Review Article

The future of thoracic surgery: articulated instruments

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Abstract: Thoracic surgery is living an enthusiastic era of thriving innovations. The changes in the fields of diagnostics, in the therapeutic options, the development of surgical techniques and the adoption of novel technologies has radically changed the horizons of our specialty. We must embrace the innovations, learn navigational bronchoscopy, understand the multiple targeted therapies, and learn new ways to operate on advanced cases. We will not be able to stay complacent with our current 3 ports video-assisted thoracoscopic surgery (VATS) technique with open instruments, therefore every surgeon needs to be watching for each latest development as it happens. In this brief manuscript we will summarize some of the most important development over the recent years and forecast how this will impact on the patients affected by thoracic malignancies. As thoracic surgeons we have to embraces these developments in order to redefine our specialty.

Keywords: Articulated instruments; robotic platform; navigational bronchoscopy; minimally invasive surgery; video-assisted thoracoscopic surgery (VATS)

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Introduction

Thirty-five years elapsed from the first successful lung transplant (1), when open thoracic surgery was living a tremendously exciting time of development and achievements in unexplored field of research.

Every discipline has its golden era of innovation. For lung transplantation, and in fact also for cardiac surgery, this was certainly in the 1980s and 1990s (2-6). For interventional cardiology it began in the new millennium and continues with the rapid advancement of transcatheter aortic valve replacement (TAVI) and soon transcatheter mitral valve replacement (TMVR) (7,8).

For minimally invasive thoracic surgery we are at the very midst of our golden era (9-15). This golden era really reached a peak with Diego Gonzalez-Rivas who shook the specialty (16). Not only with uniportal pulmonary lobectomy but by the speed and enthusiasm with which he managed to change the face of our specialty. Having only invented uniportal lobectomy in 2011, it is now the predominant version of minimally invasive thoracic surgery across Asia and in many parts of the world. Change does not have necessarily to be slow and to wait for 3-year multicentre trials. Combined with passion and YouTube, Gonzalez-Rivas and co-authors (16,17) showed that we can share ideas and develop new concepts very rapidly with the new era of multimedia sharing of cases, videos and innovative ideas.

Background

Minimally invasive approaches for major pulmonary resection were described in 1992 (18,19) but throughout the 1990s and the early millennium adoption was slow, and hampered by inadequate stapling, vision and the lack of any specialized instruments. In the United Kingdom the utilization of

video-assisted thoracoscopic surgery (VATS) lobectomy has increased from 9% to 50% in only the last 5 years, as our instrumentation, mentoring, and specialization has taken off. Over the next 5 years we forecast that this figure for VATS will actually become static and then reverse as the robotic figures increase exponentially from less than 5% now to around 50% by 2023. But even what we call 'robotics' today will not be the robotics of 5 years' time: at least 8 new robotic systems will come onto the market over the next 3 years. They will miniaturize, they will crash in price, they will bring us back to the patient's bedside, or they will overlay imaging, or they will provide safety warnings or enhanced pre-operative planning or the ability to rehearse the operation in advance (20,21). They will certainly transform training and bring us into line with the flight simulator model of the airline industry and remove the need for us to train on patients, and instead train on simulators.

Also the patient profiles will not stay the same while we develop our instrumentation and techniques. Lung cancer screening will transform the type of patients that we see to predominantly very early lung cancers. Navigational bronchoscopy will mean that the physician (possibly a thoracic surgeon) will go in bronchoscopically, perform biopsy and then ablate or freeze that nodule, and then sample all the N1 and N2 nodes at the same sitting. Then we will just follow the patient up, armed with their full list of available targeted therapies should they relapse. Advanced surgery will be reserved only for patients with areas of resistant mutations after multiple rounds of targeted therapy. These operations will be highly complex as they will have dense adhesions as immunotherapy causes an intense inflammatory reaction around the neoplasms.

So over the next 15 years we must all be very much ready for constant seismic change in our specialty and be prepared to move with the times, adopt new technology fast, learn navigational bronchoscopy, understand the multiple targeted therapies, and learn new ways to operate on advanced cases. We will not be able to stay complacent with our current 3-port VATS technique with open instruments, therefore every surgeon needs to be watching for each latest development as it happens.

Thus we hope this has set the scene in order to understand why it is so important to know what is on the horizon at the moment.

Review of novel platforms and tools applied to pulmonary surgery

Firstly, we address the new robotic systems. There are 8 new platforms coming available to the market and to look out for. The 'big companies' are investing very heavily in high quality robotic systems to rival Intuitive in the future.

The Medtronic Robotic System is currently called 'Hugo' and is a neat plug and play design with independent arms on modules that can be wheeled to the patient and a surgeon console that can also be moved fairly freely. The major advantage that the Medtronic system will have over the competition is outstanding compatibility with its range of staplers, energy devices and the excellent network of support already available provided by Medtronic. The working versions of this platform may be available in 2019.

The second giant is the Ethicon-Google pair up in the form of a company called VERB surgical (www.verbsurgical.com). This is probably the most ambitious project of all of the start-up companies. With the energy of Google, and actually being developed in Google's original office buildings, there are visionary features being developed like intelligent machine learning, google hangouts, multiplatform sharing of videos in active development. The system itself is rumored to have the arms integrated under the operating table. The company is describing it as being 'always there, always on' and being a whole new way of performing integrated surgery, bringing in scan data and perioperative data into one unified platform.

Google features together with total compatibility with everything that Ethicon offers, make this an incredible system of the future. In 2020 or later may be the first time that we will be able to see it working on patients, but does not promise to be inexpensive.

Transenterix have a currently working robotic platform that is in clinical use called the Senhance Surgical System (www.transenterix.com). They feature 5 mm instruments, each arm on a separate moveable gantry, haptic feedback and a camera controlled by your own head movement. However, they promote themselves as a cost sensitive solution and therefore have made some compromises in the system including many of the instruments not being wristed. In addition, the controllers emulate laparoscopic instrument handles and thus many describe the system as a remote laparoscopic instrument holder, but with quite a larger price. As a result their website reports the sale of only 4 systems in the 2nd quarter of 2018.

AvateraMedical (www.avatera.eu) are a German company who are developing a 4-arm robot from a single cart in a similar fashion to Intuitive with a closed surgeon console, again similar to Intuitive. Not much is known about this system, other than it is very similar to the intuitive system!

And not to be outdone, there is another system called REVO-1 manufactured in South Korea that was launched for clinical use in March 2018 (www.revosurgical.com). This takes the similarity of its system to the Intuitive system to a new dimension! It is a 4-arm, single cart system, with a very similar closed surgeon console and the main differentiation is just price. It couldn't look more like an Intuitive Xi if it tried.

Medicaroid are a Japanese company (www.medicaroid.com/) whose main interesting factor is that they have paired up with Kawasaki, the giant robotic manufacturer of car assembly plants. Currently there is little known about developments of this system or release timings so unlikely we will see anything till after 2021.

But we have left the most exciting systems to the end of this list.

Cambridge Medical Robotics have a working system called Versius and are ready to install this into 6 UK hospitals in the next 6–12 months (www.cmrsurgical.com). Our institution hopes to be 1 of these 6. This was designed in reverse to usual systems as they asked the question as to what they thought the British National Health System could sustain financially for a robotic system and they came up with the answer that it could not sustain any upfront cost and the per case costs had to be the same as current re-useable laparoscopic instruments. Thus they embarked on designing a system that met this. Two hundred Cambridge graduate engineers have now designed an immaculate system with 5 mm robotic arms, each standing on their own small portable modules to be wheeled up to the patient. It uses any standard endoscopic ports and has a surgeon's console with hand controls far more like an Xbox than cardiac surgeons Castro needle holders. It is very small and portable to any operating room. The price structure is the real game changer, with no up-front costs and instruments that time in hours of use, not number of cases.

But the final revolution of the future in thoracic robotic surgery will surely be the Intuitive da Vinci SP surgical System. This finally has FDA approval for urology and is the holy grail for thoracic surgery. With 3 robotic arms and an amazing snake camera all through a single 2.5 cm port that spread apart on entering the chest, finally uniportal robotics is here, which will not only make uniportal robotics far more simple for all users but will open up the reality of subxiphoid-only uniportal robotic surgery, which must surely be the least invasive approach in Thoracic possible. Currently subxiphoid uniportal is performed in a very tiny minority of cases due to its extreme technical difficulty (22), it will now be possible to do this for virtually every thoracic case, as long as your institution have around $3–4 million to invest.

Assuming that pure robotics is the only future could not be more misleading. We will see a melting of VATS and robotics with the advent of 'wristed' VATS instruments. We have had the pleasure of using the Flexdex surgical instrument (www.flexdex.com) for lobectomy, thymectomy and diaphragm plication (https://www.youtube.com/watch?v=4xTnqHKlmJ8). Currently version 1 is only a needle holder, but version 2 will have Maryland graspers with bipolar energy, Cadiere style graspers, hooks, scissors and maybe even suture-cut needle holders. And at only a few hundred dollars each, this brings wristed instrumentation to all VATS Surgeons. They are FDA approved and CE marked.

And this is not the only company working on 'wristed' instrumentation. A company called Livsmed (www.livsmed.com) from South Korea have been demonstrating a suite of fully wristed instruments that can be used in both hands that seem to be very similar to robotic Marylands, graspers and needle holders. They already have a full suite of instruments and have performed cases clinically in South Korea although they are not FDA approved or CE marked.

Thus one alternative glimpse of the future is to be having two wristed instruments in your hands and a robotic camera holder such as AutoLap or Freehandsurgeon (www.mst-sys.com or www.freehandsurgeon.com) with a 3D camera. With this set up you have every element of a robotic system (wristed instrumentation, control of the camera, 3D vision) and none of the disadvantages (assistant required to perform the stapling, surgeon away from the patient's bedside, lack of tactile feedback) and because you do not need an assistant, this set up will actually be cheaper than the VATS surgery offered today, and safer than current robotics!

So the future of minimally invasive surgery is exciting and very fast moving. The future of thoracic surgery will certainly change quickly so we must move with it. We have mentioned some of the novel robotic and wristed VATS instruments that will be available very soon but something that should be already in the surgeon instrumentation is navigational bronchoscopic systems. The current available system is called Superdimension (www.superdimension.com) from Medtronic, but new entrants to the market are already coming including the $700 million company called Auris (www.aurishealth.com) who have developed a 'robotic' bronchoscope purely because they see the future of biopsy and ablate. Also a 3 mm filament for bronchoscopies is

under development, with one hundred times magnification allowing on-table real-time microscopy in the parenchyma to identify tumour tissue as opposed to inflammation or normal alveoli.

Conclusions

These developments are just around the corner. All these systems require general anaesthesia and we must learn the lessons of the cardiac surgeons who were slow to enter the catheter labs and who lost the leadership in TAVI and coronary revascularisation. The surgical community must enter the world of bronchoscopy and embrace this more minor procedure with as much enthusiasm as subxiphoid uniportal robotic surgery.

The future will see a melting of VATS and robotic technologies, where VATS instrumentations and camera will close the gap with robotic ones, the procedure cost will fall, the surgeon will move back to the patient's bedside and will regain tactile feedback through thoracoscopic articulated instruments.

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