

From the Pages of History

History of Cardiac Anesthesiology

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History

History is replete with prejudice, pathos and superstition. The history of cardiac and great vessel surgery and anesthesia to sustain surgical effort is no exception¹. The early history of anesthesia for operations on the heart is that of anesthesia itself. The evolution of heart surgery per se was slow. Experimental work had started in 1882. Block successfully closed heart wounds in rabbits and strongly advocated its use in man². Billroth nonetheless continued a steadfast opposition to any cardiac interference and 1883 wrote, "A surgeon who would attempt such an operation (cardiac surgery) should loose the respect of his colleagues³".

This anecdote from early years of heart surgery indicate the challenges faced by the anesthesiologists: the need to preserve life while enabling the surgery on the heart. The first operations were not performed on adults but on infants and children with congenital malformations of the heart and great vessels; malformations if left uncorrected caused early death⁴. Surgeons and their anesthesiologist peers next addressed correction/ replacement of damaged heart valves^{5,6}; then the treatment of coronary artery disease^{7,8}. They then accomplished heart transplantation and used artificial heart pump devices to sustain life⁹. The measures that preserved life in these patients were next applied to patients with similar heart disease but undergoing non cardiac surgery; previously considered too dangerous to apply.

Hassel's review supplies authoritarian rendering of the history of cardiac anesthesia and Mushin and Benumof similarly described related field of thoracic anesthesiology^{3,10,11}.

The Beginnings (1896-1937)

Ludwig Rehn of Frankfurt first successfully sutured a stab wound of the heart in September 1896- an event many consider as the beginning of cardiac surgery. Following this, only modest efforts at cardiac surgery occurred in the next forty years (example closed pulmonary embolectomy, pericardiectomy, closed valvotomies etc.). However other important advances were occurring that led to its subsequent development. Blood typing and transfusion [1900-15], discovery of heparin and its neutralization by protamine [1916-39], cuffed rubber endotracheal tube [1919-1926], online carbon dioxide absorber [1924], Cyclopropane [1933], Thiopental [1934]¹²⁻¹⁴.

Closed Heart Surgery (1938-1951)

In 1938, Robert Gross, MD, a surgical resident, first successfully ligated a patent ductus arteriosus of a seven year old boy at Children Hospital, Boston. Anesthesia was provided by Ms Bessie Lank, RN, via a tight fitting mask¹⁵. In October 1944, Clarence Crawford, MD, of Stockholm, first successfully repaired a coarctation of aorta. Alfred Blalock, MD, in November 1944, successfully created a subclavian to pulmonary artery shunt to palliate Tetralogy of Fallot at Johns Hopkins Hospital¹⁶. In 1946, Merel Harmel and Austin Lamont described anesthetic management for the 100 Blalock Tausig operations, the first cardiac anesthesiology paper¹⁷. Historically, cardiac anesthesia began with preoperative care for these early surgeries. Early surgeons were quick to recognize the importance of the cardiac team and critical role the (cardiac) anesthesiologists played in achieving success. Gross and Hufnagel and Nylin repaired coarctation of aorta within short time of the initial Blalock- Tausig shunt. In 1948, Charles Bailey, MD, of Philadelphia started a successful series of closed mitral commissurotomies. Anesthesia for Bailey's cases was provided by Kenneth Keown, MD, who in 1956 authored the first book on cardiac anesthesia¹⁸. Charles Hufnagel, MD, in 1952, began inserting aortic valve in the descending aorta to palliate aortic regurgitation without the benefit of left heart bypass, with anesthesia provided by John O'Donnell, MD and Thomas McDermott.

Open Heart Surgery (1952-1959) Arrives

In September 1952, F J Lewis, MD, closed an atrial septal defect under direct vision using moderate surface hypothermia at the University of Minnesota. On May 6, 1953, John H Gibbon Jr, MD, did the same utilizing total cardiopulmonary bypass with a heart lung machine. Dr Gibbon had no other success, which was partly due to lack of participation of physician anesthesiologists¹⁹. A year later, C Walton Lillehei, MD, at the University of Minnesota started his remarkable series of open heart surgery, utilizing the subject's parent as a biological pump oxygenator (controlled cross circulation)²⁰. Anesthesia was provided by R T Patrick, MD. Cardiac anesthesiologists now had to learn about the pump, invasive monitoring, anticoagulation and bleeding and "pump lung"²¹.

Explosive growth of Cardiac surgery (1960-1969)

Rapid growth and expanded application of cardiac surgery in the 1960s required many more cardiac anesthesiologists with new knowledge and skills. Advances in cardiac surgery spurred the development of Cardiac Anesthesiology. We changed from open drop ether to modern anesthetics and ventilation with endotracheal tube¹⁶. Successful prosthetic heart valves were implanted in 1960. Human heart transplantation and aortocoronary bypass grafting occurred in 1967⁹. In the same year, J Earl Wynards, MD, and colleagues of Montreal published first articles on anesthetic management of patients undergoing CABG for CAD. He also described post operative ventilation for improved peri-operative outcome⁸. Mustard's operation for transposition of great arteries in 1963 and 1968, was facilitated by the reintroduction of deep hypothermia and circulatory arrest by the groups in Seattle and Auckland. Closed chest massage was introduced by Peter Safar, MD so also permanent implantable pacemaker and heamodilution prime.

Many important early contributions to pediatric cardiac anesthesiology were made by Dr Arthur Keats. Keats described the anesthetic problems in CPB, heparin anti coagulation, the safety of tracheal intubation in pediatric patients and the hemodynamic effects of anesthesia and controlled ventilation among many others¹⁶. He reviewed the peri-operative management of 400 infants anesthetized between 1956-1963 as well as specific problems associated with excessive airway pressure in TOF patients²².

Monitoring of left atrial pressure became common gave new insight in discrepancies between left and right heart functions²³. The appearance of surgical intensive care units and ICU ventilators offered new avenue for the anesthesiologists. The introduction IABP in 1967 offered a new approach (mechanical circulatory assist) for the treatment of peri- operative cardiac failure.

Monitoring

The first patients undergoing cardiac surgery were anesthetized with minimal monitoring such as finger on a temporal or carotid artery¹. However, as surgery became more complex and particularly after cardiopulmonary bypass was employed, monitoring of hemodynamic variables became an important component of cardiac anesthesiology. In 1972, Civetta and Gabel described the use of pulmonary artery catheter (Swan Ganz catheter) intra and post operative period²⁴. In 1973, Lappas et al demonstrated that pulmonary capillary wedge pressure accurately reflected left atrial pressure intra operatively which in turn reflected left ventricular filling and function²³. Indeed invasive monitoring and expertise sometimes seemed to define cardiac anesthesiologists. They demonstrated their skill by their ability to "slip in" invasive lines quickly and deftly, equating this skill, perhaps erroneously with superior knowledge. The need for arterial pressure monitoring and access to arterial blood samples provided sufficient reason for inserting an indwelling arterial catheter. Measurement of central venous pressure seemed similarly beneficial in helping to

estimate blood volume and heart function; although Echocardiogram is now considered a better reflection²⁵. At MGH, Laver explained the philosophy of hemodynamic monitoring versus clinician's intuition: "If the measurement contradicts your clinical impression, change your clinical impression."

The introduction pulmonary artery catheter in 1970s provoked controversies. Some outstanding cardiac anesthesiologists considered the technology essential for optimal management of cardiac surgical patients. Reports in 1987, indicated that use of PAC added little to the management of many cardiac surgical patients. Like all tools and drugs, risks and benefits need to be balanced. In select patients with left ventricular dysfunction PAC facilitated successful management but in many others it imposed unnecessary risks and expense.

Cardiac anesthesiologists and surgeons had no view of the internal anatomy of the heart as the complexity of surgery progressed. Trans esophageal echocardiogram (TEE) changed all that.

In 1980, introduction of 'M mode' (One dimension) TEE by Matsumoto was followed by 1980²⁴. Cahalans description of 2 D echocardiogram and deBruijn and colleagues report of color flow Doppler TEE in 1987²⁶. More recently TEE allows 3 dimensional view of structures and even better visualization²⁵. TEE has permitted cardiac anesthesiologists to literally look into the heart and become intraoperative cardiac diagnostician, providing the peri-operative diagnosis and guiding the surgeons for the appropriate procedures. Cardiac anesthesiologists can now inform the surgeons in real time of new intraoperative findings make new diagnosis and confirm proper repair of cardiac lesions. TEE has transformed the intraoperative experience for patients, anesthesiologists and surgeons alike particularly in congenital heart and valvular surgeries. No other monitoring technology has provided comparable benefits to intraoperative decision making.

Anesthetic Drug Regimen

Before 1969, Cyclopropane, Ether or Halothane dominated anesthesia for cardiac surgical patients. The flammability of the first two led to the dominance of halothane. Death during induction of anesthesia and inability to differentiate cardiac and pulmonary failure after cardiopulmonary bypass post operatively were common. A search for better approaches to anesthesia led to the introduction of high opiod anesthesia by Lowenstein at MGH^{27,28}. It was noted that high dose of intravenous morphine given, post operatively relieve pain and by depressing respiration enabled patients to tolerate tracheal tubes and mechanical ventilation. The paper published in 1969 in New England Journal of Medicine, documented the hemodynamic effects of high doses of morphine in patients with valvular heart disease changed the conduct of anesthesia. However, patients with coronary artery disease, surgical stimulation during high dose morphine anesthesia was accompanied by tachycardia and hypertension; that increased the oxygen demand and consumption. The originators of high dose 'opiod anesthesia' documented limitations of the technique including patient awareness^{27,28}.

The obligatory period of post operative ventilation was an initial stimulus for using high dose opioid. While advantageous in many patients, it proved unnecessary in some patients. Subsequent small and big studies revealed, not surprisingly, that there is no ideal 'cardiac anesthetic'. Optimal care for any given patient requires matching patient's pathophysiology with the pharmacology of the anesthetics and other drugs by the knowledgeable and skilled clinicians.

Present day, anesthesiologists deliver a mixture of drugs: moderate dose of opioid (fentanyl or sufentanyl), is used to minimize adrenergic response to noxious stimulation. Muscle relaxants keep the patient from moving. Potent inhaled anesthetics augment relaxant effects, protect the heart, modify hemodynamic perturbations and together with benzodiazepines curtail memories of intra operative events^{29,30}.

1970-1979: Cardiac Anesthesia Gets Organized

Joel Kaplan, MD, among others, "sold" the importance of cardiac anesthesiologists to surgeons and anesthesiology residents. He popularized the use of V5 lead (1976) and PAC to detect myocardial ischemia (1981) and nitroglycerine infusion to treat it³¹. He edited a comprehensive textbook on Cardiac anesthesia, which became the standard textbook (1979)³⁰. Fellowship in cardiac anesthesia appeared and attracted many residents who became leaders in this sub specialty. In 1972, the Association of Cardiac Anesthesiology was founded followed by the Society of Cardiovascular Anesthesiology (SCA) in 1978³².

1980-1989: Maturation of Cardiac Surgery and Anesthesia

With the introduction of cyclosporine in 1980, heart transplantation grew from about 100 per year to 2400 per year in the next five years. The first artificial heart was implanted in 1982, and although it failed as a permanent device, it paved the way for LVAD and RVAD. Internal mammary artery became the bypass graft of choice for coronary artery bypass. Mitral valve repair gained acceptance. Better understanding and modulation of the pathophysiology of CPB was being achieved. Alpha stat management during hypothermic CPB was advocated in 1983 and became widely practiced. Measurement of cerebral blood flow in humans during bypass, spurred interest in the effect of CPB on the brain, followed in 1986 by Nussmeier and Slogoff's study of cerebro protective effects of barbiturates during CPB. The Alabama group drew attention to systemic inflammatory response to CPB in 1981 and this led to the serendipitous discovery of the benefits of aprotinin in reducing blood loss during CPB by David Royston MD and others in 1987. By the end of the decade, membrane oxygenators had nearly replaced bubble oxygenators, and centrifugal pumps were gaining in popularity. Sebastian Reiz, MD and colleagues in 1983 called attention to isoflurane steal and in 1985, Stephen Slogoff and Arthur Keats emphasized the incidence and significance of peri-operative myocardial ischemia²⁸. At the end of this decade, Kenneth J Tuman, MD and others and Drs Slogoff and

the outcome. In 1987, Joel Kaplan, MD, started the first journal devoted to cardiothoracic anesthesia and in the same year nitric oxide was identified as the endothelial derived relaxing factor^{30, 33}.

1990-2001: Leadership

Major changes have occurred in cardiac surgery in past 11 years^{31,34}. This called for adaptive changes by cardiac anesthesiologists. Some of these were "fast tracking", warm bypass, retrograde cerebral perfusion, augmented venous return, minimal access, port access, Off pump coronary artery surgery and use of stentless valves. Heparin coated circuits and modified ultra filtration were introduced and also use of nitric oxide in the OR and in the ICU. Cardiac anesthesiologists conducted studies of small animal models (egs Grocott, Hindman), cardiac molecular biology, inflammatory response to CPB, effect of CPB on coagulation (Levy, Despotis, Gravlee) and multi centre outcome studies (Mangano). Anesthesiologists in collaboration with surgeons and cardiologists, contributed to the development of guidelines for pre-operative evaluation of cardiac patients for non cardiac surgery (Fleisher). Cardiac anesthesiologists edited or coedited two textbook on cardiopulmonary bypass (Gravlee, Davies, and Mora). CSA, ASA and the American Society of Echocardiologists developed "Practice guidelines for Peri operative TEE" in 1996 (Thys et al). In 1999 "Guidelines for Comprehensive Intraoperative Examination" were written (Shanewise et al). In 2000, SCA submitted an application to the Accreditation Council for Graduate Medical Education for resident education program in the sub specialty of Cardiac Anesthesia. Cardiac anesthesiologists have long held leadership positions in ASA, subspecialty societies including the Society of Education in Anesthesia and their hospitals and departments including chairmanships. Now they are advancing to even higher levels of leadership, including atleast five deans of Medical Schools (Kaplan, Reves, Roizen, Slogoff and Miller).

Indian Scenario

1. The first departments of cardiac anesthesiology were established at Sri Chitra Tirunal Institute of Medical Sciences and Technology, Thiruvananthapuram and All India Institute of Medical Sciences, New Delhi. Both these institutes started PDCC course in cardiac anesthesiology and subsequently DM program in Cardiac anesthesiology. Now other institutions like Nizams Institute of Medical Sciences, PGI Chandigarh and SGPGI at Lucknow have started DM courses in cardiac anesthesiology. Indian Association of Cardiovascular Thoracic Anesthesiology was formed in 1996 and now has more than 2500 life members. The association conducts training in TEE and awards diploma, FIAC TA. in cardiac anesthesiology and TEE. IACTA conducts annual conferences and have vibrant scientific program.

Summary

The success of surgery for the heart is direct result of ten important factors

- 1) Anesthetic developments that allowed Sternotomy /thoracotomy to be accomplished successfully.
- 2) The development of antibiotics that minimize or prevent post operative infections.
- 3) The development of blood banks which allowed blood and blood products to be stored and used as needed.
- 4) The ability of cardio-thoracic surgeons to solve the mechanical problems of various heart lesions.
- 5) The desire of the practitioners of Medicine to aid their patients by referring them to cardiac centers.
- 6) The courage of the patients, Physicians, surgeons and Anesthesiologists in attempting the unknown and entering upon uncharted course.
- 7) Improved Heart lung machines that provide better tissue oxygenation and perfusion.
- 8) Pre-operative and post operative respiratory care.
- 9) Monitoring equipments and improved peri-operative anesthetic care.
- 10) Improved anesthetic agents.
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In this field no single factor can be stated to be responsible for the success of Cardiac Surgery. It is truly the team work of the entire medical profession, nursing personnel and hospital staff, that has afforded so many patients a new lease of life.

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Types Count, Numbers Don't!

It is known for some time that gut microbiota play a significant role in our health. Microbiome profiling is done diagnostically to find out the contribution of each type to the clinical status. However, until now it is quantitative, reflecting the assumption that the contribution of each type of microbe was proportional to its numbers in the gut microbial population. This assumption may not be correct. In a new study carried out in University of Oregon, the researchers introduced one type of intestinal bacteria at a time, and also in combination, to zebra fish with germ-free gut and measured the phenotypic effect by observing the bacterial numbers and the host neutrophilic response. To their surprise, they found that the dominant effect was not always caused by quantitatively dominant type of bacteria but by microbes that were in small numbers. The implication is that the measurement of "per-capita" contribution of each type of bacteria is necessary to understand the effect. The authors suggest that the microbiome profiling should be qualitative rather than being merely quantitative to reap the full diagnostic and clinical benefit in human diseases like IBD (*Cell Host & Microbe*. Volume 18, Issue 5, p613-620, 11 November 2015)

- Dr. K. Ramesh Rao