A Brief History of the Patient Safety Movement in Anaesthesia

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Summary

Approaches to safety began slowly. It took a century for ether to be fully accepted as a safer choice to chloroform and for PIN indexing for gas cylinders to be introduced as a safety design.

In the 1960s, Ross Holland in Australia and Gai Harrison in South Africa initiated longitudinal studies of mortality caused by anaesthesia, showing progressive declines over the next decades in first world countries.

In 1974, Cooper suggested applying the critical incident technique to identify the contribution of human behaviour to harm from anaesthesia, and in 1978 produced his seminal essay on preventable anaesthesia mishaps.

The medical indemnity crisis prompted the 1984 International Committee for Prevention of Anaesthesia Mortality and Morbidity (ICPAMM) meeting in Boston, at which Pierce conceived the Anesthesia Patient Safety Foundation, formed in 1985.

Cheney and others collected anecdotes from US “closed” malpractice claims, focussing attention on common errors, thereby pointing the way to their correction. A 1990 closed claims report found that respiratory events underlay 35 % of total claims, largely preventable with better monitoring. Parallel approaches included Lunn and Devlin’s 1988 launch of the National Confidential Enquiry into Perioperative Deaths in the UK, the Runciman-led formation of the Australian Patient Safety Foundation, and the Australian Incident Monitoring Study.

In 1985, the 9 Harvard hospitals implemented monitoring standards, standards that other institutions then adopted. Similar movements arose in Australia, and the UK. The International Task Force of Anaesthesia Safety led to international standards adopted by the World Federation of Societies of Anaesthesiologists in 1992. In 1999, an Institute of Medicine report (“To Err Is Human”) found that anaesthesia-related mortality had decreased from 2 deaths per 10,000 anaesthetics in the 1980s to about 1 death per 200,000 for fit patients. The WFSA Global Oximetry initiative, begun in 2004, led to The Lifebox Foundation, making pulse oximetry available to every anaesthetised patient.

In 1988, Gaba described mannequin-based anaesthesia simulation at Stanford University. In 1991, he convened a conference focussed on human error in anaesthesia, and the organisational theory of safety in healthcare. This work led to the introduction of crisis management algorithms and checklists.

Retrospective medical record reviews by the 1991 Harvard Medical Practice study (and by a similar Australian study in 1995), prompted the development of a comprehensive classification of things that go wrong. Runciman developed a 12,000 category classification subsequently enlarged to the 20,000 category “Generic Reference Model”. With input from 250 international experts, this formed the basis for the International Classification for Patient Safety.

Arguably, improving the training and status of anaesthesia providers plays the key role in improving patient safety in anaesthesia.

Preface

Individual anaesthetists and others have advanced the safety of anaesthesia by improving drugs, devices, infrastructure, training, and techniques. These contributions have been supported by the strengthening of human factors such as teamwork, and the introduction of checklists, protocols and algorithms. To describe key elements of this story, we provide sketches of some key players, outline advances made by a few more, and mention and cite selected publications of some others. Our sketch relates only to clinical anaesthesia and largely to a few English-speaking countries. We apolo-

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gise to the many who made important contributions not mentioned in our brief account.

The Past—A Framework of the History of Patient Safety in Anaesthesia

The potentially lethal effects of anaesthesia became known shortly after Morton's historic demonstration [1]. Ann Parkinson, of Spittlegate, Lincolnshire, died during ether anaesthesia in early 1847. The coronial inquest, reported in the Times of London, sparked a lively debate on the risks of etherisation [2]. Within three months of chloroform's introduction, Hannah Greener died suddenly whilst inhaling it for a minor procedure [3, 4]. This young girl had painful bilateral ingrown toenails. One had been successfully removed under ether, but she had been nauseated postoperatively and feared the second anaesthetic, 'crying continually and wishing she was dead rather than submit to it' [5]. Although chloroform had advantages over ether, its safe use required greater skill. Only a few practitioners (e.g., John Snow and Joseph Clover) possessed such skill, and deaths associated with chloroform dominated mortality from anaesthesia for the next 50 years, attracting considerable media attention. The use, and perforce the deaths from use, of chloroform, waned and then virtually ceased after a further 50 years [5].

The risks of anaesthesia soon after its discovery did not concern most patients. Pain consequent on disease or injury was commonplace, and patients remembered the horrors of operations without anaesthesia. Furthermore, the hazards of surgery eclipsed those of anaesthesia; before the 1860s advent of antisepsis, amputation carried a mortality of 30% and Caesarean section a mortality exceeding 80% [5].

Stories like those of Anne Parkinson and Hannah Greener powerfully influenced human behavior. Such reports provided the first of five parallel approaches to improving safety in anaesthesia.

Approaches to Improving Safety in Anaesthesia

1. Telling stories
2. Counting the dead (or injured)
3. Trying to understand what went wrong, and why
4. Developing preventive and corrective strategies
5. Evaluating the interventions

Progress in each of these occurred over three periods:

- The first century (1846–1945) after the discovery of anesthesia, ending with the advances during World War II.
- The post war years (1946–1978), ending with Jeff Cooper's seminal paper on anaesthesia incidents [6].
- The recent years (1978–2012).

Table 41.1 A sample of the causes of death during the first 100 years of anaesthesia, selected to illustrate the diversity of causation

Uncalibrated chloroform dilution reservoir bag leading to overdose
Phosgene poisoning from chloroform decomposition with open gas lights
Misconnection of tubes leading to inhalation of liquid chloroform
Chloroform inhalers which when tilted, deliver liquid chloroform
Explosion with ether from open flames, electrical sparks, static
Explosions in patients' mouths or airways associated with ether
Ignition and burning of cuff of tracheal tube
Vomit forced into lungs by attempted resuscitation
Carbon dioxide instead of oxygen in a wrongly marked cylinder
Nitrous oxide instead of oxygen in a wrongly marked cylinder
Wrong volatile agent in bottle—no consistent colour coding
Toxic metabolites (phosgene) of trichloroethylene with sodalime
Percaine (nupercaine) confused with procaine (10-fold potency difference)
Ten times dose error because decimal point missed
Symbol for drachm (dram; 4.4 g) confused with symbol for ounce (28.3 g)
Death from infected anaesthetic agent for spinal anaesthesia
Air embolism during high pressure intravenous infusion
Cardiac arrest from combination of chloroform and adrenalin
Asphyxiation from poor positioning of patient with a lung abscess
Blocked tracheal tube
Airway obstruction due to impacting the epiglottis into the larynx with a gag
Electrocution by an ECG machine

From Sykes WS. Thirty seven little things which have all caused death. In Essays on the First Hundred Years of Anaesthesia. Volume 2, Chapter 1 (pp. 1–23), 1960. E & S Livingstone Ltd, London with permission

The pursuit of safety in anaesthesia is a work in progress: David Gaba argues that anaesthetic practice has yet to adopt many risk-reducing approaches accepted in other high risk environments (e.g., commercial aviation, mining and the nuclear power industry) [7].

Approach 1. Story Telling

Stanley Sykes collected anecdotes of lethal anaesthetic-associated errors during the first century of anaesthesia [5]. Table 41.1 documents the diversity of errors. Similarly, stories or 'cautionary tales' reported to medical indemnity organisations have been collected and published [8, 9]. They allow large numbers of practitioners to benefit from the experiences of an unfortunate few. This approach remains relevant today.

Approach 2. Counting the Dead

Death is a clear and objective endpoint, but several problems hinder attempts to monitor improvements in safety from the study of deaths nominally due to anaesthesia [10]:

- How much do surgery or pre-existing patient-related problems contribute?
- Are all deaths reasonably attributed to anaesthesia (i.e., the numerator) identified, recorded and reported?
- Has the total number of anaesthetics given (i.e., the denominator) been determined [11]?
- Does anaesthesia include sedation, analgesia or the use of other potent drugs, particularly when used by practitioners other than anaesthetists, or when not recorded as anaesthetics in emergencies and remote or unusual locations [12]?
- What time period between anaesthesia and death must be exceeded to exclude anaesthesia as a causal or associated factor? The number used has varied from a few hours to thirty days or longer [13].

A further confounder affects mortality rate comparisons at different points in history. Early studies of "anaesthetic deaths" typically examined deaths occurring in fit people having minor procedures. Increasingly, deaths included those in association with more complex and invasive procedures carried out in sicker patients, some at the extremes of age.

Several investigators counted deaths associated with anaesthesia in the first 100 years. John Snow collected 50 cases of chloroform associated deaths [5].

Sykes recorded that, in the early days, chloroform caused at least 1 death for every 3000 cases, whereas ether seemed to be associated with less than 1 in 12,000. An 1871 report cites a zero mortality from nitrous oxide, a rate of 1 in 2,723 for chloroform and a rate of 1 in 23,704 for ether [14].

After World War II and with the adoption of curare, more complex surgery was undertaken in increasingly sicker patients. Over a dozen studies of anaesthesia mortality were reported, and two important longitudinal studies commenced [12, 13]. In 1959, Ross Holland approached the Director-General of Health of the state of New South Wales, Australia, seeking and receiving ministerial support to obtain statutory immunity for a study of deaths associated with anaesthesia. With Douglas Joseph, he established The Special Committee Investigating Deaths Under Anaesthesia (SCIDUA), which began in 1960. This work continues to this day under the overall auspices of the Australian and New Zealand College of Anaesthetists (ANZCA) and the current chairmanship of Neville Gibbs. Since 1997, data has been garnered from each state and from New Zealand, providing the best longitudinal information on anaesthetic mortality in the world. Holland reported a mortality rate in the 1960s of around 2 deaths per 10,000 cases. This fell to 1 per 25,000 by the end of 1980, and is today thought to be about 1 in 50,000 overall, and perhaps 1 in 200 000 (approximately) for fit patients having minor procedures [15–20].

Gainsford ("Gai") Harrison in South Africa recorded comparable figures from a 30-year longitudinal study [21–23]. Mortality decreased from 1:1,000 in 1958 to 1:10,000 in 1986.

These results indicate that anaesthesia mortality has fallen progressively in high income countries, notwithstanding increasingly complex surgery in sicker and older people. Concurring with these observations, the 1999 report of the Institute of Medicine, "To Err Is Human", stated that anaesthesia-related mortality had fallen from 2 deaths per 10,000 anaesthetics in the 1980s to about 1 death per 200,000 or even 300,000 [24].

Not everyone agrees that this reflects the overall picture. Robert Lagasse's recent review calculated an overall rate of 2 deaths per 10,000 anaesthetics. A prospective study in The Netherlands found an overall rate of 1 death per 13,000 anaesthetics [10–25]. This is far better than the 15–40 times greater (0.3 %) overall healthcare-associated mortality associated with admission to an acute care hospital [26, 27]. Of course, healthy patients having minor procedures have very low hospital- and anaesthesia-related mortality in high income countries today, and estimates of an overall rate are of limited value without some indication of casemix. Clearly, older people with serious co-morbidities undergoing major surgery have a higher risk of dying, but estimates of how much higher vary substantially, depending on factors including the reliability of denominator data, the time period included in the assessment, and the process of attribution of causality. Few would dispute the claim that anaesthesia is, in general, much safer today than it was a few decades ago, but two facts should counter any complacency. First, potentially avoidable deaths continue to occur, even in healthy young patients [19, 28]. Second, some low-income countries have anaesthesia mortality rates 100 times those cited here [29, 30].

The pioneering work in Togo, by Aboudoul-Fataou Maman, is anaesthesia patient safety history in the making. As a medical student, Maman found that, because of deficiencies in anaesthetic standards, many patients died after surgery in the hospital in which he trained, and so decided on a career in anaesthesia. He went on to initiate a classic quality improvement programme. With colleagues, he documented the very high rate of perioperative mortality in his institution, identified factors contributing to this [30] and introduced corrective strategies. These included preoperative evaluation by medical staff, protocols for nurses, triage of difficult cases to specialists, the promotion of local and regional anaesthesia, the creation of recovery rooms, and the training of nurses in the use of morphine. His data have made an important contribution to the World Health Organization's Safe Surgery Saves Lives initiative [31] and the Global Oximetry Project [32] (now Lifebox: see www.lifebox.org).

In 1991, Pedro Ibarra was instrumental in seeing landmark legislation passed by the Colombian Congress (Ley 6 de 1991–Sixth Law of 1991) that, for the first time, defined a medical specialty (anaesthesia) in law. This set the stage for the introduction of minimal standards in Colombia in 1992 and, later, in the rest of South America (promoting, amongst other things, the widespread option of pulse oximetry) The impact of these minimal standards is evidenced by a drop in malpractice claims in Colombia where anesthesia is now ranked 12th among medical specialties.

Approach 3. Understanding What Goes Wrong and Why

Anaesthetic agents, techniques, equipment—"the system"—or humans may underlie things going wrong. How do we identify the problems?

Implicating Drugs

For a century after chloroform's introduction, its inherent toxicity was debated, especially in relation to lightly anesthetised patients receiving noxious stimuli [5]. The landmark 1954 publication by Henry Beecher and Donald Todd supported the notion of the inherent toxicity of anaesthetic agents [33]. This report examined outcomes after 600,000 anaesthetics administered over five years in ten university hospitals, finding that the data "strongly suggests an inherent toxicity" for neuromuscular blocking drugs, particularly curare. A furore followed. Sixteen distinguished anaesthesiologists sought to refute the suggestion [34], and from a study of 33,000 cases, Dripps concluded that neuromuscular blockers did not increase risk [11]. It became clear that the use of curare without reversal by neostigmine placed patients at risk of fatal respiratory failure.

Halothane was introduced in the mid 1950s, and soon replaced all other potent inhaled anaesthetics. Although its hepatotoxicity was rare, it led to halothane's replacement in the 1970s and 1980s by enflurane and isoflurane. In the 1960s and 1970s, volatile inhaled anaesthetics and succinylcholine were found to trigger malignant hyperthermia in susceptible individuals. In 1975, Harrison reported that dantrolene was an effective specific antidote and mortality fell from 80 % to virtually nil [35]. It is now appreciated that the drugs used in anaesthesia today rarely contribute directly to mortality, provided they are used with adequate skill and care.

Implicating Equipment

As Sykes noted, inadequate equipment was identified early as a major cause of mortality and morbidity (Table 41.1) [5]. Understanding equipment became fundamental to safety in anaesthesia, with contributions from many anaesthetists, notably Jerry and Susan Dorsch in the USA [36] and John Russell in Australia [37], whose books have become established as readily understandable references in this field. Equipment for anaesthesia has become more complicated, and the increasing incorporation of electronics and computers within anaesthesia devices creates new risks. There are particular challenges in providing equipment for low income regions of the world that is affordable, appropriate, and simple to maintain. Mike Dobson and Phoebe Mainland, working through the World Federation of Societies of Anaesthesiologists (WFSA), have advanced the case with the International Standards Organization (ISO), for standards that address these needs.

Implicating Techniques, Training and the System

Early academic leaders recognized that an environment conducive to safe anaesthesia required proper training, infrastructure and support. Robert Macintosh forcibly expressed the importance of proper training in 1949 [38]. These points were articulated in the 1993 International Standards for a Safe Practice of Anaesthesia [39], and repeated when these standards were subsequently revised [40]. Greater understanding has developed about techniques for airway management, patient positioning, ventilatory support, cardiopulmonary bypass, and crisis management.

Implicating People

In a lengthy, fascinating, and at times vitriolic paper (already cited above), MacIntosh argued in 1949 that there should be no deaths due to anaesthetics, and that those that did occur were mostly (if not all) attributable to failures on the part of the anaesthetist, rather than any inherent dangers in the drugs used or any underlying pathology that the patients might have [38].

Debate about the legitimacy of "anaesthetic death" as a default diagnosis for all otherwise unexplained perioperative deaths continued through the 1950s, 1960s and 1970s. Longitudinal studies by Holland [15, 16] and Harrison [22, 23] considerably increased our understanding of why things go wrong. In 1979, Arthur Keats published an important paper in which he criticised Macintosh's 1949 article. He accepted that a proportion of anaesthetic deaths are attributable to error but suggested that this proportion might be about 10 %. He argued that many of the drugs and techniques used in anaesthesia are inherently hazardous (citing malignant hyperthermia and succinylcholine-induced hyperkalemia as examples) although he agreed that attribution of deaths to anaesthetic drugs was unacceptable, without demonstration of a cause-effect relationship [41]. In 1979, William Hamilton, a friend and hunting companion of Keats, followed with a very balanced editorial [42], accepting many of Keats' points but suggesting that the proportion of deaths attributable to error might be closer to 90 %. Clearly a better conceptual framework was needed to sort out the relative contributions of drugs, equipment, the "system", patients, and anaesthetists themselves.

Incident Reporting, Mortality Committees and Human Factors

The earliest statement on the importance of critical incidents probably came from RH Todd, anaesthetist to the Prince Alfred Hospital in Sydney, who wrote the following in 1889: "An accident may be defined as any event in the course of the administration which interferes with the simple process of inducing and maintaining a state of surgical anaesthesia. Some of these accidents are of slight importance in themselves, but in as much as small accidents are often the forerunners of greater ones, successful results may depend on a readiness in anticipating, and failing this, a promptitude in remedying small accidents." [43] He then went on to classify accidents as impediments to free respiration, and those in which cardiac failure occurs, with lists of causes.

In 1974, Jeffrey Cooper was a bioengineer at the Massachusetts General Hospital (MGH). Whilst helping carve a pumpkin at a Halloween party, he struck up a conversation which led to an invitation to speak on human factors in healthcare. The resulting lecture, 'The anaesthesia machine: An accident waiting to happen', led a listener to suggest that he use the critical incident technique pioneered by Flanagan in World War II. This led to the study which resulted in his landmark first paper on anaesthetist-reported incidents, demonstrating the multifactorial cause of most problems and the important contribution of human behaviour to things that go wrong [6].

In 1987, David Gaba introduced the concepts of "Normal Accident Theory" to the anaesthesia literature [44]. Gaba, Cooper [45], and then others, advanced the principles of a systems-based (rather than a person-based) response to error. At about the turn of the century, Alan Merry and Alexander McCall Smith (who was then Professor of Law in Edinburgh) extended these ideas into the debate about the most appropriate legal and regulatory response to human error [46].

Cooper's seminal publication coincided with a medical indemnity crisis that had begun in the mid 1970s, characterised by increased litigation and steep rises in insurance premiums [47, 48]. These factors and others led Cooper, with Ellison (Jeep) Pierce—(then President of the American Society of Anesthesiologists) and Dick Kitz (then Chairman of Anaesthesiology at Harvard), to organise the first meeting of the International Committee on Anaesthesia Mortality and Morbidity (ICPAMM) in Boston in 1984 [48, 49]. This focused attention on how anaesthesia-related adverse events happened, and how they might be prevented. During the meeting, Pierce conceived the idea of the Anesthesia Patient Safety Foundation (APSF). With Cooper and others, Pierce formed the APSF in 1985 with the motto "to ensure that no patient should be harmed by anesthesia" [50]. The APSF became a potent advocate for preventing harm rather than cleaning up the mess after an (often tragic) event.

The Closed Claims Study

The Closed Claims Study also arose from the 1984 ICPAMM meeting, where preliminary findings were presented on "closed" malpractice claims [51]. Fred Cheney, then Chairman of the ASA Committee on Professional Liability, saw the value of such a study. He formed a team including Robert Caplan, Karen Posner and Karen Domino, and pursued the cooperation of medical indemnity organisations. Limitations notwithstanding [52], this approach produced an influential series of papers (from ICPAMM to the present) including a 1990 report showing that adverse respiratory events underlay the largest single class of injury (35 % of the total), and an even larger percent of payouts [53]. It showed that better monitoring would prevent 75 % of these injuries. Another landmark study showed the tendency of human beings to display "outcome bias"—the strong human tendency to find fault if there has been a bad outcome – even when there was no question of conciliation or compensation [54].

The ASA used the Closed Claims data to develop practice standards, guidelines and advisories which have increased safety. The Closed Claims Study now possesses the findings for 8,000 malpractice cases, from 34 insurance organisations that insure nearly 15,000 anesthesiologists.

A decrease in the cost of malpractice insurance for anaesthetists has been evident world wide. It is difficult to say how much of this is the direct result of the outcomes of Closed Claim Studies, or how much is due to improved training, newer and better monitoring, new drugs, crisis management algorithms etc.

The National Confidential Enquiry into Perioperative Deaths (NCEPOD)

John Lunn and Brendan Devlin launched NCEPOD in 1988, following a report on surgical and anaesthetic practice during 1985–86 in three UK regions. The report compared patients who had died in hospital within thirty days of a surgical procedure, with "index" (control) cases, using information from those who had cared for these patients [55]. Although frequencies could not be calculated, because of the voluntary nature of the data source and low response rates, NCEPOD reports led to substantial improvements in the availability of resources, supervision of junior staff, appropriateness of surgery and access to critical care facilities [55, 56].

The Australian Patient Safety Foundation

Inspired by developments in the US, William Runciman called a meeting in Australia of 65 influential anaesthetists in 1987. The group comprised department heads and academic leaders, together with past and current deans of the Faculty of Anaesthetists. Standards for anaesthesia monitoring were proposed, and the group decided to form the Australian Patient Safety Foundation (Aus.PSF) to promote patient safety in anaesthesia and, more ambitiously, throughout healthcare

[57]. An early initiative developed a voluntary national incident reporting system for anaesthesia – the Australian Incident Monitoring System (AIMS). In 1993, 30 publications resulted from analysis of the first 2,000 incidents [58]. This, with the US Closed Claims Study, established the utility of oximetry and capnography in anaesthesia, and influenced the promulgation of the International Standards for a Safe Practice of Anaesthesia, which were endorsed by the General Assembly of the WFSA in 1994 [59].

The International Classification for Patient Safety

Unexplained disparate results between retrospective medical record reviews by the Harvard Medical Practice study in 1991 [60], and by a similar Australian study in 1995 [61, 62], prompted the development of a comprehensive classification of things that go wrong in health care. This showed that there were, effectively, no qualitative or quantitative differences between adverse events in Australia and the US, but also confirmed how safe anaesthesia had become. Anaesthesia-related adverse events contributed less than 2% of the total events, compared with nearly 50% for surgery [61]. Anaesthesia related events were also, on average, less severe. Following this study, Runciman developed a 12,000 category classification (the Generic Occurrence Classification), subsequently expanded into "the Generic Reference Model", with 20,000 categories [63]. With input from 250 international experts, this formed the basis for the new International Classification for Patient Safety (ICPS) [64]. The Australian team led by Runciman, now has responsibility for populating the ICPS framework with concepts and preferred terms on behalf of the World Health Organisation (from 2006 onwards). This is being done in collaboration with the "Common Formats" project for reporting to Patient Safety organisations in the US. To this end, Runciman was a member of the National Quality Forum—the group in the US which oversaw this project.

Several other anaesthesia patient safety experts have promoted patient safety across all of healthcare [65]. For example, Cooper participated in the Institute of Medicine report "To err is human.…"; and was a key player in the formation of the National Patient Safety Foundation of the American Medical Association. In 2010, Alan Merry was appointed to chair the Board set up to establish the New Zealand Health Quality and Safety Commission.

Approach 4: Developing and Implementing Preventive and Corrective Strategies

As problems have been identified and understood, so preventive and corrective strategies have been developed and applied. Many problems listed in Table 41.1 were amenable to solution and were solved in the first century of anaesthesia. Some, such as the correct identification of drugs with look-alike and sound-alike names, "decimal point" confusion, and problems with airway management continue to this day. Possible solutions to some of the causes of drug administration error have been developed and evaluated, but not yet widely implemented [66].

Improving the System Through Engineering

If it is possible to eliminate a problem by design, then this should be done. In the post war years, problems with equipment, particularly equipment used to deliver gases and vapours, were common [67–69]. In 1940, two patients died because carbon dioxide cylinders were substituted for oxygen cylinders, having had their green colour painted over with black [69]. The introduction of PIN indexing for gas cylinders in 1954 [69] is a classic example of an engineering solution to remove a latent factor [70] in the system that sets people up to make mistakes. Other examples include breathing circuits that can only be assembled in the correct manner [71, 72],and modifications to gas flowmeter systems of anaesthesia machines that prevent the administration of hypoxic gas mixtures.

Monitoring and Standards

By the mid 1980s, it became evident that some problems could not easily be "designed out" (inadvertent oesophageal intubation, breathing circuit disconnections, and adverse reactions to drugs or surgical stimuli), but more effective management was possible if they could be rapidly detected. Equipment monitors (the Ritchie Whistle was an early example of an alarm to warn of oxygen supply failure [73]) and highly effective patient monitors set the scene for the widespread promulgation of standards of care. These included pulse oximeters providing beat-to-beat measurements of arterial blood saturation (invented in 1972 by a bioengineer, Takuo Aoyagi and first used on patients by a surgeon, Susumu Nakajima, in1975 [74, 75]) and capnographs providing breath-by-breath measurements of carbon dioxide concentrations (the modern infrared capnograph was developed in 1937 by Karl Luft [76]) In 1986, the nine Harvard hospitals initiated the Harvard Monitoring Standards as a standard of care, thereby beginning a wider adoption of monitoring; John Eichhorn and Jeff Cooper played major roles in this process [77]. Monitoring devices became de facto standards across the US and prompted the setting of standards in Australia, UK, and the rest of the world. Eichhorn was the organiser of the International Task Force of Anaesthesia Safety that led to the original 1993 international standards for safe practice of anaesthesia [39], and a major contributor to the revision of these standards in 2008 [40]. Anaesthesia safety standards were proposed for Australia during the 1987 meeting that gave birth to the Australian Patient Safety Foundation [58]. The 1980s Closed Claims Study and the 1990s AIMS, indicated that half of all incidents could be detected by monitors, and that up to 90% of these would be detected by capnography and oximetery [53, 59]. These monitors have become the standard of care in high income regions of the world, but many operating rooms internationally are without them. In 2008, the revised International Standards for a Safe Practice of Anaesthesia [40] effectively elevated the use of pulse oximetry to a mandatory requirement for elective anaesthesia, in concert with the aims of the Global Oximetry project [32] (see below). National anaesthesia societies and the WFSA have endorsed these initiatives to enhance the safety of anaesthesia

Crisis Management.

It had long been recognised in the aviation industry, that if a cockpit crisis occurred, it was not managed effectively if dealt with through deductive reasoning. By the time a solution was found in increasingly complex aircraft control systems, it was invariably too late. Instead, pre-compiled responses, the basic steps of which could be learned by rote, were instituted. These algorithms enabled pilots to respond to crises in an ordered manner, and were designed to reach a management solution, with or without determining an immediate cause. In the early 1990s in the US, David Gaba spearheaded advances in the use of pre-compiled algorithms for the management of crises during anaesthesia [78]. This was followed in Australia by the development of a specific set of crisis management algorithms for anaesthesia, tested against 4,000 incidents [27]. The development of courses to pioneer the systematic management of crises in anaesthesia (including the use of algorithms when appropriate) was pioneered in the US, Australia and New Zealand [79].

The need to monitor things that might go wrong will persist. Each new initiative or technological advance contains new ways of making mistakes. An early example might be the introduction of the laryngoscope, that facilitated safe insertion of an endotracheal tube, but potentially damaged the patient's teeth. Unintended consequences, or "revenge effects", can have major implications [80].

A Just Culture-Speaking Out

In responding to accidents in healthcare, the focus has shifted from one on individual culpability, through one in which no blame is attributed, except in egregious circumstances, to a current view which emphasises a just culture [46]. There are times when "whistle blowing" is called for. Steve Bolsin exemplifies the importance of speaking up when things persistently go wrong. He is famous as the "whistle blower" whose actions changed the mortality of paediatric surgery at the Bristol Royal Infirmary from 30 to 5%. He conducted the Cardiothoracic Anaesthesia Audit in the UK from 1990, when he came to realise the high mortality rate in his own unit. When his efforts to address this were blocked, he took his concerns to the media with the result that a major enquiry ensued. Many lessons were learned [81] and changes followed both at Bristol and in the United Kingdom generally [82]. His actions also had the less salutary effect of leading to his unemployment in Britain. This proved to be a watershed in the patient safety movement in the UK [83].

Human Factors and Simulation

In 1991, Gaba convened a conference on Human Error in Anaesthesia. Sponsored by the APSF and the United States Food and Drug Administration, the meeting brought together 30 experts in the field of human factors in patient safety, including James Reason and Jens Rasmussen. Reason, a psychologist from Manchester, had just published his classic book, Human Error[70], in which he advanced the view of accident causation that has subsequently became famous as the "Swiss Cheese Model." [84] He distinguished the role of active and latent failures in producing an accident, emphasising that latent failures lie dormant in a complex system, until by confluence of one or more additional failures, often triggered by an active failure, an accident occurs. The meeting launched important developments in the understanding of the role of human error in anaesthesia, and in the organisational theory of safety in healthcare, in particular the idea of learning from high-risk environments like aviation and nuclear power [7, 85]. The meeting accelerated the uptake of simulation as a tool for teaching and research in anesthesia [86–89].

Engineer Stephen Abrahamson, and anaesthesiologist Judson Denson, in the mid-1960s, had created Sim One, the first anaesthetic simulator [90, 91]. Little came of this until 1986, when Gaba developed mannequin-based anaesthesia simulation at Stanford University and subsequently promoted its teaching and research potential. Soon after, Nik Gravenstein and Mike Good developed the Gainesville Anesthesia Simulator, along similar lines. Complex pathophysiological scenarios could be used in teaching human factors and crisis management [7]. Dan Raemer conceived of the Society of Simulation in Healthcare and chaired the "Board of Overseers" which established the Society in January 2004. *The Simulation in Healthcare Journal* began publication in January 2006, and the use of simulation for training, research and assessment in anaesthesia is now widespread.

Drug Administration Error in Anaesthesia

The "wrong drug" problem featured prominently in the 1993 AIMS reports [56], and has remained a recalcitrant problem in anaesthesia despite numerous case reports, high profile legal proceedings [92, 93] and calls for improvement [94, 95]. This probably reflects the fact that there is no simple solution to the problem, which is indeed multifaceted. In January 2008 and again in 2010, Bob Stoelting chaired APSF consensus conferences to develop new strategies for safe medication delivery. The latter conference developed a new paradigm to reduce medication errors, based on four key principles: Standardization, Technology, Pharmacy/Prefilled/Premixed (medication), and Culture (STPC) [96]. Between 1972 and 1983, the DAME system at Duke University used technology to ensure correctness of anaesthetic drugs at the point of administration, but technological challenges led to the demise of the system. Many automatic anaesthesia record keeping systems are in use today but few have focused on improving the safety of drug administration. Alan Merry has led a team in New Zealand investigating drug administration error in anaesthesia over the last decade. The primary focus of this work has been the elucidation of the principles likely to enhance the safety of drug administration in anaesthesia, and the results provide support for the concepts of STPC [66, 97–99]. The challenge from 2013 onwards is to promote widespread uptake of these principles.

The Role of Anaesthesia Societies, Colleges, and Academic Departments

Arguably, improving the training and status of anaesthesia providers has been the most important factor in improving patient safety in anaesthesia in high and middle income countries.

Clover demonstrated early that specialisation is important to safety. He gave up general practice to pursue anaesthesia, and administered 10,000 anaesthetics (more with chloroform than ether) before losing a patient under chloroform in 1874 [2].

Improved training has resulted from the activities of many anaesthetists through academic departments, societies, colleges and other organisations. Academic departments have been critically important in providing a focus and home for researchers and educationalists, for advancing the scientific basis of anaesthesia through research, and promoting the standing of anaesthetists. Ralph Waters was appointed to the University of Wisconsin in 1927, with the challenge of creating an academic department of anaesthesiology. He had four major objectives: to provide the best possible anaesthetic care to patients; to teach interns and residents the fundamentals of clinical anaesthesia; to educate postgraduate doctors in anaesthesia; and to continue research into the scientific foundations of anaesthesia [100]. He appreciated the importance of establishing similar academic departments across the country and famous anaesthetists who promulgated the “Wisconsin model” included Emery Rovenstine and Robert Dripps. Lord Nuffield established the first Chair of Anaesthesia in Europe at Oxford in 1936, and Robert Macintosh (who had visited Waters) was appointed to this position. He too advanced teaching and research in anaesthesia, and many leaders in anaesthesia, including academic anaesthesia, trained under Macintosh in Oxford and the first and subsequent generations of “offspring” of Ralph Waters. The detailed stories of the development of education in anaesthesia are told in other chapters of this book.

Organisations such as the American Society of Anesthesiologists (ASA) in the US, the Australian and New Zealand College of Anaesthetists (ANZCA) in Australia and New Zealand, the Royal College of Anaesthetists (RCA) in the UK, and several national anaesthesia societies have promulgated standards and have furthered their application through education and advocacy. The WFSA has been particularly important in this regard, because it provides a forum for all anaesthesiologists (i.e., medically qualified anaesthetists) to collaborate. The WFSA evolved from discussions at the International Anaesthesia Congress in Paris in 1951, and was established in 1955 with 26 founding member societies (there are now well over 100). Its primary aim was “to make available the highest standard of anaesthesia to all the peoples throughout the world.” The World Congress of Anaesthesiologists is arguably the premier international anaesthesia conference; it brings together anaesthesia providers from all over the world thereby advancing education and collegial support, both of which are critical for improving the standards, and therefore safety, of anaesthesia in low income countries of the world, if not everywhere. In particular, it provides a voice for many important contributors who might not otherwise be heard. The Education Committee of the WFSA, particularly under the leadership of Angela Enright has provided training and educational resources to thousands of anaesthesia providers, physicians and non-physicians, who would otherwise have had access to neither. Under Kester Brown’s presidency, the Safety and Quality of Practice Committee was established. This Committee was elevated to the status of a Standing Committee in 2004; amongst its other contributions to patient safety it initiated the global oximetry project and oversaw the first four pilot projects. This established the concept of combining education with the provision of affordable and robust oximeters, as a viable and effective strategy in advancing the standards of safe anaesthesia [32].

Global Initiatives to Improve Safety in Anaesthesia and Surgery

Anaesthesia and surgery are inextricably linked. The recognition that the delivery of healthcare is itself a science, has been pivotal to advancing the safety of patients undergoing surgery, as has recognition of the importance of teamwork, communication and collaboration between the members of the perioperative team [101–104].

Perhaps the greatest contribution from an anaesthesiologist in this context has come from Peter Pronovost, an anaesthesiologist and intensive care physician at Johns Hopkins [105]. In 2001, he began to study healthcare acquired infections, and demonstrated that implementing a five item checklist protocol dramatically reduced central line associated bacteraemia (CLAB) [106]. He extended this work to the state of Michigan. The mean rate of CLAB per 1000 catheter-days decreased from 7.7 to 1.4 at 16 to 18 months of follow-up [107]. This approach has now been adopted in many countries, undoubtedly saving many thousands of lives and millions of dollars. Pronovost established the Quality and Safety Research Group at Hopkins, and has been very effective in promoting the importance of rigour in research into patient safety (see below).

A major influence in this area has been the WHO Safe Surgery Saves Lives initiative, led by Atul Gawande. This initiative was undertaken in response to the problems of iatrogenic harm associated with surgery globally (a great deal of which is attributable to inadequate anaesthesia services in low income regions [108]). It resulted, amongst other things, in the development of the Surgical Safety Checklist and the advancement of the Global Oximetry project (now the Lifebox project) [32]. Olaitan Soyanwo, Jeff Cooper, John Eichhorn, Iain Wilson and Alan Merry formed the safe anaesthesia working group in this major interdisciplinary safety initiative. A landmark multicentre international evaluation of the Checklist, published in 2009, provides compelling support for believing that the widespread adoption of the Checklist has reduced avoidable harm to patients and indeed saved many lives [101]. Gawande's books[109−111] and regular articles in the New Yorker have been powerful instruments in advancing patient safety to a wide readership, extending an awareness of the importance of safety in healthcare well beyond the limits of those directly involved with the provision of healthcare.

The Lifebox Foundation was established in 2011, as a charitable organisation to further the Global Oximetry initiative of the WFSA. This initiative began at the 2004 Congress in Paris. Its aim was to sustainably improve safety in low income countries by providing high standard, robust, affordable pulse oximeters, supported by education and advocacy where appropriate. Since 2009, the project has included the WHO Checklist. The WHO Checklist explicitly addresses risks related to anaesthesia, and is designed to promote communication and teamwork within the operating room [101–104]. The inclusion of pulse oximetry within the checklist was intentional, to emphasise that its use during elective cases is viewed as mandatory (in line with the revised International Standards for a Safe Practice of Anaesthesia) [40]. Beneath this is a powerful message – that anaesthesia needs adequate resources, both in respect of its providers and their level of training, and the necessary equipment. In 2010, the global gap in pulse oximetry was estimated as 77,700 (95% confidence limits 63,195 and 95,533) [112]. By mid 2012, the gap has been reduced to 75,000 [113]. This very substantial ongoing project has depended on close teamwork between many people, including in particular Gavin Thoms, Iain Wilson, Angela Enright, Isabeau Walker, Ellen O'Sullivan, Florian Nuevo, Alan Merry, and Atul Gawande [32, 114].

Approach 5: Assessing Preventive and Corrective Strategies

Measuring the effectiveness of preventive and corrective strategies in patient safety for anaesthesia is difficult because things go wrong so infrequently, making conventional prospective quantitative research costly, and/or a logistical nightmare [115]. Compounding the problem, anaesthesia-related "signals" tend to be lost amongst the "noise" produced by complex procedures and patient-comorbidities.

Nevertheless, measurement is integral to quality improvement (and safety is integral to quality in healthcare) [116]. Donabedian introduced the framework of structure, process and outcome for measuring quality in healthcare [117, 118]. In 2009, for the first time, as an interesting output from the WHO Safe Surgery Saves lives project, some basic metrics were defined to assist in estimating the quality of surgical services in a particular country. They included the number of operating rooms, number of operations, number of accredited surgeons, number of accredited anaesthesia professionals, day-of-surgery death ratio, and postoperative in-hospital death ratio [119, 120]. It is reflective of the challenge in improving the standards of anaesthesia globally, that to meet the definition for their respective structural measures, a surgeon has to be a physician, but an anaesthetist does not.

The difficulties in measuring outcomes in anaesthesia have been touched upon in Approach 2, above, in relation to studies of anaesthetic mortality. Nevertheless, indirect evidence suggests that progress has been made. In 1989, Eichhorn reviewed one million anaesthetics provided to ASA 1 and 2 patients at Harvard University hospitals between 1976 and 1985, finding eleven major intra-operative accidents, of which seven resulted from unrecognised lack of ventilation [121].This finding prompted the introduction of the Harvard Monitoring Standards in 1985.

Indirect evidence from Australia supports the efficacy of introducing oximetry and capnography in the early 1990s. In 2005, Runciman noted that a five year study of medico-legal files, and an analysis of the last 2,000 incidents reported to AIMS had not revealed a single case of inadequate ventilation or undetected oesophageal intubation, although there had been several such problems resulting in brain damage or death each year before 1990 [27].

In Cooper's 1978 study on adverse events in anaesthesia, human errors in drug administration accounted for 19% of events, equalling ventilation and breathing circuit errors at 19.5 %. As noted, today's ventilation and circuit problems are passably low, but harm from drug administration error continues.

A major focus of the work by Merry's group into drug administration error (mentioned above) has been to quantify the extent of the problem. To this end they introduced a method of facilitated incident reporting in that a response is required after every anaesthetic, whether it be a simple negative reply or a more comprehensive account. This established, for the first time, realistic estimates of the likely rate of drug administration error in anaesthesia (about one error for every 130 anaesthetics) [98, 122]. This rate was orders of magnitude higher than most previous estimates, but is itself most likely to be an underestimate.

Amongst the many important contributions of Pronovost to advancing safety in healthcare are his recent contributions to articulating the importance of rigour in research in this field [123–125]. Lucian Leape, Donald Berwick and David Bates made an important point in 2002 [126]: they observed that safety in anaesthesia (as in aviation) had not been based on evidence but rather "by applying a whole host of changes that made sense, were based on an understanding of human factors principles, and had been demonstrated to be effective in other settings." This idea was further advanced the following year by a (now famous) ironical "systematic review" of randomized trials of parachutes as an intervention to manage "gravitational challenge."[127]

In 2011, Shekelle, Pronovost and their co-authors provided a more sophisticated analysis of these issues. They explain why randomized trials are clearly not needed for parachutes, but why rigorous empirical evidence (not necessarily from randomized controlled trials) might well be required for many of the interventions aimed at improving patient safety. Their key points are that an intervention to improve safety should be based on a sound theoretical construct; it should be sufficiently well described to be reproducible; desired outcomes should be clearly defined, the possibility of unintended consequences should not be overlooked; and the influence of context should be taken into account. This is really just a restatement of the essential elements of rigorous research into many other aspects of healthcare, but this important article underlines the point that there is no justification for abandoning rigour in research just because it happens to be in the field of patient safety.

This does not imply slavish subservience to artificial "hierarchies" of evidence [128]. Randomized trials certainly have a role but they are expensive, difficult to undertake, and may be difficult to interpret. Two examples of randomised controlled trials to investigate patient safety initiatives are the well known study by Moller and co-authors into pulse oximetry [129, 130] and a recent study in over 1000 patients by Merry's group investigating an intervention to reduce error in the recording and administration of drugs in anaesthesia [66]. In their own ways each of these studies has provided insights into the challenges associated with evaluating safety initiatives. The negative result from the former study has contrasted with the almost universal perception of the value of pulse oximetry, and with other indirect evidence supporting its value. With the benefit of hindsight their result was predictable given that the outcomes for which the study was powered statistically would not be expected to be influenced by hypoxaemia [114]. In the latter study, the practical difficulty of getting compliance from a large number of participants in adhering to key elements of practice guidelines was well demonstrated.

If the randomized controlled trial is thought of as a hammer, not every problem is a nail. Research methods need to be appropriate to the questions to be answered, and to the context in which they are being considered [114, 128].

It is salutary to note that a number of recent, highly influential studies into checklists [101–104] and into the reduction of CLAB [107] have not been randomised trials. A very important incidental outcome from the Keystone project was some clarification, in the US context at least, of the distinction between quality improvement research and human-subject research involving novel interventions. There is a need for some pragmatism in regulatory requirements if the evaluation of large scale implementations of established best practice is to be affordable and practical [131].

Evaluation is fundamental to quality improvement, but uptake of best practices as evidence emerges is essential if gains in patient safety are to be realised. Despite the evidence supplied by studies such as those cited above, the adoption of initiatives supported by sound research to improve safety in healthcare has been patchy [132, 133], and anaesthesia has been no exception.

The Future

The history of the patient safety movement in anaesthesia is a proud one, with many fine achievements. Much progress notwithstanding, there remains much to be done. The biggest challenges lie in underfunded areas of the world but even in wealthy countries, preventable deaths continue to occur. The goal of the APSF, that "no patient shall be harmed by anesthesia" has yet to be achieved.

Improving safety is an iterative process. At each iteration, the emphasis must be on identifying the most important of the residual problems, coming up with practical and affordable solutions, and implementing them. There is a place for pragmatism and for applying things simply because they make sense, but not for abandoning the commitment to the scientific foundations of anaesthesia that has been the hallmark of the contributions to patient safety of many of the anaesthesiologists discussed in this chapter. Ongoing commitment to this fundamental principle will provide powerful impetus in adding to the impressive advances that have justified this speciality's reputation for leading the pursuit of patient safety. The goal of the APSF may be aspirational, but it has served our patients well, and will continue to do so, well into the foreseeable future.

Notable Names

The following list gives a brief insight into the contributions to patient safety, of some of the individuals mentioned in the body of this chapter. The list is in order of appearance, and is by no means exhaustive. Limitations on space have determined that many deserving contributors are omitted, and some appear elsewhere in this book. The authors offer their apologies to those people.

David Gaba (1954-) graduated from Yale University School of Medicine, in 1980. He introduced human factors and the organisational theory of safety into anaesthesia and healthcare, first by Normal Accidents Theory and then by High Reliability Organisation Theory. He is credited with inventing modern mannequin-based immersion simulation, work he conducted from 1986 to 1992. He subsequently introduced Crew Resource Management into anaesthesia (Anesthesia Crisis Resource Management), and then to healthcare in general (Crisis Resource Management). His ongoing research on human performance, cognition and human factors using simulation as a tool has been a model for the scientific advancement of patient safety.

W Stanley Sykes (1894–1961) served as an anaesthetist before and during World War II, including while a prisoner of war, for which he was awarded an MBE. He returned to general practice, but remained fascinated by things that go wrong with anaesthesia, becoming a prolific writer of matters medical and a series of thrillers. His "Essays on the first 100 years of Anaesthesia" [5] provide a rich tapestry of background, trivia, contemporary accounts, and important milestones in the development of anaesthesia and the safety of anaesthesia for that early period.

Gainsford "Gai" Harrison (1926–2003), a graduate of the University of Cape Town, contributed to the safety of anaesthesia in three areas: He conducted a 30-year longitudinal study of anaesthetic mortality; he was a world authority on anaesthesia for patients with porphyria; and he was pivotal in introducing dantrolene to treat malignant hyperthermia.

Aboudoul-Fataou Ouro-Bang'na Maman (1974-) was born in Tchalo (Sokode) and graduated from the University of Lome, Togo in 2002. He obtained a Diploma in pain management ("Capacité d'Evaluation et de Traitement de la Douleur") from the University of Montpellier 2, in France, in 2004, and a Diploma of anaesthesia from the Faculty of Health Science, Cotonou (Benin) in 2006. He worked in Togo, Martinique, and Guadeloupe. He translated the book "Safe Anesthesia" into French in collaboration with the WFSA publication committee.

Robert MacIntosh (1897–1989) was born in New Zealand and baptised with the Maori name Rewi Rawhiti. He pioneered the safety of anaesthesia in the English speaking world outside of the US. In World War I he served as a pilot in the Royal Flying Corps, was shot down in 1917, taken prisoner and escaped several times. After the war, he trained in medicine in London, and in 1937, became the first Professor of Anaesthesia outside the US. He was a proponent of "safe and simple' anaesthesia". In the 1940s, he argued that most "anaesthetic accidents" were preventable. With William Mushin, he tried to launch research on this topic in 1944. Despite initial opposition, in 1949, the Association of Anaesthetists appointed a committee to investigate anaesthesia-associated deaths, a committee that is still active.

Arthur Keats (1923–2007) graduated from the University of Pennsylvania in 1946. Henry Beecher mentored him during his residency at the Massachusetts General Hospital from 1948–1951. He was the first Chair of the Scientific Evaluation Committee of the Anesthesia Patient Safety Foundation (APSF). From 1970–1973 he was Editor in Chief of the journal Anesthesiology. He was also a member of the FDA's Respiratory and Anesthetic Drug Advisory Committee.

Jeffrey Cooper (1946-) was born and received his early schooling in Philadelphia, Pennsylvania. He received his BS in Chemical Engineering (1968), and an MS in Biomedical Engineering (1970) from Drexel University, and a PhD in Chemical Engineering at the University of Missouri (1972). He is a Professor of Anesthesiology at Harvard Medical School, and is the father of incident reporting in anaesthesia – indeed, in medicine. He received several honours for his work in patient safety, including the 2003 John M. Eisenberg Award for Lifetime Achievement in Patient Safety from the National Quality Forum and the Joint Commission and the 2004 Lifetime Achievement Award from the American Academy of Clinical Engineering. He has a particular talent for supporting and mentoring others, and both authors have cause for considerable gratitude in this respect.

Ellison (Jeep) Pierce (1929–2011) was President of the American Society of Anesthesiologists, founder of the APSF, and an elected Fellow of the Royal College of Anaesthestists. He received awards and citations from the Food and Drug Administration, the American Medical Association, the Royal Society of Medicine and the Russian Society of Anesthesiology. To quote from his obituary in the APSF Newsletter *"when the specialty was faced with a malpractice crisis at the start of the 1980s, Jeep thought about protecting* *patients first and doctors second. That was a risky political move, but he didn't hesitate. He just did the right thing."*

Frederick Cheney (1935-) completed his specialist training in 1964 and joined the Faculty at the University of Washington where, 30 years on, he became Chairman. As Chair of the American Society of Anesthesiology Committee on Professional Liability, he organised the Closed Claims Study. From 1989, he concentrated his research activities on the ASA Closed Claims Project. In 2007, he created an endowed Chair of Anesthesia Patient Safety in the name of his mother, Laura Cheney.

John Eichhorn (1947-) was born in Cleveland, Ohio, attended Princeton University, and graduated from Harvard Medical School in 1973. He was the creator and original Editor of the newsletter of the APSF. He was a member of the WHO Safe Anesthesia Working Group, and the Safe Surgery Saves Lives global initiative. In recognition of his seminal contributions he was awarded the 2010 John Eisenberg Award for Individual Achievement in Healthcare Quality and Safety from the Joint Commission of the National Quality Forum in the USA.

JS (Nik) Gravenstein (1925–2009) was born in Berlin. He graduated from the University of Bonn Medical School in 1951 and from Harvard Medical School in 1958. He contributed to the safety of anaesthesia as head of several departments of anaesthesia, as Editor of the International Journal of Clinical Monitoring, as author of a book "Clinical Monitoring Practice", and as a pioneer in high fidelity simulation. A founder of the APSF, he was a Board Member for ten years. He led a team at the University of Florida which developed the "Gainesville Anesthesia Simulator". He was a "calm and collected" mentor, and a gracious and generous host and teacher (to W.B.R. amongst many). On Gravenstein's retirement, Jeep Pierce stated "I have not met a greater gentleman who has contributed more to the specialty of anesthesia than Nik Gravenstein".

Dan Raemer (1950-) graduated in Electrical Engineering from the University of Massachusetts in 1972. He then studied BioMedical Engineering and received a Master of Science in 1975, gaining a PhD in Bioengineering from the University of Utah. In Vermont, he and others started a program providing clinical engineering services to hospitals throughout the State (this program continues today). In 1993 he joined the nascent Boston Anesthesia Simulation Program begun by Jeff Cooper. He streamlined the pilot courses that had been introduced into coherent curricular entities that could be applied to large cohorts of anesthesia trainees. He expanded simulation and crisis resource management into other fields such as emergency medicine, intensive care, medicine (codes), and air rescue and turned them into ongoing programs. His vision was responsible for the creation and success of the Society for Simulation in Healthcare.

Angela Enright (1947-) was born and raised in Ireland, graduating from University College Dublin. She interned at St Vincent's Hospital, Dublin, then moved to Canada, training in anaesthesia at the University of Calgary, Alberta. She was President of the Canadian Anesthesiologists Society in 1994–95, and chaired the Organizing Committee for the 12th World Congress of Anesthesiologists held in Montreal in 2000. She is known for her promotion of education around the world, particularly in low income areas, in many ways following in the footsteps of Kester Brown but adding her own mix of excellence, charm and inspiration. As the immediate past President of the World Federation of Societies of Anaesthesiologists she coordinated and largely undertook the development of extensive educational material – translated into several languages. She is a Founding Director of the Lifebox Foundation. She was awarded the Order of Canada in 2011.

T.C.K. (Kester) Brown (1935-) was born in Kenya. He became the Director of Anaesthesia at the Royal Children's Hospital in Melbourne, and developed a worldwide reputation for himself and his Department. He became a member of the WFSA Education Committee in 1984, and President of WFSA in 2000. He was dedicated to helping those with limited resources and opportunities. He encouraged others to share in this passion, and mentored both of the authors. He advanced patient safety through his teaching, advocacy and personal example.

Atul Gawande (1965-) was born in Brooklyn, New York. His parents, both doctors, were immigrants from India. He grew up in Athens, Ohio. He graduated from Stanford, and he majored in Philosophy, Politics and Economics at Balliol College, Oxford as a Rhodes Scholar. It may seem unusual to include a surgeon in a chapter on the history of the patient safety movement in anaesthesia, but Atul Gawande is no ordinary surgeon: his contribution to patient safety in anaesthesia has been exceptional and has not ended. He joined Al Gore's presidential campaign in 1988, worked closely with Bill Clinton during his 1992 campaign, and went on to become a senior advisor in the Department of Health and Human Services. He returned to school (Harvard), in 1993 completing his medical training and specialising in surgery. He has a Master of Public Health (from the Harvard School of Public Health). In 2007, he became director of the WHO Safe Surgery initiative, which has a strong emphasis on the importance of anaesthesia to the safety of patients worldwide.

Olaitan Soyannwo (1945-) was born at Ilisan-Remo, Ogun State, Nigeria. She went to Mayflower school, Ikenne and Queen's College, Yaba, Lagos and then the University of Ibadan Medical school, qualifying in 1971. She trained in anaesthesia in England and has been a Consultant in Anaesthesia and Intensive Care at the University College Hospital, Ibadan since 1981, serving as Professor and Head of Department of Anaesthesia and Dean of the Faculty of Clinical Sciences. She was a key member of the Anaesthesia Safety Group of the Safe Surgery Saves Lives Campaign, and her advocacy (in the face of external scepticism about the relevance of "expensive technology" to low income areas of the world) facilitated the decision to include pulse oximetry on the WHO Safe Surgery Checklist. She was a major contributor to the revision of the International Standards for a Safe Practice of Anaesthesia.

Iain Wilson (1936-) was born in the UK and graduated from Glasgow University. While training in anaesthesia he worked in the Royal Air Force (1979–85) and as a Lecturer at the University of Zambia (1986–8), where he co-authored the first perioperative outcome study in the region. He is internationally known for his contribution to training, and chairs the Publications Committee of the WFSA where he established Update in Anaesthesia, and Anaesthesia Tutorial of the Week, as freely available training and CPD resources. He is a co-editor of the Oxford Handbook of Anaesthesia. He was a member of the Anaesthesia Safety Group of the Safe Surgery Saves Lives Campaign and led the WFSA Global Oximetry project in Uganda (79). He was elected President of the Association of Anaesthetists of Great Britain and Ireland in September 2010, bringing the influence and resources of this organisation to the support of the Lifebox initiative.

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