The power of data in the operating theatre

Colin Dobbyne CEng MIET examines the IoT technology that could modernise operating theatres from isolated workspaces to being part of an active collaborative support system, or what he refers to as 'Surgery 4.0'. He explains the technology needed to radically change the way surgery is performed, the potential benefits, and how to remove current barriers.

In the main, we are locked in 'Surgery 3.0', which is where we have been for almost 60 years. Surgery started thousands of years ago as a manual intervention, performed in the best light that you could find – this was 'Surgery 1.0'. This carried on until the late 19th century and the advent of electricity and the light bulb, in particular, transforming surgery and giving rise to the birth of effective endoscopy – which, for the purposes of this article, I will refer to as 'Surgery 2.0'. The next evolution – Surgery 3.0 – came with the invention of the silicon chip in 1961; electronics rapidly brought significant advances with sophisticated systems – such as anaesthetic machines, electro-surgical units, programmable logic controllers, computing, sensors, endoscopic cameras, lasers and so on.

In a typical operating theatre, equipment is arranged around the room and a nurse sets up each device as required by the surgeon – very rarely are these machines connected to the network. The floor is often covered in cables and cords, making it easy to trip, pull out an essential plug during surgery or damage the equipment. This is improved upon with an integrated operating theatre, but even those, in their current form, although more ergonomic, only provide a moderate improvement in greater efficiency, better teamwork and reduced stress levels,[1] and do not really progress us to the next stage.

Before surgery begins, preoperative data is provided for each case. This may come digitally from different systems that talk clumsily to each other, or even on paper; generally, there is no ability for external communication with operating theatre devices. Even if physical connection were possible, the vast majority of integrated operating theatre systems are closed and proprietary, meaning they are not designed to share data easily.

image courtesy of Health Quality and Safety

Paper-based systems can lead to errors, so could technology make surgery safer?

To address this problem, we have joined forces with a number of medical technology companies, working in consultation with a select group of surgeons, to collaborate and co-develop a new category of integrated operating theatre system. The 4 Medical IT Alliance members are Big Blue Solutions, Netgear, ZeeVee, and NDS Surgical Imaging.

Why does the operating theatre need to be connected?

In terms of invasive therapy, the operating theatre is the cockpit of a hospital. A place where split second decisions can have a significant impact on a patient's life – positively in the main, but occasionally catastrophic. It is also the profit centre of the hospital, with a constant drive for improvements in outcomes and costs. It just seems common sense then, that in the same way you would not send an aircrew into congested airways with no radar, radio or ground intelligence, you should not send a surgical team into the void, cut off from potentially life-saving support from modern technology.

In all other technical fields, the move towards better communication, crew/team resource management and the availability of reliable information has improved performance and increased safety. So why has it not been done yet in surgery?

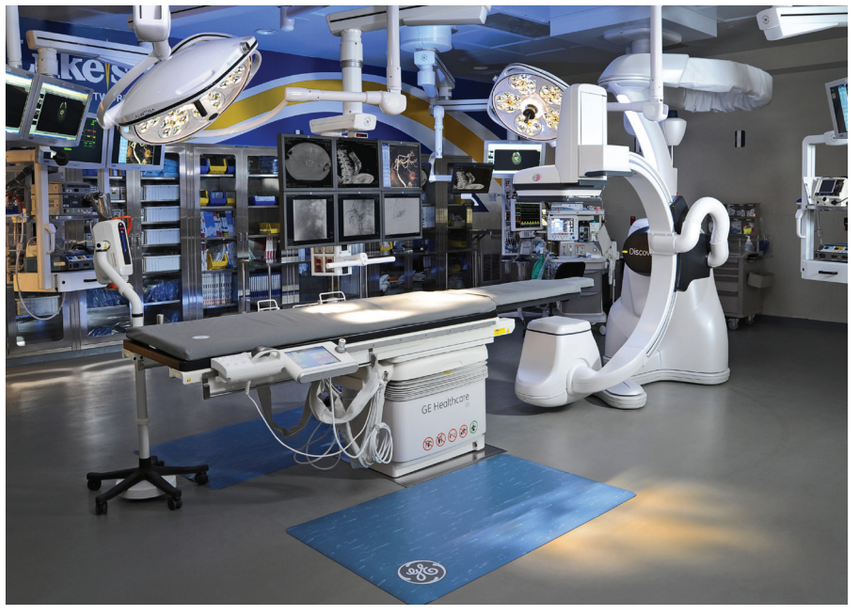
If you consider this connectivity unnecessary in operating theatres, believing ▶

that surgeons and teams carry with them all the knowledge they need, then consider for a moment the fundamental issue of wrong-site, wrong-patient errors (WSPEs). Approximately 1 in every 100,000 procedures results in a WSPE – that doesn't sound much until you consider that in 2019 there were 48 million surgical procedures conducted in the US alone.

Analysis of these errors reveals that communication issues were the prominent underlying feature[2] and that 80% of WSPEs are a direct result of simply confusing left and right. Although this does not account for the unfortunate woman who underwent an invasive cardiac procedure intended for another patient; a subsequent enquiry revealed 17 distinct and avoidable communication errors that culminated in this wrong-patient procedure going ahead.[3]

Preoperative briefings are now commonplace and proven to reduce such errors, but what about improving the procedure in more subtle ways. If our surgical teams are capable of operating on the wrong patient, or removing the wrong part of an organ, or removing the wrong organ altogether, what more subtle improvements could be made if they had better communication and better information at their fingertips?

Surgeon responsibility is so great and the risks so high that it makes sense for them to benefit, in a preoperative briefing or even during surgery at a moment of indecision, from the distillation of the experience of everyone else who has ever carried out a given procedure, rather than being stranded by their own personal experience; to be informed in the choices they make and to benefit from a collaborative support system that is somehow monitoring surgery, managing resources and generally watching their backs for the welfare of the patient.



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Hybrid integrated operating theatre

What is Surgery 4.0?

The 4 Medical IT Alliance vision is that the operating theatre should be a cyber physical system just like almost every other aspect of our life, from driving and navigation, where cars are constantly streaming and receiving data, to how we learn and shop online. These two cyber systems alone take care of our safety, warn us of delays or dangers, of weather patterns and things to do, and our preferences are constantly honed.

Imagine surgery like that, where every piece of available data is scanned to predict or forewarn of clear and present dangers, where information is made available, where treatment options are presented at decision bifurcations, where aftercare is tailored to the patient, and where the hospital's resources are constantly analysed in order to modify scheduling to achieve 100% optimised efficiency – saving money and improving outcomes.

We believe that the data generated in an operating theatre is the hospital's data, and any hospital partner with the authority and credentials to use that data meaningfully, to turn data into insights to improve the hospital's efficiency, productivity and ultimately patient outcomes, should have free, secure and safe access to it – this democratisation of data and knowledge is crucial if we are to make this transformation.

The Commission on the Future of Surgery, set up by the Royal College of Surgeons to identify likely advances in medicine and technology in the next twenty years, singled out four main areas:

- Minimal invasive surgery and robots.
- Imaging, virtual reality, augmented reality and 3D printing.
- Big data, genomics and artificial intelligence.
- Specialist interventions, such as printing of tissue or organs and nano-surgery.[4]

The 4 Medical IT Alliance open-platform operating theatre control systems include the necessary interfaces for the harnessing of big data and the Internet of Things (IoT) to address each of these four identified areas and much more, and play a major role in publishing and subscribing to a democratised and limitless knowledge base for improvements across all medical fields, not just surgery.

So, what technologies have the power to disrupt current practice and theatre design? Surgery 4.0 is made possible by the IoT, the interconnection via the Internet of IP addressed devices, together with video over IP, big data, cognitive computing and

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GE Healthcare command and control centre

artificial intelligence. To do all of these wonderful things – to gather and store information and data, move it around at speed, process it, analyse it, machine-learn from it, repackage it and send it to some action point, requires a lot of transmission and processing power.

Technologies set to have the biggest impact will be those like 5G, the latest and fastest wireless communication system that will overcome current physical infrastructural limitations in transporting large amounts of data and cloud-based storage and processing solutions from companies like AWS, Azure, Google and Alibaba.

New technologies such as blockchain, quantum computers, the underlying principles of machine learning, combine to create a cyber-world that demonstrates real intelligence with unparalleled abilities in problem solving. In addition, there is edge computing: the decentralisation of processing power to pre-process or completely process data at source before sending or publishing.

Processing power and storage should be distributed, unlimited and unbreakable with redundancy built in. This is in stark contrast to the current norm where machines effectively learn everything for the first time, again and again, and where the inefficient duplication, storage and processing of that data is local.

To meet the requirements of Surgery 4.0, we need the convergence of all signal and data types to the IP standard, and so any new technology that promotes this convergence and provides the processing power, storage and low latency transfer of secure and encrypted data streams will empower Surgery 4.0 and so much more.

Improving surgery

While future autonomous surgical robots might well represent 'Surgery 5.0', for now I believe that we should rather focus on augmenting our current human surgeons and robots, today, to do exactly that. But if we could connect the surgeons and the machines to data gathering services, we could democratise their combined knowledge. In some ways, this digital human augmentation could be seen as a vital step in actually providing the knowledge that the machines of the future will need to create an unbreakable, incomparably powerful ▶

Getting connected: forming an alliance in operating theatre IoT

In the main, the operating theatre is digitally cut-off from the rest of a rapidly evolving and connected healthcare world. This is because of inherent limitations in current system design and the underlying technology deployed. To create a new category, that of an open platform and standard IP system, a converged video and data services infrastructure was needed that operated on a standard 10G IP switch. Software Defined Video over Ethernet (SDVoE) is a zero latency video transmission standard that is used extensively in professional IP video applications where real-time high quality video is required. The SDVoE Alliance founders include Sony, Netgear and ZeeVee. 4 Medical IT can be viewed as a subset of SDVoE Alliance members specifically addressing the healthcare market.

Each member brings its own particular skill and core technologies: NDS Surgical Imaging, a manufacturer of LCD surgical displays and video management systems; ZeeVee, is a manufacturer of medical grade SDVoE encoders and decoders; Netgear, develops high performance 10G switches, tuned for 4K video and data services; and Big Blue Solutions offers 25 years' experience in operating theatre control system design.

Important factors in the design were the need to be vendor neutral and to interoperate with a wide choice of other manufacturers; to manage 4K video over IP with zero-frame latency and lossless transmission; to seamlessly integrate with DICOM and PACS imaging systems and that facilitate the secure collection and distribution of data and multimedia streams from operating rooms, across hospital networks and beyond, to exchange data with online services and efficiency management programmes – Surgery 4.0.

The system has already been adopted by a renowned endoscopic equipment company and several integrated operating theatre integrators around the world. Perhaps the most important service that a connected operating theatre can provide is education from live surgical video transmission and video-on-demand libraries of exemplar procedures. It goes without saying that educating the next generation of surgeons and clinicians is crucial to the continued advances in surgery.

There is a small hospital at the foot of Mount Kilimanjaro that has one of the best surgical video links in the world, enabling the sharing of 4K video and data between classrooms and operating theatres – but it has taken a while to get there. In 2008, I made my first visit to the Kilimanjaro Christian Medical Centre (KCMC) in Tanzania as part of a team from Northumbria Healthcare NHS Foundation Trust. My role was to build an audio-visual telecommunications link to allow surgeons at the Trust to mentor their counterparts in Tanzania in laparoscopic surgery, with the aim being that they would then be able to carry out keyhole surgery themselves. The budget was tiny, but there was a lot of enthusiasm and a passion to succeed.

The project was a success, and to date there have been over 1,000 cases performed. It was recognised by the *British Medical Journal* in 2014, winning the Karen Woo award for Surgical Team of the Year. The picture (left) shows me working on 'the link', as it became known, trying to bring together two countries over 5,000 miles apart.[5]

Since then, I have made several return visits to work on the link, adding functionality and taking advantage of a much-improved local internet and hospital LAN. Dr. Chilonga Kondo of KCMC and his two trained colleagues have now treated more than a thousand patients and now provide courses themselves for new trainee surgeons, coming from all over East Africa.

collaborative support system.

Once we open up the data doors to operating rooms, we can take advantage of these underlying technologies of cheaper offsite storage and the power of computing. We already have the ability to upload scans to cloud-based 3D modelling laboratories. The importance of these services will only increase and, in some specialities, such as paediatric urology, 3D surgical planning is widely considered to be mandatory in order to perform safe and effective surgery.

3D technology leads us on to the ability to create devices, implants and prosthetics from additive manufacturing, or 3D printing as it is often called. This will surely advance into creating artificial tissue and bespoke organ manufacturing.

The 4 Medical IT Alliance is currently working on many support services, such as feeding command and control centres from GE Healthcare, providing desktop status views for theatre managers, providing remote support helpdesks for medical physics and IT staff, blackbox recordings to enable research into best practice by the correlation of statistics to outcomes, and cloud-based content management to share that knowledge in a global community.

There will be many more surgical and support applications emerging, once it is generally accepted that the operating theatre is not a data black hole, but rather a hotbed of informed interventions and a generator of a wealth of data from intelligent machines, assisting the entire patient journey.

Is there such a thing as having too much data?

Having too much data is not an issue – the problem is access to data. In the operating room that means having to mine for it or plead with companies for a specialist piece of software to interface to their system.

All activities can produce data: it could be logs, status reports, statistics, messages, audio and video footage and so on. The problem is that the data can be in any format and on any media – the trick is to compile those data streams into something coherent and usable. This is why the 4 Medical IT Alliance has designed its system to use open standard protocols and provide open APIs to give the best chance of exchanging data with other systems.

Hospital systems, whether inside the operating theatre or not, can play a part in publishing and subscribing to a common data platform. Every single piece of data has the power to be useful and we should gather as much of it as we can and then figure out what is, and what is not, of benefit. The problem is that we currently have very inefficient data management systems. We typically maintain multiple systems for queuing data; what is needed

Robot assisted surgery: da Vinci robots in action.

is a centralised system that efficiently stores and can publish that data, but only to those systems that need or want it – subscribers. Platforms, such as Kafka, can collate, normalise and distribute large streams of data in a publisher/subscriber process.

What are the obstacles to knowledge sharing?

There are a number of factors holding us back, and they are from all stakeholders. The first are the surgeons themselves, as there is still some residual fixed mindset resisting communication technology. There has been little demand on suppliers to include services to enable artificial intelligence and knowledge sharing. Even the latest 4K integrated operating room control systems fundamentally only push video around a room, and they tend to be closed proprietary systems from endoscopic manufacturers, whose primary interest is in promoting endoscopy, not communications and data-sharing. And those endoscopic companies that do wish to open up to the IoT, and the non-endoscopic companies that purport to focus on data-enabling, are hampered by choosing underlying technology that is, in turn, proprietary and closed.

The professional video and broadcast television industries that provide the technology for endoscopy and 3D robotics have fought over video standards for years, and rarely have they agreed on a standard. We currently have formats such as SDI, HDMI, DisplayPort, HDBaseT, VGA, SOG and DVI. The problem is that these signal types cannot be transmitted over a data network.

Current technology providers for the suppliers of integrated operating theatres use a non-standard and proprietary form of encoding and decoding – but what they call video over IP is actually their exclusive version of IP; it cannot be shared outside of its own eco-system without buying another single-source decoder to convert to a common video format.

In conclusion, we have the users, the manufacturers and the underlying technologies combining to make it difficult to make operating theatres accessible and break out of a vendor lock. Over time, this situation must change – as a younger generation of surgeons will not subscribe to the fixed mindset and hospital systems will demand deeper integration, as evidence-based white papers incrementally and relentlessly demonstrate the improvements to be gained by knowledge sharing and artificial intelligence. Ultimately, this will force the opening up and accessibility of the operating theatre. CSJ

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About the author

Colin Dobbyne CEng MIET is an experienced product designer for operating theatre control and workflow systems. He has designed systems for Smith and Nephew, Conmed Linvatec, Maquet and most recently Karl Storz Endoscopy. He is the founder of product development consultancy Big Blue Solutions and the 4 Medical IT Alliance, a new body that unites a group of medical technology companies working together to create an integrated operating theatre control and workflow management system.