Foundation Year Doctor Essay Prize Runner-up

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The Practice of Anaesthesia is Far, as yet, from Achieving Stability
What Will Anaesthesia Look Like in the Next 25 Years?

When reporting on their notable study of deaths associated with anaesthesia and surgery, Beecher and Todd commented on the 'great changes' that they had observed in anaesthetic techniques during the five-year period of data collection between 1948 and 1952. They concluded at the time 'the practice of anaesthesia is far, as yet, from achieving stability'. [1]

They were, of course, referring to the evolution and clinical progression of the anaesthetic specialty, which proceeded with pace during the course of the second half of the 20th century and continues to do so today. The Royal College of Anaesthetists (RCoA) was awarded its Royal Charter in 1992, marking its independence as a professional body and over the last twenty-five years its goal has been to ensure the quality of patient care through maintenance of standards in anaesthesia, critical care and pain medicine. It has worked towards this goal on a backdrop of significant progress and development in anaesthetic tools and techniques. The last twenty-five years have seen, amongst other significant changes, the introduction of propofol into widespread clinical use, the development of the faster-acting inhalational anaesthetic agents and the mandatory use of continuous capnography for general anaesthesia and deep or dissociative sedation. [2]

But while drug development and advancement of intra-operative clinical monitoring may have characterised the last twenty-five years, what changes do the next twenty-five years hold for the anaesthetic profession? It is reasonable to expect that with a National Health Service (NHS) facing unprecedented and increasing demand, the profession may face quite different challenges in the future. Older patients and those with more complex physiology are undergoing operations and requiring intensive care. The nature of operations themselves is changing, with newer surgical techniques being associated with 'new' physiological responses and an increase in endoscopic and laparoscopic procedures necessitating the requirement for safe 'outpatient anaesthesia'. Patients are expecting, quite rightly, a higher degree of input into and control over their planned interventions and the medical profession as a whole is becoming more accountable. How will the profession and the RCoA adapt and progress to meet these challenges and to support the maintenance of the NHS as a world-class service?

Perhaps expansion of the role of the anaesthetist will characterise change over the next twenty-five years. The concept of 'peri-operative medicine' and the role of the anaesthetist as a peri-operative physician, according to some, will define the future of anaesthesia and may even be fundamental to the longevity of the profession. [3] Exploitation of anaesthetist expertise, beyond those employed in the operating theatre, to minimise peri-operative morbidity and mortality through, for example, pre-assessment clinics, may improve outcome for patients undergoing surgery. [4, 5] Enhanced recovery programs, which seek to facilitate early recovery after surgical procedures, make use of this peri-operative approach. Through appropriate peri-operative provision of information, optimisation of nutrition and ensuring effective pain control, such programs have been shown to reduce surgical complications as well as length of stay. [6] Anaesthetists are ideally placed to lead enhanced recovery programs, with expertise in assessment and optimisation of physiology as well as in effective analgesia.

And drug development, of course, continues. Sugammadex, a selective relaxant binding agent, is now available for the reversal of the neuromuscular blocking agents rocuronium and vecuronium. The faster-acting benzodiazepine receptor agonist remimazolam is in phase three clinical trials. Research into and development of etomidate analogues, with reduced propensity for adrenal suppression, is being carried out in an attempt to add to the hypnotic catalogue. So perhaps pharmacological development will be an omnipresent factor in the progression of the profession.

But perhaps the most exciting change will be supported by the technological revolution. Medicine has found itself in the 'Information Age', a time of significant advancement in computer software and technology. Beyond social media, smartphones and laptops, the rise of 'Artificial Intelligence' has led some to believe that society is heading towards so-called 'Technological Singularity', a time when computer systems will be so advanced as to render the human race unnecessary. [7] With this in mind, whilst humans still remain fundamental to the process of anaesthesia, it would be reasonable to predict that the technological revolution will underpin progress in anaesthetics over the next twenty-five years.

Whilst the use of 'robots' (or computer-assisted technology) has been the subject of much excitement within various surgical fields, it has also been, if more quietly, generating interest within the practice of anaesthesia, not only as a strategy for improving patient safety, but also as an opportunity for the role of the anaesthetist to evolve. Development and uptake of such technology could lead to significant changes in the dynamics of an operating room or intensive care unit, as well as advancement and optimisation of the skills of anaesthetists.

To add context, automated systems have been developed that are able to control the rate of drug delivery in response to real time changes in target outcome measures. Intravenous fluid infusion, for example, can be automatically titrated to cardiac output and systemic vascular

resistance. In one study automated intravenous fluid administration was able to achieve optimal goal-directed fluid therapy (as measured by maintenance of a pre-load independent state, or of an average cardiac index of $\geq$ 2.5 L/min/m^2) for 96.3 % of the time. [8]

Even more sophisticated, accurate depth of anaesthesia can be induced and maintained by infusion of general anaesthetic, which is automatically titrated to the depth of hypnosis, as measured by electroencephalographic monitoring. Systems have been developed that monitor the Bispectral Index (BIS; Covidien Ltd., Dublin, Ireland) - an algorithmic analysis of electroencephalographic information - to automatically control delivery of hypnotic.

Such automated or 'closed-loop' systems have been shown not only to be practical and effective but also perhaps even more effective than manual, human-controlled systems. In a multicenter study of two-hundred and forty-two patients undergoing major surgery, randomised to receive either closed-loop or manual delivery of general anaesthesia, closed-loop anaesthesia delivery was shown to achieve target depth of anaesthesia, as measured by BIS, for a significantly longer time than manual delivery. Target BIS was achieved for 81.4 $\pm$ 8.9 % of the anaesthetic time, versus 55.34 $\pm$ 25 % ($p < 0.0001$), this being the primary outcome measure. [9] In simple terms, the robot was able to deliver a more consistent level of hypnosis than the human.

Such systems offer the potential to diminish, or possibly remove altogether, the consequence of human inefficiency or error within the process of anaesthesia. Maintenance of target mean arterial pressure does not have to depend on an anaesthetist's timely and accurate response to changing clinical monitoring parameters on a computer screen. Effective and consistent hypnosis does not have to rely on an anaesthetist's prediction and interpretation of the pharmacokinetics and/or pharmacodynamic profile of a particular hypnotic in a particular patient.

So, do we need the human? The Sedasys® system, which administers propofol for the initiation and maintenance of minimal to moderate sedation *without the direct supervision of the anaesthetist* has been approved for use in adult patients undergoing colonoscopy or oesophago-gastro-duodenoscopy by the Food and Drug Administration in the United States of America (albeit after two initial applications for approval were declined and despite a wave of criticism from anaesthetists and with the subsequent cessation of production owing to poor sales). Whilst the system requires that an anaesthesia physician is on-call and immediately available while in use, *direct supervision* is not required. Sedasys® may not be the system to do it, but the idea that there is a machine that can be used to anaesthetise people, that is not under the direct control of an anaesthetist is one worth paying attention to.

Beyond the 'pharmacological robots', there is also scope for using robots in regional anaesthetic procedures - so called 'manual robots'. More akin to the robots currently being used to carry out surgical procedures, these ones re-create the manual gestures performed by humans when carrying out practical procedures. A 2014 review considered the current evidence for robots in regional anaesthesia and concluded that robots could indeed improve performance and safety in regional anaesthesia. [10] With the current level of interest in surgical robots, it follows that development in manual anaesthetic robots will continue.

Perhaps even more futuristic, robots have been taught to intubate! In 2012, Hemmerling *et al* published a report on their experience of robotic oral tracheal intubation of twelve patients using the Kepler Intubation System (KIS). [11] KIS, which consists of a joystick, robotic arm, laryngoscope and software control system and is controlled by an operator, performed successful oral tracheal intubation in eleven out of twelve patients, within a reasonable time frame. Whilst only a small, pilot study, a 91 % success rate, coupled with an absence of untoward events (including no dental injury, oesophageal intubation, mucosal damage or lip bleeding) suggests that robotic intubation has the potential to become a part of modern-day anaesthetic practice.

In practice, exciting as these technological advances are, a robot will never really be able to take the place of an anaesthetist. Because being an anaesthetist is about much more than being able to secure an airway, or to deliver regional and general anaesthesia or to maintain cardiac output. It is about understanding what it means to take over control of a person's physiology. It is about caring for a person at the absolute worst moment of their life and realising that caring goes beyond the physical. It is about understanding and acknowledging the psychological burden of a life of chronic pain. It is about teaching and leading and inspiring – with one goal – to improve the quality of patient care. A robot can perform none of these things. That said, it would be remiss not to use the opportunities offered by technology in order to move the profession forward.

The reality is that whatever comes to define change in the practice of anaesthesia over the next twenty-five years, whether it is pharmacological or technological advancement, or re-focusing of expertise through peri-operative involvement of anaesthetists, the role of the anaesthetist is set to evolve.

The real question ought not to be about what will be the biggest change, but how the various changes and developments can be exploited to allow the profession to evolve in such a way as to be able to meet the new challenges faced in the 21st Century NHS.

If advances in pharmacology can provide drugs with improved safety profiles and if developments in technology can enable those drugs to be delivered safely, can anaesthetists become less

beholden to the operating room and play a bigger role in the peri-operative management of patients?

Watch this space.

References

1. Beecher, H.K., Todd, D.P. A study of the deaths associated with anesthesia and surgery: based on a study of 599, 548 anesthesias in ten institutions 1948-1952, inclusive. *Annals of Surgery*. 1954; 140(1): 2 - 35.
2. The Royal College of Anaesthetists and the College of Emergency Medicine Working Party on Sedation, Anaesthesia and Airway Management in the Emergency Department. Safe Sedation of Adults in the Emergency Department. 2012. Available at https://www.rcoa.ac.uk/system/files/CSQ-SEDATION-ED2012.pdf. Accessed 28/3/2017.
3. Grocott, M.P.W., Pearce, R.M. Peri-operative medicine: the future of anaesthesia? British Journal of Anaesthesia. 2012; 108 (5): 723 – 6
4. The Association of Anaesthetists of Great Britain and Ireland. Pre-operative Assessment and Patient Preparation. The Role of the Anaesthetist. 2010. Available at https://www.aagbi.org/sites/default/files/preop2010.pdf. Accessed 1/4/2017
5. National Confidential Enquiry into Patient Outcome and Death. Knowing the Risk. A Review of the Peri-operative Care of Surgical Patients. 2011. Available at http://www.ncepod.org.uk/2011report2/downloads/POC_fullreport.pdf. Accessed 1/4/2017
6. Ljungqvist, O *et al*. Enhanced recovery after surgery – a review. JAMA Surgery. 2017; 152(3): 292 - 298
7. Vinge, Vernor. Technological singularity. *Whole Earth Review*. 2003. Available at http://www.wholeearth.com/uploads/2/File/documents/technological_singularity.pdf. Accessed 28/3/2017. (Originally published 1993).
8. Joosten, A *et al*. Goal-directed fluid therapy with closed-loop assistance during moderate risk surgery using noninvasive cardiac output monitoring: A pilot study. British Journal of Anaesthesia. 2015; 114 (6): 886 - 92.
9. Puri, G.D *et al*. A Multicenter evaluation of a closed-loop anesthesia delivery system: a randomized controlled trial. Anesthesia & Analgesia. 2016; 122(1): 106 – 14
10. Wehbe, M *et al*. Robotics and regional anaesthesia. Current Opinion in Anaesthesiology. 2014; 27(5): 544 - 548
11. Hemmerling, T.M *et al*. First robotic tracheal intubations in humans using the Kepler intubation system. British Journal of Anaesthesia. 2012; 108(6): 1011 - 6