EDITORIAL VIEW

Technology and the future of anesthesiology

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ABSTRACT

Technological advances are leading to the possibility of remotely controlled or veven completely autonomous delivery of anesthesia. Advances in other specialties, as well as the paradigm shift towards functional medicine, are promising improvement in overall state of health, and reducing the numbers and types of surgical procedures, thereby reducing the required numbers of the relevant workforce, including anesthetists, in future. The specialty of anesthesia needs to transform into a more over-arching role of perioperative medicine in order to stay relevant.

Key words: Technology; Artificial intelligence; Nano-medicine; Functional medicine; Perioperative medicine; Anesthesia workforce.

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Anesthesiologists, in the course of providing care for their typical patient, are multitasking being simultaneously involved in processing a lot of information, trouble shooting monitors, performing clinical procedures, scribing detailed case record, and lynch-pinning the operating room team, while working under high pressure avoiding mistakes and ensuring safety. This calls for automation of tasks as much as possible.

During the last decades, the risks associated with anesthetic care have been dramatically reduced.[1] Technological advancement and automation has played a significant role in improving patient safety, as well as the working environment of anesthesiologists. Anesthesia Information and Management Systems (AIMS) with integrated decision support, Target-controlled infusion systems, better design of anesthesia machines, closed-loop delivery of anesthesia, and point of care ultrasound guided procedures, are some examples.

The trend for technological innovations continues. Robots have been developed to establish peripheral and central venous access, to perform endotracheal intubations, and to assist the administration of regional anesthesia. Tele-anesthesia offers the possibility of distant preoperative assessment of the patient's fitness for anesthesia, aid of trained personnel to perform anesthetic tasks, and the control of anesthesia delivery in a distant location with the use of automated anesthesia drug delivery systems to maintain a target depth of anesthesia.[2]

The new millennium has witnessed exponential progress and developments in technology occurring at an unprecedented scale. This, on one hand, is contributing towards improvement in provision of healthcare, yet on the other is changing the face of medicine itself. There is a paradigm shift in medicine unfolding, which is likely to render our specialty irrelevant unless we align it with the needs of the future.

There are two main drivers for this change, namely, the future demographics, and the global healthcare bill. The United Nations has estimated that by 2050, a fifth of the global population will be comprised of those aged above 65 years.[3] This is likely to see a rise in a myriad of age related chronic health problems. The global healthcare spending is projected to expand[4] from the current level of around US$ 8 Trillions, to US$ 18.28 Trillion by 2040. Experts are trying to explore and devise ways and means to curtail this expense to more affordable levels. This has led them to revisit the way we see the divide between health and disease.

In the conventional medicine model, an individual is healthy until he or she develops signs of an illness, at which point he seeks medical intervention which usually is in the shape of administering drug molecules or removing / remodeling tissues by way of surgery.

The concept of functional medicine, which recognizes another intermediary domain of "functional imbalance" between health and illness, whereby the individual has started to have underlying biochemical imbalances in physiology which would eventually lead to explicit symptoms of disease. Such imbalances could be structural, hormonal, inflammatory, immune, microbial, absorptive, toxic, emotional, and so on. The functional medicine aims to target these imbalances, while the person is "healthy" by the standards of conventional medicine, to reverse or slow down the progress of the sub-clinical disease. This is envisaged to be achieved through optimizing interplay of lifestyle, genetics, and environment; new targets are being identified and manipulated in bioanalytical, chemical and sensory processes, food and gut microbiology and biotechnology, gut health and inflammation, obesity and metabolic disorders, etc.

In the USA, more than 75% of healthcare spending is on people with chronic conditions.[5] The functional medicine is expected to improve health, reduce illness, and realize significant reduction in this expenditure. The healthcare apparatus will need to reach out to the "healthy" but functionally compromised individual in the comfort of their normal living space; an integration of healthcare facility and the individual's usual living / workplace is an important building block of this model.

Technological advancements are at the bedrock of this revolution. The main avenues where technology is helping us reshape medicine can be broadly divided into the artificial intelligence (AI), robotics, nano-medicine, and the genetically targeted medicine. A brief synopsis of each one of these follows.

The concept of AI stems from the superiority of computers at performing repetitive tasks, whereby humans are prone to suffer from tiredness, loss of attention, and boredom. There is an exponential superflux in affordable computational power, and mass accrual of big data has made it possible to develop and propagate deep machine learning algorithms. These algorithms, when applied through reasonable computational power, can perform analyses and tasks at a small fraction of time taken by conventional methods.

It is unclear if the AI would obviate the need for having human doctors at some point in future, however, it has outperformed the latter using some specific bench-marks in some specialties.[6] This is particularly true for the disciplines not requiring a degree of emotional intelligence. For example, IBM Watson system has been employed for clinical decision support, and is outperforming human diagnostic capabilities in autism, pneumonia, and in predicting heart attack and stroke. Other software are already performing better than human doctors in interpreting radiological images, and diagnosing skin cancer.

Internet of thing is bringing the patient – healthcare provider interaction to a whole new level. It is now possible to have a completely patient centered service provision. The patients would be continuously monitored from the comfort of their home, or even on the move, connected to the healthcare providers through, for example, their smartphone, or their smart car. Their compliance with the prescribed level of exercise, food and medicine intake, etc. can all be monitored with appropriate prompts and suggestions issued automatically as needed. If their medicine cupboard is running low on supply, replacement could automatically be requested from their doctor / pharmacy. If they develop a condition, such as a dysrhythmia, first aid including automated electronic defibrillator could be dispatched to their location, ambulance service notified, and the hospital bed prepared for them, all by their smartphone.

In the field of telemedicine, a step ahead from tele-monitoring, the automated critical care system (ACCS) is being trialed by the US Navy, and the system for maintenance of intravenous anesthesia for battle casualties developed by the US Army (AutoTIVATM) is awaiting FDA approval. These systems means a critically injured patient could be looked after either fully autonomously, or in assist mode by a physician hands off from a remote location, while awaiting transfer to the healthcare facility, or in transit.

Augmented reality is changing the way we teach medicine, and explain surgical procedures to the patients. With the passage of time we are expecting to see a continuation of exponential progress in AI ability to perform more tasks with improving proficiency.

Development of robots with fine motor capabilities has made possible the operative techniques, and precision surgery with minimal access, which were previously considered very difficult. In addition to surgery, those are being trialed for other interventional and anesthetic procedures, such as endotracheal intubation, intravenous and central venous cannulation, nerve blocks, resuscitation, and automated drug delivery systems, etc.

Nano-medicine is the field dealing with repairing, constructing, monitoring and controlling of human biological systems at the molecular level, by applying engineered nano-devices, nano-robots and nanostructures. It is commonly dubbed as "swallowing a doctor". Almost 100 FDA approved nano-molecules are already in practice, and twice that undergoing trials. The volume of sales of nano-medical products is expected to expand from the current level of US$150 billion, to almost US$ 300 billion by 2022.[7]

Nano-medicine is developing mainly in the directions of drug delivery, in-vivo imaging, and developing novel therapies. Some examples include delivery of some cancer drugs (Paclitaxel, Doxorubicin, Irinotecan, etc) by nano-particles, whereby cancer cell specific antibodies locate and enter the target cell and deliver the toxic payload. In vivo MRI image enhancement is achieved by Quantum dots which have light emitting properties. C-dots (Cornell dots) are infused with organic dye which will light up with fluorescence, helping surgeons to see the illuminated cancer cells and remove those completely. Dendrimers are being studied for drug delivery, gene delivery, nano-sensors, dye enhancement, blood replacement, etc. blood purification may be achieved using magnetic nano-particles (Dynabeads) which can bind target molecules (toxins, proteins, pathogens, etc.) and help remove magnetically. Nano-robots are being trialed for introduction into the body through a syringe and perform selective precision surgery internally.

Genomic medicine is helping define the Inter-racial, and even inter-individual, differences in pharmacokinetics, and pharmacodynamics of a given drug. The objective of genomic medicine is self-programming through the Microbiome for precision medicine. The human genome project managed to decode approximately 92% of the genome, and the testing kit has become very affordable. However, progress on the development of personalised drugs and their dosing has been rather a bit slow.

All above developments collectively imply a reduction in global disease burden; Functional Medicine promoting health at pre-morbid stage and reducing progress to becoming actually sick, and the technological progress reducing the overall numbers of surgical procedures as well as the actual human input in performance of those procedures. Within our lifetimes we can expect these technologies to replace the surgical and anesthetic workforce, or take on a significant role in assisting them reducing their numbers required.

This has prompted the luminaries in the field of anesthesia to suggest expanding our role from the operating room in to a new discipline: the perioperative medicine, with a broad involvement in anesthesia assessment before surgery, exercise testing and preparation for surgery, enhanced recovery after surgery, and integrated care for the elderly, as a few examples.

The Royal College of Anaesthetists (UK) vision document[8] of 2014 prompted, "Unless we re-engage with the wards to provide care before and after surgery, we will lose relevance … A retreat to the operating theatre will be to the detriment of the specialty". The American College of Perioperative Medicine[9] was established in 2016 with a mission to "transform the way care is delivered across the perioperative continuum by breaking down the silos in our healthcare system".

In conclusion, technological advances have helped improve safety and quality of anesthesia, and are paving the way to semi-autonomous or even possibly completely autonomous surgery and delivery of anesthesia. Advances in other realms of medicine are improving overall state of health, and reducing the numbers and types of surgical procedures required, thereby reducing the numbers of the relevant workforce, including anesthetists, in future. It is of paramount importance to brace these changes, and transform the specialty of anesthesia into a more over-arching role of perioperative medicine in order to stay relevant.

Conflict of interest: None

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