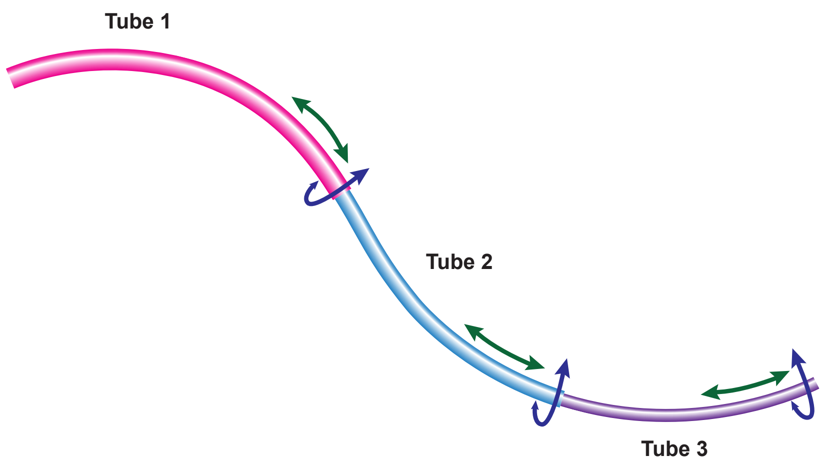
Robotics in rhinology – fantasy or the future?

BY ISABELLE JM WILLIAMS

Robotic surgery is advancing, but its use in rhinology lags due to spatial constraints and high costs. Innovations in flexible robots may bridge this gap in the future.

We are in a new era, one of artificial intelligence and robotics. In 2016, there were about 4000 robots scattered around the world's hospitals and they took part in 750,000 operations [1]. Electronics have become smaller and smarter, expanding the range of procedures surgical robots can be involved in.

The nose and paranasal sinuses occupy small, bone-enclosed cavities abutting the eyes, brain, and major vessels. Similarly, the pelvis, also housed within bone, accommodates essential organs and structures. Despite the widespread adoption of robotic-assisted surgery within the confines of the pelvis for prostate and gynaecological surgery, its utilisation remains conspicuously absent in nasal, paranasal and skull base surgery. This is in contrast to the increasing use of transoral robotic surgery (TORS) during head and neck procedures [2].



Continuum tubular robot (CTR) distal end with three tubes that can be rotated and translated relative to one another.

The principles of oncological dissection: challenging en-bloc resection

En-bloc resection of cancers has traditionally been the 'gold standard', aiming to prevent local recurrence, tumour seeding and spread [2]. Challenging the established oncologic principle of en-bloc resection, a seminal paper published by the late Wolfgang Steiner demonstrated 100% adjusted five-year survival rates in patients with laryngeal cancer treated with transoral endoscopic laser microsurgery (TLM) [3]. Whilst the goals of both en-bloc and TLM resection remain the same – that is to completely excise the tumour with negative margins – the methods of reaching these goals differ dramatically, with the latter enabling the extent of dissection to be tailored in real-time based on the tumour and surrounding tissue anatomy.

Tumours of the nose, paranasal sinuses and skull base: the rise of the endoscope

Piecemeal dissection – that is progressive disassembling of the lesion keeping in view the limits between normal and diseased tissue – underpins most dissection of sinonasal malignancies due to the narrow margins of surrounding tumour-free tissue. Achieving disease-free margins with en-bloc resection without devastating damage to surrounding healthy tissue is near impossible in these cases, with such close proximity to the orbit, brain, cranial nerves and carotid arteries [4].

Endoscopic surgery has transformed rhinologic and skull base surgery, using the nose and sinuses as natural corridors to access the sinonasal cavities and structures lying beyond. Piecemeal debulking aims to identify and resect the bulk of the tumour, removing the tumour pedicle 'en-bloc'. Whilst Levine et al criticised this approach for the theoretical inability to obtain negative margins [5], there is good quality evidence that an endonasal approach can give patients similar survival, with improved morbidity, when compared with en-bloc external resection [6]. Indeed endonasal surgery is now firmly embedded into UK National Multidisciplinary Guidelines for the management of nose and paranasal sinus tumours [7].

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Robots in rhinology: the current state of play

The robot offers a three-dimensional (3D) magnified view and allows for bimanual operation with articulated arms and

"The viability and utility of robotics in rhinology hinges upon the evolution of our approach to treating and managing sinonasal disease"

suppression of tremor. How does it provide such a view? Via an endoscope. Modern endoscopy, with 0-, 30- and 70-degree scopes, a variety of instruments, which although straight, can be introduced at many different angles, some with curved tips (with an accuracy of 0.1mm), provides excellent 3D vision (up to 16-fold magnification) with bimanual operation via both nostrils.

Whilst TORS has been described for skull base surgery, with the first clinical application occurring in 2012 for the resection of recurrent nasopharyngeal carcinoma [8], a nasal/oral combined approach was needed. Furthermore, cadaveric studies show promise for robotic systems in naso- and parapharyngeal tumour dissections [9], yet there remains insufficient data in human studies to establish their current utility and safety.

Traditional robots such as the DaVinci® (Intuitive Surgical Inc) are limited in small, restricted spaces such as the skull base, whereby adaptability, dexterity and safe interactions with tissue are necessary. Continuum robots (CRs) have recently emerged, able to generate snake-like, smooth curvilinear motions with infinite degrees of freedom, with the potential to reach further into body cavities along non-linear paths [10]. Moreover, inspired by nature, engineers have begun exploring the design and control of soft-bodied robots composed of compliant materials, giving a robot the ability to absorb energy and/or deform to their surroundings and external constraints [11]. However, despite the flexible, cable-like design of contemporary CRs, many remain unsuitable for endoscopic sinus surgery due to their size and limited manoeuvrability.

Current limitations

Unlike endoscopy, whereby tools can be inserted at separate angles to the endoscope via a separate nostril or another external access point, in a robotic system, tools are confined to the working channel. Manipulation of multiple rigid tools via a single working port is challenging, especially in restricted anatomical spaces. Whilst soft robots could overcome this issue by increasing the flexibility of instruments, there are trade-offs, including lower force exertion, poorer controllability, and a lack of sensing capabilities [12].

With the cost of a DaVinci® robot standing at around £1 million, the overall costs accompanying robotic development and integration into standard practice represent a significant obstacle that demands careful consideration. The NHS is currently grappling with strained funding and resources, exacerbating the challenge. Furthermore, surgical trainees are facing difficulties in accumulating experience, particularly in basic procedures, let alone mastering more complex techniques.

With newer, more advanced robots, there is the potential for the robot to move into the skull base. Crucially, it is the surgeon's expertise that guides decisions regarding surgical margins, informed by factors such as lesion appearance, texture and behaviour during gentle dissection or laser vaporisation. Without a solid grasp of fundamental principles and the cultivation of expertise in using and being assisted by a robot, the robotic system remains an inferior, less safe option compared to traditional open and endoscopic methods.

Conclusions

The viability and utility of robotics in rhinology hinges upon the evolution of our approach to treating and managing sinonasal disease. Biological therapies may reduce the need for endonasal surgery for patients with chronic rhinosinusitis (CRS), while intensity modulated radiotherapy, proton beam and novel immunomodulatory agents are radicalising the way some sinonasal malignancies are being treated in the first instance. Moreover, as our understanding of tumour biology expands, new treatment approaches emerge.

The method of surgery must not trump the importance of a complete understanding of the natural history of the disease being treated, from benign, infective disease, such as CRS, to aggressive sinonasal tumours invading the skull base and periorbita.

If the principles of robotic surgery can obey the fundamental laws of physiology and oncology, and technicalities are overcome, rhinologists, as early adopters of innovation, will likely adapt to this paradigm shift which embraces and advances the technology of the revered Hopkins rod. Indeed, some already have [2].

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