The Future of Surgery

Prepared for the RCSEng Commission on the Future of Surgery

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Before considering the future, we must first take a moment to ask the question “What do surgeons actually do?”

Broadly speaking we:

1) Make decisions (With our head)
2) Restructure tissues (With our hands)
3) Aim to keep people happy (With our heart)

So how will we use technology to make our head, hands and heart better?

Making Decisions (Head)

The executive problem solving associated with surgery is deep and broad. There is probably no area more resistant to applying future decision technologies than surgery, but conversely the prize for those achieving it is immense. Historically advances in surgical capabilities have been tied to advances in information sharing technologies: oral traditions, writing, lectures, universities, illustrations, photography, video and the internet to name but a few. The transformative technology of the current generation is the technology broadly referred to as artificial intelligence. Currently surgical decision making expertise is developed over a career, to be transferred to the next generation (see fig 1).

Unfortunately this entails a great deal of waste as surgical decision units (surgeons) retire/die. The ability to train large decision capable distributed computing networks would be of benefit as it would allow one system to achieve the experience of a lifetime in a short space of time, while preserving this ability for eternity (fig 2).

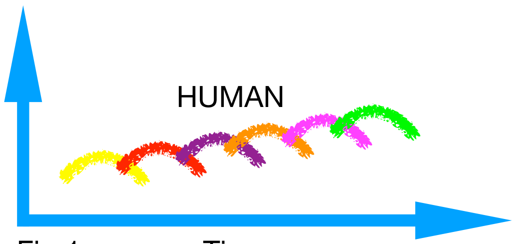

Fig 1

VS

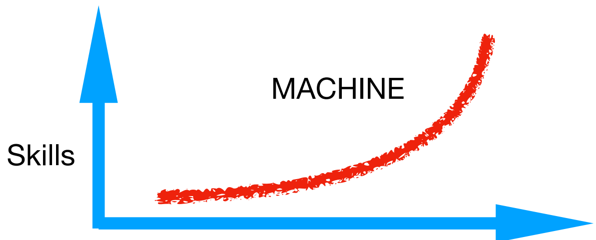

Fig 2

Recently, Google Deepmind machine intelligence taught itself chess to an unparalleled level of expertise in under 4 hours, outstripping 1500 years of human development [1] and combined effort. Clearly this level of "general" (problem solving) AI is far off as the messiness of real world data still confounds us, however the ability to utilise multiple narrow Ai’s (AI that concentrates on one skill) to augment both the appreciation and solution finding to a problem is increasingly feasible. The collaboration of human and machine intelligence to deliver healthcare is therefore the model of the near to mid future and will require fundamental change to how we make decisions, With the goal of maximising the outcome for the patient and improving the efficiency of the surgeon. Human excels at relationships creativity and empathy. AI at repeatable complex tasks [2].

The current model is predicated to a named consultant. A hopefully benign dictator navigating the diagnostic and therapeutic pathways of the patient, to a desired goal. Although held as a gold standard there are fundamental problems with this model. Wide variations in practice, mental health, skill levels, ethics and proficiencies leads to an erratic service, requiring intense regulation and control. The move towards a distributed decision making system would overcome these issues - but has not been realised due to the difficulties in creating an efficient system to deliver it. The multi disciplinary meeting is an example where attempts have been made to create a distributed decision making system for complex problems requiring the combined problem solving abilities of multiple intelligent agents (Pathologist, surgeon, oncologist).

To create a distributed decision making framework with human intelligence at it's core would require 3 interrelated areas (fig 3)

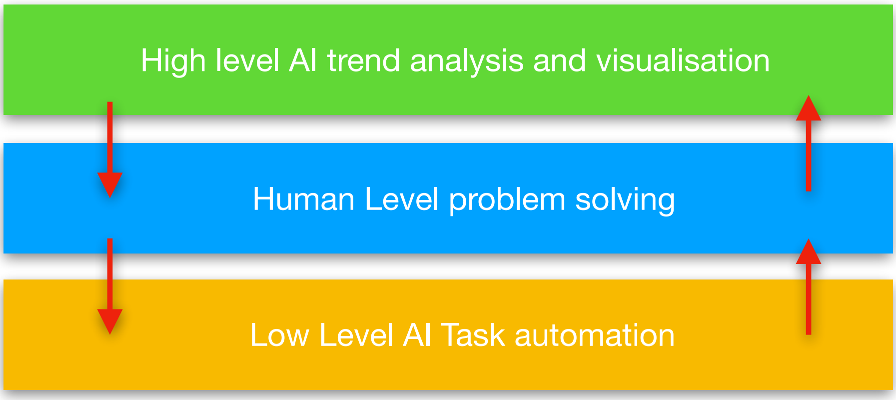

Fig 3

1) Low level: AI automation of low complexity tasks. For instance - fluid management, pain relief, nutrition, admin, booking, pre-op screening. The purpose of which would be to reduce cognitive load on surgical decision makers. This level of automation is currently being achieved by many industries from travel to food processing.

2) High level: Visualisation/effective representation of population wide and high level trends in surgical care to allow for human decision makers to react to macro trends that are not obvious from an individual perspective. This high level Ai is currently being achieved by climatologists (ensemble based simulation) and the financial industry [3].

3) Human Level: A network of human decision making assets that allow for general problem solving and the integration of high and low level functions. Critically these decision making units would be coordinated by information sharing and actioning tools that would even out the vagaries of human decision making. This would require intuitive platforms/interfaces allowing for reduced cognitive burden but supra human insights [4].

The development of high and low level AI platforms is the preserve of data scientists, however the human level is most definitely the area that the RCS would have to take a leading role. No longer must the surgeon be viewed as "God" a single lone unit having full control over the management of a patient. This view of one continuously responsible surgeon is widely held as the gold standard. However, when this premise is deconstructed it could not be further from the truth. The only reason that this notion has been held is that multiple rotating decision units cannot effectively transfer the required data or maintain/communicate a cohesive management approach. Inventing the technology that could achieve this would allow for standardisation, 100% coverage, elimination of fatigue, system accountability, reduced psychological morbidity etc. The concept of accountability of AI is currently being tackled by the autonomous car industry and is likely to be well established by the time it is implemented in the surgical profession [5].

A further thought must be given to the care and optimisation of human assets. The biological processors in our head need maintaining like any other machine and given that the average surgeon costs £10million to train it's continual abuse and operation outwith warrantied conditions is neither sensible or economical (surgeon burnout costs to a health care system is well documented [6]). A distributed system would allow for cognitive load to be distributed depending on the capacity on the system. This requires us to discover technologies that both monitor our cognitive abilities and how to optimise them. A well known adjunct is sleep, exercise and caffeine, but are there other ways to optimise performance. Other neuromodulation both chemical and like the US army trans cranial magnetic stimulation focus helmets have been shown to improve decision making in high stress situations [7]. How do we ensure mental health is factored into the network?

Restructuring Tissue (Hands)

The fundamental skill of restructuring tissue is really the USP of the surgeon, but how will that change? Putting aside the inevitable migration to sharper, lighter, stronger, better instruments - how will the act of surgery conceptually change. Completely autonomous surgical robots for all but the most basic procedures are unlikely to exist in the near future. However, the move towards surgery as a semi automated process is not as far fetched as many people would think. For instance the surgical stapler could be regarded as a semi automated process, the bowel is lined up and with the actuation of a lever an anastomosis is formed. The transformation for the surgeon from being 1st violin to the role of a conductor would therefore be required. Supported by a distributed decision making system the robotic platform would carry out a series of sub procedures, augmented and directed by human level intelligence.

The training of robotic hands would likely follow the model being developed by self driving cars. Rather than expressly programming every movement, we should instead allow the robotic control systems to observe how human surgeons interact with tissue. To do this will require more than just high resolution video, but a full data set of haptic feedback from both surgeon, instrument and tissue. The first technical hurdle is therefore to create the nursery operative teaching environment. A simulated model with the necessary force sensors to accurately observe how skilled surgeons operate. The next stage would be to create a system to observe live surgery with proxies for tissue handling sensors. From these data sets semi autonomous robots could start with simple operations to further validate the operative model. Once an effective system for teaching the robotic platform is developed it would then exponentially improve due to the almost limitless surgical data input that would be possible. This type of robotic learning platform would lend itself to surgical assisting as well as operating and may well be the best first steps into this area. The second key development is low latency data networks that would allow remote operation without instrument lag. This will become available in the near future with the development of 5G networks optimised to collect information from automated cars to improve the driving model.

In the interim before autonomous and semi autonomous robots the continued enhancement of human surgical skills is a key area for technological development. Previously discussed strategies to enhance the surgeons cognitive function through biological, technical and behavioural methodologies aside, the operating theatre is a key area for performance assessment and mitigation. Through extensive discussion with professional sporting teams, the identification of mental and physical fatigue, before performance drop off is a critical factor. Professional football teams do not wait until their star striker performance drops before enacting a substitute. They also rely on low fidelity sensor data to give a proxy measurement of performance that is more sensitive than simple human observation. Why is this not the case in surgery? Operating until you are finished (in both interpretations) is widely regarded as noble practise - but that would not be the view of a pilot or long distance bus driver. The science of performance assessment and augmentation (deliberate learning method) should be applied to surgery and ethically we must consider the role of performance enhancing technologies and pharmaceuticals for the surgeon.

Further enhancement of the mechanical function of surgery can be attained through the use of technologies to reduce cognitive load and optimise manual function- guidance systems, orientation aids, ergonomic adjustments, physical support, comfort enhancements and physical/ cognitive strain sensors.

Aim to keep people happy (Heart)

"The job of any good doctor is to keep the patient amused while nature takes it's course" Voltaire

While hopefully no longer true, this quote illustrates the enormous component that bedside manner plays in the delivery of healthcare. For many millennia we did not possess any truly effective treatments other than reassurance and empathy. While commonly held views are that the face to face interaction is the gold standard of patient support, this does not really reflect the emerging trends in human social interaction. In many ways a direct interface with another human can be a stressful and sub standard experience. Talking about embarrassing conditions can be difficult face to face and there is also evidence to show that children can interact in a less stressful way with a device as the medium rather than face to face [8]. Multiple behavioural strategies have been employed by tech giants like Facebook to drive interaction and use of technology platforms, what if this could be translated to the healthcare field?

Developing technologically augmented approaches improving the holistic experience of patients will centre on the following areas

1) Identification of stress/emotion
2) Identification of patient preferences
3) Effective and consistent information transfer
4) Incentivisation of positive and continued health behaviour
5) Development of AI optimised patient advocates/project managers

A recent and fascinating development has been the ability for cognitive systems to analyse the natural language used by people. Human language is an intensely complicated medium for a computer to communicate (hence the required development of computer languages) but recently huge breakthroughs have been made in the field of natural language analysis. This has allowed the understanding of emotion, sarcasm, intent, dialects and context in written and spoken communication. Overlaid with the ability to interpolate voice stress patterns and machine vision is driving an explosion in cognitive technologies. Harnessing the ability to identify a patients emotional state and progress over time holds enormous possibilities for the consumer and healthcare industry. Indeed this is currently being driven by online companies creating market leading customer relation systems.

As the drive towards precision medicine gains pace in the analysis of the genome and its effect on the treatment regimes, very little time has been directed at how patients would like to be treated. The ability to analyse a persons online profile and to make very deep and significant conclusions about likes/dislikes has been well explored by the consumer industry. Through a process called data scraping, companies can determine what drives you, how to tailor messages, what time of the day to contact and even what words to use to optimise a sale. This technology could and should be used to tailor clinical packages of care. Imagine having the ability to know how best to get a patient out of bed, how much information do they want and how best to explain risk to that particular person in that particular circumstance.

Building on the above two principles would allow an intelligent system for transferring safe, correct and consistent information to the patient. Much of the anxiety and to be honest complaints in clinical care stem from different parts of the team saying different things at different times. Having a platform like this could be revolutionary for the consent process, allowing people to truly make informed choices, rather than a rushed and pressurised face to face process.

The manipulation of human behaviour to satisfy the demands of large corporations has proven the principle that peoples actions can be controlled, typically through a system of minor levelled rewards. Application of this in healthcare has been superficially attempted by retrofitting health and lifestyle apps into a clinical process. However, there is a distinct absence of this approach being deployed in an overt fashion as a medical device. Further work must be done on adapting our existing medical device regulation to enable the creation of medical games with a demonstrable therapeutic effect.

Finally the experience of many people in our healthcare system is sub optimal. The reasons for this are legion, however it cannot be ignored that the rich enjoy better treatment than the poor [9], even when within a national free at the point of service healthcare system. This may be due to the fact that healthcare requires a certain degree of patient advocacy that the rich can access or transfer skills from their professional lives. Would it not therefore be a great leveller if the creation of AI agents to ensure efficient, standardised and effective care is being carried out? An AI agent that could ensure timely appointments, advise on treatment plans and provide tailored info bundles could go a long way to levelling these health inequalities.

Conclusion

Technology is expanding at an exponential rate. Unfortunately the healthcare industry is not keeping pace and our systems feel out of date. This will only exacerbate as the differential rates of advancement stay the same. To keep pace with the explosion in old age and associated morbidity we must reverse this pace differential. Only through time, effort and political will can we ensure that the necessary technology is available in our hospital environment [10]. Alder Hey's partnership with the STFC Hartree high precision computing centre is we feel a model for how real world healthcare applications of artificial intelligence can be achieved [11].

The beautiful thing about the future is its unpredictability and although the above themes of creating technologically enabled health systems is possible, it is by no means inevitable.

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