raden M, Detre KM. Acute coronary events associated with percutaneous transluminal coronary angioplasty. Am J Cardiol 1984; 53; 12C-16C

a Bard Limited, Crawley, UK.
b Biomedicus Inc, Eden Prairie, Mn, USA.
c Medtronic, Luton, UK.
d Sechrist, Anaheim, CA. USA.
e Instromedix, Hillsboro, OR, USA.

3. Agress CM, Binder MJ. Cardiogenic shock. Am Heart J 1957; 54; 458-477
4. Afifi A, Chang PC, Liu VY, Luz PL, Weil MH, Shubin H. Prognostic indexes in acute myocardial infarction complicated hy shock. Am J Cardiol 1974; 33; 826-832
5. Shawl FA, Domanski MJ, Wish MH, Davis M, Punja S, Hernandez TJ. Emergency cardiopulmonary bypass support in patients with cardiac arrest in the cardiac catheterization laboratory. Cathet Cardiovasc Diagn 1990; 20;120-122
6. Whittaker S, Rees MR, Hick DG, Davies GA. Case report - emergency percutaneous cardiopulmonary bypass. Perfusionist 1990; 15,1; 8
7. Pavlides GS, Cieszkowski J, Timmis GC, O'Neill W. Successful resuscitation of a patient with critical aortic stenosis and cardiac arrest by peripheral cardiopulmonary support system. Cathet Cardiovasc Diagn 1990; 20;120-122
8. Reichman RT, Joyo CI, Dembitsky WP, et.al. Improved patient survival after cardiac arrest using a cardiopulmonary support system. Ann Thorac Surg 1990; 49; 101-104
9. Vogel RA, Shawl FA, Tommaso C, et.al. Initial report of the National Registry of elective cardiopulmonary bypass supported coronary angioplasty. J Am Coll Cardiol, 1990; 15;23-29
10. Shawl FA Percutaneous cardiopulmonary support in high risk angioplasty. Cardiol Clin 1989;7;865-875
11. Kantowitz A, Tjonneland S, Freed PS, Phillips SJ, Butner AN, Sherman JL. Initial clinical experience with intra-aortic balloon pumping in cardiogenic shock. JAMA 1968; 203;988
12. Da Luz P, Weil H, Shubin H. Current concepts on mechanisms and treatments of cardiogenic shock. Am Heart J 1976; 92; 103-113
13. Phillips SJ, Ballentine B, Slonine D, et.al. Percutaneous initiation of cardiopulmonary bypass. Ann Thorac Surg 1983; 36; 223-225
14. Litzie K, Roberts CP. Emergency femoral-femoral cardiopulmonary bypass. Proceed Am Acad Cardiovasc Perf 1987; 8
15. Shawl FA, Domanski MJ, Wish MH, Davis M. Percutaneous cardiopulmonary bypass support in the catheterization laboratory: technique and complications. Am Heart J 1990; 120,1;195-203
16. Ueda O, Kohchi K, Koga N. Percutaneous transluminal coronary angioplasty with cardiopulmonary bypass for stenosis of the most proximal part of the left anterior descending coronary artery. Br Heart J; 1990; 63,3; 178-9

Questions and Comments

Q. We've experienced a lot of the same types of results that you have on our patients that we are supporting during angioplasty and during mitral and aortic valvularplasty. However my question would address your statement that you make sure your patients have proper volumes before they come to the cath lab. That's a problem that we encounter on

TABLE 1 - SELECTION CRITERIA

Patients scoring 3 or more for elective PCPB

PARAMETER	SCORE
Ejection fraction < 15%	3
Ejection fraction 15 - 25%	2
Ejection fraction 25 - 35%	1
Target vessel(s) supplying 35 - 50% of viable myocardium	1
Target vessel(s) supplying > 50% of viable myocardium	2
Inoperable	3
Previous myocardial infarction	1
Previous cardiac surgery	1
NYHA angina class III or greater	1

TABLE 2 - PATIENT DEMOGRAPHICS GROUP 1

Patient Number	Sex	Age	Risk Score	Procedure
1	Male	59	7	PTCA
3	Female	51	4	PTCA
5	Male	63	3	PTCA
6	Male	39	4	PTCA
7	Male	59	7	PTCA
8	Male	41	5	PTCA
9	Female	80	3	BAV
11	Male	55	4	PTCA

PTCA = Percutaneous Transluminal Coronary angioplasty. BAV = Balloon Aortic Valvuloplasty

TABLE 3 - BYPASS DATA GROUP 1

Patient Number	Bypass Time (minutes)	MBP (mm Hg)	PAD (mm Hg)	Mean Flow ($l \cdot min^{-1}$)	Urine Output ($ml \cdot min^{-1}$)	Fluid Transfusion (ml)
1	37	80	9	2.5	*	500
3	87	85	10	1	2.3	500
5	108	65	10	1.5	1.4	1500
6	167	80	10	2	3.7	300
7	63	85	10	1.5	5.3	0
8	68	85	9	1.5	1.8	200
9	231	75	9	0.5	0.7	0
11	63	70	8	0.5	3.8	200

MAP = Mean Blood Pressure. PAD = Pulmonary Artery Diastolic Pressure. * = Urine Catheter Blocked.

TABLE 4 - PATIENT DEMOGRAPHICS GROUP 2

Patient Number	Sex	Age	Procedure
2	Male	64	PTCA
4	Male	54	ER & PTCA
10	Female	80	ER
12	Male	78	ER & PTCA
13	Male	63	ER & PTCA
14	Male	55	ER & PTCA

ER = Emergency Resuscitation. PTCA = Percutaneous Transluminal Coronary Angioplasty.

every single patient that we place on the support system. What is your criteria for volume administration pre-support time?

A. Our criteria is very hit-or-miss and has no scientific basis. About a day to a day-and-a-half prior to the procedure, the patient comes into the hospital, they have an array of tests, blood flows, are placed on IV fluid administration. They probably received two to three liters of IV fluid from that time until being placed on bypass. This is in addition to the fluids they are taking orally. Up until approximately the night before the procedure. But it's very empirical.

Q. Once we are on bypass, fluid administration is played very much by ear. Some units have developed super algorithms for determining fluid requirements. Unfortunately, they pretty much require that you know systemic vascular resistances which in turn requires that you know the cardiac output. In minimal support systems it is virtually impossible to determine the cardiac output of these patients. What we found to be the best indicator is that of urine flow. If we begin to see any diminishing of the rate

TABLE 5 - BYPASS DATA GROUP 2

Patient Number	Bypass Time (minutes)	MBP (mm Hg)	PAD (mm Hg)	Mean Flow ($l \cdot min^{-1}$)	Urine Output ($ml \cdot min^{-1}$)	Fluid Transfusion (ml)
2 +	1781	100	25	2.5	1.5	3900
4	100	65	5	3	9	1300
10 +	40	*	*	4	*	200
12 +	60	70	12	1.5	*	5250
13 +	359	65	18	5	1	4450
14	98	60	15	5	*	500

MAP = Mean Blood Pressure. PAD = Pulmonary Artery Diastolic Pressure. * = Not Measured. + = Patient Died.

of urine flow then the patient begins to receive 400 to 500 ml of fluid immediately. You find that usually within 10 minutes the urine flow is back to normal if not exceeding the previous level.

TABLE 6 - ANGIOGRAPHIC RESULT OF PTCA

Patient Number	LAD		Diag		Cx		RCA		VG	
	Occl	Sten	Occl	Sten	Occl	Sten	Occl	Sten	Occl	Sten
1	o					+		+		
2	+			+	+			o		
3				+	-					
4	+			+						
5		+					-			
6	+							+		
7								-+		+
8		+					+			
11		+		+		-		+		
12		+						o		
13	+						o			
14	+						+			

LAD = Left Anterior Descending. Diag = Diagonal Branch. Cx = Circumflex. RCA = Right Coronary Artery. VG = Vein Graft. Occl = Occlusion. Sten = Stenosis. + = Successful Dilation. - = Unsuccessful Dilation. o = Not Attempted.

TABLE 7 - ANGIOGRAPHIC RESULT OF PTCA

	LAD		Diag		Cx		RCA		VG		Totals
	Occl	Sten	Occl	Sten	Occl	Sten	Occl	Sten	Occl	Sten	
Successful	5	4	0	4	1	1	2	3	0	1	21
Unsuccessful	0	0	0	0	1	1	1	1	0	0	4
Not Attempted	1	0	0	0	0	0	1	2	0	0	4
% Success of Attempts	100	100		100	50	50	67	75		100	84