Evolution of anesthesia for cardiac surgery

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Since anesthetic techniques and concepts of patient management evolve only in response to new surgical treatments of disease, the evolution of cardiovascular anesthesia has been dependent on the successful application of surgical techniques for the treatment of heart disease. In the evolution of both, however, there was a large disparity in time in the course of events that mark the conceptual evolution of the therapy and its actual technical success in treating patients. Thus the concept of surgical treatment of mitral stenosis was at least 25 years old before its success in the late 1940s. And the concept of an extracorporeal circuit to permit operations within the great vessels preceded its successful application by 20 years. Similar lags preceded the general acceptance of tracheal intubation during anesthesia and the control of respiration to ensure carbon dioxide homeostasis. In recounting the evolution of anesthesia for cardiac surgery, therefore, it is necessary to recognize the credit due the conceptual innovators and assume proper humility for progress that was primarily attributable to the products of technological development and growth of new knowledge not directed specifically to improvement of cardiac anesthesia. Just as cardiac catheterization and angiography did not develop for the purpose of facilitating surgical therapy, so the development of nonflammable anesthetic agents and high quality operating room monitors was not a direct response to the needs of cardiac anesthesia. The evolution of cardiac anesthesia is primarily a history of the special application of technical and conceptual advances in the management of all surgical patients and was based on special understanding of the pathophysiology of heart diseases.

The beginnings of cardiac anesthesia can be pinpointed to the first report by Harmel and Lamont[1] in 1946. Although patent ductus arteriosus and coarctation of the aorta had been surgically treated before this time, there are no recorded descriptions of the anesthetic management. Harmel and Lamont reported their experiences with the Blalock-Taussig operation in their first 100 patients, 23 of whom died, a remarkable result because the diagnoses were made without benefit of cardiac catheterization, and only primitive anesthetic equipment was available for infants and children; endotracheal tubes suitable for some infants were not available. Even though their resources were limited they were good observers and recognized some major anesthetic problems, even though they were unable to solve them (*Table 1*).

They used a to-and-fro anesthesia system with assisted respiration, fearing that excessive pressures required for controlled respiration would increase the 5% incidence of postoperative tension pneumothorax and interstitial emphysema. However, no postoperative chest drainage was used and some pleural effusion existed in almost half their postoperative patients.

McQuiston[2,3] in 1949 and 1950 reported his experiences with 362 children who underwent cardiac operations including 218 who received a systemic-pulmonary shunt, primarily the Potts operation (*Table 2*). By contrast, McQuiston insisted on the need for controlled respiration with cyclopropane to ensure a quiet operative field to permit careful anastomosis. He assumed no relationship between control of respiration and postoperative pneumothorax or emphysema. However, chest drainage with negative pressure was used in all patients. He avoided the use of curare, because he could diagnose severe hypoxia during occlusion of the pulmonary artery by the onset of respiratory efforts despite control of respiration. He first used atropine instead of procaine

Table 1. Anesthesia for congenital pulmonary stenosis; Harmel and Lamont, 1946[1]

Observations
Induction of inhalation anesthesia was slow and required high anesthetic concentrations
Cyanosis decreased after preoperative morphine and after induction of anesthesia
Cyanosis increased after the pleura was open
Hypoxia developed during lung collapse and occlusion of the pulmonary artery
Recommendations
Preoperative morphine to decrease oxygen demand
Cyclopropane or intravenous morphine to effect a quiet operative field
Endotracheal cyclopropane; ether anesthesia

Table 2. Anesthetic problems in cardiac surgery in children; McQuiston, 1949 and 1950[2,3]

Observations
Good prognosis if cyanosis decreased after induction of anesthesia and vice versa
Recommendations
Surface hypothermia (92 to 93 F) to reduce oxygen demand
Controlled respiration with cyclopropane-oxygen
Atropine to treat bradycardia
Instillation of procaine into pericardium before exploration to decrease arrhythmias

block of the vagus to treat bradycardia, and with great wisdom used surface hypothermia to reduce oxygen demand of these cyanotic children. Laryngeal edema secondary to tracheal intubation at times requiring tracheostomy was not a rare complication, and a steam room was constructed to treat this complication. As witness to the surgical and anesthetic skills possessed by Potts and McQuiston, no mortality was reported in 112 patients with patent ductus and seven with coarctation. McQuiston mentioned the techniques of thiopental-curare for these same operations in Minneapolis, the use of ether at Mayo Clinic, the use of an Ayres system and even high spinal anesthesia by others. Unfortunately, these experiences have never been recorded.

The success of surgical treatment of congenital heart disease led more venturesome surgeons to attack acquired valvular disease. In 1951 Keown et al[4] reported on the anesthetic management of the first 50 patients on whom Bailey performed mitral commissurotomy (*Table 3*). Finding ether and cyclopropane unsatisfactory, they evolved a novel anesthetic technique based primarily on the continuous administration of 0.2% procaine intravenously, supplemented with thiopental, decamethonium, and N_2O. Arrhythmias, particularly tachycardia leading to pulmonary edema, seemed to be their greatest concern. Interestingly, at the end of operation they insisted on removing both the endotracheal tube and all intravenous lines to prevent coughing and fluid overload.

In 1953, Brown and Sellick[5] described their method of anesthesia, which had evolved from the management of 400 patients for cardiac and great-vessel operations. Their techniques like those of Keown et al[4] included the continuous infusion of procaine, thiopental, tubocurarine, and N_2O, which permitted the use of cautery to facilitate operation. They reported no data on results but their description of management leaves no doubt as to their astuteness as clinicians (*Table 4*). They pointed out that positive pressure of controlled operation does not decrease venous return in the presence of an open chest and believed that thiopental was contraindicated in constrictive pericarditis and cardiac tamponade.

Table 3. Anesthesia for mitral commissurotomy; Keown, et al, 1951[4]

Observations
Ether and cyclopropane were poorly tolerated by patients with mitral stenosis
Cardiac irritability was the major intraoperative problem
Coughing and straining perioperatively were poorly tolerated and should be prevented
Ventilation was restricted
Recommendations
Intraoperative electrocardiographic monitoring
Severe limitation of intravenous fluids
Intravenous procaine, thiopental, decamethonium, and N_2O for anesthesia

Table 4. Anesthesia for cardiac surgery; Brown and Sellick, 1953[5]

Observations
Importance of constant observation of the heart for quality of contractions, dysrhythmias, and manipulations
Importance of synchronizing ventilation with surgical maneuvers during controlled respiration
Excessive hypertension caused arrhythmias; moderate hypotension decreased cardiac work
Recommendations
Cautery to facilitate operation
Immediate availability of diluted resuscitative drugs in syringes
Anesthesia with IV procaine, thiopental, and tubocurarine-N_2O

Finally, O'Donnell and McDermott[6] in 1955 described their experiences with 42 patients in whom a Hufnagel valve was inserted into the descending thoracic aorta to treat severe aortic insufficiency (*Table 5*). Like Keown et al[4] they found that their patients tolerated a thiopental-N_2O-ether sequence poorly and one patient died during induction of anesthesia. They therefore used awake intubation after transtracheal tetracaine, then thiopental, and N_2O supplemented with intravenous morphine and at times with ether. It is not clear why they used no curare. They recognized the need for a high systolic pressure to provide an adequate perfusion pressure in these patients. They noted that hypotension frequently occurred with any anesthetic agent. It is remarkable that only two patients did not tolerate cross-clamping of the thoracic aorta in the presence of wide open aortic insufficiency with this anesthetic technique.

By 1955, it was clear that intracardiac operations would be feasible through the use of extracorporeal circulation and that new operations requiring development of new anesthetic techniques would replace imperfect ones. The further evolution of these anesthetic techniques, which is beyond the scope of this presentation, was based largely on the recorded observations and hazards that have been mentioned, and they are not many. To this list should be added the report of Little and Sutton,[7] in 1955, who reported on an anesthetic technique for mitral commissurotomy, which was an improvement on that suggested by Keown et al,[4] particularly in their use of a continuous infusion of succinylcholine (*Table 6*). More significant than their innovation, however, was their scholarly approach to the problem of mitral valve disease, its pathologic physiology, anesthetic and surgical requirements, and a careful description of their interactions in all aspects of perioperative care. Their report provided an orderly model for the logical approach to the solution of anesthetic problems associated with correction of a specific cardiac disease.

Continued improvement in the results of surgical treatment of the cardiac diseases described resulted not only from the availability of better drugs (halothane, propranolol) and improved equipment (ventilators, monitors, plastic cannulas), but also from the acqui-

Table 5. Anesthetic problems of surgical correction of aortic insufficiency; O'Donnell and McDermott, 1955[6]

Observations
Ether anesthesia was poorly tolerated because of cardiac depression
Recommendations
Oscilloscope and direct writing electrocardiogram for continuous monitoring
Maintain systolic blood pressure >100 mm Hg by phenylephrine infusion
Start two infusions with 15-gauge needles
Defibrillator available in operating room

Table 6. Succinylcholine-N_2O anesthesia for mitral commissurotomy; Little and Sutton, 1955[7]

Recommendations[7]
Little or no parasympatholytic drug as premedication
Anesthesia with N_2O ± meperidine and succinylcholine 0.2% infusion
Intubation and extubation with apneic technique using succinylcholine
Tracheal suction only when absolutely necessary
Control of cardiac arrhythmias with procaine amide, neostigmine or atropine
Compression of carotids at time of valve fracture, if history of atrial fibrillation

sition of new knowledge. New knowledge, both basic and clinical, led to important changes in concepts of patient management (*Table 7*), which more subtly affected treatment outcome. Here, it is as difficult to identify the innovators as it is to measure the impact of a change in concept. Suffice it to recognize the importance of conceptual contributions to progress and the contributors whoever they are.

Table 7. Important conceptual contributions in the evolution of cardiac anesthesia

Safety of tracheal intubation of infants
Understanding hemodynamic effects of controlled respiration
Resolution of the "curare-death" issue by succinylcholine
Continuation of some and cessation of other preoperative drugs
Hazards of diuresis and fluid restriction
Understanding effects of anesthetics on the heart and regional circulations
Appreciation of benefits of hemodilution and hazards of polycythemia

References

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