# THE ANAESTHETIST'S ROLE IN OPEN HEART SURGERY*

W. A. DODDS, M.D., H. B. GRAVES, M.D., J. E. NIXON, M.D., L. E. DAVIES, M.D., AND G. E. SLEATH, M.D.†

ANAESTHESIA AS A SPECIALTY has taken great strides forward over the past fifteen years. This advancement has been due to the introduction of many new agents and techniques which have greatly improved surgical conditions and, therefore, increased the scope of both diagnostic and operative surgical procedures.

Recently, major developments have occurred which, once again, have opened up new surgical fields and have also caused the anaesthetist to re-explore the fields of pharmacology, physiology, and patho-physiology. In 1950, Bigelow and associates[1, 2] introduced hypothermia as a technique and since its introduction its use has become widespread in many fields of surgical endeavour. Hypothermia as a technique is usually handled by the anaesthetist, and has made it necessary for him to become an expert in the handling of such monitoring devices as direct pressure recordings, continuous electrocardiograms and electroencephalograms, blood pH and $CO_2$ determinations. In 1954, cross-circulation procedures, which were the fore-runners of total body perfusion in 1955, at the University of Minnesota[3, 4] made the team handling of surgical cases a necessity. Since 1955, many centres have developed "open heart" techniques and total body perfusion has become routine for the correction of intracardiac defects.

At the Vancouver General Hospital, open heart surgery was initiated in October, 1957, and since that time over two hundred cases have been operated on utilizing total body perfusion. These cases include children, infants, and adults with either congenital or acquired heart disease. The ages have ranged from eight months (10.5 lbs.) to 55 years. These cases have been selected entirely by the need for surgical intervention, with no particular regard to mortality figures. The over-all mortality has been about 25 per cent, a figure which compares favourably with other centres. The method of handling these cases was selected and developed in the animal laboratory‡ and it was found necessary to involve many individuals from various specialties before attempting clinical cases. These cases are now handled by a team which includes cardiologists, radiologists, surgeons, anaesthetists, haematologists, nurses from both operating room and recovery room, and technicians. Any surgical procedure with a mortality rate of 25 per cent would seem to require the undivided attention of all concerned. It is the role played by the anaesthetists on this team at the Vancouver General Hospital that I am principally interested in describing.

*Presented at the Second World Congress of Anaesthesiologists, Toronto, Canada, September 4–10, 1960.

†Department of Anaesthesiology, Vancouver General Hospital, and the University of British Columbia, Vancouver, B.C.

‡Animal work carried out at the Strong Laboratory with grants from Federal Health (#609–9–88), and the B.C. Heart Foundation.



Can. Anaes. Soc. J., vol. 8, no. 3, May, 1961.

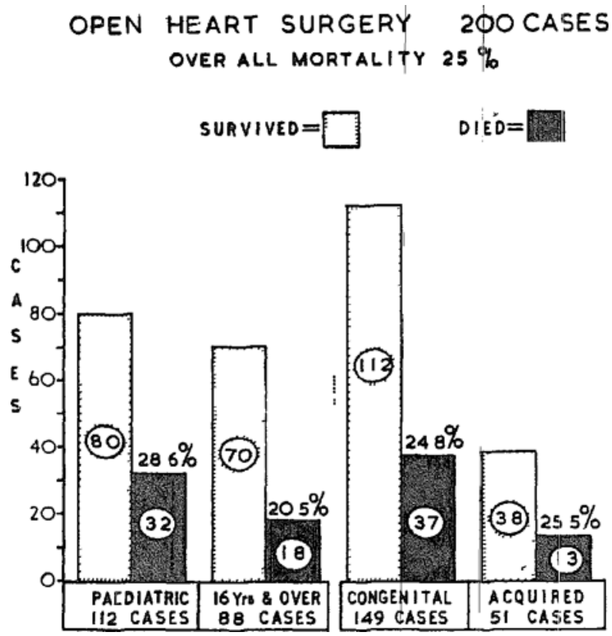


FIGURE 1. Mortality with reference to age and to congenital and acquired lesions The mortality percentage is high due to the inclusion of the earlier cases

The initial investigation of these patients is carried out by the cardiologist with the aid of the radiologist and haematologist. These investigations include history, examination, X-ray, electrocardiogram, right and/or left heart catheterization, angiocardiography, dye studies, and coagulation factors.

Before surgery is slated, the patient is presented at cardiac surgical rounds attended by all personnel concerned. Here the investigative findings are assessed and a diagnosis established. Once the diagnosis is established, the surgeons and anaesthetists must outline a plan to be followed in the operating room. This plan encompasses the management of perfusion, anaesthesia, surgery, and the postoperative care of the patient.

The perfusion is planned to suit the individual and his defect. Blood requirements, rate of perfusion, and estimated length of perfusion are considered. Also, special arrangements which may be necessary, such as coronary perfusion for aortic valvular surgery, method of cardiac arrest to be employed, and extra cannulations which may be used to decompress the left side of the heart, are discussed.

The anaesthesia is planned for the patient, taking into consideration such factors as age, cardiac output, pulse pressure, hypertrophy of one or both ventricles, arrhythmias, blood volume, the presence of cyanosis or myocarditis, pulmonary flow, and the hemodynamic status of the patient. Consideration is given to having the patient as free from cardiac failure as possible by use of digitalis, diuretics, and bed rest if necessary.

The management of the surgical procedure is discussed from the standpoint of position on the table, incision to be used, and the approach to the lesion. The method of repair is outlined. At this time, it is often necessary to entertain the possibility of other lesions to be looked for at the time of surgery, as well as diagnostic pressure studies and saturations which may be of value during the procedure.

The postoperative care is outlined as to the necessity for respiratory assistance or tracheotomy or both. The postoperative cardiac management covers the control of blood volume, myocardial action, and arrhythmias. Consideration is given to the effect of hemodynamic changes occurring after the repair.

In the operating room, two anaesthetists are required: one concerns himself with the usual anaesthetic procedure, and the other with the supervision of the perfusion and the set-up and operation of the monitoring devices. The general duties of an anaesthetist are to maintain the patient during surgery. This involves pain relief, good surgical conditions, adequate oxygenation, maintenance of blood volume, and cardiovascular stability. Since the perfusion and the monitoring devices are necessary to maintain these patients during surgery, it is our opinion that the anaesthetist should control this equipment, and the surgeons, who are well aware of the limitations of the technique, are left free to handle the complex problems confronting them at the table.

The patient is premedicated lightly in order not to interfere with homeostatic mechanisms which, in the cardiac patient, are easily depressed. Some psychological preparation is usually necessary at this time, owing to the lack of sedative effect. The usual premedication is seco-barbital, grs. ī to īss̄ for patients over ten years of age, 90 minutes preoperatively, meperidine, 0.75 mg. per lb. of body weight, and the usual dose of hyoscine, according to age, one hour preoperatively. These patients come to surgery awake, but relaxed and usually with no fall in arterial blood pressure. They are placed on a circulating blanket used for maintenance of body temperature, and given a "sleep dose" of thiopental sodium, slowly. Following an adequate dose of d-tubocurare and positive pressure ventilation with oxygen, the patient is intubated and respirations are controlled. Maintenance of anaesthesia is by means of nitrous oxide and oxygen 4:2 L. and the slow intraveous infusion of a .04 per cent meperidine solution. The total dose of meperidine ranges from 20 mg. to 150 mg., depending on the size of the patient and the length of the procedure. The predetermined dose of meperidine is run in at a rate calculated not to depress the blood pressure and to be absorbed as the chest is opened. Further d-tubocurare is usually necessary during opening of the chest, and just prior to perfusion. Following perfusion, nitrous oxide and oxygen only are required. The patient is usually awake and talking as the endotracheal tube is removed.

Recently, some patients with congenital heart disease have been intubated using succinylcholine and maintained on 0.5 to 1.0 per cent halothane. This concentration of halothane has not markedly reduced arterial pressures. However, without increased doses of curariform drugs, tidal volume was noticeably decreased, producing, in some cases, inadequate ventilaton. Also, since these patients did not respond more quickly at the end of the procedure, there did not seem to be any advantage to the use of halothane. We have thought it not advisable to use halothane in the presence of acquired heart disease with its myocarditis and the likelihood of myocardial depression. In fact, it has been our opinion that the resuscitation of hearts from ventricular fibrillation or cardiac arrest has been more difficult in the presence of halothane anaesthesia. Owing to the electrical hazard in the operating room, no explosive agents are used. Careful observation of the patient and strict adherence to the fundamental principles of good anaesthesia is perhaps of more importance than the actual agents used.

Following induction, polyethylene catheters are inserted in the right and left antecubital veins and advanced well past the axilla. One of these is used for intravenous infusions and one to record venous pressures. A radial artery is cannulated to record arterial pressures; an alternative method may be used when the internal mammary artery is cannulated after the chest is opened. The electrocardiogram and electroencephalogram electrodes are inserted subcutaneously, a catheter is inserted into the bladder, a thermometer in the rectum, and the patient is positioned for surgery. Meanwhile, a technician has been assembling the pump oxygenator. The pump is of the finger type (Sigmamotor) and has a range of from less than 200 to 4,000 c.c. per min., which has been adequate for all perfusions. It is adjusted to operate in a totally occlusive manner. Hemolysis records have been kept on all cases, and show a range of increased plasma haemoglobin of from zero to 120 mg. per cent, with an average increase of 35 mg. per cent.

The oxygenator used is a bubble-type, as developed at the University of Minnesota.[4] If the calculated flow rate is over 1,500 c.c. per min., two oxygenators are used and the oxygen flow varies from 3 to 5 L. in each oxygenator. The bubbles are dispersed in debubbling chambers coated with a silicone preparation (Dow Corning Antifoam A). The oxygenated blood is collected in a helix reservoir, where further debubbling is accomplished as well as warming of the blood to body temperature by means of a thermostatically controlled water bath. The oxygenated blood is returned through the femoral artery, after passing through stainless steel filters (Abbott). The venous blood is collected in a venous reservoir by gravity drainage from the superior and inferior vena cavae. The pump is precalibrated to deliver flows of 50 c.c. per kilo per min. to adults and 60–70 c.c. per kilo per min. to children. Also, calibrations are carried out to enable the operator to increase the flow to a known quantity during perfusion if this be necessary to maintain adequate blood pressure. The various components, such as the reservoir and tubing of the oxygenator, are varied according to the size of the patient. Excessive pressure in the arterial line is kept to a minimum by inserting the largest possible catheter into the femoral artery. Intracardiac blood is gently suctioned off and returned for oxygenation. The reservoir is primed preoperatively with heparinized blood.

A careful calculation of blood loss is kept by weighing of sponges, and drapes and measurement of the amount suctioned. This loss is estimated throughout the case and losses are replaced intravenously with citrated blood. The gain or loss from the circulation during pumping is accurately measured after the perfusion and this figure is incorporated into the final estimations. Further checks on blood volume are made by pre and postoperative weighing of the patient, observation of the heart itself for venous filling following by-pass, as well as recorded arterial and venous pressures. One gram of calcium chloride is given intravenously for each litre of stored blood to counteract the citrate effect. During by-pass, the lungs are inflated to a continuous pressure of 5–10 cm. of water with nitrous oxide and oxygen. The venous pressure, arterial pressure, electrocardiogram, and electroencephalogram are observed continuously as well as periodic arterial and venous oxygen saturations and pH estimations. By these observations, the anaesthetist can be assured that the patient is receiving adequate perfusion or, if not, steps can be taken to improve the perfusion. The perfusion is judged satisfactory if the arterial pressure is over sixty, the venous pressure is zero, the electroencephalogram after an initial period of slow increased amplitude waves, returns to a pre-perfusion tracing (usually one to two minutes), the arteriovenous oxygen difference is maintined, and the pH is above 7.4.

The surgeons are required to wait for one to two minutes for stabilization of the perfusion, and to ensure proper functioning of the cannulae before proceeding with the cardiotomy. The continuous observation of the electrocardiogram during perfusion (Lead II) has been most valuable. First, from the standpoint of avoiding heart block which usually occurs as a needle is placed through the conducting bundle; if this needle is removed without tying the suture, permanent damage may be avoided. In our series we have had two cases with permanent heart block which are surviving over one year, and one case which died post-operatively, not as a result of the block, as the heart rate was maintained by electrical stimulation of the myocardium. Secondly, the electrocardiogram is observed for signs of myocardial anoxia during intermittent aortic clamping or inadequate coronary perfusion during aortic valve surgery.

Before by-pass, the patient is heparinized with 1.5 mg. of heparin per kilo of body weight and, following perfusion, the heparin is neutralized with 3 mg. of protamine per kilo, or, more recently, hexadimethrine bromide (Polybrene-Abbott). Postoperatively, the blood-clotting mechanism is investigated for circulating heparin and extra protamine may be necessary. Cardiac arrest has been produced in the past, using potassium citrate, but this technique is now replaced by intermittent aortic clamping or, more recently, arrest produced by selective cooling of the myocardium by means of a heat exchanger and coronary perfusion.

In all cases, body temperature has been maintained by use of a warming blanket and warming the helix reservoir. It is possible, in the future, that total body cooling may be carried out during by-pass using the heat exchanger in order to reduce the rate of flow. However, with no real limitations in time or volume of our perfusion, this does not seem necessary.

After over two hundred cases of total body perfusion using Sigmamotor pumps and bubble oxygenator as described, we have found no serious limitations to the technique. The average length of by-pass has been forty-five minutes, with the longest being two hours and ten minutes, and the shortest, five and one-half minutes. There have been no serious complications directly related to hemolysis, inadequate oxygenation, silicone intoxication, or, we believe, to bubbles entering the circulation from the oxygenator. In our hands, the most serious disadvantages of this type of perfusion apparatus has been the time-consuming preparation of the tubing and the expense per case of the disposable parts (approximately $75).

In the post-anaesthetic room, the patient receives constant attention from all

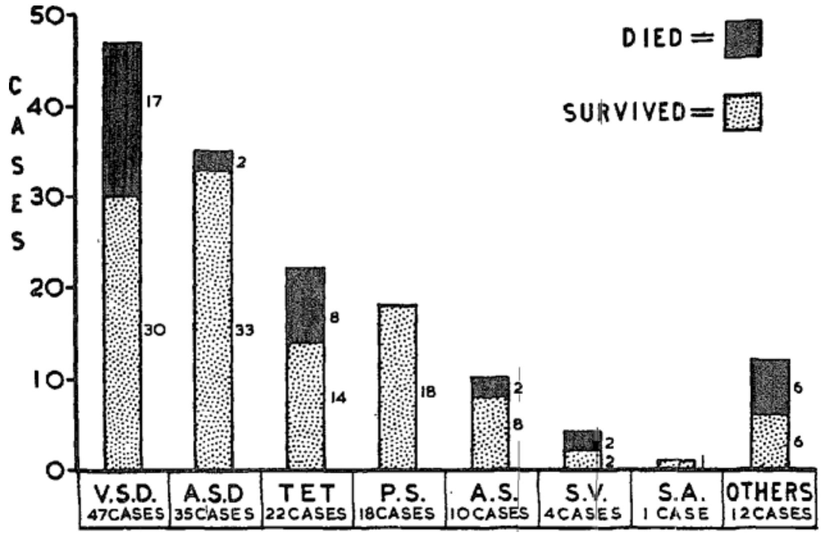


FIGURE 2. Mortality related to defect in congenital heart lesions.

personnel, until the respiratory exchange, arterial and venous pressures, cardiac rate and rhythm, and pH have stabilized. The respirations are assisted either continuously or intermittently using an intermittent positive pressure respirator (Bird). The cardiac action is observed for arrhythmias on a continuously recording cardioscope, pH determinations are made every fifteen minutes until stable, and acidosis is combatted by increasing respiratory excursion or the intravenous use of sodium bicarbonate. Blood is replaced as lost through chest drainage, and excessive bleeding is counteracted by coagulation factor estimations. Chest X-rays are taken routinely to check for haemothorax and atelectasis.

The post-operative care of these patients is very exacting and demands a thorough understanding of the defects involved and the surgical correction. Minute-to-minute changes in respiration, cardiac output, blood volume, myocardial irritability, and conduction mechanisms must be observed and combatted during the initial critical period. Any let down in the team effort at this stage may prove disastrous to a patient who, with careful scrutiny, would have recovered. Our mortality in these cases has been mainly due to diagnostic and surgical problems such as:

(*a*) failure to recognize additional defects such as a second ventricular septal defect or a ventricular septal defect associated with pulmonary stenosis or patent ductus arteriosus;

(*b*) pulmonary hypertension in the presence of ventricular septal defect, or ventricular septal defect associated with prolapsed aortic cusp;

(*c*) inability to correct the defect, as in advanced calcific deformity of aortic or mitral valves;

(*d*) Air emboli from the surgical field as in the repair of mitral valve disease, and emboli to the brain or to the mesenteric vessels from thrombi in the left atrial appendage;

(*e*) apparent inability of the myocardium to maintain adequate cardiac output postoperatively owing to myocarditis, ventriculotomy, or valvular deficiencies.

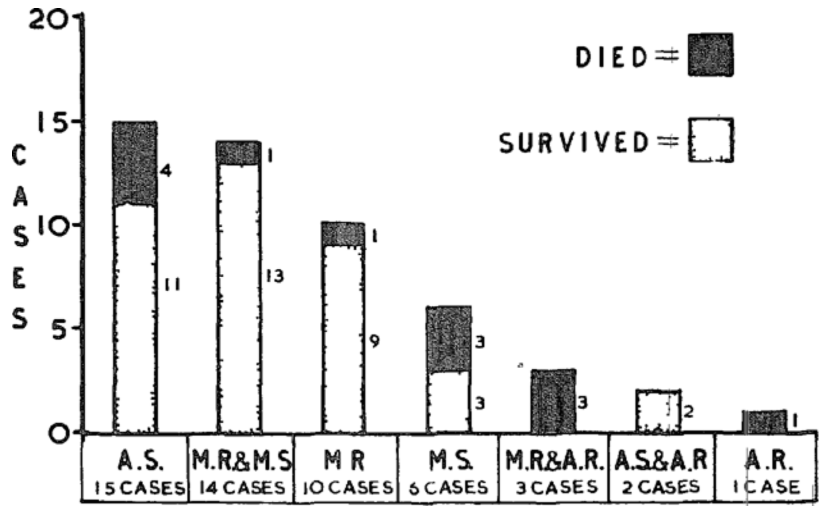


FIGURE 3 Mortality in acquired heart disease.

## SUMMARY

There are many types of pumps and oxygenators in use today, all of which, when handled properly, are satisfactory. No doubt, in the future, there will be many improvements in both pumps and oxygenators. However, at this time, the limitations of open heart surgery do not lie in perfusion techniques, but rather in accurate diagnosis of the defect or defects and the surgical ability to correct these defects. The anaesthetist may broaden the scope of surgical correction in these cases by taking his proper place on the open heart team and maintaining the patient during the procedure, leaving to the surgeon only those problems involved in correction of the defect. In order to do this, the anaesthetist, besides his usual anaesthetic duties, must take an active interest in the diagnosis and have a real understanding of the complexities of the defect to be repaired, as well as a thorough understanding of perfusion problems and the postoperative complications.

## RÉSUMÉ

Au cours des cinq dernières années, la chirurgie à coeur ouvert ou la chirurgie cardiaque où l'on emploie une pompe et un oxygénateur s'est développée rapidement. Dans les endroits où l'on a obtenu du succès dans ce domaine, on a attaché une grande importance à l'équipe dirigeant les opérations. Nous prenons l'opportunité actuelle pour préciser le rôle de l'anesthésiste dans cette équipe, maintenant que la période d'adaptation est passée. Au début, on attachait une grande importance aux méthodes employées pour dévier la circulation mais actuellement, depuis l'apparition de plusieurs types d'oxygénateurs et de pompes qui se sont avérés à point, on a concentré l'intérêt sur le diagnostic, les soins au cours de l'opération, la correction chirurgicale et les soins post-opératoires.

Après avoir opéré maintenant au-delà de 200 cas de lésions acquises ou congénitales chez des enfants ou chez des adultes, les anesthésistes ont assumé et joué un rôle de première importance comme membres de cette équipe depuis

la précision du diagnostic—qui est un facteur important au point de vue de la conduite de l'anesthésie, de la méthode de perfusion et de la technique chirurgicale proposée—jusqu'à la salle d'opération où l'anesthésiste assume la responsabilité de l'anesthésie, la mise en marche de la perfusion, le fonctionnement des moniteurs qui renseignent sur l'état du malade. Voilà ce qui laisse au chirurgien l'entière liberté d'essayer de résoudre les problèmes qui se présentent à lui.

Parmi les moniteurs, on compte: un électrocardiogramme, un électro-encéphalogramme, un appareil mesurant la pression artérielle et la pression veineuse, un oxymètre mesurant les saturations en oxygène et des appareils mesurant l'activité métabolique. Après une grande série de cas, nous estimons qu'il s'impose de contineur ces études pour mieux comprendre les réactions du malade au cours de ces opérations et aussi à cause du changement continuel des méthodes de perfusion et de correction chirurgicale.

L'anesthésiste suit la malade dans la salle de réveil et se concentre sur les problèmes de la respiration et du métabolisme et fait équipe avec le chirurgien pour rétablir l'équilibre chez le malade.

## REFERENCES

1. Bigelow, W. G., Callaghan, J. C., & Hopps, J. A. General Hypothermia for Experimental Intracardiac Surgery: The Use of Electrophrenic Respirations, an Artificial Pacemaker for Cardiac Standstill and Radio Frequency Re-warming in General Hypothermia. Ann. Surg. *132*: 531–537 (1950).
2. Bigelow, W. G., Lindsay, W. K., & Greenwood, W. F. Hypothermia: Its Possible Role in Cardiac Surgery. An Investigation of Factors Governing Survival in Dogs at Low Body Temperature. Ann. Surg. *132*: 849–866 (1950).
3. Warden, H. E.; Cohen, M.; Read, R. C.; & Lillehei, C. W. Controlled Cross Circulation for Open Intracardiac Surgery. J. Thoracic Surg. *28*: 331 (1954)
4. Lillehei, C. W.; DeWall, R. A.; Read, R. C.; Warden, H. E.; & Varco, R. L. Direct Vision Intracardiac Surgery in Man Using A Simple Disposable Artificial Oxygenator. Dis. Chest *29*: 1 (1956).