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CORRESPONDENCE

Is it the surgeon or the technology performing the operation?

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Dear Sir,

In a day and age where technological advances are redefining all aspects of our lives, we find ourselves compelled to reform our practises in a fashion that matches this boom. Healthcare, often a field left trailing behind with regard to technological advances, can be a massive beneficiary of such breakthroughs. This requires medical professionals, computer scientists and engineers to make a collaborative effort and adapt to the unique challenges presented by the field of medicine.

One area of healthcare that is consistently searching for new technology is surgery. April 2016 marked the first operation done using a virtual reality camera at the Royal London hospital [1]. Augmented reality and three-dimensional (3D) printing have been utilised in 3D reconstruction of tumours, aiding surgeons in decision-making, preoperative planning and training. Experts predict surgical robot like systems will double in market value to $6.4 billion by 2020 [2]. It is clear that the 'age of the machine' is fast approaching in the field of medicine and the benefits are evident. Robotics in the form of the 'da Vinci' system allow for more precise surgery motion, where moving the tool by 1 cm results in a 1 mm movement, in addition to minimising tremor from the handler and allowing for minute objects to be handled. The development of 5G will allow for remote control of these 'da Vinci' systems and the opportunities arising from such advancement are endless. Machine learning learns and responds to data, recognising patterns in a process which can empower practitioners to make quicker and more accurate diagnoses and hence hastier referral and treatment of patients [3].

Training of surgeons is a field where technology continues to play an increasing role. In an eloquent review, Kneebone et al. concluded that whilst surgical competence has no attainable definition, the components of a competent surgeon can be identified and outlined [4]. By understanding such components, one can utilise technology and other means to assist in the training of 'competent' surgeons. If we agree on the holistic understanding of competency in surgery as the ability to successfully apply professional skills and knowledge to new situations and familiar tasks, then one can appreciate the very positive role played by technologies like machine-learning with its pattern recognition algorithms. However, the reality is the components of a competent surgeon exceed just the application of skills and knowledge.

If we were to pose the question—can technology successfully replace surgeons—then a deeper understanding of the desirable skillset of a competent surgeon is required. Surgeons are not mere technicians, indeed the best surgeons will also possess a myriad of non-technical attributes. Let us start with a look at what attributes technology can replace or make redundant. The best surgeons excel in depth of knowledge, emotional stability, visuospatial ability, and professional values such as teamworking and communication. Furthermore, Elstein et al. broke down the technical skill of expert surgeons and identified movement economy, consistency and automaticity of performance to be markers of surgical expertise [4]. This automaticity allows for multiple tasks to be performed and minimises surgical error. Studies in laporoscopic surgery have demonstrated that experts are also better at monitoring and evaluating their own performance to improve based on their self-feedback [5]. All the above are essentially the fundamentals of any automated machine and hence one can deduce that technology in the form of artificial intelligence and deep-learning can exceed human capabilities in the aforementioned domains.

The reality is, the plethora of domains attributed to a competent surgeon are not limited to the ones mentioned above which can be replaced by technology. In fact, a crucial

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differential was made by Ericsson et al. [6] in the types of surgical experts, splitting them into 'routine' and 'adaptive' experts. Routine experts are skilled technicians that almost perfected their complex routines and can deal effectively with familiar surgeries and problems by applying their experience—very similar to how an automated machine would deal with a task. The distinction, however, is when faced with a novel problem, 'routine' experts will strive to adapt the problem to their familiar solutions and routines, not the other way around. This is where the indispensable 'adaptive' experts excel—their competency lies in their flexibility, innovation and creativity in problem solving. New problems represent opportunities to stretch their boundaries and nourish their judgement skills. This is a much more complex concept which many attribute to the ingenuity of the human brain, something far more challenging to replicate by technology. Whilst many agree a machine's prowess lies in its automation and ability to learn from an infinitely large amount of data in record time, volume alone cannot replace human judgement when the problem faced is unprecedented, a data outlier, an exception to the algorithm.

Furthermore, how can we expect machines to replace the human judgement when a large part of a surgeon's decision-making takes endless tangible and non-tangible factors into consideration. Patient's preferences and background, family's wishes, cultural and religious considerations, emotional and ethical implications are just some of the many factors a surgeon will juggle when putting the patient's best interest first. This tailored approach to patients is what makes them unique individuals rather than codes in an algorithm or a data set. Surgeons find themselves constantly making difficult decisions, sometimes there can be no right or wrong, no 1 or 0 for a code, in fact more often than not the decision is much vaguer and will differ from patient to patient and surgeon to surgeon. This cannot be appreciated from a data set, this requires a different kind of experience from surgeons to technical aptitude, this is what makes doctors humans, and this is where a robot would fall short.

This is of course not an attempt to render artificial intelligence useless nor deny the huge potential role of machine-learning. As mentioned previously, technology can already replicate much of a surgeon's skillsets and is starting to find uses in different specialties with some refinements. In addition, a growing domain of surgical training is human factors—a problem that we can only attempt to minimise but cannot eradicate as long as a human is involved in any step of the surgery.

Whilst we explore the limitations of the existing technology itself, another major challenge is the implementation of such advancements. Perhaps the most striking of these challenges would be the very high cost of these technologies—or as Russells et al. [7] describes it in her book *Technologies in Hospitals*—controlling the cost means that some things, although beneficial, are not beneficial enough. There is also the demanding task of training experts and healthcare professionals who will be utilising these technologies, and the complexity and rigidity of existing healthcare systems combined with ethical dilemmas means that it will always be an up-hill battle to revolutionise common medical practise.

Many analysts and observers therefore agree that technology is never meant to replace surgeons, but would find its greatest success in augmenting and facilitating their decision-making and execution. Whilst today technology cannot completely replace a surgeon, only time can show if it will ever be able to. If history has taught us anything, however, it would be to never underestimate how advanced technology can get.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was not required for this study.

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