BYPASS GRAFTING OPERATIONS USING CONVENTIONAL TECHNIQUE WITH OFF-PUMP CORONARY ARTERY BYPASS GRAFTING IN TWO IDENTICAL GROUPS CONDUCTED AT THE PENANG HOSPITAL (1999-2000)

BY

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ABSTRACT IN BAHASA MALAYSIA

Ini adalah suatu kajian prospektif yang telah dikendalikan di Jabatan Pembedahan Kardiotorasik, Hospital Penang, Pulau Pinang, melibatkan sebanyak seratus orang, sepanjang setahun daripada bulan Januari 1999 ke Januari 2000. Lima puluh pesakit telah menjalani pembedahan secara "off-pump" (OPCAB), yang telah dibandingkan dengan lima puluh pesakit lain yang telah menjalani pembedahan secara "on-pump" (CPB) dengan alat "heart-lung machine". Pesakit yang sedang menghadapi penyakit seperti sakit buah pinggang, penyakit lumpuh, penyakit lelah, dan serangan sakit jantung baru-baru ini telah diasingkan dan di beri rawatan secara pembedahan "off-pump (OPCAB)".

Pesakit di dalam kumpulan ini telah mengalami masalah yang sama; seperti sakit jantung, kekurangan daya upaya semasa berkerja, iaitu NYHA kelas II, III dan IV. Sebelum menjalani pembedahan, pesakit-pesakit yang didapati mengidap sakit kencing manis, darah tinggi, darah berlemak tinggi, merokok dan yang mempunyai penyakit yang sama di kalangan ahli keluarga dari kedua-dua golongan telah di teliti. Pemeriksaan yang sama, sebelum pembedahan, telah dilakukan di kedua-dua kumpulan pesakit. X-ray dada, pemeriksaan ECG, Echocardiography, angiogram telah dilakukan untuk seratus pesakit ini. Pendarahan semasa dan selepas pembedahan, keadaan buah pinggang, Echocardiography, ECG dan X-ray dada telah dibandingkan. Perbelanjaan diantara OPCAB dan CPB pembedahan telah dibandingkan. Kajian telah menunjukkan bahawa

pesakit yang telah menjalani pembedahan jantung secara "off-pump" (OPCAB) telah menerima faedah yang lebih baik daripada pesakit yang telah menjalani pembedahan secara CPB. Ini menunjukkan bahawa lebih banyak lagi pembedahan akan dilakukan secara OPCAB pada masa yang akan datang.

ABSTRACT IN ENGLISH

This is a prospective study conducted at the Department of Cardiothoracic Surgery, Penang Hospital, Penang, with a total of one hundred patients were studied over a period of one year between January 1999 to January 2000. Fifty patients who had undergone coronary artery bypass surgery off-pump (OPCAB) were compared with fifty patients who had undergone coronary artery bypass surgery on the heart-lung machine (CPB). Patients who had associated problems of renal failure, stroke, bronchial asthma and recent myocardial infarction were included in the off-pump CABG surgery. The symptoms did not differ in both the groups. They had experienced angina, decreased effort tolerance, palpitations, with NYHA class II, III and IV. The predisposing factors of diabetes mellitus, hypertension, hyperlipidemia, smoking, previous family history of heart disease were studied in both these groups. The same pre-operative investigations were performed in both groups of patients. Chest x-ray, ECG, echocardiography, femoral angiogram were done for these one hundred patients. The intra-and post operative bleeding, pre and post operative renal status, echocardiogram, ECG and chest X-rays were compared. The cost effectiveness of both the OPCAB and CPB procedures were reviewed. There was, generally, a better outcome in patients who had undergone a coronary bypass by the off-pump (OPCAB) method as when compared to those by the CPB method. This indicates that more cases can be done by the OPCAB method in the future.

Quotations:

"Its pretty easy to go upstairs and point at the patients that have been on pump and the patients that have been off pump"

- James C. Hart, M.D.

" The patients respond to beating heart Cabg so much better and are extubated within 2-6 hours"

- David Perkowski,M.D.

" I saw my two post - op patients today in the unit. Both were awake , smiling, no bleeding, no strokes, sitting up, and delined. As they sat up, swung their legs over the side of the bed, and begged me to listen to how good their lungs sounded, they told me how appreciative they were. I could not think of another time EVER that an on-pump patient had EVER looked this good this quickly"

- Michael D, Moran M.D,
Cardiologist

1 INTRODUCTION

Suitable techniques for cardiopulmonary by-pass has in the last 15 years become a realistic standard procedure.The pump oxygenator taking over the function of the lungs, permits operation on intracardiac defects as it provides a quiet, peaceful heart and a clear view of the heart unobscured by blood. This procedure is not without its complications and hence has led to the alternative method of CABG operations using off-pump technique and minimally invasive procedures. Originally, only short periods of CPB was feasible but now up to 6 hours are possible. Nevertheless, there are several grave complications associated with on-pump CABG. This has lead to the resurgence of the off-pump technique in several centers. Everyday, all over the world, approximately 2000 off-pump operations are being performed. New fields are being explored, such as prolonged partial bypass, to assist the action of the heart in episodes of acute heart failure. Video assisted minimally invasive coronary operations without cardiopulmonary bypass is indeed going to be the mainstay of management in the near future. A multicenter study from the Benetti Foundation in Argentina was carried out by Frederico et al in 1994. The aim of this study was to avoid the risks associated with CPB. It has led to the interest in off-pump CABG. The incision used was through a small anterior thoracotomy. The results showed that this method is a new promising technique that can be considered an alternative to most angioplasty and complementary to the conventional CABG operations [Frederico et al]. The main issues in "beating heart" coronary operations are the reduced medical costs and the avoidance of the CPB associated risks. There is a dramatic decrease in costs due to both the decrease of disposable materials and to the reduction in total

hospital stay and intensive care stay. Frederico et al proved this in their study with zero morbidity level for non cardiac complications and to a faster recovery post-operatively. A few of our cases needed to be on PTCA right from the pre-operative stage of management. Studies have shown that the outcome is favourable even for these patients if the CABG is done off-pump. This study also emphasises the advantages of a combined right and left small thoracotomies. 'Off pump' CABG operations have led surgeons to learn the use of tissue stabilising techniques to stabilize the target vessels on the epicardium. A stable myocardial function is maintained, ensuring adequate total body perfusion. The use of Medtronic Octopus Tissue Stabilising System (OTS) allows for improved exposure, with minimal hemodynamic compromise. It enables the surgeon to do multi-vessel 'off-pump' (OPCAB) CABG [J. Hart et al, 1997]. The economic outcome of 'off-pump' (OPCAB) CABG has led to the revival of this technique [Ascione et al, 1999].

2 LITERATURE REVIEW

2.1 History

- Early 20th century: *Lehrbuch der Chirurgie*, edited by Wullstein and Wilms, contained a short chapter describing heart wounds.
- 1910: Alexis Carrel: performed the 1st experimental coronary artery procedure (shunt between the descending aorta and coronary artery using a free carotid artery graft).
- Nevertheless, full-fledged experimental studies directed to the clinical use of coronary artery bypass grafting did not appear until the middle of that century.
- Early experiments: In 1940, Murray developed a number of direct suture anatomosis of systemic arteries including the internal mammary artery to the coronary artery involving a free arterial graft.
- 1956-1965: experiments aimed at solving the immediate problems, and to protect against jeopardizing the coronary circulation were dealt with. These studies first used blood perfusion or autoperfusion to prevent cardiac fibrillation. Then, the study moved on to cardiopulmonary bypass and cardioplegia method to achieve a motionless arterial target for the suturing process.
- 1953: V.P. Demikhov in Moscow, used LIMA to LAD graft by means of a cannula on the beating heart of a dog.

- 1965: Amosova Sinyakin demonstrated suturing techniques with automatic suturing instruments (circular vessel suturing apparatus called VCA-4 or ASC-4) in experimental dogs.
- During the mid 1950s, Prof. Vasili I. Kolesov started work on coronary revascularization for the treatment of heart disease (ligation of both internal mammary arteries, in the hope of increasing collateral flow to the mediastinal coronary arteries). This was called the Fieschi operation. Next he used the tunneling of bleeding internal mammary arteries to the L ventricular wall. This was called the Vineberg procedure.
- 1950s: W.Longmire was one of the pioneers of coronary bypass surgery. He had to perform a couple of earliest internal mammary artery to coronary anastomosis during a thrombo-endarterectomy. It later proved to be a good operation.
- 1961: Goetz and colleagues conducted experiments with non sutured mammary artery anastomosis (joining of the internal mammary artery to the R coronary artery on the beating heart by means of a tantalum ring. It took 17 minutes. Catheterization was done 2 weeks after the surgery and it confirmed the patency of the anastomoses.
- 1964: Prof. Kolesov introduced direct suturing between the internal mammary artery and coronary arteries (done in 1964).
- 1965: Khan and colleagues showed the use of vascular staplers for anastomosis in calf. Further work was delayed until recent renewed efforts by Tulleken and colleagues, Nataf and colleagues and others.

- 1966: Prof. Kolesov used the gastroepiploic artery for the Vineberg procedure, retrograde (1966) and bilateral internal mammary artery anastomosis (1969) and the use of abdominal artery grafting on experimental basis. He pioneered the use of internal mammary artery to coronary artery anastomosis for the treatment of acute myocardial infarction and pre-infarction conditions. He retired in 1976, his research group carried on with his work. He died in 1992.
- 1973: Garrett et al used the saphenous vein graft to perform CABG on a beating heart.
- Despite the widespread use of CPB bypass, Prof. Kolesov prefered to avoid CPB or to simplify it. He advocated that for ill patients, on-pump bypass must be avoided as it is a heavy burden for the patients heart.
- 1975: Trapp and Bisarya and Anekey reported successful cases operated by the off-pump method.
- 1982: Benetti et al (Argentina, South America) pioneered the off-pump CABG Lower morbidity, mortality and reduced costs were reported. This was particularly true of high -risk patients. Similar findings were reported by several other centres.
- *Minimally invasive direct coronary artery grafting was demonstrated by Subrmaniam, Robinson et al, Califiore et al, Janssen, Yim et al.
- Mack and Nataf introduced the video-assisted cardiac surgery. They showed how this method greatly reduced the invasiveness of the procedure and they developed it further. Despite the initial uncertainty, the quality of the anastomosis and the benefits of the procedure, this off-pump direct

visualization has received increasing acceptance. The advent of mini-thoracotomy, done off-pump, on a beating heart where LIMA is anastomosed to the LAD as originally proposed by Benetti and popularised by Califiore et al represented an important development in coronary surgery in recent years. This is limited to patients with single LAD lesions.

- Recent progress: Development of myocardial tissue stabilizers, flow occluders, etc, video-assisted dissection of LIMA have been developed.
- The use of robotics have emerged to expand these techniques and complete the thoracoscopic coronary surgery. The develpoment of coronary artery surgery spans practically throughout the entire 20^{th} century with intervals between the breakthroughs becoming progressively shorter. However, there was a distressing gap between the origination and the acceptance of ideas regarding less invasive coronary artery surgery.
- Under research now: The MIDCAB operation performing LIMA to LAD anastomosis by percutaneous angioplasty or other methods to provide effective myocardial revascularization via a non-invasive approach and at a lower cost.

2.2 ANATOMY

The pericardium which invaginates the heart is a serous sac similar to the pleura. The outer parietal layer is invested by a strengthening fibrous coat. The pericardium encloses the heart and the root of the great vessels. The pericardium occupies the middle mediastinum and is attached to the sternum by the superior and inferior sternopericardial ligaments.The arterial supply of the heart is provided by the right and left coronary arteries. The right coronary artery arises from the aortic sinus, passes forewards to the coronary sulcus between the pulmonary trunk and the right auricle. It then descends in the coronary sulcus onto the diaphragmatic surface of the heart. A marginal branch passes towards the apex along the acute margin of the heart and ramifies over the right ventricle. Next the coronary artery passes from the left and turns onto the back of the heart and terminates as the posterior interventricular branch. It supplies both ventricles and anastomoses, near the apex, with the left anterior interventricular branch of the left coronary artery [Figure 2.1]. The left coronary artery arises from the left aortic sinus. It passes forewards to the left and divides between the pulmonary trunk and the left auricle into an anterior interventricular branch (LAD) and the circumflex branch. The LAD passes towards the apex of the heart in the anterior interventricular groove. It supplies both ventricles and the interventricular septum and anastomoses near the apex with the posterior interventricular branch of the right coronary artery. The circumflex artery circles toward the back of the heart in the coronary sulcus. It has a marginal branch which follows the left margin of the heart, supplying the left ventricle. The circumflex artery ends on the back of the left ventricle, anastomosing with the posterior interventricular branch of the right coronary artery.

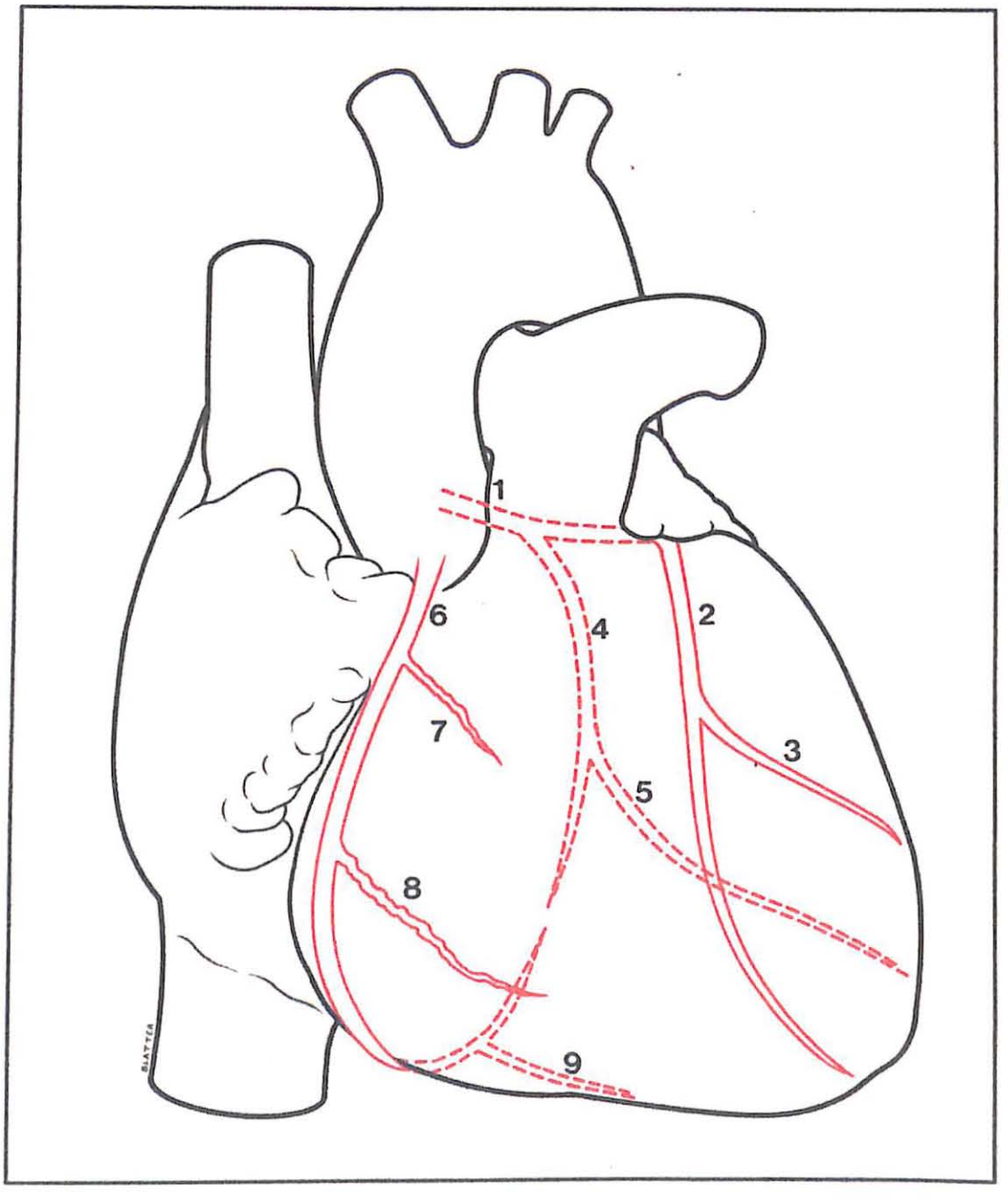

Diagram A

1. Left main.
2. Left anterior descending (LAD).
3. Diagonal.
4. Circumflex.
5. Obtuse marginal.
6. Right.
7. Right ventricular branch.
8. Acute marginal branch.
9. Posterior interventricular.

Figure 2.1 Diagram A

A posterior artery of the left ventricle frequently swings down the back of the left ventricle near the termination of the circumflex, matching the distribution of the posterior vein of the left ventricle. The branch supplying the SA node arises from the right coronary artery in 54% of cases, distal to its conal branch. It supplies the deep aspect of the right atrium, circles the base of the superior vena cava and ends in the SA node at the cephalic end of the sulcus terminalis.

An intermediate artery arises from the right coronary artery nearly opposite its right marginal branch and ascends over the right atrial surface. An anastomotic atrial branch arises from the circumflex artery near its origin and passes towards the right, towards the internal surface of the left atrium. It may anastomose with the terminals of the right sinuatrial artery and is usually involved in the variant cases in which the sinuatrial artery is a left coronary branch. The circumflex also gives rise to an intermediate atrial branch which distributes along the left atrium above the coronary sulcus. The AV node artery arises from the right coronary artery opposite the origin of the posterior interventricular artery (85%) and penetrates deeply to the AV node (LAD) and posterior interventricular arteries. Of these, those from the LAD pass two-thirds of the way into the septum, those from the posterior interventricular arteries pass one third of the way into the septum.The terminal anastomoses between the arteries are usually small and require enlargement for survival in case of occlusion of any of the larger branches of the coronary arteries. Interference with the coronary circulation results in ischemia and pain (angina pectoris) or a varying amount of permanent damage to the myocardium. A small area of damage usually allows recovery by connective tissue replacement in the infracted area, but massive damage is likely to be fatal. The coronary artery bypass surgery in which the venous autografts are inserted to bridge the affected areas, has saved many lives. The three most common locations of coronary occlusion, in descending order of frequency, are proximally in the LAD, proximally in the right coronary artery and proximally in the circumflex artery. The veins, for most part of the heart, follow the arteries [Fig 2.2].

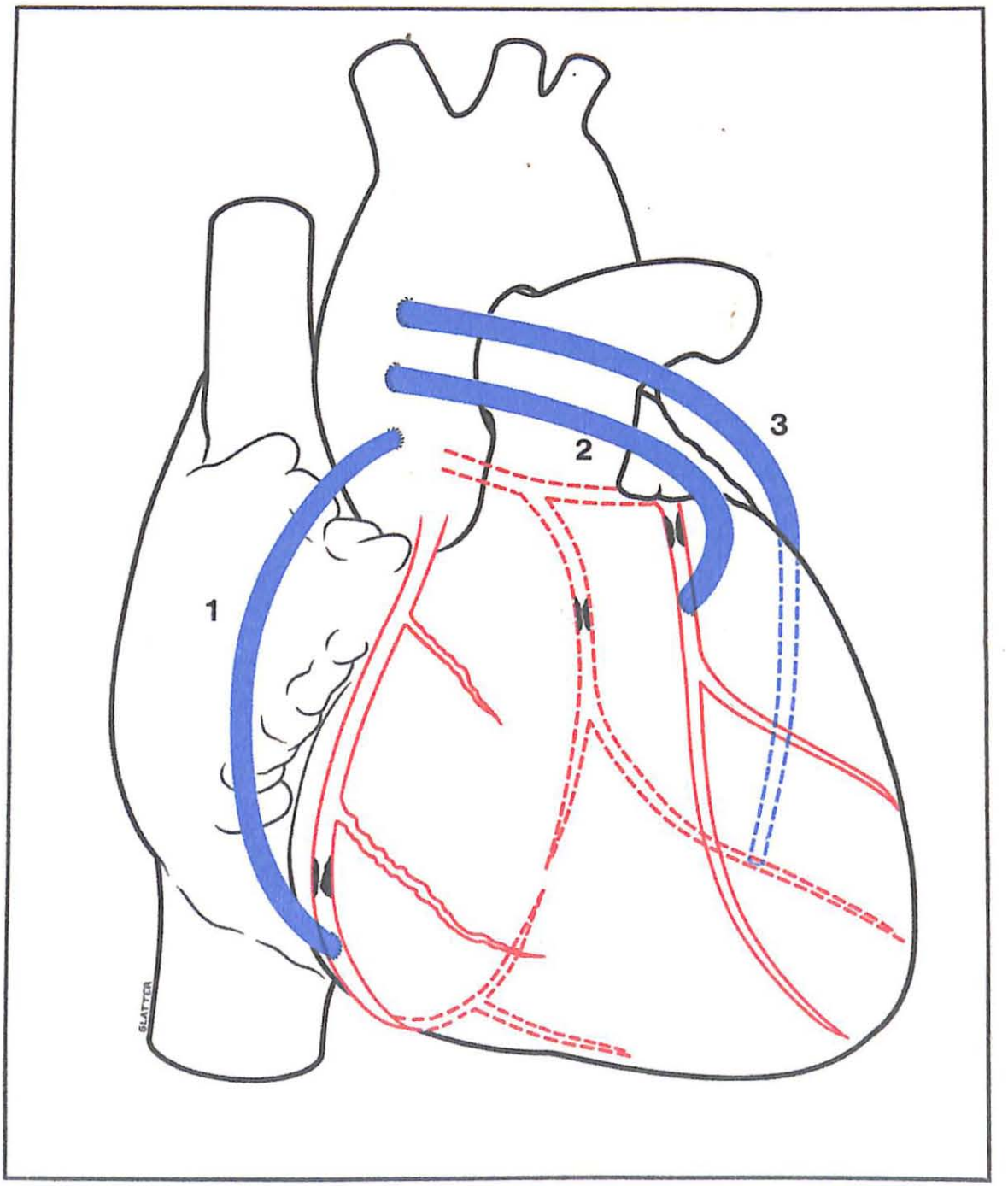

Diagram B

1. Graft to right coronary artery.
2. Graft to left anterior descending coronary artery.
3. Graft to obtuse marginal branch of circumflex coronary artery.

Figure 2.2 Diagram B.

2.3 INCIDENCE

The incidence of coronary artery disease is more in males than in women but the odds are equal in both sexes in the post-menopausal women and men of the same age.

2.4 INDICATIONS OF OFF-PUMP CABG

The following are the indications for performing an off-pump CABG:

- Coronary artery disease
- Severely calcified aorta, especially the ascending aorta
- Renal disease, renal insufficiency
- Pulmonary disease, emphysema
- Previous stroke, cerebrovascular accident
- Diffuse peripheral vascular disease
- elderly patients
- Poor ventricular function
- Re-operations
- Jehovah's witness religious group (refuse blood transfusion based on religious beliefs)

2.5 CONTRAINDICATIONS OF OFF-PUMP CABG

There are several contraindications to off-pump CABG and these are as follows:

- Deep intramyocardial vessels
- Small distal targets
- Hemodynamic instability due to cardiac manipulation or ischaemic precondition
- Acute myocardial infarction with cardiogenic shock

2.6 ADVERSE EFFECTS OF CPB CABG

On-pump CABG (CPB), has several adverse effects affecting multiple organs. The pathophysiology of this "pump syndrome" is illustrated in Fig. 2.3 below.

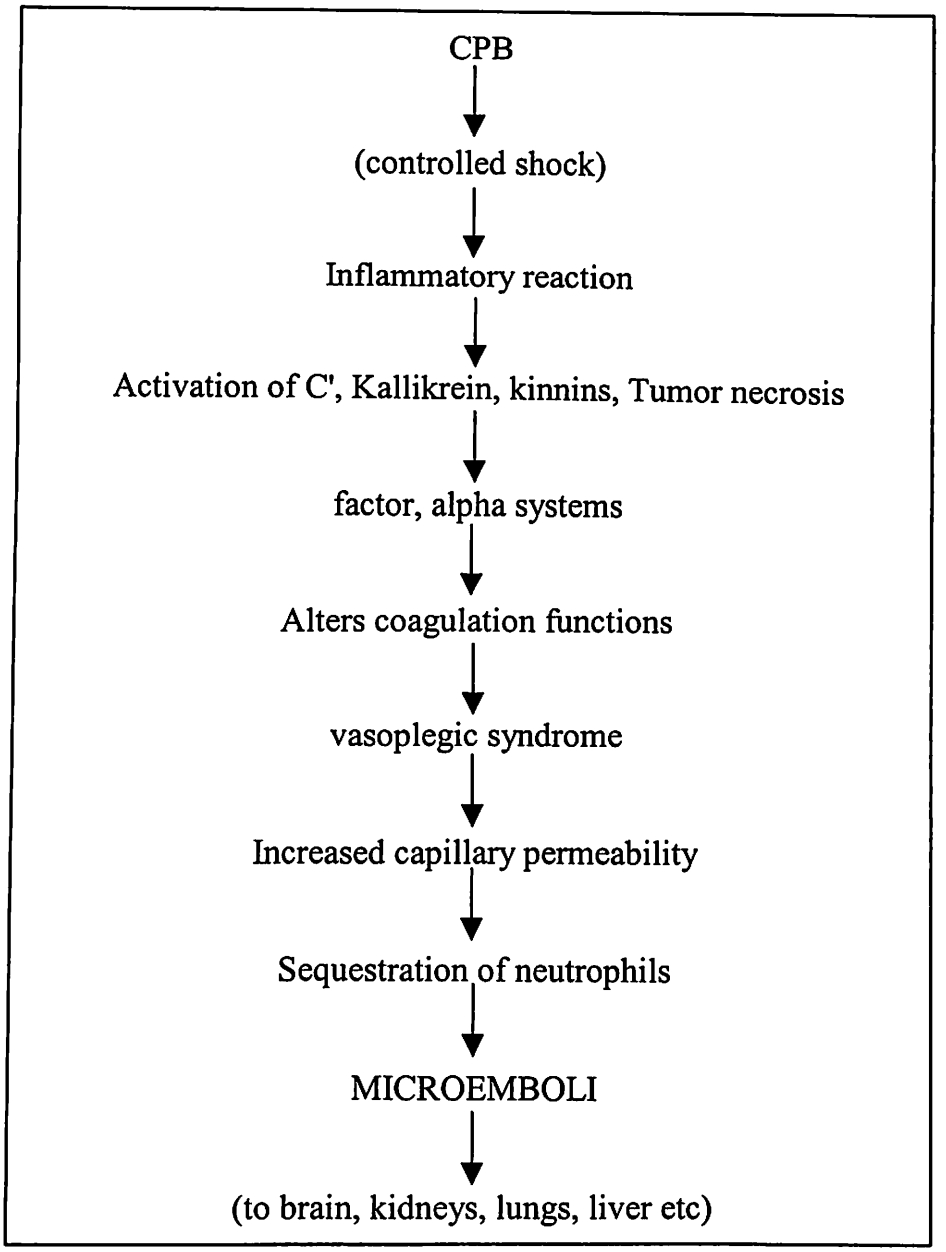

Figure 2.3 Pathophysiology of pump syndrome.

2.6.1 Renal Failure

After CPB CABG, renal failure is usually due to acute tubular necrosis. This is due to renal vasoconstriction. The exact local mechanism is not understood as yet. It is believed to be due to a physiological shunt which diverts blood from the artery to the vein, thereby depriving the renal tissue of its blood supply. Acute tubular necrosis can occur in the event of a brief hypotensive episode intraoperatively. Other mechanisms may be involved including the intravascular (glomerular) thrombosis, tubular obstruction and the renin-angiotensin system. Incompatible blood transfusion damage in the extracorporeal apparatus, long perfusions, septicaemia, hypoxia and acidosis have also been implicated in the etiology of renal failure in CPB CABG. The plasma haemoglobin released by red cell trauma after CPB operations can pass through the kidney and appear in the urine without any sign of renal disturbance. Renal embolism with clot, air or airfoam is a rare cause of renal failure. The acute tubular necrosis usually causes oliguria (less than 400 ml/day). Anuria is rare in acute tubular necrosis and if present, it suggests the presence of bilateral renal embolism or bladder neck obstruction due to an associated prostatic hyperplasia. Renal failure can occur without oliguria, as seen in non-oliguric renal failure in valve replacement done on CPB.

2.6.2 Cerebral Damage

Cerebral damage after CPB CABG is due to embolism and cerebral ischemia. CNS complications due to cerebral embolisation occurs at the time of decannulation, aortic clamping and declamping. A common complication is the development of a stroke.

Intracranial hemorrhage, hypothermia, metabolic derrangements can also contribute to cerebral disturbances after CPB CABG. It is manifested as psychiatric disorder or present with post-operative neurological signs which may be so severe as to result in coma and death. Embolism may be due to air trapped within the left side of the heart after open heart surgery. The nitrogen content of air is absorbed slowly. Thus air embolism is more dangerous than oxygen or carbon dioxide embolism. This can occur if frothing occurs in the oxygenator or if cold blood comes into contact with warm tissues. De-airing of the grafts and the chambers of the heart is very important at the end of the anastomosis of the grafts.

The presence of a preoperative mitral valve lesion will predispose the patient to the risk of developing a cerebral thrombo-embolism from the left atrium and appendage. Left ventricular aneurysms often contain clots which can embolise. Thrombosis along the left atrial suture lines and prosthetic valves is another cause of post-operative thrombo-embolism. Fat embolism can occur due to the release of fat globules from the pericardium after median sternotomy incisions or due to trauma to mediastinal fat by suction injury of the coronary aspirators into the extracorporeal equipment. Fibrin embolism has been shown to be common with certain oxygenators resulting in diffuse brain damage. Occasionally, foreign materials such as sutures, patches can reach the brain as emboli. Cerebral ischemia can cause severe cerebral damage. The ischemic event could manifest are noted in hypoglycemia, diabetic coma, gross electrolyte imbalance or a very low pH. Drugs added due to a very low intraoperative cardiac output, a low flow from the pump oxygenator. This can also result from using pure oxygen in the pump oxygenator leading to a low arterial carbon dioxide tension. It is also seen if the patient is hyperventilated intraopeartively. Cerebral anoxia develops faulty oxygenation techniques by the

anaesthetist, with large left to right shunts, pulmonary complications and ventilatory inadequacies result in cerebral damage. Other causes of cerebral damage in CPB CABG is due to raised intracranial pressures from subdural hemorrhage, hypertensive crisis, cerebral dehydration with hypertonic solutions and with obstruction to one jugular vein. In this instance, the venous cross communications cannot be relied upon to overcome the resultant raised intracranial pressure. Profound hypothermia can cause cerebral damage due to ischemia rather than from direct damage from hypothermia. Cerebral symptoms may be seen due to metabolic disturbances but it is rare. Mental and neurological changes can occur due to the pump oxygenator. The psychological disturbances are of various degrees ranging from slight disorientation to frank psychoses. Treatment postoperatively at the CICU can bring about a fear of impending death with its unsureal atmosphere. They can have a lack of sleep, anxiety fragmented speech and use the wrong words while attempting to talk. Hallucinations occur when the cardiac output improves. Patients can also experience disorders of conciousness, unequal pupils, hemiparesis, convulsions, hyperpyrexia, hyperreflexia and extensor responses. Slowing pulse, spreading hemi-paresis or hemi-sensory loss could point to the evolvement of cerebral oedema. An associated papilloedema will definitely indicate a CT scan of the brain with further neurological assessment. The pathology of cerebral damage is due to changes brought about by ischemia and anoxia. It consists of diffuse neuronal loss in the cerebral cortex with less changes in the medulla. Cerebral odema may or may not be present. Clot and calcium embolism may cause cerebral infarcts. Diffuse local areas of cerebral damage may be seen due to air or fibrin embolism.

2.6.3 Hepatic Failure

Jaundice may occur after cardiac surgery for various reasons. Older patients with pulmonary hypertension and myocardial insufficiency are likely to develop hepatic failure. Hepatic function could be depressed during and after the surgery. Anaesthesia, especially halothane, hypothermia, a low flow with poor tissue perfusion from the pump oxygenator and raised plasma hemoglobin aggravate these effects. The kidneys will also suffer from a reduced renal blood flow. Thus renal and hepatic failure can occur simultaneously.

Post-operatively a low cardiac output with a high venous pressure may worsen hepatic damage. Drugs and sepsis also play a role. Transfusion viral hepatitis may occur after cardiac surgery with an incubation period of 14-100 days. Cytomegalovirus hepatitis may also occur.

2.6.4 Hematological Disorders

Blood damage in extracorporeal circulation is of a complex nature and causes accelerated destruction of red blood cells in the post-perfusion period. Hemoglobin levels can fall to as low as 3-5 gm/dL.Subacute bacterial endocarditis or protracted low grade infection may cause anemia. Gastrointestinal bleeding may occur from anticoagulant therapy and result in anemia. Post operatively, despite good drainage variable amount of blood lies in the chest cavity. Post operative chest X-ray will show a widening of the mediastinum. Intravascular hemolysis will occur due to artificial materials used in CPB. A patient with

sickle cell disorder will do well with off-pump CABG with a preoperative spleenectomy before the CABG. The amount of blood to be transfused (packed cells) is calculated with the following formula:

Vol. of blood = 3.5 X (Desired level of Hb - Actual Hb level) X body weight

Failure of the hemostatic mechanism after CPB is a major problem requiring chest reopening. The circulating heparin may not have been neutralised well with protamine.

Recrudescence of heparin activity after effective neutralization can occur. It is called heparin rebound phenomenon. The cause is unknown. Heparinised blood returns into circulation from stagnant peripheral vessels or to fibrinolytic degradation of the heparin protamine complex. An increase thrombin time due to a decrease in levels, allows heparin to reappear. Excessive dose of protamine prolongs coagulation, but fortunately this rare. Qualitative platelet defects are seen when platelets are exposed to the CPB circuit with alpha- granule release. Alteration of platelet membrane receptors occurs. The degree of platelet dysfunction co-relates with the duration of CPB and the degree of hypothermia after bypass. Hemodilution on CPB and consumption in extracorporeal circuit will decrease platelet count by 30%-50%. The thrombocytopenia worsens as the CPB time increases. These are the quantitative platelet defects. A transient fall in the platelet count to 30% is noted on giving protamine. CPB lowers most of the coagulation factors by 50%, especially factor V by 80%. Hemodilution is more pronounced if patients have a small blood volume. The use of intra-operative cell-savers will eliminate clotting factors. Fibrinolysis occurs due to activation of the plasminogen during CPB.

2.6.5 Other Factors

CPB predisposes to the development of paradoxical septal wall motions of the cardiac musculature. There is an increased rate of morbidity and mortality .It involves increased utilization of resources. There is an increased incidence of reopening of the chest for blood loss and bleeding. The post-operative stay is prolonged as when compared to the off-pump CABG. Peri-operative incidence of myocardial infarct is more with CPB.

2.7 INCIDENCE OF MAJOR POST-OPERATIVE COMPLICATIONS WITH AND WITHOUT CPB IN A STUDY DONE BY ENIO BUFFALO IN 1995.

The above study conducted by Enio Buffalo et al has established that complications of CABG with CPB is more than with off-pump CABG (Table 2.1). Patients benefit from an off-pump CABG. A similar study was done by the cardiothoracic teams of three hospitals in the USA i.e. Allegheny University Hospital/ Medical College of Pennsylvania, Harrisburg Hospital and Park Nicolet Clinic/Health System Minnesota. They had similar results showing that off-pump CABG had many advantages over the CPB CABG.

Table 2.1 Incidence of major post-operative complications with and without CPB in a study done by Enio Buffalo in 1995.

Complication	With CPB (509 cases)	Without CPB (200 cases)
Perioperative MI	18 (3.5%)	2 (1%)
Arrythmias	25 (5.6%)	5 (2.5%)
CVA	3 (0.6%)	0 (0%)
Acute renal failure	8 (5.1%)	0 (0%)
GIT bleed	7 (1.4%)	2 (1%)
Excessive bleeding	16 (3.0%)	3 (1.5%)
Prolonged intubation	40 (7.8%)	9 (4.5%)
Vasoplegic syndrome	10 (2.1%)	2 (1%)
Total	**127 (24.9%)**	**23 (11.5%)**

2.8 COST- EFFECTIVENESS

Costs are reduced when CABG is performed by the off-pump method. CPB patients require a prolonged CICU stay, and general ward stay post operatively due to all the above mentioned complications. With CPB, time spent in the hospital is reduced, with fewer post operative complications. Thus more number of patients can be treated by the off-pump technique using the available resources. It also decreases the waiting list for coronary surgery. The estimated cost of coronary artery bypass operation at the Cardiothoracic Surgery Unit at Penang Hospital is as follows (Table 2.2):

Table 2.2 Showing the cost of OPCAB and CPB CABG at Penang Hospital, Penang.

Type of operation	**Off-pump (OPCAB)**	**CPB**
Cost (in ringgit Malaysian)	RM3,200.00	RM 4,864.00

The cost of utilizing the extracorporeal equipment alone being RM2064.00.

3 OBJECTIVE OF STUDY

1. The primary aim of this study is to assess the usefulness of the off-pump coronary artery bypass surgery for elective patients with coronary artery disease.

2. The secondary aim is to assess the following parameters in these patients :
   a) Morbidity
      i. Infection
      ii. Ventilation time
      iii. Cost effectiveness
   b) Mortality
   c) Peri-operative infarcts based on ECG findings
   d) Clinical outcome
      i. Renal status pre and post operatively (assessed with serum creatinine)
      ii. Duration of CICU stay (assessed with time of extubation)
      iii. Treatment with inotroph
      iv. Gross neurological status
      v. Post operative bleeding
      vi. Post operative blood transfusion
      vii. Post operative wound infection of the chest and the leg.
      viii. Post operative lung complications
      ix. Angina

x. Pericardial effusion

xi. Ejection fraction

xii. Pre-operative risk factors

xiii. Incidence of wound infection

4 MATERIALS AND METHOD

4.1 GENERAL DESCRIPTIONS

Suitable techniques for cardiopulmonary bypass has in the last fifteen years become a realistic standard procedure. The pump oxygenator takes over the functions of the heart and the lungs, thus permitting a quiet, non-beating heart with a clear view unobscured by blood. Originally only short periods of bypass were feasible. Now periods of up to 6 hours are possible. Nevertheless, there are several grave complications associated with the use of the CPB machine. This has led to the use of the off-pump method of CBG using the Octopus II tissue stabilizer (by Medtronics Inc.) in several centres around the world.

A total of 100 patients were involved in this prospective study. Fifty of them were operated using the CPB method and another fifty patients were operated by the off-pump method. Patients were selected randomly into the two groups of study. Those with pre-operative risk factors of arrythmias were excluded from this study. Both groups had patients with various other medical problems such as diabetes mellitus, hypertension, gastrointestinal bleeding, gastritis, ischaemic heart disease, chronic obstructive airway disease, renal disease, and others. They were all assessed pre operatively by the same parameters. Baseline blood investigation of full blood count, blood urea and electrolytes, serum creatinine, coagulation profile were done. Routinely, blood was grouped and cross matched prior to surgery. A pre-operative angiogram was performed. All the 100 patients had under gone investigations such as ECG, echocardiography, chest x-ray preoperatively. They were all grouped together and given a "pump talk" i.e. a briefing about the