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An introduction to anaesthesia

General anaesthesia

Nitrous oxide was first synthesized by Joseph Priestley in 1772, and had been known to have analgesic properties since the turn of the nineteenth century, but it was mostly used as a recreational drug (laughing gas). Horace Wells, a dentist in Connecticut, USA, noticed that an assistant under the influence of the gas suffered a significant injury to his shin, but appeared unaware until later. Wells subsequently had one of his wisdom teeth extracted painlessly whilst inhaling nitrous oxide and went on to use the gas in his own practice in 1844. Unfortunately, in 1845, when invited to demonstrate the effects on a patient having a dental extraction at Harvard Medical School, the patient complained of pain and Wells was denounced as a fraud. These early administrations of nitrous oxide carried the risk of severe hypoxia as it was given in close to 100% concentration to obtain an adequate effect. This was solved in the late 1860s, when it was supplied in cylinders under pressure and given in conjunction with 20% oxygen, which lead to an increase in its use.

The first successful public demonstration of painless surgery occurred on 16 October 1846 at Massachusetts General Hospital. William Thomas Green Morton, a dentist, presided over the inhalation of ether vapour (diethyl ether, $(C_2H_5)_2O$) by Edward Abbott while John Warren, the senior surgeon, removed a tumour from Abbott's jaw. It wasn't until a few weeks later that a name for the state induced was proposed by Oliver Wendell Holmes, Professor of Anatomy and Physiology at Harvard University: 'anaesthesia,' from the Greek *an* (without) and *aisthesis* (sensation). Compare the simple device used by Morton (Figure 1.1a) with one of today's anaesthesia machines (Figure 1.1b).

Unsurprisingly, news of this discovery spread rapidly and on 19 December 1846, Dr Francis Boott, a physician in London, encouraged James Robinson, a dentist, to give ether to a patient for the extraction of a wisdom tooth. The result was so impressive that Dr Boott persuaded Robert Liston, Professor of Surgery at the University of London, to allow ether to be given during the amputation of Frederick Churchill's leg, which proved to be a complete success.

Despite the spreading popularity of ether anaesthesia, it was acknowledged that there were problems controlling the dose as the liquid cooled as it vaporized. The first person to apply scientific methodology to giving ether vapour was John Snow, a London physician who invented several pieces of equipment to allow the delivery of known concentrations. He subsequently used chloroform in preference to ether, and in April 1853 successfully gave chloroform to Queen Victoria during the birth of her eighth child, Leopold. He repeated this process in April 1857 at the birth of Victoria's last child, Beatrice. By the end of the nineteenth century, combinations of nitrous oxide, ether and chloroform, with oxygen, were being used widely to achieve anaesthesia.

Over the next 50 years a number of other inhaled anaesthetics were introduced, including ethyl chloride, cyclopropane and trichloroethylene but ether, chloroform and nitrous oxide dominated. The next major breakthrough came when in 1951 Charles Suckling, working at Imperial Chemical Industries (ICI) in Manchester, synthesized halothane and in 1956 it was first used clinically by Michael Johnstone at the Manchester Royal Infirmary. This was the start of the modern era of inhaled anaesthetics and the next 40 years saw the synthesis of several complex halogenated ethers, which yielded the drugs in use today: isoflurane, sevoflurane and desflurane.

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Companion website: www.lecturenoteseries.com/anaesthesia

(a)

(b)

Figure 1.1 (a) Replica of the ether inhaler used by William Morton to give the first public demonstration of general anaesthesia, 16 October 1846, in Massachusetts General Hospital. Reproduced with kind permission of the Association of anaesthetists of Great Britain and Northern Ireland. (b) Modern integrated anaesthesia system.

The other key discovery that revolutionized general anaesthesia was of neuromuscular blocking drugs or 'muscle relaxants'. Amazonian Indians were known to apply a plant extract called curare to the tips of their arrowheads that left their prey paralysed. In 1812, it was shown that artificial ventilation could keep animals alive until the poison wore off and they made a full recovery. The science behind this observation was revealed in 1850 by the French physiologist Claude Bernard when he showed that curare acted at the neuromuscular junction. In 1900, the anti-curare effects of physostigmine were described and so the effects of curare could be reversed when needed, rather than waiting for spontaneous recovery. Interestingly, the first clinical use of curare was not in anaesthesia, but in the treatment of tetanus in 1934. It was not until 1942 that Harold Griffith and Enid Johnson at Magill University, Montreal, used curare as part of their anaesthetic for a patient undergoing an appendicectomy. Curare (d-tubocurarine) was first introduced into clinical practice in England by Gray and Halton in Liverpool in 1946. Five years later suxamethonium (succinylcholine) was introduced into clinical practice, again after a considerable delay since its first description in 1906. In 1966, pancuronium, the first synthetic muscle relaxant,

was introduced, followed in the early 1980s by vecuronium and atracurium.

Finally, no writing on the history of general anaesthesia is complete without a brief mention of tracheal intubation. This evolved from the use of metal tubes in the eighteenth century which were passed into the trachea to aid with resuscitation. It was William MacEwen, a Glasgow surgeon, who deliberately first introduced a flexible metallic tube into a patient's trachea through which chloroform in air was given. The patient required the removal of a tumour at the base of their tongue and would otherwise have needed a tracheostomy. Numerous similar techniques followed, but it was Magill and Rowbotham who first passed tubes into the trachea to secure the airway and allow unhindered access to the face and airway to perform reconstructive surgery. The endotracheal tubes that Magill went on to develop were reusable, made from rubber, and became the universal standard for over 40 years. They have now been replaced by single-use tubes made from polyvinyl chloride (PVC).

Local and regional anaesthesia

The Indians in Bolivia and Peru had chewed the leaves of the bush *Erythroxylum coca* for its stimulant properties which enabled them to go on prolonged hunting trips without tiring. In the mid-1850s, the active ingredient, an alkaloid named cocaine, had been extracted and was investigated by Freud as a remedy for morphine addiction and use in psychoneurotic patients. Aware of the effects of cocaine in 'deadening' mucous membranes, he asked a colleague, Carl Koller, an eye surgeon in Vienna, to carry out some investigations. Koller experimented firstly on animals, then himself and friends and finally on patients. He showed that instilling cocaine into the conjunctival sac made eye operations completely painless for the first time. By the 1890s, cocaine was being used for nerve and plexus blocks, but many of the pioneers were unaware of its addictive properties and experimented upon themselves, becoming addicts in the process. This problem lead to the development of safer alternatives and by the turn of the twentieth century, stovaine and procaine (novocaine) were widely used. Lignocaine (lidocaine) was synthesized in 1943 and first used clinically in 1948 and bupivacaine appeared in 1963.

The development of central neural blockade or spinal anaesthesia came about by accident in 1885. James Corning, a New York neurologist, accidentally injected cocaine intrathecally in a dog and, noting its profound effect, repeated the injection in a patient. He coined the term 'spinal anaesthesia', suggesting it might have a use for surgery. In 1898, August Bier, a German surgeon, gave the first deliberate spinal anaesthetic for surgery with cocaine. Having repeated the technique successfully on a further small group of patients, Bier allowed his assistant to give intrathecal cocaine to him, thereby proving his faith in the technique. The introduction of stovaine and procaine eliminated the risk of toxicity and addiction, and the popularity of spinal anaesthesia spread.

Epidural anaesthesia soon followed, firstly using a technique of giving the drugs via the caudal route. The lumbar route, which is widely used today, was popularized in Europe in the 1930s by the Italian surgeon Achille Dogliotti and in the UK in the 1940s by Charles Massey Dawkins. Shortly after, the first use of a catheter in the epidural space to allow continual analgesia was described.

Anaesthesia today

Anaesthesia has progressed from the early days of dripping ether or chloroform onto a piece of gauze held over the patient's face. Lack of control and the use of relatively toxic drugs meant that effects were often unpredictable and complications, including death, were not uncommon. Monitoring the patient meant feeling their pulse, looking at their colour and observing rate and depth of breathing. Training was done 'on the job' and there were no standards or regulations.

Currently in the United Kingdom, doctors who have completed their medical training then undergo a further seven years training to become anaesthetists. During this time, they take part in a structured training programme and sit postgraduate examinations to become a Fellow of the Royal College of Anaesthetists (FRCA) [1.1]. In addition, many also undertake additional subspecialization training, for example in critical care, pain management, cardiothoracic, neurosurgical or paediatric anaesthesia. Anaesthetists form the largest group of specialists within the NHS and it is estimated that over 60% of patients will encounter an anaesthetist during their time in hospital.

Today, anaesthetists must have a detailed understanding of physiology, pharmacology, anatomy and physics. This knowledge is essential; during a routine

anaesthetic (if such a thing exists!) a wide variety of anaesthetic techniques, sophisticated equipment and drugs is available and the correct combination of these must be used to achieve the effect required. Many of the drugs used and the 'stress' of surgery have significant effects on the patient's physiology. As a result, patients must be closely monitored; during most operations the anaesthetist will use a wide variety of different electronic monitors which give information on the physiological changes taking place, concentrations of anaesthetic drugs and oxygen and performance of ventilators. Such advances have made modern anaesthesia extremely safe; since the 1960s, mortality attributable to anaesthesia has fallen 10-fold, from 357 to 34 per million anaesthetics.

Today's anaesthetist no longer works in isolation giving patients anaesthesia to allow surgery; they work as part of a team and take on a greater number of roles and responsibilities than ever before.

The preoperative assessment

Although not all patients need to be seen by an anaesthetist in a preoperative assessment clinic, all patients do need to be assessed by an appropriately trained individual. This role is frequently undertaken by nurses. They will take a history, examine the patient and order investigations, according to the local protocol. The primary aim is to identify those patients at low risk of complications during anaesthesia and surgery and who can be listed safely without the need to be assessed at this point by an anaesthetist. Clearly, not all patients achieve this goal and will need further investigations prior to being seen by an anaesthetist in the clinic.

The anaesthetic assistant

Many surgical procedures performed today would not be possible without the advances that have been made in anaesthetic drugs, techniques and equipment available to anaesthetists. However, it is important to recognize the fact that, unlike even 50 years ago, anaesthetists are now the leaders of a team of healthcare professionals caring for patients pre-, intra- and postoperatively. Whilst working in the operating theatre, they are always assisted by either an operating department practitioner (ODP) or an anaesthetic nurse. These individuals have undergone a training programme in order to assist the anaesthetist in the safe delivery of anaesthesia, and have a wide variety of responsibilities, from checking and preparing equipment to assisting in the resuscitation of patients.

Physicians' assistant (anaesthesia)

The latest member of the anaesthesia team, introduced in 2004, is the physicians' assistant (anaesthesia) (PA(A)). PA(A)s are fully trained professionals who have completed a postgraduate diploma and work under the direction and supervision of a consultant anaesthetist, a typical situation being where one consultant anaesthetist supervises two PA(A)s or one PA(A) and an anaesthetic trainee. The roles of the PA(A)s are generally to help increase operating theatre efficiency by allowing quicker turnround between operations, thereby increasing the throughput of patients. They have also found roles in the preoperative assessment clinic, cardiopulmonary exercise testing and cardiac arrest team.

Immediate postoperative care

Any patient who has received an anaesthetic will spend some time in a postoperative or postanaesthesia care unit (PACU), often simply known as the 'recovery unit'. This is a specialized area where patients are closely monitored by specially trained nurses or ODPs for a period of time immediately after anaesthesia and surgery. The PACU was developed in response to the significant number of preventable deaths that occurred during recovery from anaesthesia and surgery. Nowadays, any patient who is not returned immediately to a critical care area will spend time in a PACU where their vital signs will be monitored and drugs given for analgesia and relief of nausea and vomiting. Ultimately, the anaesthetist retains overall responsibility for this aspect of patient care until discharged to a ward.

Anaesthetists in critical care

In 1952, Copenhagen suffered a devastating polio epidemic that resulted in hundreds of patients experiencing respiratory and bulbar failure. Many only survived because around 1000 medical and dental students were recruited to ventilate manually these patients, often for several weeks, via tracheostomies (Figure 1.2). As a result, the following year, Bjorn Ibsen, the anaesthetist who had suggested this solution for the management of these patients, set up the first intensive care unit (ICU) in Europe and many consider him to be the 'father' of intensive care.

During the 1960s and 1970s, ICUs were gradually established in the United Kingdom and Professor

Figure 1.2 Young child being ventilated by hand via a tracheostomy during the 1952 polio epidemic in Copenhagen. Reproduced with kind permission of the Medical Museum, University of Copenhagen.

Ron Bradley, who was probably the first full-time intensive care clinician, ran the ICU at St Thomas' Hospital in London. As hospitals established intensive care units, many were run by anaesthetists by virtue of their training and experience of caring for ventilated patients. Today, intensive care has become a multidisciplinary specialty with dedicated ICU nurses, physiotherapists, pharmacists, dieticians, technicians, radiologists and microbiologists. The dedicated staff and specialized equipment in the modern ICU allow support or even temporary replacement of the function of many of a patient's organ systems in the face of critical illness and injury. It is this knowledge and skill that underpins intensive care medicine (ICM). In the UK, intensive care has now become a stand-alone specialty, with the formation of the Faculty of Intensive Care Medicine (FICM) in 2010, with a separate training programme as of 2012. As a result, training in ICM is now accessible to staff from other medical specialties, for example respiratory medicine, renal medicine, cardiology and emergency medicine, as well as from the more traditional route via anaesthesia [1.2] [1.3].

Anaesthetists in pain management

The purpose of anaesthesia is to enable pain-free surgery. This has led to anaesthetists using their skills to become involved in the management of pain in both the acute and chronic setting. In 1990, a joint publication from the Royal College of Surgeons of England and the College of Anaesthetists (as it was then), *Pain after Surgery*, highlighted the need for hospitals to develop services to ensure adequate pain relief, and reduce the incidence of side-effects and the associated postoperative morbidity and mortality. Anaesthetists have taken a leading role in the multidisciplinary acute pain teams that are now established in hospitals to achieve this.

Chronic pain management in both cancer and non-malignant conditions is also an area where anaesthetists have developed a subspecialty interest. Chronic pain affects all ages and all parts of a patients' wellbeing and successful management requires a biopsychosocial assessment of all the aspects of life affected by pain.

To achieve this, anaesthetists were at the forefront of the establishment of 'pain clinics', now more appropriately called pain medicine or pain management. These allow patients to be treated on an outpatient basis where, in addition to assessment and psychological support, injections, neuromodulation and participation in rehabilitation teams are used to provide individual pain management programmes.

The Faculty of Pain Medicine of the Royal College of Anaesthetists was established in 2007 to provide guidance on standards in pain medicine. The Faculty also sets the training requirements and an examination for those new to the specialty and intending to pursue a career with an interest in pain management.

Anaesthesia in the future

Although the safety of surgery and anaesthesia has improved dramatically over the past 50 years, evidence suggests that patients suffer a significant amount of avoidable harm after major surgery. However, much of this harm is preventable by intervention before or after surgery, for example preoperative correction of anaemia, postoperative analgesia and fluid balance. Traditionally, the surgical team has had responsibility for the care of patients in this period. Increasingly, surgeons are focusing on training in the technical aspects of more complex procedures, and patients have complex medical needs. It is falling to other specialists to provide care for patients in the perioperative period. As a result, the subspecialty of perioperative medicine is beginning to evolve and it is anaesthetists who are taking the lead thanks to their unique combination of training and experience.

The anaesthetist of the future is likely to play an increasing role through the patient's journey, from the point of decision to operate until discharge home, to ensure the individual needs of each patient are met and the potential for harm minimized.

FURTHER INFORMATION

[1.1] www.rcoa.ac.uk
[1.2] www.ficm.ac.uk
[1.3] www.ics.ac.uk