

# ANAESTHESIA



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*Front cover*

First use of ether for a surgical operation (Morton at Boston 1846). Courtesy of Mary Evans Picture Library.

# ANAESTHESIA



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## Office of Health Economics

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- To collect data from other countries.
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## Introduction

Anaesthesia is the art or science of rendering the patient unaware, thereby providing an indispensable foundation for surgery. Although man had unsuccessfully been attempting to eliminate the pain of surgical procedures for many centuries, anaesthesia was not introduced into medical practice until the first half of the nineteenth century. Since then considerable progress has been achieved in the form of safer and more effective agents and vastly improved surgical techniques and this has facilitated the alleviation of many painful conditions and reduced substantially the incidence of premature mortality. Anaesthesia has therefore played a vital, albeit indirect, part in the major advances in the quality of human life.

The precise mode of action of pharmacological agents producing anaesthesia has yet to be fully understood, although a number of theoretical explanations have been attempted (Table 1). Nevertheless, increasing knowledge of both human physiology and the effects of drugs on the body means that the anaesthetist now possesses a high degree of control over the preparations he employs.

A state of surgical anaesthesia does not simply imply unconsciousness. More accurately, it is a state of reversible insensibility which incorporates three separate components: narcosis, analgesia and muscular relaxation. However, no single agent can satisfactorily produce variable levels of these three elements and this has, of course, stimulated research into and the development of drugs to serve specific anaesthetic purposes. Consequently it is now possible to select the combination of drugs which is most appropriate to the particular requirements of different surgical procedures and patients. This has considerably reduced the incidence of dangerous side effects and death attributable to complications of anaesthesia is now an extremely rare event.

Concomitant with these developments has been the emergence of the anaesthetist as a specialist in his own right. The image of the 'gas man' has been shed to a large extent and the modern day anaesthetist (of which there were nearly 3,000 in England and Wales in 1973) is widely regarded as a highly skilled and essential part of the medical team. His function extends well beyond the surgical operation itself; he is particularly involved in the pre-operative preparation and post-operative care of the patient and has other responsibilities throughout the whole field of pain relief.

This paper is primarily concerned with the use of general and local anaesthetics in providing a means whereby surgical pro-

**Table 1** *Some theoretical explanations of the mode of action of anaesthetic agents*

General anaesthetics interrupt the process whereby the brain cells facilitate the generation of nerve impulses. The brain is more susceptible to their effects than other parts of the body because it receives proportionally more blood, it has a greater capacity to absorb the anaesthetic agents which possess a high affinity for fatty substances and because the nerve cells which are responsible for the conscious state are the smallest and most delicate in the body and hence the first to be affected. Larger nerve cells are depressed fairly late in the process. For example, respiration is maintained until a point of overdose is attained.

- |   |   |   |
|---|---|---|
| 1 | Lipoid Solubility Theory<br>(Meyer and Overton) | The narcotic action of certain drugs is attributable to their solubility in the cell lipoids and their potency is dependent on their affinity for lipid tissues in the presence of body fluids.   |
| 2 | Surface Tension Theory<br>(Traube)              | The potency of anaesthetic agents is related to their ability to lower the interfacial tension at cell surfaces.  |
| 3 | Cell Permeability Theory                        | Absorption of narcotics at the cell interface decreases cellular permeability, producing narcosis.  |
| 4 | Synaptic Transmission Theory<br>(Wyke 1959)     | Anaesthetics depress the central nervous system by interfering with synaptic transmission (the passage of impulses across the nerve junctions). Recent research, using isolated preparations of brain tissue, has indicated that general anaesthetics depress the type of transmission which results in excitation, rather than inhibition, of successive nerve cells. But individual anaesthetic agents affect synaptic transmission in different ways. These investigations suggest that halothane, for example, decreases the amount of chemical transmitter liberated by the presynaptic nerve terminals following an afferent nerve impulse whereas ether, methoxyflurane and trichloroethylene reduce the sensitivity of the post-synaptic membrane to the released transmitter (MRC 1975). |
| 5 | Pauling's Theory<br>(1964)                      | Hydrogen bonding could lead to the formation of lattices or clathrates and the amino-acid side chains of proteins could, at body temperature, take up this configuration in the presence of anaesthetic agents. Anaesthetic molecules were visualised as being incorporated in the interstices and giving the structure stability which would not occur in the absence of these molecules at body temperature. The existence of these clathrates, or microcrystals, could interfere with ionic mobility, or enzyme activity, thereby disrupting the process involved in the normal function of the cell or cell membrane.   |

cedures can be undertaken rather than with their function as a direct form of therapy (for example, local pain relief). A brief historical outline of the subject is followed by a general survey of the benefits and risks which have resulted from the everyday use of anaesthesia. In this context consideration is also given to the questions of health care resource allocation posed by advances in medical technology. Finally the possible alternatives to conventional, chemically-induced anaesthesia, like acupuncture and electro-anaesthesia, are examined.

## The historical development of anaesthesia

The advent of safe and sophisticated anaesthetic practice is a recent phenomenon but there is abundant evidence to suggest that since early times man has frequently experimented with ways to reduce his perception of pain. The Assyrians knew of the anodyne and soporific properties of poppy and mandrake whilst the *nepenthe* of Homer is illustrative of the Greek attempt to alleviate both mental and physical suffering. In the thirteenth century, *mandrake* was extensively used as an anaesthetic agent by Hugo de Lucca and, later still, the narcotic effects of this plant were noted by Shakespeare who also made frequent but unspecified references to anaesthetising draughts. Analgesic potions had therefore been known for a considerable period of time but their utilisation was probably the exception rather than the rule, as many surgeons were deterred by the numerous failures associated with so precarious a means of preventing pain. Furthermore, patients themselves realised that the large doses necessary for effective analgesia could prove to be highly toxic and even lethal.

The lack of confidence in these potions meant that alcohol was probably the most frequently employed anaesthetic agent to help individuals endure surgical procedures. As an alternative, compression of the nerves around the site of the operation had been occasionally attempted, notably by Benjamin Bell (1749–1806), the Edinburgh surgeon, but this risked serious and permanent damage.

Mesmerism, although used by James Esdaile (1808–59) in over 250 apparently painless operations at his hospital in India, achieved minimal success in Britain (James 1975). These measures, therefore, did very little to prevent the pain of surgery and it was not until the end of the eighteenth century that real pro-

gress began to be made, based largely on the crude empirical work of a few distinguished individuals.

Studies of oxygen and the nature of respiration generated interest in the possibility that some diseases might benefit from the inhalation of certain gases. Humphrey Davy, whilst superintendent of the Medical Pneumatic Institution at Bristol (1798–99), carried out a series of investigations into the characteristics of nitrous oxide. In ascertaining that the gas was safely respirable he discovered its analgesic properties and noted that it could probably be used to eliminate pain during surgical operations.

Although Davy's interest in the subject waned the development of anaesthesia was carried on by Hickman (1800–30), a rural doctor. He surmised that interference with respiration would result in a temporary loss of consciousness thus paving the way for painless surgery. His experiments on animals, in which the onset of unconsciousness was expedited by the forced inhalation of carbon dioxide, gave credibility to his theories. However, he failed to convince his colleagues that these findings could readily be applied to man.

In America during the first half of the nineteenth century a dentist named Wells (1815–48) was prompted by a lecture on the effects produced by inhaling nitrous oxide into considering the possible benefits of the gas in dentistry. He was successful in extracting teeth painlessly on a number of occasions and although the demonstration he gave at Massachusetts General Hospital was a failure (probably because the patient was not given enough gas) sufficient interest had been generated to encourage further investigations.

Another American dentist, William Morton (1819–68), performed a number of tooth extractions using ether which he then employed, under the name 'letheon',<sup>1</sup> in October 1846, to anaesthetise a patient who was to undergo an operation for the excision of a tumour of the neck. The news of this and subsequent successes quickly reached England and in December of the same year at University College Hospital, London, Liston (1794–1847) painlessly amputated a leg at the thigh with ether being inhaled by the patient as an anaesthetic.

The advantages to be gained from anaesthesia inevitably resulted in its rapid application to a widening range of surgical procedures. In 1847 it was introduced into obstetrics by James

1 Morton disguised the smell of ether with aromatics and called it 'letheon' so that he could patent his preparation and as an attempt to avoid the derision stemming from the hedonistic use of the same gas by some of the more fashionable members of society at that time.

**Table 2** *A selected chronology of events in the development of anaesthesia, 1847-1951*

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- 1847 John Snow published his book *On the Inhalation of Ether in Surgical Operations*.
- 1853 Snow administered chloroform to Queen Victoria, hence 'chloroform à la reine'.
- 1858 John Snow's book *On Chloroform and Other Anaesthetics* published.
- 1860 Alkaloid from coca leaves purified by Gaedicke - cocaine.
- 1863 Use of nitrous oxide in dentistry popularised by Colton.
- 1864 Report of Chloroform Committee of Royal Medical and Chirurgical Society confirmed that chloroform was the agent of first choice.
- 1868 Andrews combined oxygen with nitrous oxide.  
N<sub>2</sub>O commercially supplied in compressed form in cylinders.
- 1872 Use of ether in England became more popular following visit of B. Joy Jeffries, an American ophthalmic surgeon.
- 1877 A portable regulating ether inhaler introduced by Clover.
- 1882 Synthesis of cyclopropane by von Freund.
- 1884 Local analgesic properties of cocaine demonstrated on the cornea by Koller.
- 1887 First practical gas and oxygen machine invented by Sir Frederick Hewitt.
- 1891 Giesel isolated tropococaine, the first alternative to the toxic cocaine.
- 1898 Spinal analgesia developed and popularised by Tuffier.
- 1902 Braun added adrenaline to cocaine to prolong its effect and retard its absorption.
- 1903 Fischer and von Mehring synthesised barbitone.
- 1904 Procaine synthesised by Alfred Einhorn.
- 1908 Bier described intravenous procaine local analgesia.
- 1920 Guedel's first paper on the signs of anaesthesia, supplanting Snow's signs.
- 1923 Ethylene introduced by Luckhardt of Chicago. *British Journal of Anaesthesia* published for the first time.
- 1926 Lundy put forward the concept of balanced anaesthesia.
- 1927 Butallylonal (Pernocton) used in Germany by Bumm. The first barbiturate routinely used for induction of anaesthesia.
- 1928 Cyclopropane shown to have anaesthetic properties by Lucas and Henderson, in Toronto.
- 1929 Sodium amytal used by Zervas, the first use of rapidly acting barbiturates in anaesthesia, given into vein.
- 1930 Cyclopropane introduced into clinical practice by Waters. Anaesthetic properties of divinyl ether discovered by Leake and Chen.
- 1933 Machine for the self-administration of nitrous oxide and air in labour designed by Minnitt.
- 1934 Lundy introduced thiopentone.
- 1941 Trichloroethylene advocated by Langton Hewer and Hadfield.
- 1942 Curare used in anaesthesia by Griffith and Johnson.
- 1947 First clinical use of lignocaine (Xylocaine) by Gordh.
- 1951 Halothane synthesised by Suckling.
-

Simpson of Edinburgh, using ether at first and then preferring chloroform. However, he had much opposition to overcome both from his medical colleagues and from the clergy ('in sorrow thou shalt bring forth children') and it was not until chloroform was given to Queen Victoria during the birth of Prince Leopold in 1853 that the practice of obstetric anaesthesia gained popularity and moral respectability. On this occasion the anaesthetic was administered by John Snow (1813-58), the first professional anaesthetist, who performed over 4,000 chloroform anaesthetics without a death and whose extensive investigations into agents and techniques represent one of the major foundations of anaesthetic practice.

The fundamentals of anaesthesia had therefore been established by the second half of the nineteenth century but a great many refinements were still required in order to transform the potentially dangerous process of inducing and maintaining a state of unconsciousness into the relatively safe and not unpleasant experience it is today (Table 2).

## The benefits and risks of anaesthesia

A quantitative evaluation of the benefits and risks which have accompanied the introduction and advancement of anaesthetic practice would involve detailed investigations into a multitude of variables (each requiring conversion to a single common denominator) well beyond the scope of the present paper. Nevertheless, it is possible to identify, in broad terms, some of the major areas of benefit and risk, the significance of the latter frequently being obscured by the self-evident nature of the former.

Before anaesthesia began to be accepted and widely used midway through the nineteenth century, surgical operations were few in number, severely restricted in range and achieved extremely variable degrees of success. Speed was of the essence in these painful operations if the patient was to survive the shock of the surgeon's incisions. The latter's skill was therefore measured in terms of his ability to perform swiftly. The surgical relief of many internal complaints was very rarely contemplated, let alone undertaken, and such problems were generally tackled by the administration of analgesic agents which would alleviate some of the suffering until death intervened.

One immediate consequence of the introduction of anaesthesia was a marked increase in the number of operations performed, although a large proportion of these continued to achieve little or no lasting success. This naturally drew attention to the defects of many surgical procedures and so opened the way for the development of superior techniques. The major impact therefore has been the complete transformation of the nature of surgical interventions from desperate, swift and painful measures (mainly the amputation of extremities) to comparatively time-consuming procedures of varying degrees of complexity which have rapidly become established as part of the normal routine and which in themselves cause little discomfort to the patients concerned.

Reduction of the overall hazards in surgery has led the elimination of the recognised dangers inherent in the administration of anaesthesia to become a rigorously pursued objective. The pre-anaesthetic examination enables an assessment to be made of the patient's ability to tolerate the effects of the agents which may be employed and thereby prepare for any potential difficulties. Today's use of sophisticated apparatus, both to dispense the anaesthetic agents and to monitor continuously the functioning of the unconscious patient's vital organs in the presence of these drugs, enables a high degree of control to be exercised over the administered dosage. Post-operative recovery, also part of the anaesthetist's responsibility, is carefully supervised, especially after complex procedures, to maximise the patient's safety and comfort.

One of the most significant advances in the safety of anaesthetic practice occurred in the early 1940s with the first use of a drug (curare) specifically to produce muscle relaxation during surgery.<sup>2</sup> These drugs have eliminated the need for dangerously deep states of anaesthesia (especially necessary for abdominal surgery) which used to give rise to considerable post-operative morbidity. The wide range of drugs which the anaesthetist now has at his disposal permits a combination to be selected which will provide suitable levels of analgesia, muscle relaxation and unconsciousness for individual patients and particular operations.

2 Muscle relaxation is essential for many surgical procedures. Before the availability of drugs specifically for this purpose it was only attained at a very deep level of unconsciousness. The latter entails a high degree of depression of many vital functions and so protracted operations were poorly tolerated, especially by high risk patients. Muscle relaxing drugs (or neuromuscular blocking agents) produce their effect by interfering with the transmission of the nerve impulses through the neuromuscular junction. They are divided into two groups: the non-depolarising or competitive group (for example, tubocurarine and gallamine) and the depolarising agents (including suxamethonium and decamethonium).

The comfort of the patient has also been considerably improved since the days when there was no alternative to strapping him to the operating table in order to prevent his violent exertions from impeding the work of the surgeon. Pre-anaesthetic medication, which has its origins in the early years of the twentieth century when morphine was used to calm patients, now consists of the use of modern sedative drugs which help to allay pre-operative fear and anxiety. The refinement of fast acting intravenously injected agents (notably the barbiturates in the 1930s) and their subsequent use has conferred psychological benefits upon the patient by eliminating the struggle which frequently used to accompany the attempt to induce anaesthesia. The creation and maintenance of a state of unconsciousness have therefore become less unpleasant as well as markedly less hazardous.

The introduction of cocaine (the alkaloid obtained from the leaves of the *Erythroxylum coca*, a tree found in South America) into medical practice in 1884 by Koller heralded the beginning of local anaesthesia. The subsequent refinement of both techniques and agents<sup>3</sup> has been of significant benefit to modern medicine in enabling fully conscious patients to undergo minor surgery without any sensation of pain. The methods are economical, the agents injectable and the equipment required is minimal. The undesirable side effects of general anaesthesia are avoided and the need for post-operative care is lessened. It is particularly suitable for brief and superficial operations where patient cooperation is required and when it has not been possible to prepare the patient for general anaesthesia. However, local anaesthetic techniques are clearly inappropriate for most major surgical procedures. Furthermore, there have been cases in which an overdose or an unexpectedly rapid absorption of the agent into the bloodstream has produced severe, sometimes fatal, reactions. But perhaps one of the major reasons why the method is not more widely used is the lack of patient acceptance (Dripps *et al* 1972). Patients often prefer to be totally unaware of the operation and this may stem from an unfounded fear that the effect of the agent will wear off prematurely.

The development of new techniques and anaesthetic agents has also produced direct economic benefit. The use of fast acting drugs (combined, of course, with improved methods of surgery) enables a number of surgical procedures which previously

3 The toxicity of cocaine was soon found to be too great for general use and today it is only employed as a surface analgesic in nose and throat surgery. The practice of local anaesthesia achieved popularity following the development of considerably safer synthetic agents, such as procaine, cinchocaine, lignocaine, amethocaine and bupivacaine.

required hospitalisation, primarily to recover from the anaesthetic (especially after ether and chloroform), to be performed on an outpatient basis.<sup>4</sup> The avoidance of accommodation costs, which constitute a significant proportion of the total cost of hospital inpatient treatment, can result in a marked saving of resources.<sup>5</sup>

However, outpatient surgery still has to overcome the problem of the recovery period, about which there is a paucity of information (Ogg 1975). Sutherland and Horsfall (1961) found a high incidence of nausea and vomiting after day case surgery for varicose vein stripping and inguinal herniorrhaphies. Fahy and Marshall (1969) reported a 44.9 per cent incidence of symptoms attributable to general anaesthesia for outpatient procedures. Ogg's own study of 100 patients attending hospital for day case surgery established that post-operative symptoms included headache (27 per cent) drowsiness (26 per cent), nausea (22 per cent), dizziness (11 per cent) and vomiting (8 per cent). These symptoms were found to be particularly common in female patients and when the duration of the operation exceeded 15 minutes. This illustrates the need to ensure that appropriate anaesthetic techniques are employed in outpatient surgery and also the benefits to be gained from the development of more efficient anaesthetic agents which facilitate rapid and complete recovery.

An important prerequisite for the more widespread use of day case surgical procedures is the development of favourable attitudes towards this concept of medical treatment. In the United States, for example, there is an apparent patient-preference for having many operations (including those for hernia) performed on an outpatient basis largely because of the high price of hospital accommodation which has to be paid for by the patient or his insurance. However, the provision of hospital care under the National Health Service at zero price at the point of consumption means that few patients are conscious of the actual and, indeed, high costs of medical treatment. Although outpatient surgery exists as a feasible alternative to hospitalisation for some of the

4 The type of case considered suitable for outpatient treatment has steadily expanded from the days when only sigmoidoscopies and cystoscopies were performed to include hernias, varicose veins, quite large tumours, a number of orthopaedic procedures, plastic and reconstructive surgery and circumcisions in children.

5 The average cost per inpatient case in acute hospitals with over 100 beds has risen by more than 90 per cent since 1970 and stood at £15.40 per day in 1974 (Hospital Costing Returns 1974). It should be pointed out, however, that day case surgery does not necessarily result in an immediate saving of money as the hospital bed that is spared is used for another patient. The benefit is realised in that more intermediate surgery can be undertaken and waiting lists are reduced.

less complex surgical procedures, this option may not be acceptable to some patients who, in the absence of cost and other constraints, consider it their right to choose to go into hospital. Thus even if an 'ideal' (short acting) anaesthetic agent did become available and was combined with the appropriate surgical techniques and organisational procedures it would be unlikely to lead to an appreciable increase in the number of outpatient operations until the tendency to regard this form of surgery as a 'second class service' has been dispelled.

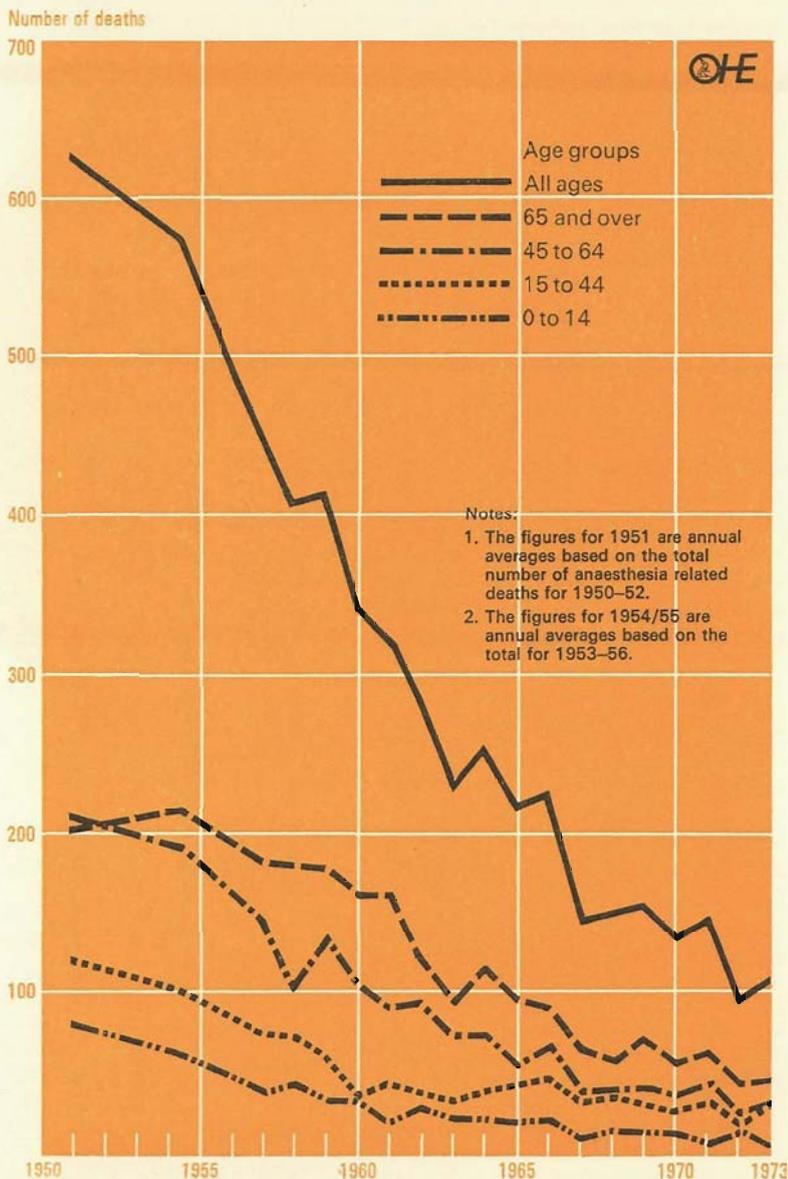
### The risks

The introduction of anaesthesia in the mid-nineteenth century and the subsequent development of both techniques and agents have generated considerable benefits in transforming the nature of surgical procedures so completely. But Hickman's hope that 'the hitherto most agonising, dangerous and delicate surgical operations may now be performed with perfect safety' has yet to be realised. The early advancement of anaesthesia was marred by frequent failure and today, like all forms of surgical and pharmacological intervention, it still involves a certain degree of risk.

The growing understanding of and ability to control the actions of pharmacological preparations has been a critical factor in raising the level of safety in anaesthetic practice, but there is always the possibility of unpredictable idiosyncratic drug reactions. Also calculated risks have often to be taken when there is no alternative to using a drug combination which is not ideally suitable for a particular patient and in cases where the chances of survival are remote without immediate action. Now that the advent of muscle relaxants has eliminated the need for dangerously deep levels of unconsciousness there is the risk, at the other extreme, that in attempting to achieve a very light level of anaesthesia the patient may be rendered immobile without being unconscious. The problem is particularly likely to arise when the lightest possible inhalation anaesthetic, usually nitrous oxide, is employed; one investigation showed that 2 per cent of patients had factual recall and 17 per cent had unpleasant memories, including severe pain (Wilson and Turner 1969). In some operations, however, such as those which may have to be performed during childbirth, the possibility of a certain degree of awareness due to very light anaesthesia may be considered acceptable (*Lancet* 1973).

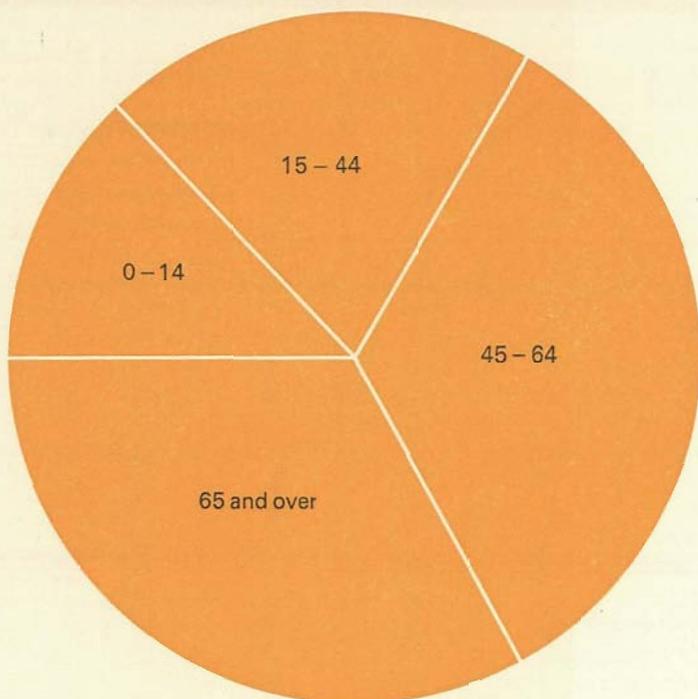
The magnitude of these and other risks will vary greatly between different situations but their consequences are likely to be less severe than in the past largely because of the modern use of

**Figure 1** Deaths under or connected with the administration of an anaesthetic, various age groups, England and Wales, 1950-73

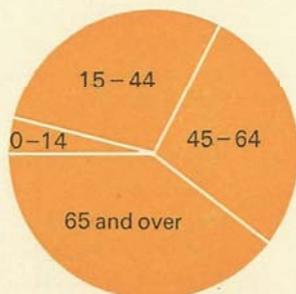


Source Registrar General's statistical review of England and Wales, parts 1 and 3, various years

**Figure 2** *Deaths in which anaesthesia was mentioned as a contributory factor, by age group, England and Wales, 1950 and 1973*



1950: 625 anaesthesia-related deaths



1973: 108 anaesthesia-related deaths

*Source* Registrar General's statistical review of England and Wales, Medical tables, 1973 and Commentary tables, 1952

monitoring equipment which, in providing early warning of the occurrence of difficulties, facilitates the swift inception of remedial action.

Figure 1 shows the number of deaths between 1950 and 1973 in which anaesthesia was considered to be a contributory factor. Although care has to be taken in interpreting these statistics because of the difficulties in isolating and determining the highly variable significance of the anaesthetic as a cause of death,<sup>6</sup> a number of interesting points emerge. First, over the 23-year period the number of deaths associated with anaesthesia has fallen by over 80 per cent,<sup>7</sup> even though an increasing number of operations requiring anaesthesia are being performed each year. (From the Reports on the Hospital Inpatient Enquiries it is estimated that the number of operations performed rose from 1.55 million in 1961 to 2.01 million in 1967, reaching 2.51 million in 1972.)

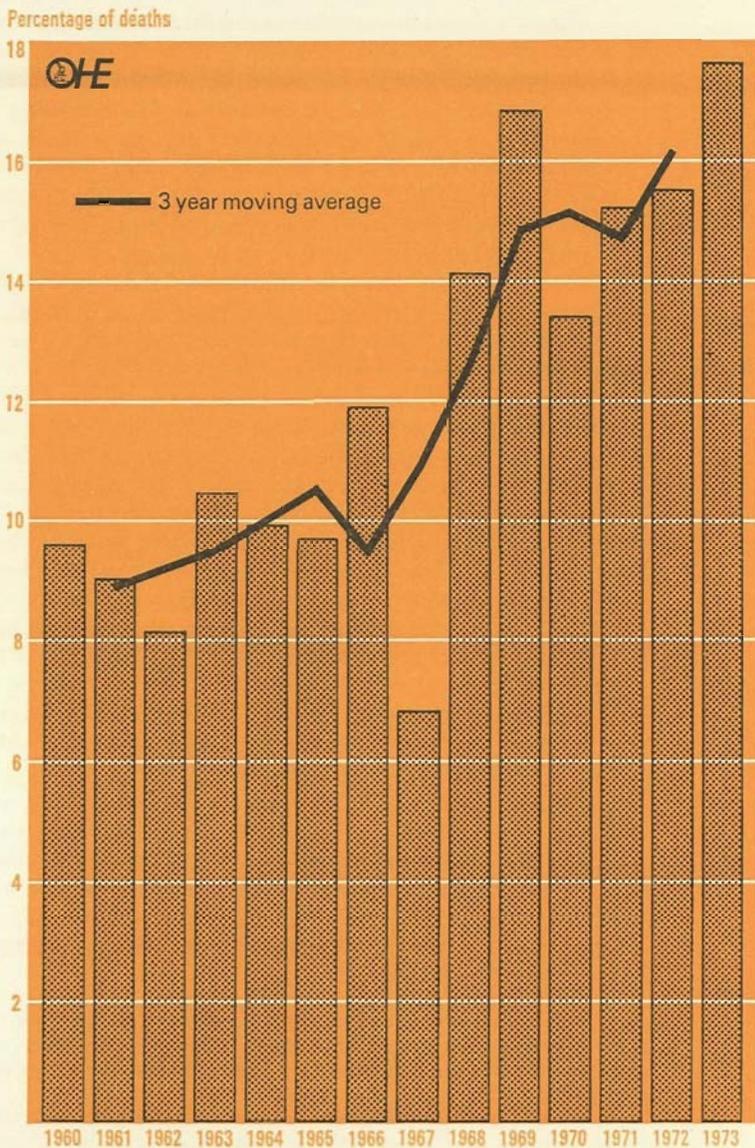
Second, slightly more than 40 per cent of anaesthesia-related mortality now occurs in the 65 years and older age group (compared to 33 per cent in 1950) in spite of the fact that the actual numbers of these deaths among the elderly has fallen by approximately 80 per cent over the 23-year period (Figure 2). To some extent, this observation indicates that the degenerative processes of old age, notably those involving the heart, blood vessels and respiratory function, diminish the ability of the body to tolerate the effects of anaesthetic agents, a factor which further complicates decisions concerning surgical procedures for elderly patients.

Finally, there has been a clear, albeit unsteady, increase in the proportion of anaesthesia-related deaths associated with accidental causes over the period (Figure 3). Presumably much of the explanation for this finding lies in the greater significance of accidents in general as a cause of death today and in the fact that operations performed under emergency conditions afford much less opportunity to prepare the patient and to determine the most suitable anaesthetic procedures (factors which have played an important part in the substantial post-war improvements in the

6 Anaesthesia-related mortality can arise from misadventures in technique or mistakes in drug administration and from the adverse effects of the agents employed: for example respiratory failure, cerebral anoxia, cardiac arrest, pulmonary oedema or hepatic necrosis.

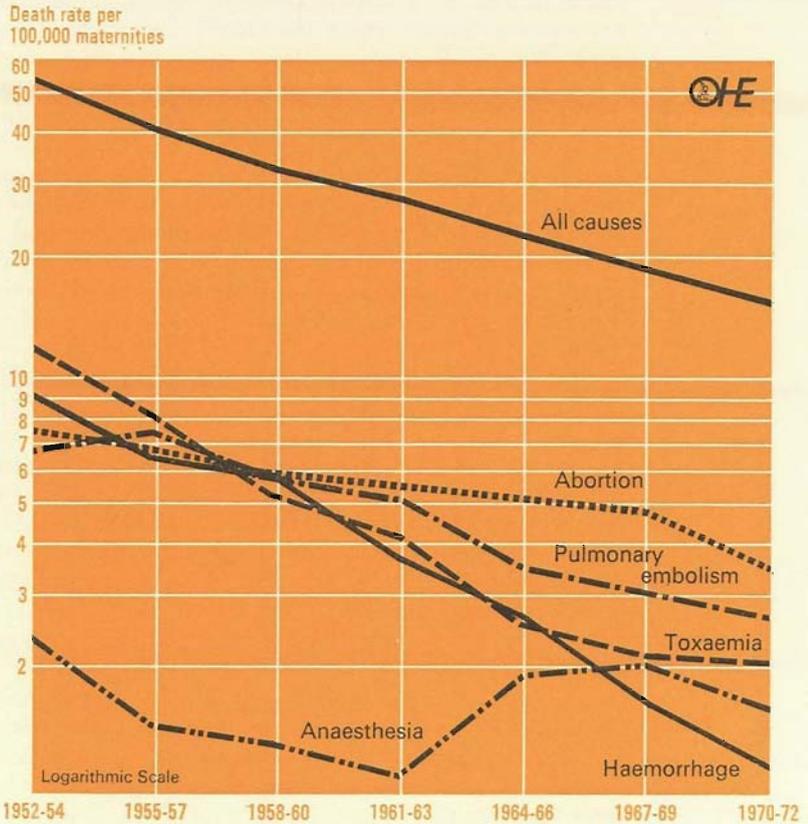
7 Accepting the limitations of the statistics involved, this declining trend can be expressed more meaningfully as a proportion of all operations performed: thus, in 1961 there were approximately 21 anaesthetic-related deaths per 100,000 operations, falling to 7 per 100,000 in 1967 and slightly less than 4 per 100,000 in 1973.

**Figure 3** *Percentage of anaesthesia-related deaths attributable to accidental causes, England and Wales, 1960-73*



Source Registrar General's statistical review of England and Wales, parts 1 and 3, various years

**Figure 4** *Maternal deaths: rates per 100,000 maternities, by cause, 1952-54 to 1970-72, England and Wales*



Source Reports on Confidential Enquiries into Maternal Deaths in England and Wales

anaesthetic service) than those which have been planned for some time.

The risks associated with anaesthesia appear to be greater in some areas of medicine than in others, a notable example being obstetrics. During the last 25 years there has been a marked reduction in maternal and foetal morbidity and mortality due to improved pre-natal and obstetrical care, the availability of blood transfusion services, the development of antibiotics and a better understanding of toxaemia. Consequently the relative importance of the effects and complications of pain relief has

increased. Investigations have shown that all drugs used for sedation and general anaesthesia cross the placental barrier by diffusion and so a critical dilemma arises in determining the appropriate dosage which the child's undeveloped systems can cope with satisfactorily while at the same time providing the necessary amount of analgesia for the mother (Nicholson 1975).

Concern was generated by the Confidential Enquiry Report for 1967-69 which revealed that maternal deaths associated with anaesthesia during childbirth had not fallen, in absolute terms, during the past two decades and that anaesthesia had become (in 1967-69) the fourth largest cause of maternal mortality (Table 3, Figure 4). Furthermore, the report recorded that the number of fatalities in which there was said to have been an avoidable factor had risen from 24 to 34 since the previous triennium.

These statistics were interpreted as being reflective of a real increase in the anaesthetic hazard (Crawford 1972). It has been suggested that a more widespread use of regional anaesthetic techniques<sup>8</sup> could prove beneficial: the patient maintains consciousness and can therefore participate in the actual birth process, the protective airway reflexes are retained and the newborn infant is spared some of the depression caused by the use of pharmacological agents. But general anaesthesia is necessary in certain obstetrical emergencies, such as breech extraction and situations requiring manual exploration of the uterus or immediate cesarean section.

On the basis of the 1967-69 report's implicit identification of the lack of specialist training of many attendant anaesthetists as a major cause of unnecessary maternal death it has been argued frequently that the risk could be reduced significantly by the full-time availability of experienced anaesthetic cover. This would facilitate a rational choice of technique for each individual patient and therefore increase the chances of success in many of the unpredictably difficult cases.

The most recent Confidential Enquiries Report, which covers the period 1970-72, shows that the actual number of maternal deaths attributable to anaesthesia fell to 37 (three-quarters of these deaths were considered avoidable) for these years although anaesthesia is still the fourth most important cause of death. It

8 It has been argued that the low price of Xylocaine (lignocaine), in the absence of patent protection, was an important factor in the slow adoption of local anaesthetic techniques in obstetric practice because it imposed an effective constraint on sales promotion which resulted in only a slow dissemination of information (Teeling-Smith 1965).

**Table 3** *Maternal deaths, by cause, 1952-54 to 1970-72, England and Wales*

	1952-54	1955-57	1958-60	1961-63	1964-66	1967-69	1970-72
Total maternities	2,052,953	2,113,471	2,294,414	2,520,420	2,600,367	2,457,444	2,298,198
Maternal deaths	1,094	861	742	692	579	455	355
<i>Causes</i>							
Abortion	153	141	135	139	133	117	81
Pulmonary embolism	138	157	132	129	91	75	61
Haemorrhage	188	138	130	92	68	41	27
Toxaemia	246	171	118	104	67	53	47
Deaths due to anaesthesia	49	31	30	28	50	50	37

*Source* Lewis 1975

remains to be seen whether or not this improvement marks the beginning of the long-awaited downward trend.

The use of general anaesthesia in dentistry has also served to illustrate the problems which may arise in the absence of properly trained personnel. Indeed, it has been the subject of much controversy in the recent past following the deaths of four young adults who had undergone dental procedures with a general anaesthetic which had been administered by dental surgeons. These fatalities raised a number of important questions relating to the suitability of general anaesthesia for conservation work, the extent to which the equipment for coping with an emergency situation could be deemed satisfactory in some dental surgeries and the number of dental assistants who are qualified and experienced in handling cardiorespiratory emergencies. But perhaps the most pertinent challenge was to the appropriateness of one person combining the duties of operator and anaesthetist. The operator anaesthetist is probably in the best position to anticipate the anaesthetic requirements as the level of stimulation changes, but the full-time responsibility for monitoring cardiorespiratory function is more suitably undertaken by another qualified person whose presence will also increase the chances of successfully overcoming a crisis (*BMJ* 1975a).

To some extent the problem is an economic one because the techniques and equipment which would help to ensure a greater degree of safety in the administration of general anaesthesia to dental patients are expensive (Evans 1975). The presence of another professional also adds significantly to the costs of treating the patient, especially as there is a shortage of the requisite personnel. The problem might be solved by training paramedical anaesthetists to do this sort of work thereby eliminating the need to use fully qualified doctors and dentists (Bourne 1975).

The need to exclude all unnecessary risks in dental anaesthesia led to a number of recommendations such as the ready availability of adequate facilities for use in the event of difficulties. More significantly it was suggested that, in those cases where general anaesthesia is essential, patients should be referred to centres which are fully staffed and equipped to minimise the risks (*BMJ* 1975). Subsequently, the president of the General Dental Council has expressed the view (initially urged by a Ministry of Health Inquiry in 1967) that no dentist should act as both operator and anaesthetist except in an emergency situation.<sup>9</sup>

9 The practice of one person acting as both operator and anaesthetist had, in fact, been condemned as long ago as 1911 by Hewitt who tried to obtain legislation to prevent it (Sellick 1975).

### The risks to medical staff

The hazards of anaesthesia are not just restricted to the patient. In recent years evidence has been accumulating to show that staff working in the operating theatre may be at risk from contamination of the atmosphere with anaesthetic gases and vapours. Long-term exposure of animals to clinical concentrations of inhalation agents is known to produce teratogenic effects and to predispose to infection (*BMJ* 1975b).

A number of reports have sought to identify the nature and magnitude of the risks faced by anaesthetic personnel. An investigation in 1967 generated concern in showing that 18 out of 31 pregnancies among 303 female Russian anaesthetists terminated in spontaneous abortion. In 1970 a high rate of spontaneous abortion among anaesthetists in Denmark was reported (Askrog and Harvald 1970) and in 1972 Knill-Jones *et al* studied 563 married women and found that it occurred more frequently when they were working than when they were not. A recent American study demonstrated an increased incidence of spontaneous abortion and also found more congenital birth defects among children of anaesthetists of both sexes (Ad hoc Committee Report 1974).

It is difficult to determine the extent to which these findings are attributable to pollution of the theatre atmosphere with inhalation agents. The use of apparatus to detect gas leaks and the monitoring of exposed personnel would certainly furnish significant control over this form of pollution but until the facts are more firmly established the potential risk can be minimised by eliminating all avoidable leakages from the anaesthetic equipment and by the use of efficient ventilation systems.

Explosion in the operating theatre constituted a significant risk when ether was the principal agent used for anaesthesia. Between 1947 and 1954, for example, 36 explosions during anaesthesia were reported to the Ministry of Health (*Lancet* 1973). Of this number only three were fatal but it led to the establishment of a working party to investigate ways of preventing such explosions. Intensive efforts to eliminate all conceivable ignition sources in operating theatres (heat, faulty electrical circuits, static electricity) followed the report. However, the introduction in 1956 of halothane and its subsequent popularity have greatly reduced the need for these measures. Currently explosion is an infrequent and insignificant hazard in the practice of anaesthesia.

Research, primarily undertaken by the pharmaceutical industry, has resulted in the availability of more satisfactory anaesthetic agents but it is a time-consuming and complex process, fraught with the problems inherent in the development and application of all pharmacological compounds. Once a new

drug has demonstrated potential benefit it is subjected to a series of rigorous testing procedures in order to identify the nature, magnitude and acceptability of any risks which may be associated with its use. The emphasis is always upon safety although the occurrence of idiosyncratic drug reactions in some patients is to be expected and cannot justly be interpreted as an indication of inadequate clinical and pharmacological examination.

One of the most intractable difficulties inherent in medical trials relates to ethical considerations. Halothane is a current example of this type of problem. It was introduced in 1956 and it possessed so many advantages over the older anaesthetic agents (non-explosive; non-irritant to the bronchial tree; smooth and rapid induction and recovery; straightforward maintenance, and a low incidence of nausea and vomiting) that it quickly achieved widespread popularity.<sup>10</sup>

It was soon suggested, however, that halothane might cause liver damage. Yet after extensive investigations the problem is still unresolved nearly 20 years later, during which time the gas has been given to over 50 million patients (Simpson *et al* 1975). The current position is that there is evidence (by no means universally accepted) to suggest that repeated exposure to halothane, especially within a short period of time, may be responsible in some way for increases in the incidence of post-operative jaundice. The identification of the existence and the nature of a direct causal link would be facilitated, to some extent, by undertaking accurate and thorough medical trials. However, the ethical dilemma which arises in exposing a group of individuals, for the purpose of experiment, to something which has been suspected of causing illness may preclude the evaluation of the problem on this basis<sup>11</sup> although it has also been argued that the issue is sufficiently unclear that a prospective medical trial would be justified (*BMJ* 1974). In spite of these considerations and the practical problems involved in a trial of this nature it is probable that an active approach would provide a more meaningful answer than a 'wait and see' policy (Simpson *et al* 1975).

Conflicting evidence and the absence of clear guidelines cause confusion and raise the possibility of negligence but, in the final analysis, the choice of anaesthetic must remain a matter for the anaesthetist's clinical judgement, determined in the knowledge of the comparative risks associated with all other alternatives.

10 It has been estimated that halothane usage rapidly rose to 70–90 per cent of patients subjected to general anaesthesia (Mushin *et al* 1971).

11 Alternatively, it may be considered equally unethical, in performing a prospective trial, to administer non-halothane anaesthesia in cases where halothane would normally be the drug of choice.

### Surgical need and health care resources

It is beyond dispute that the benefits which have accrued from the introduction and subsequent improvement of anaesthesia substantially outweigh the risks. The ability to maintain a state of controlled unconsciousness for considerable periods of time and the availability of intricate support systems have permitted a significant extension of the bounds of surgical possibility. But it has also raised a number of questions relating to the limits to which medicine should be taken.

The fact that in the present state of knowledge it is impossible meaningfully to define and quantitatively to measure surgical need has important implications for the use and abuse of health care resources. The considerable advance in medical technology during the last 25 years has been accompanied by significant changes in society's attitude towards ill health such that even minor complaints are no longer tolerated. Surgery is now comprised of a wide spectrum of procedures of greater or lesser urgency, with true emergencies at one end and 'a variety of semi-frivolous interventions which must be considered a luxury' at the other extreme (Bunker 1974). This growth in demand for 'non-essential' surgery has absorbed a considerable volume of resources. In addition, the elimination of much premature mortality has been responsible for creating expectations that all such deaths should be avoidable. Individuals suffering from an illness for which there is no cure often express a desire for some form of surgical intervention which the surgeon may feel ethically obliged to perform even though it is extremely unlikely to produce any lasting benefit. Some of the operations for the 'relief' of cancer are examples of this type of problem. Similarly some of the major organ transplant procedures, which are particularly resource consuming, are still mainly at the experimental stage and have yet to demonstrate unequivocal benefits.

All surgical interventions entail a certain degree of risk which should not be obscured by the dramatic progress of medical technology in the recent past. Bunker (1974) has pointed out that approximately two million operations a year are performed in Great Britain and, with an immediate post-operative mortality of 1 to 1.5 per cent, this implies between 20,000 and 30,000 deaths.<sup>12</sup> This mortality figure might represent a high non-

<sup>12</sup> This mortality is assumed to be almost wholly attributable to surgery rather than a consequence of anaesthesia. It is, of course, extremely difficult to identify accurately cause and effect in many instances of post-operative mortality when so many factors of uncertain significance have to be taken into account and when in so many cases a policy of non-intervention would lead to a very much higher risk of imminent death.

monetary cost of surgery which could only be justified by a large return in benefits although, as yet, the latter remain conspicuously unmeasured.

A number of studies have attempted to demonstrate that more surgery is associated with a larger number of deaths. Lichtner and Pflanz (1971), investigating the incidence of appendicitis in the Federal Republic of Germany, concluded that the observation of a higher mortality rate from the condition compared to elsewhere was attributable to the larger number of appendectomies performed in Germany. Surgery for small-celled carcinoma of the bronchus was shown in an MRC controlled clinical trial to reduce survival rates marginally compared with radio therapy alone (MRC 1966). It has been reported that the risk of elective herniorrhaphy at the age of 65 or above may be four times as great as the risk of not operating (Bunker 1974).

Exercises of this nature must be interpreted with caution as they do no more than make generalisations which tend to conceal variations (frequently interrelated) in the expertise of surgeons, the provision and standard of medical care facilities and in the capacity of individual patients to survive. Furthermore even if it were possible to show that some operations shorten life expectancy this does not necessarily mean that they should not be undertaken. The expectation of relief from disability of discomfort may outweigh the risk of post-operative mortality. Nevertheless, there is a need for more data and information to provide a foundation from which judgements can be made about the benefits and risks which may be anticipated from different types of surgical intervention.

It is therefore apparent that, in order to minimise the wastage of scarce health care resources and to reduce the risk of surgery, the ability to perform an extensive range of surgical procedures has to be balanced critically against the genuine need for and benefit accruing from such interventions. Although this dilemma is difficult to resolve, no one would exchange the problem for the suffering of the not so distant past.

# Alternatives to drug induced anaesthesia

## Acupuncture

In the absence of any suitable alternatives, the induction and maintenance of unconsciousness by pharmacological agents has continued to dominate anaesthetic practice in the western world although a great deal of interest has been expressed recently in the possible use of acupuncture.<sup>13</sup> This is one of the nine branches of traditional Chinese medicine and it can be used either as a direct form of treatment or to create a state of insensibility to pain.<sup>14</sup> In simple terms it involves the insertion of needles at specific points on the body which are then agitated, either manually or electrically, to produce the desired effect.

A scientific explanation for the phenomenon has yet to be developed. Understanding has frequently been sought in terms of some form of hypnotic effect although recent experiments with anaesthetised dogs would suggest that hypnosis is not involved. An alternative hypothesis attempts to take into account the apparent necessity for the needles to be vibrated by suggesting that this causes areas of the cerebral cortex to become 'locked on' to the rhythmic stimulation and thus 'busy' and unable to react to other stimuli in the normal way (Bull 1973).

On the basis of extensive studies on humans and experimental animals Chinese authorities argue that acupuncture changes the

13 This growing interest stems, in part, from observations by individuals attending demonstrations in China of startling successes using acupuncture anaesthesia. For example, it is reported that a young man with tuberculosis conversed quite normally with the surgeons who were removing his left lung. One acupuncture needle had been inserted into his right shoulder and this apparently rendered him insensitive to painful stimuli. In another operation a patient had a tumour painlessly removed from his throat after a single needle had been placed in the side of his neck (Duke 1972).

14 The use of acupuncture needling to block surgical pain is only 10 to 15 years old, although it has been employed as a form of therapy for at least 2,000 years (Geiger 1973). Its latter use is based on the hypothesis that the body contains certain channels through which energy flows. In these meridians the life force normally functions uninterrupted but if any part of the body is suffering from some disorder, the flow in the relevant meridian will diminish, disturbing the body's equilibrium and causing illness. If needles are introduced at certain points along these meridians they stimulate the nervous system and restore the body's natural balance (Inglis 1964). However, Wall (1974) claims that it is now generally accepted that this 'system of tubes connecting the needle points to the organ' does not exist and points out that **there are three** simultaneously active schools of acupuncturists: for one the points are scattered all over the body; for another they are all concentrated in the ear lobe, and, more recently, a third school inserts the needles into the general area of the pain.

patient's perception of both the intensity and quality of pain by specific blocking actions at two and perhaps three levels of the central nervous system, without the cortical depression and alteration in consciousness that accompanies chemical anaesthesia (Geiger 1973). They believe that the effect of needling is on the proprioceptors-muscle spindles and related stretch and pressure receptors. It induces a vigorous neurological discharge over proprioceptive pathways which acts, by a kind of competitive inhibition, to block pain impulses carried over cutaneous nerves and other afferent pain fibres. However, it is emphasised that this explanation is still incomplete and further investigations are necessary.

It has also been proposed that social and psychological mechanisms play a significant part in the successful practice of acupuncture (Wall 1974). Adequate preparation of the patient is of particular importance and four or five days are usually devoted to test needlings, instruction on the nature of the operation and the development of a rapport, based on a mutual sense of trust, duty and obligation, between the patient and the staff. The patient is thus able to approach the operation in a totally confident state of mind. Wall argues that the pain of surgical procedures is eliminated by a combination of three classical techniques – relief of anxiety, suggestion and distraction – which are backed up, when necessary, by the pharmacological agents of analgesia. This explanation suggests that there is no need to propose that hypnosis is involved or that any known or unknown physiological reflexes are activated and much of the success of acupuncture in China can probably be attributed to cultural differences which play a significant part in determining the individual's reaction to, and ability to tolerate, pain.

The use of acupuncture 'anaesthesia' is not as widespread in China as is commonly believed<sup>15</sup> and the successful application of the technique appears to be restricted to a relatively small range of less complex surgical procedures, which includes, in particular, thyroidectomy and thoracotomy. Furthermore, it is very rarely used in children under the age of 10 years, emergency cases, semi-conscious patients and in any condition where adequate preparation and co-operation are not possible.

### Electro-anaesthesia

It has been known for thousands of years that electricity can produce instant unawareness (for example, the effect of lightning)

15 One of the hospitals visited by Wall (1974) carried out 5,200 major surgical procedures in 1973 and only 6 per cent of them were under acupuncture anaesthesia. Geiger (1973) reported a figure of between 20 and 30 per cent.

but it was in 1902, at the Hospital Necker in Paris, that Leduc undertook his important investigation into the anaesthetising effects of high frequency electric currents. This stimulated further experimentation, especially with the type and magnitude of current employed and, in 1956, a technique devised by Knutson was used on five patients from a mental hospital. The experiment was a failure and chemotherapy was required to control the complications caused by the passage of electric current. Nevertheless, research into the problem continued, culminating in the successful use of electro-anaesthesia during an operation performed at the Hospital Necker in 1972. Within four months the French Academy of Medicine had authorised the use of the technique and since then the Necker team have employed electro-anaesthesia in more than 400 operations, including arterial grafting, kidney transplantation and other urological and intestinal procedures.

According to French sources electro-anaesthesia can be sustained for considerable periods of time and the patient regains consciousness as soon as the electrodes are disconnected. Recovery is rapid and post-operative sensations of 'wooziness' are avoided, although a certain degree of analgesia may be retained for up to 48 hours. It has been estimated that in the immediate post-operative period patients receive only one-thirtieth the analgesics and soporifics they need after conventional anaesthesia. The availability of suitable electro-anaesthetic techniques may also mean that surgery would no longer be contraindicated in many patients suffering from cardiac, respiratory, renal or hepatic insufficiency (Limoge 1975).

Electro-anaesthesia has not entirely dispensed with the use of pharmacological agents: the majority of patients receive a 'conventional' pre-medicant and starter consisting of a neuroleptic and an anxiolytic. And it should also be pointed out that all patients who undergo electro-anaesthesia are intubated and artificially respired with either pure oxygen or a mixture (equal parts) of oxygen and nitrous oxide. The point has been made that the use of a combination of these two gases tends to obviate the original need for electro-anaesthesia. Furthermore, hyperventilating patients with oxygen can by itself create sufficient analgesia for surgery (Clutton-Brock 1975).

A major problem associated with the technique is the difficulty in obtaining sufficient muscle relaxation. Higher electric currents result in a greater degree of muscle rigidity but lowering the current increases the likelihood of patient response to painful stimuli. The exact nature of the side effects which may result from the use of electro-anaesthesia also awaits clarification. The French re-

searchers have found short-term amnesia in one or two cases and headaches in a few others. But a number of South African workers have reported that some patients developed post-operative epileptic fits, indicating that there may be a link between the technique and damage to brain cells.

It is generally accepted that the ability to use electro-anaesthesia with complete safety and confidence would represent a significant breakthrough by removing virtually all of the concern about the uptake, distribution, metabolism and excretion of conventional anaesthetic agents. This point was echoed by Sances *et al* (1972) in their international symposium report on 10 major surgical procedures (lasting between 50 minutes and three hours) which had been successfully carried out under electro-anaesthesia. They also emphasised the potential benefits for poor-risk patients. But electro-anaesthesia is at a relatively early stage of development and many problems have yet to be overcome. Indeed, it has been suggested that very little progress has been made (from the human point of view) since Leduc's first achievements in this field and that there is still a multiplicity of conflicting claims in such fundamental areas as the choice of a safe, reliable and effective magnitude of current and about the degree of analgesia which can be obtained with the technique (Von Poznak 1971).

## Conclusions

Anaesthesia has helped to transform the nature of surgical interventions from being mainly heroic, painful and frequently unsuccessful measures to procedures which can be approached with justifiable confidence and an expectation of real benefit. The swift and interdependent advances in all areas of medical technology in the post-war period have facilitated the alleviation of much unnecessary suffering and current research will extend further the bounds of surgical possibility. But such progress has also focused attention on the problem of defining genuine surgical need and the implications this has for the allocation of already scarce health care resources.

The improvement of drugs and techniques continues to increase the safety of anaesthetic practice but there is still a certain degree of risk inherent in creating a state of unconsciousness. Apart from adverse reactions the problem of prolonged and unpleasant post-operative recovery, especially after lengthy and

complex procedures, has yet to be overcome. This particular obstacle is not encountered to the same degree when local analgesia can be employed as a suitable alternative but lack of patient acceptance of this method is an important factor which continues to restrict its use.

Certain areas of medicine (for example obstetrics) reveal that there is a shortage of anaesthetic personnel and the consequences for the patient may be serious. This is particularly ironic in view of the fact that it has been shown that as much as 47 per cent of the time of junior anaesthetic staff may be spent, among other things, waiting for emergencies and in gaps between work (Nightingale and Taylor 1966). Although the provision of an anaesthetic service must inevitably involve a certain degree of spare capacity efficient manpower organisation in all departments is a necessity if the benefits of clinical research, in the form of new treatments, are to become available to the patient (Jennings 1975).

Currently there is concern about the risks confronting the anaesthetist and other theatre personnel who are continuously inhaling low concentrations of anaesthetic agents. This had led to a reconsideration of the effectiveness of air conditioning plants and other methods of reducing the gas vapour levels in the operating environment. But to a large extent the solution to the problem will require an accurate assessment of the nature of the risks involved and a satisfactory definition of what constitutes a safe or tolerable level of pollution by anaesthetic gases.

At present there is no alternative to the conventional forms of anaesthesia although the use of acupuncture has been effectively demonstrated on a number of occasions. It has advantages in ease of use and avoids the post-operative effects of and dangers inherent in general anaesthesia. But the use of acupuncture in Britain is limited and various reports intimate that it has only a low success rate (around 10 per cent, Mann 1973). Nevertheless, the renaissance of western interest in this subject may lead to a reappraisal of old theories and new experiments from which a clearer understanding of the pain mechanism may result.

In the short term research will continue to be aimed at developing improved anaesthetic agents which cause few side effects and are rapidly expelled from the body. As knowledge of the underlying process by which anaesthetic agents produce unconsciousness expands the chances of developing more effective and suitable pharmacological agents will become correspondingly more favourable.

In the long term conventional, chemically-induced anaesthesia may be replaced or supplemented by other methods which pro-

duce insensibility to pain by interfering (possibly electrically) with the transmission of nerve impulses. As is the case with all forms of medical intervention, these new methods will probably entail some form of risk but it is the extent to which these hazards can be controlled that will determine which developments are acceptable and therefore adopted and which are not.

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