# Machine learning and the future of otolaryngology

BY CIAN HUGHES AND SUMIT AGRAWAL

If you are over 30 years of age, you have witnessed a technology revolution that has grossly affected how we live: computers have come from being an oddity to an everyday feature in our households and places of work; the cellphone is ubiquitous; hardcopy letters by mail are rare as we can communicate instantaneously through email. And yet, what we have witnessed is only the beginning. **Drs Hughes** and **Agrawal** give us a glimpse of what is still to come, and what will be featured at the IFOS World Congress in Vancouver.

## Machine learning in healthcare

Over the last five years there have been significant advances in high performance computing that have led to enormous scientific breakthroughs in the field of machine learning (a form of artificial intelligence), especially with regard to image processing and data analysis. These breakthroughs now affect multiple aspects of our lives, from the way our phone sorts and recognises photographs, to automated translation and transcription services, and have the potential to revolutionise the practice of medicine.

The most promising form of artificial intelligence used in medical applications today is deep learning. Deep learning is a type of machine learning in which deep neural networks are trained to identify patterns in data [1]. A common form of neural network used in image processing is a convolutional neural network (CNN). Initially developed for general-purpose visual recognition, it has shown considerable promise in, for instance, the detection and classification of disease on medical imaging.

Automated image segmentation has numerous clinical applications, ranging from quantitative measurement of tissue volume, through surgical planning/guidance, medical education and even cancer treatment planning. It is hoped that such advances in automated data analysis will help in the delivery of more timely care, and alleviate workforce shortages in areas such as breast cancer screening [2], where patient demand for screening already outstrips the availability of specialist breast radiologists in many parts of the world.

## Applications in otolaryngology

Artificial intelligence is quickly making its way into our specialty. Both otolaryngologists and audiologists will soon be incorporating this technology into their clinical practices. Machine learning has been used to automatically classify auditory brainstem responses [8] and estimate audiometric thresholds [9]. This has allowed for accurate online testing [10], which could be used for rural and remote areas without access to standard audiometry (see the article in this issue by Dr Matthew Bromwich).

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Machine learning algorithms have also been central to the development of multiple assistive technologies that can help patients to overcome or alleviate disabilities. For example, in the context of hearing loss, significant advances in automated transcription apps, driven by machine learning algorithms, have proven particularly useful in recent months for patients who find themselves unable to lipread due to the use of face coverings to prevent the spread of COVID-19.

In addition to their role in general image classification, CNNs are likely to play

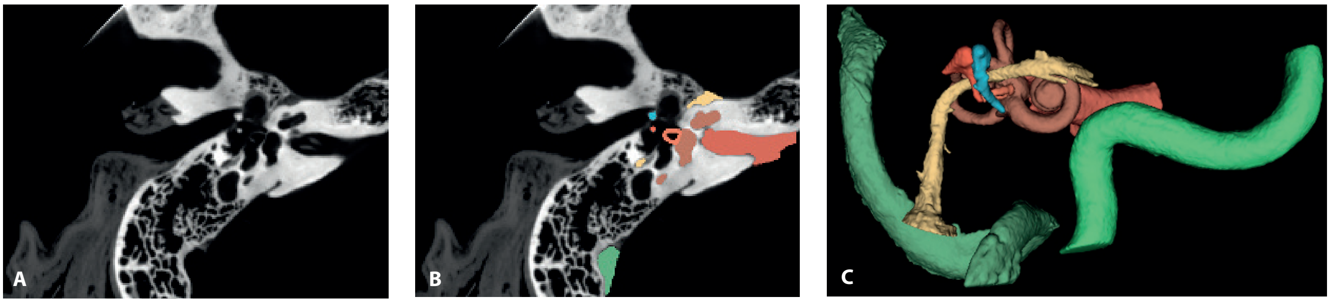


Figure 1. (A) CT scan of the right temporal bone. (B) Structures of the temporal bone automatically segmented using a TensorFlow based deep learning algorithm. (C) Three-dimensional model of the critical structures of the temporal bone to be used for surgical planning and simulation. Images courtesy of the Auditory Biophysics Laboratory, Western University, London, Canada.

> **"Automatic analysis of critical structures on temporal bone scans have already facilitated patient-specific virtual reality otologic surgery"**

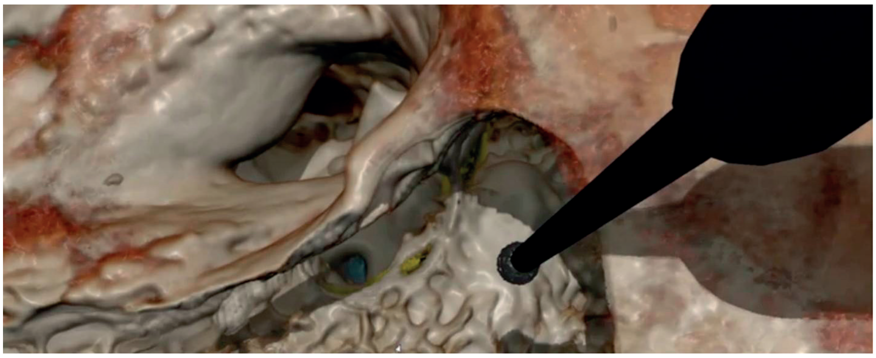

Figure 2. The virtual reality simulator CardinalSim (https://cardinalsim.stanford.edu/) depicting a left mastoidectomy and facial recess approach. The facial nerve (yellow) and round window (blue) were automatically delineated using deep learning techniques. Image courtesy of the Auditory Biophysics Laboratory, Western University, London, Canada.

a significant role in the introduction of machine learning in healthcare, especially in image-heavy specialties such as otolaryngology. For otologists, deep learning algorithms can already identify detailed temporal bone structures from CT images [3-6], segment intracochlear anatomy [7], and identify individual cochlear implant electrodes [8] (Figure 1); automatic analysis of critical structures on temporal bone scans have already facilitated patient-specific virtual reality otologic surgery [9] (Figure 2). Deep learning will likely also be critical in customised cochlear implant programming in the future.

Convolutional neural networks have also been used in rhinology to automatically delineate critical anatomy and quantify sinus opacification [10-12]. Deep learning networks have been used in head and neck oncology to automatically segment anatomic structures to accelerate radiotherapy planning [13-18]. For laryngologists, voice analysis software will likely incorporate machine learning classifiers to identify pathology as it has been shown to perform better than traditional rule-based algorithms [19].

## CONCLUSION

In summary, artificial intelligence and, in particular, deep learning algorithms will radically change the way we manage patients within our careers. Although developed in high-resource settings, the technology has equally significant applications in low-resource settings to facilitate quality care even in the presence of limited human resources. This and more will be explored in more detail in the scientific programme in Vancouver.

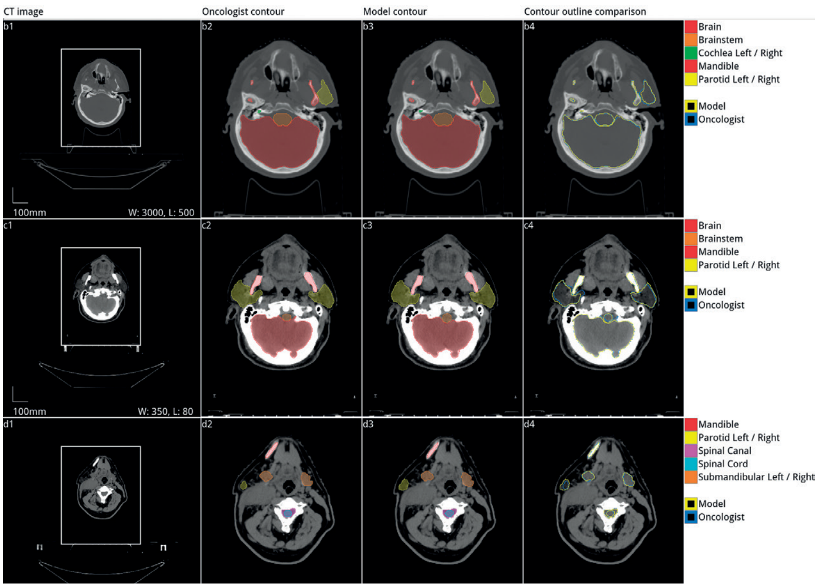


Figure 3. Automated segmentation of organs at risk of damage from radiation during radiotherapy for head and neck cancer. Five axial slices from the scan of a 58-year-old male patient with a cancer of the right tonsil selected from the Head-Neck Cetuximab trial dataset (patient 0522c0416) [20,21]. Adapted with permission from the original authors [13].

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