Augmented and Virtual Reality[1]

With an increasingly diverse range of information sources presented to the surgeon during surgery comes an increased need for training and for new methods of displaying and interacting with data during surgery.

Surgical training has typically been based around the apprenticeship model. However, with the increasing demand for training, this is no longer a scalable solution. Providing virtual training and simulation systems could be a way to impart new skills, analyse capabilities, perform critical benchmarking of performance and leave more time for the more advanced training to be done via the traditional apprenticeship model. Training in robot-assisted surgery for example, particularly for new applications and systems, will be essential for patient safety. Robots and virtual reality systems may themselves play a valuable role in supporting the training of surgeons where plastic phantom systems are insufficient.

The current boom of low-cost wearable augmented and virtual reality headsets has spawned a growth in proof-of-concept surgical applications. However, there remains challenges to deploying these more widely within clinical settings. Medical grade hardware will be required, along with integrated software, usability studies and workflow analysis, in order to make products that are both informative to the surgeon, and beneficial to the patient. A true system wide approach to providing the right information at the right time, in the right manner will enable surgeons to make better decisions, and ultimately reduce risk for the patient.

Intraoperative Imaging and Sensing

In recent years there has been significant innovation in intra-operative imaging and sensing including advances in X-ray technologies, including robotised gantries, bespoke ultrasound sensor systems including photoacoustics, fluorescent sensors, optical coherence tomography, Raman spectrometry, in theatre nuclear detectors ranging from single gamma probes and Cherenkov radiation detectors to complete PET and SPECT systems. These novel technologies will allow in-vivo, real-time characterisation of tissue metabolic function, classification and spatial extent of disease and monitoring the spatial extent of the response to therapy. We are beginning to see the emergence of intraoperative imaging that enables accurate in-vivo cytology and histology without the need for biopsy and subsequent analysis. UK academic groups and SMEs have been at the forefront of many of these developments.

Intra-operative systems integrated around whole body imaging such as MRI have been introduced in neurosurgery, cardiac interventions and tumour ablation. Temperature sensitive MR imaging sequences are used to provide near-real time monitoring of high intensity focused ultrasound. MRI and other imaging technologies are being developed to guide and monitor a wide range of minimally invasive therapeutic procedures. Hybrid imaging systems such as PET-MRI allow simultaneous monitoring of structure and function.

Surgical Data Science and Big Data[2]

Increasingly, every part of the clinical workflow is digitised, with patient information, medical records and imaging data all becoming available and archived in appropriate formats. As more intelligent devices are integrated into the operating room, real-time

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[1] Information in this paragraph is based on: Kneebone et al. “Surgical Training using Simulation” http://www.bmj.com/content/338/bmj.b1001.full

[2] Information in this paragraph is based on: Maier-Hein et al “Surgical Data Science: Enabling Next Generation Surgery”, https://arxiv.org/abs/1701.06482

physiological and anatomical information about surgery becomes available in real-time. This gives rise to the emerging field of Surgical Data Science, which aims to integrate real-time data, with a holistic view of all the data available pertaining to a given patient and the prior knowledge of a given procedure (e.g. success rates of a given approach). The aim is to provide knowledge and context based information to the surgeon to assist during surgery. This will require integrated digital operating rooms, and fast infrastructure such as network and big data storage arrays, along with AI or machine learning techniques to distil information into relevant and comprehensible statements.

Surgical Data Science enables the study of the correlation of patient outcomes to digital data acquired at all stages of the surgical pathway: increasingly complex computer-assisted intraoperative guidance systems, for instance, offer a new way of capturing the details of surgical procedures (instrument location, energy dose and duration, timings, etc.). These data provide a rich source of data to study how treatment actions influence outcomes for different patient disease profiles so that optimal treatment protocols can be devised.

The very rapid development in technology presents significant challenges for regulatory-compliant systems development since traditional engineering practises to ensure safety become increasingly complex, time-consuming, and difficult to apply. This presents a barrier to clinical translation. As a result, robust, highly adaptable development approaches that, for example, formally take into account statistical uncertainty in hardware and software processes, are likely to be increasingly relevant.

Although in its infancy, developing standards for data processing, accumulating nation-wide or even global data-sets and putting the infrastructure in place could see the UK lead the way in terms of intelligent, next generation surgery.