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Information, Knowledge and Technology: Role in Anaesthesia Patient Safety

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Abstract

Anaesthesia which was once the riskiest of all medical specialties is now the safest.[8,14] This evolution has come at a daunting cost paid through years of disasters. The early adoption of information technology (IT) and knowledge management (KM) principles in the quest for patient safety in anaesthesia has yielded a great return for both patients and anaesthetists.

Many of the departments of anaesthesia around the world are involved in research to further refine patient safety through acquiring knowledge in new realms of patient management. Meanwhile, anaesthetists are exploring new frontiers for action in implementing comprehensive patient safety.

In this paper a brief historical overview is followed by a closer look at the developments in anaesthesia in relation to new technology. The impact of advances in knowledge on the delivery of enhanced patient safety is presented along with a brief review of lessons learned and ambitions for the future.

1. Historical Overview

The launch of the successful practice of anaesthesia started in 1846 when William Morton (1819-1868) performed the first successful demonstration of ether anaesthesia in the Massachusetts General Hospital, Boston, US. News flew across the Atlantic and, in the same year, a dentist called James Robinson (1813-1862) in England also conducted successful anaesthesia [1].

Initially, the practice was generally erratic and associated with many deaths and catastrophes. Therefore, injury, damage or deaths due to anaesthesia have historically been an issue of great concern. Anaesthesia when started in the mid-19th century was not an independent specialty or practice but rather a corollary of medical practice to soothe patients' pains. It was administered by a diverse mix of physicians, surgeons and dentists [1]. It is noteworthy that the information about anaesthesia in the early days is anecdotal and patchy, which may be due to the nature of the practice as auxiliary to other disciplines.

The first scientific effort to quantify and standardise the practice was made by John Snow of London, England, (1813-1858). John Snow's efforts were not built upon and development was painfully slow through the latter half of the 19th and the first quarter of the 20th centuries; some 60 to 70 years [1].

As with any new technology, a strong debate then erupted about the efficacy and safety of the first two important agents in anaesthesia, ether and chloroform. A decisive solution came along with better knowledge in 1881 when Lyman, reporting on mortality [2], declared that chloroform had resulted in 333 deaths in one year and ether in 29. This fact was enough to finally halt the use of chloroform in anaesthesia [2]. Obviously, an early victory for information and knowledge.

The pace of development started to pick up in 1917 with the innovation of the "Boyle" apparatus close to the end of the First World War. This progress was boosted in the early 1930s with the advent of the intravenous anaesthetics [1].

Information about the anaesthetics administered to patients was virtually non-existent. It consisted of only very short notes in operating theatre registers. It was not until later that Dr Gilbert Brown of Adelaide, Australia, recommended that each patient had a separate record of anaesthesia [2]. Gilbert Brown collected anaesthetic mortality data at the Royal Adelaide Hospital between 1932 and 1936 including information about the anaesthetics administered. He followed up with analysis and generated knowledge from the aggregated information. Thereafter, Brown acted to disseminate this generated knowledge to all the anaesthetists across Australia through the newly inaugurated Australian Society of Anaesthetists [footnote a], thereby completing his exercise in KM in anaesthesia [2].

Modern anaesthesia had its real inception in 1942 with the introduction of drugs which induce controlled muscle relaxation, ie, controlled paralysis. This group of drugs handed the full control of the patient's respiration to the anaesthetist. Immediately, this development was followed by the inventions of controlled respiration and ventilator techniques [1].

In 1948, anaesthesia was recognised as an independent specialty in the UK. Research in anaesthesia as a discipline in itself prospered, yielding knowledge which was used to continually refine understanding and techniques. The effects of those advances became most noticeable in the 1950s and continued well into the 1980s [1].

2. Knowledge for Safety in Anaesthesia

This overview of the role of knowledge in safety in anaesthesia will look into the need for information and knowledge technologies in affecting patient safety. This is followed by a review of efforts made in the recent past, current efforts, a glimpse into the future and, finally, hints on the lessons learned and suggestions about future knowledge practice for New Zealand anaesthetists.

2.1. The Need for Information Technology and Knowledge

The arduous development of anaesthetic patient safety has come via an age of catastrophic experiments. Lack of knowledge was usually the cause. Knowledge about the pharmacological effects of the agents used and the changes in physiology of the human subjects was inadequate, so was the design of the apparatus used to deliver the anaesthetics. Without belittling the efforts of the pioneers who laid the principles of anaesthesia, it is not unfair to contend that every critical development in anaesthesia has grown as a fresh lawn on a cemetery of unintended victims; unfavourable outcomes have always stimulated the search for better means.

The nature of the state of being under anaesthesia lends itself to a situation of insecurity due to the patient's loss of consciousness and loss of the primitive protective reflexes which protect an organism from noxious environmental factors. During this state, the management of the anaesthetised subject is usually transferred to the one who administered the anaesthetic. How do they communicate? How does the anaesthetist ensure the welfare of his or her subject? Information is the answer.

Through information the anaesthetist forms a dynamic mental image of his or her patient. This image is continuously updated through data. Information which has been previously well-matured into knowledge through observation and research is especially useful in the assembly of the picture. Through information an anaesthetist can recognise that the patient has started to sense pain; likewise, he or she could rightly decide on the need for a blood transfusion, estimate the amount and speed of drugs to administer and/or other measures to control the situation. To closely observe the patient, each type of vital data, eg, pulse, blood oxygen saturation, or level of expired carbon dioxide is gained by specialised sensors and transmitted through an independent data channel. These data are interpreted for monitoring, recording and anticipating changes. In the recent practice of anaesthesia, an abundance of monitoring equipment and techniques has led to an overload of data in need of interpretation into information, relevance evaluation and storage or dumping.

In no other branch of medicine is the data, information and knowledge chain so immediately and dynamically woven as in the conduct of anaesthesia. Decisions are urgent; results are immediate. Therefore, anaesthesia necessitates the use of relatively intelligent systems to deal with the numerous data channels, to set alerts and alarms, and to integrate the relevant information from different channels together. The use of computer systems to spontaneously interpret the data into useful patient information, verified against a background of knowledge from a knowledge base, is an ongoing effort. It could be very supportive to present the anaesthetists with possible solutions to their current case situations, rather than flooding them with streams of irrelevant vital data about all the biological parameters of the patient. The amount of the possible raw data would be more of a distraction as it could be well beyond the human brain's capacity to integrate.

2.2. Anaesthesia Knowledge Efforts; Recent Past and Current

2.2.1. Early Adoption of IT and Knowledge Solutions

While the whole health care industry was lagging behind for more than a decade [3,4] in adopting new and effective IT tools, the situation in anaesthesia was dissimilar. It seems that the lessons of the past have dwelt somewhere in the collective mind of anaesthetists. At the time new technologies were introduced into health care, anaesthetists were pioneering the efforts to adopt it into their practice.

As early as 1968, efforts were underway to code anaesthesia data onto the then new IBM information recorders. Punch cards were used to code and tabulate anaesthesia data so that statistics could be easily collated and information drawn from them. In addition to being a fast retrieval method for accurate analysis, this method was regarded as reliable, simple and easy to use. Sanchez and Switkin [5] reported in 1969 on the coding of anaesthesia data on a new IBM information recorder. They devised and used a dictionary of codes to punch the cards according to numerical values. The method appeared very efficient then, but when compared to the direct digital input possible nowadays, it looks like an extremely cumbersome process.

In 1984, an example of knowledge generation through data recording and information extraction was set by the University Department of Anaesthesia of the Glasgow Royal Infirmary. They used an Apple II microcomputer system to collect anaesthesia patient data both on-line and off-line and stored it for later analysis. Printing of a full record of the patient anaesthetic at the end of the operation was also possible [6].

2.2.2. Institutional and Research Solutions

At a meeting of the American Society of Anesthesiologists in 1984, the inauguration of the Anesthesia Patient Safety Foundation (APSF) was proclaimed. The declared goals of the APSF were:
The mission of this corporation is to assure that no patient shall be harmed by the effects of anesthesia. The purposes of this corporation are: to foster investigations that will provide a better understanding of preventable anesthetic injuries; encourage programs that will reduce the number of anesthetic injuries; and promote national and international communication of information and ideas about the causes and prevention of anesthetic morbidity and mortality [7].

The APSF laid a cornerstone for KM in anaesthesia, namely the sharing and dissemination of knowledge, not only on the local level but also in the international sphere. The APSF started its knowledge dissemination through a newsletter by ordinary mail, reaching over 60,000 readers quarterly. Currently, all issues of the APSF's newsletter are accessible through their website [7].

Working to realise their second goal by fostering research designed to uproot the causes of avoidable injuries due to anaesthesia, the APSF awards four or five research grants of about US$65,000 every year. Anaesthesia simulators, which are very useful in training, were among the most prominent results of these research grants [7].

The APSF enabled those concerned with patient safety to join forces with the American Society of Anesthesiologists (ASA). In 1986, the ASA made the use of patient respiration monitors (pulse oximetry and capnography) in anaesthesia one of its guidelines for the safe practice of anaesthesia in the US. By 1990 almost all hospitals in the US had adopted the technology [8].

Then, in 1988 as the new era of the personal computer (PC) was dawning, the Department of Anesthesiology, New York University Medical Center, developed their own IT solution [9]. They took a PC and built the software [footnote b] in six months using a simple relational database program and the programming experience of one of their anaesthetist team members. The software, a computerised anaesthesia database, enabled the organised collection of anaesthesia information and their subsequent analysis. Data analysis helped monitoring the quality of anaesthesia care provided. The value of the project was not only in the knowledge generated but also in the setting of an example for the other specialties in medicine [9].

2.2.3. Expanding on Technology

With the turn of the 1990s, a totally new development arose; computing power increased and costs started to dwindle towards the more reasonable, giving a boost to the design and utilisation of artificial intelligence applications. In 1993, as the result of co-operation between the Department of Automatic Control and Systems Engineering, University of Sheffield, and the University Department of Anaesthesia Western Infirmary, Glasgow, a pilot study was published about an expert system powered by a knowledge base which could control general anaesthesia. The knowledge base was developed over three years of training in the system. This knowledge base was fed the patient data online and used Bayesian [footnote c] inference techniques and fuzzy logic [footnote d] to recommend on the concentration of the inhaled anaesthetic agents. The system was called RESAC (real-time expert system for advice and control) and the testing results showed that anaesthetists were satisfied with the system's recommendations [10].

Although no computer system to date is capable of comprehensive patient management in a complex discipline as anaesthesia, or in any other specialty, it is still helpful in sharing the load and giving timely advice and cues.

As cumulative experience with the new technologies grew, activities broadened and started to cover all aspects of the practical technology. The move to create and integrate electronic patient records, or computer-based patient records has already begun. The Society for Technology in Anesthesia (STA) published a policy statement in 1998 supporting the availability of electronic anaesthesia medical records. The STA shed light on the value of conducting research on large numbers of cases rapidly and easily with the possibility of outcome assessment and follow-up. They advocated the use of automated digital data entry into electronic records. In the meantime, they recommended the acquisition of standards to protect the patient-physician confidentiality [11].

The recommendations of the STA were followed shortly by an extensive study on anaesthesia outcome, conducted by the Departments of Anaesthesiology and Intensive Care Medicine, University of Ulm, Germany, and the Department of Medical Informatics, University of Utah, US. The study included about 96,000 cases and was based on building a large database of perioperative patient information over five years. It was conducted between 1992 and 1997 in multicentres all over Germany. A minimal dataset was collected to standardise the long-term methods of reporting the daily outcome measures to use in outcome assessment. Consequently, the study revealed anaesthesia outcomes and the incidence of complications. The use of electronic records and data validation methods enabled comprehensive analysis of results, and paved the way for future outcome assessment in anaesthesia [12].

2.2.4. Optimising Knowledge

Fairly recently, computing power grew intensely, monitoring became ubiquitous, data flow has become phenomenal, and information is piling up. Information accumulation both online and offline has crossed the human brain's capacity for interpretation. So the need to sift, summarise, and present lean information became a necessity.

Too many parameters to process are presented to an anaesthetic team. It is beyond the members' capacity to integrate immediately. In addition, it might be a form of distraction to the anaesthetist away from the early signs of a crisis in "formation" until he/she finds themselves in the middle of it [13].

In 2000, Dorman and Fackler [13] on examining the data issues in automated information systems in anaesthesia, considered the systems, especially in crisis management, to be an attempt at "running before crawling." Nevertheless, they held an optimistic view on the long term and advocated critical issues necessary to mange the data loads. The issues included reducing the number of data variables presented to the anaesthetic team, presenting the data after interpretation into information relevant to the situation at hand, and integrating the different data elements (information) which might have contributed to the current situation. In addition, they recommended the use of significant alarms only. Refinements using those principles have been embedded in the rules being currently used in cardiac anaesthesia [13].

Knowledge optimisation was required to relieve anaesthetists from the chores which divert attention from the early detection of the fine indicators of a developing crisis. To mitigate this problem, the use of automated therapy through "closed-loop" systems which became possible via the utilisation of complicated algorithms on automatic delivery systems was also recommended by Dorman and Fackler [13].

More efforts are needed to develop systems capable of supporting actual crisis identification by delivering early, accurate and useful information. Nevertheless, all those helpful tools and techniques are not capable of managing a real crisis situation, they could only help reduce the anaesthetist's load and allow a niche for careful observation of the more subtle signals.

3. A Glimpse into the Future

3.1. Ambitions

In 2000, David Gaba, while advocating anaesthesia as a model for patient safety also promoted human factors and the systems approach to safety [14]. Shortly afterwards in 2002, Weinger and Slagale, indicated that patient safety has become a major public concern and that many studies in the preceding decade illustrated the value of using human factors techniques in studying patient safety [15]. Others have also reached the same conclusion, eg, the World Alliance for Patient Safety, WHO, in 2005 promoted research on human factors [16], Sharma and Rooksby, also in 2005, stressed the importance of the human factor in errors [17], and Singh, Petersen and Thomas in 2006 contended that medical diagnostic errors have both cognitive human factors and systems components [18]. The overall result was a shift of the centre of attention of research on medical errors in general and in anaesthesia in particular to understanding of the human factors in patient safety and the potentially associated sources of errors.

As a consequence of the use of information technology tools, and further stimulated by the new trend of patient safety pioneered by anaesthetists, insight into the human factor in adverse events came under research scrutiny. A new approach was adapted to explore the degree of vigilance in practice and its relation to a host of factors, eg, level of experience, workload, job complexity, attitude, motivation, system design, and equipment [15].

In another dimension, using computer analysis of job performance data, the nature or degree of repetition of jobs was considered and events were classified into routine and non-routine events (NRE). The latter usually requires a higher degree of vigilance. The NRE concept helped analyse the anaesthetic job process, allowing enhancement and refinement of the quality of job performance. Thus, the use of the currently ubiquitous computing power and IT will build valuable additions to the tools of delivering patient safety [15].

The lead nowadays is in the development of intelligent systems which could be of real help in the operation room environment. In 2002, a prototype system was developed which can generate a list of possible complications for each particular case dynamically during operations. It is a decision-support system to help resolving intra-operative problems and gives the anaesthetist the chance to exclude all possibilities one by one. It could also be used as an intelligent integrator of alarms and alerts generated by electronic monitoring techniques [19].

Despite having reached the stage of safety in anaesthesia, which is regarded as the safest among the medical disciplines [14], efforts to improve performance have not ceased. Due to the relative scarcity of the major complications, the new focus has now moved from the major problems themselves to trying to anticipate their occurrence, and on to the more obscure ones. From Paris, France, Böelle, Bonnet and Valleron [20] in 2001 described using a computer system for monitoring patients, collecting data and analysing it, using statistical methods, to elucidate the patterns preceding the occurrence of significant anaesthetic events. Their study comprised 8032 patients over a three-year period. This study served the key objective of performance monitoring and could prove beneficial in anticipation of complications beforehand [20].

3.2. Horizons

Recently, using Internet technology, an On-Line Electronic Help (OLEH) developed by the European Society of Anaesthesiologists was launched. The initial testing results are encouraging. It bridges the gaps in knowledge of anaesthetists at all levels by being handy and on-line. It is designed to provide live, on-line support in real situations and in training by using operating theatre scenarios which are currently being evaluated [21].

In pursuing the quest for patient safety, anaesthetists, having to a great extent secured the indoors territory by having established a culture of patient safety and installed support systems in many localities of practice, started to look across the borders of their discipline to spread the word about patient safety. Anaesthesia information systems have helped to increase compliance in the administration of prophylactic antibiotics before operations and improved the compliance rate from 69 percent to 92 percent after one year. Anaesthetists hope later to implement clinical guidelines for patient care, thereby assigning new roles to themselves [22]. The broad perspective of this role starts with the institution of a comprehensive perioperative patient safety programme. Such a programme would aim at integrating the roles played by the various care givers in the preoperative, operative, and immediate postoperative periods. It would also verify operative fitness, reviews current medications and compatibility with the prospected interventions and medications.

4. Lessons Learned and Suggestions

4.1. Lessons Learned

4.1.1. Knowledge

Knowledge, through learning from our own failures and the dissemination of the learned lessons on a wide scale, is an effective safeguard of patient safety. The World Alliance for Patient Safety in its most recent report [23] has considered knowledge the enemy of unsafe practice and research. It encouraged sharing knowledge of patient safety internationally among researchers and health practitioners [23].

As a vehicle for knowledge generation, the reporting of adverse events should be common practice in all clinical settings. The role of reporting has also been stressed by the World Alliance for Patient Safety which gave a prime role to expert analysis of data and information in order to extract and disseminate knowledge. Learning from experience would justify the resources put into those systems. Making a difference by reporting would also encourage participation and more active roles by individuals as well as institutions.

In addition, reporting would help generate alerts about important newly recognised hazards, warnings drawn from analysis and investigation of specific cases, cumulative evidence of recurring patterns of error, and/or indicators of system failure. This could lead to the development of fresh "best-practice" guidelines for implementation [16].

4.1.2. National Reporting System

It is noteworthy that although New Zealand has assumed a leading role in the implementation of an effective health information strategy, a national reporting system is not yet in place. Only guidelines for reporting adverse medicine reactions and defective medicines have been posted on the web by MEDSAFE [24, 25]. Also a Medical Warning System attached to the National Health Index, used mainly to provide alerts to health care providers, seems to be underutilised [26]. National reporting systems are operating under different types of sponsorship: governmental, private and non-governmental in Australia, the Czech Republic, Denmark, England and Wales, Ireland, Japan, the Netherlands, Slovenia, Sweden, and the US. In all of those systems, the central and basic issue is confidentiality of reporting [16].

It is noteworthy that confidentiality is especially important as it plays a fundamental permissive role in the operation of the voluntary reporting systems which otherwise would be a mere decoy system. In the case of overt errors reporting is mandatory and legally binding. The problem lies in the near-misses which might result in obscure or minor future functional disabilities. Those afflictions could be very difficult to relate to a specific anaesthetic, medication, or, simply, illness. Most practitioners avoid voluntarily attracting attention to events which resulted in no immediately apparent harm.

4.1.3. Vigilance

Vigilance is the single most important asset for patient safety in clinical practice. This does not mean only in dealing with patients but also with material pertaining to them, eg, referral notes, laboratory test results, pathology reports, etc. The positive identification of patients, intended operation, operation site, and the responsible surgeon are four cornerstones in avoiding the "wrong mix" mishaps where a patient undergoes another’s operation or the operation is performed on the healthy side of the body.

4.2. Suggestions

4.2.1. Reporting System for Critical Events in Anaesthesia

Initiating a common electronic reporting system for critical event reporting in anaesthesia for anaesthetists in New Zealand would definitely help sharing information among all anaesthetists. The system would need to integrate with the available reporting systems and with the available practices. To this end, a simple web-based design would be optimal. Using the web obviates the need for the expensive dedicated communication infrastructure and has the advantage of being universally accessible. Even using a dedicated server could initially be avoided by using "web hosting" services which are both spacious and cheap. The only relatively costly requirement would be the software and the web page design costs. Maintenance of confidentiality in this respect is of paramount importance followed by the provision of educational assistance. The discussion of reported incidents on a much wider scale than usually takes place in departmental reporting systems would benefit a larger sector of patients as well as anaesthetists [17].

4.2.2. Assuming a Greater Role in Comprehensive Patient Safety

About two-thirds of all patients admitted to hospitals are seen by anaesthetists, who were the first in the medical profession to start and practice incident reporting [17]. Because of anaesthetists’ expertise with patient safety issues it would not be unusual to assign a comprehensive patient safety role to anaesthetists. In almost all surgical procedures, most invasive procedures and sometimes non-invasive ones, an anaesthetist is involved. Therefore, an anaesthetist from all the medical specialties could be the one most suitable to play this role.

4.2.3. Standardisation of the Use of Anaesthesia Information Management Systems (AIMS) and Integration with Mobile Technology

Spreading the use of AIMS and standardisation of the technology is of great benefit for research, education and patient safety. It is about time to quit paper data recording in preoperative rounds. No doubt eventually all patients' records will be in an electronic format; it is only a question of time and cost. Keeping two systems, a paper-based system in parallel to an electronic one, despite having some legal value and implications, seems unnecessary work load duplication. Efforts to legalise electronic signature and electronic document reproduction should receive greater support. With the increasing use of AIMS and with the expansions now available in memory and storage capacity of handheld IT devices which have proved cost-effective [27], it is advisable to use handheld computers to integrate the preoperative anaesthetic assessment information, as it arises, with the main system and to obtain current patient information held in the main system. The nature of the preoperative assessment rounds, where structured sets of data are reviewed, helps the easy implementation of this system which is still recorded on paper. Initial trials are generally well-accepted; the handheld devices seamlessly connect, in addition to being flexible and inexpensive [28].

The same principle of using handheld devices could be extended for quality control of anaesthesia patient services. Quality data are synchronised with the anaesthesia database through suitable software. It gives feedback to the anaesthetist as to the compliance with practice guidelines and the results. Integration of the surgical and anaesthetic clinical auditing supports learning, quality improvement and error prevention in all aspects of perioperative care for all involved care givers, also replacing paper-based records [27].

4.2.4. Active Patient Records' Surveillance

An active patient surveillance initiative is based on automatic trigger selection of cases with abnormal laboratory results, high risk medications, and/or antidote medications. The implementation of an active surveillance program could be independent or complementary to the proposed comprehensive patient safety program. It could help early intervention and prevent or alleviate serious or fatal errors [29].

4.2.5. Anaesthesia Simulation Training

Across all types of simulation training, evidence of increased knowledge and confidence was provided in 2006 by Owen et al [30]. Anaesthesia simulators could present a genuine chance for training on situations only encountered in real emergency where training would be extremely hazardous [30]. The use of simulators could help scheduling assessments in education settings and periodic evaluations of practising anaesthetists; a common obligatory practice in the aviation industry [31].

4.2.6. Empowering Patients; Multimedia Solutions

Operation risks and the choice of alternatives sometimes need difficult and lengthy explanations to obtain a genuine informed consent. Active participation of patients in the decision-making about their treatment choices could be achieved by offering better access to knowledge about planned operations or procedures. In this domain, multimedia solutions have proved superior. Multimedia, whether video or computer, has the capacity to better demonstrate the complex medical scenarios and highlight choices. Better knowledge and understanding were attainable with multimedia when compared to the traditional methods [32].

5. Conclusion

Institutionalisation of patient safety was the right move by anaesthetists to secure patient safety at the right time. In optimally utilising technology to effect this purpose they protected the patients and protected themselves too [8].

Inauguration of the APSF was a crucial step in the pursuit of patient safety. The outcome was a 40- to 60-fold drop in mortality. In 1999, the US Institute of Medicine, commenting on the absence of any policy among health care providers to enhance patient safety and to reduce errors, made only one exception: anaesthesia. This was reflected in anaesthetists paying the lowest insurance premiums against malpractice suits of all practising doctors. This is in contrast to what was prevalent 20 years before that [8].

The devices used by anaesthetists protected and extracted knowledge. The monitors used in conjunction with computers and the establishment of databases placed the foundations for research and data analysis, to generate, disseminate and use knowledge. One of the important technological advances in training anaesthetists was the introduction of simulation training. Simulators allowed intensive training on programmed emergency procedures and crisis management. The use of highly sophisticated mannequins for situational and invasive training provided the opportunity of performing invasive procedures which could not be performed on live subjects except in real emergency situation [8].

Nevertheless, over-reliance on technology should not give us a false sense of security and safety. The importance of tacit knowledge in the practice of anaesthesia cannot be overlooked [33]. It is warned that the limitation of the apprenticeship-mode of training could be detrimental to the development of anaesthetic expertise. In the UK, the trend is to assign trainees' clinical sessions to consultants to facilitate acquisition of the tacit constituent of knowledge [34].

The data-information-knowledge continuum in anaesthesia is a thread started over 160 years ago, and is still being knitted into a protective cover to make the conduct of anaesthesia as vigilant and as knowledge-based as possible.

Footnotes

a. The Australian Society of Anaesthetists was established in 1934, and Dr Gilbert Brown was its first elected president.

b. This was a locally developed application and was not commercially marketed. It was easy to tailor, change, and amend the application to the needs because they had the source code and the programmer was a staff member. Dbase III+© and two other programs; Relational Report Writer© and Dgraph© for Dbase were used to develop the application. A single floppy disk was used to install the program by copying eight files onto the hard disk; two other commercially available programs must be on the system to function.

c. Bayesian inference is a statistical inference method using Bayes' theorem and named after him. The method uses evidence or observations to update or to newly infer the probability that a hypothesis may be true.

d. Fuzzy logic is a problem-solving methodology which can handle vague, ambiguous, or missing information much like human thinking but faster

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