How can otolaryngology as a specialty use technology to reduce our carbon footprint and increase our sustainability while improving delivery of high-quality healthcare and improve outcomes for our patients?

Maisie Fitzgerald

5th Year Medical Student

University of Cambridge

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Introduction

Since the start of the 21st century, surgery has been undergoing a technological revolution [1]. Otolaryngology, also known as Ear Nose and Throat (ENT), is a surgical speciality that has technology at its core, due to the use of a great number of instruments and devices, from endoscopes to nerve-monitoring systems. This essay will argue for a tiered approach to the use of technology, meaning a step-wise progression from simple to complex technologies. This approach will help guarantee that ENT's use of technology will provide it with a sustainable future, rather than one tainted with the environmental costs of technological progress.

A Tiered Approach

Whilst the need for the surgical community to respond to the threat of climate change has gained momentum in recent years [2] [3], there is plenty of progress still to be made. In response to the question of the role technology has to play, it is easy to leap into scrutinising the newest, smartest technologies that claim to be 'green'. However, I will argue for a more modest approach to using technology to make ENT more sustainable. Before creating new technologies, it is important for otolaryngology to recognise and appreciate technology in its simplest form. The use of reusable items in theatre, such as caps and gowns, is a necessary step towards more sustainable ENT surgery. The specialty also needs to utilise existing technologies that are already widely distributed, most notably smartphones. Only after exploring these simple and existing technologies can otolaryngology look to creating novel technologies. This tiered approach is summarised in Figure 1 and will be explored throughout this essay.

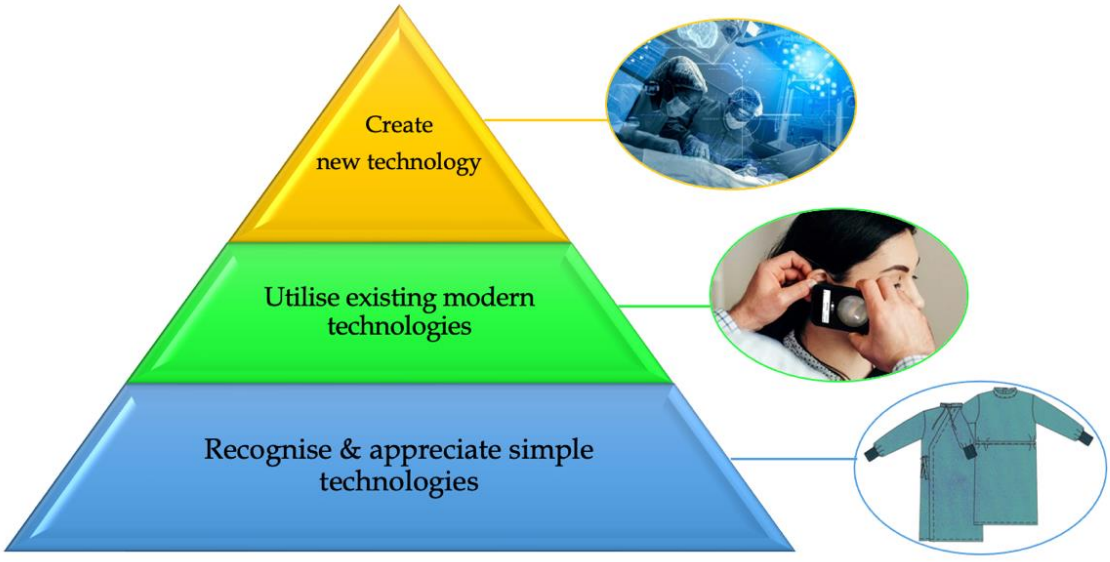

Figure 1 - The Technology Pyramid

Healthcare & Sustainability

Broadly-speaking, sustainability is 'the quality of causing little or no damage to the environment and therefore able to continue for a long time' [4]. Focussing on sustainability in healthcare specifically, sustainable value can be understood as the degree to which patient outcomes off-set costs to the environment, society and its finances – see Figure 2 [5] [6]. Whilst this essay focusses on environmental sustainability, it is worth noting that efforts to reduce the environmental impacts of healthcare often have beneficial social and financial impacts also. For example, a single-use tourniquet costs £13.65, whereas a reusable tourniquet is only 61p per use, and is clearly far better for the environment [7]. Furthermore, carbon footprint can be thought of as a measure of environmental impacts. It is the total amount of greenhouse gases (carbon dioxide and methane) produced by the actions of an individual or group [8]. As such, the carbon footprint of ENT can be defined as the total greenhouse gas emissions produced by the professional endeavours of members of the speciality in various settings, such as operating theatres and clinics. Striving to reduce these emissions will help to shrink ENT's carbon footprint and help to make it more sustainable.

$$Sustainability = \frac{Patient\ outcomes}{\underset{(the\ 'triple\ bottom\ line')}{Environmental + social + financial\ impacts}}$$

Figure 2 - Sustainability in healthcare, taken from the Green Surgery Challenge Impact Report [5]

It is estimated that the National Health Service (NHS) is responsible for 4-5% of the UK's total carbon footprint [9]. As such, the NHS has a key role to play in the UK's broader target to be carbon neutral by 2050 [10]. Operating theatres are particular offenders, contributing up to a quarter of the total carbon emissions generated by hospitals [11]. This environmental impact is only expected to rise further due to the growing population, along with increased access to healthcare, plus more people living longer with chronic disease [12]. In response, the NHS became the first healthcare service in the world to set itself the target of reaching carbon net zero [13]. Since the first 'Delivering a Net Zero Health Service' report was published in October 2020, its importance has been put into legislation under The Health and Care Act 2022 [13] [14]. These measures reflect a move towards sustainability within healthcare in general, thus they apply to all specialities, including ENT.

As shown in Figure 2, patient outcomes are inextricably linked to sustainability in healthcare. Consequently, improved patient outcomes should be a corollary of efforts to increase the sustainability of ENT. Additionally, these efforts will help to reduce disease burden due to the direct effects of global warming on health. In fact, climate change has been labelled "the biggest threat to global health in the 21st century" [15]. According to The World Health Organisation, there could be 250,000 additional deaths per year between 2030 and 2050 as a

result of climate change [16]. Regarding the climate-related ENT disease burden in particular, there are specific conditions known to be sensitive to the effects of carbon emissions [17]. For example, the prevalence and severity of allergic rhinitis is related to the diversity of airborne pollen, which in turn is affected by air pollution [18] [19]. There is also evidence to suggest that air quality affects the prevalence of obstructive sleep apnoea in children [20]. Therefore, reducing the carbon footprint of healthcare practices, including ENT, will help to prevent morbidity and mortality related to climate change.

Recognising & Appreciating 'simple' Technologies

When discussing the use of technology for change, it is tempting to immediately dive down a rabbit hole of exploring innovative, state-of-the-art technologies. However, I argue that the definition of 'technology' should first be examined. In its simplest form, technology is anything that is implemented with the intention of changing the world in some way [21]. As such, the understanding of ENT technology need not be limited to the newest scopes or robots. Technology is everywhere; from the scrub caps donned by everyone in an ENT theatre to the bins used to dispose of different items. Whilst including such seemingly simple items in an understanding of technology might seem too broad, it would be an oversight not to consider simple solutions to ENT's carbon footprint in the first instance. After all, Occam's razor famously promotes simpler explanations and answers over ones that encompass multiple entities [22]. Therefore, this section will consider how ENT can recognise and appreciate simple technologies in order to be more sustainable.

One group of simple technologies are reusable operating theatre items, including scrub caps, drapes and gowns. These can replace wasteful single-use items. ENT should use reusable items because they are included in the Intercollegiate Green Theatre Checklist [2]. This comprises a series of steps to make surgical teams more sustainable[1]. It is the outcome of The Royal College of Surgeons of Edinburgh, Royal College of Surgeons of England and Royal College of Physicians and Surgeons of Glasgow coming together to declare a climate emergency [3]. There is a compendium of evidence to support the interventions listed on the checklist, including reusable items. Reusable scrub caps, drapes and gowns also played a key role in the first carbon net zero operation performed in the NHS [11]. Therefore, otolaryngology should use reusable theatre items as a first step in using technology to reduce its carbon footprint.

In addition to interventions promoted by the Green Theatre Checklist, there are further simple technologies specific to ENT. For example, a prospective study revealed that alcohol wipes reliably disinfect the tips of mucosal atomization devices after use, removing the need for single-use plastic tip guards [23]. I argue that similar studies should be carried out on more single-use equipment used in ENT in order to identify other areas where reusable

[1] One section of the Green Theatre Checklist concerns Anaesthesia. Whilst the steps that fall under this section are very important for sustainable practice, detailing them would be beyond the scope of this essay.

technologies could be implemented. Failing this, reprocessing is a technology that should be used to minimise the environmental impact of single-use items. For example, coblation wands, adenoid blades and microdissection needles are all single-use ENT devices which can be reprocessed in order to reduce waste, and therefore make ENT more sustainable [24]. In summary, the first step towards making otolaryngology more sustainable is to recognise and appreciate technologies as simple as reusable and reprocessed equipment.

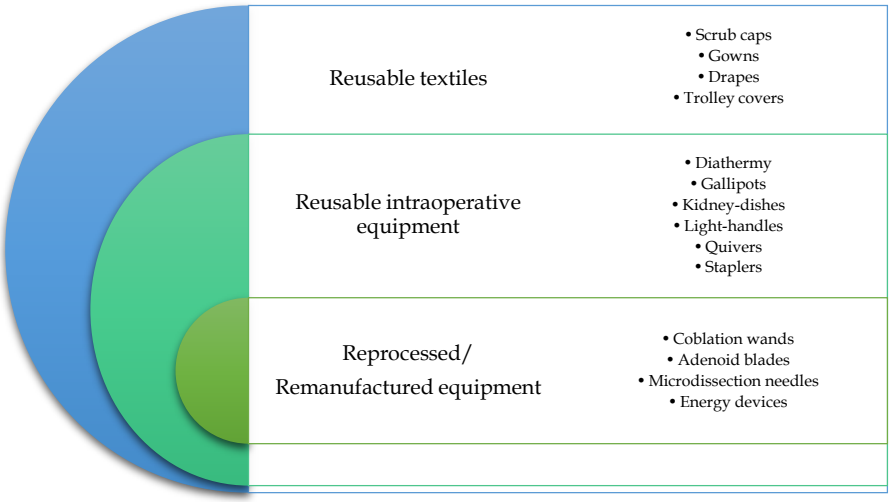

Figure 3 - Simple technologies for use in ENT, adapted from the Green Theatre Checklist [3]

Utilising Existing Modern Technology

Revolutionary change of practice in operating theatres to adhere to the Green Theatre Checklist will undoubtedly take significant effort and time. Given the pressing nature of the climate emergency, further steps must be taken to make ENT more sustainable. Therefore, we should also consider devices that fall under a more modern understanding of technology. The introduction and consolidation of modern technology in day-to-day life has not been without detrimental effects on the environment [25]. It is obvious, however, that devices such as computers and smartphones are here to stay. Therefore, it is pertinent that such devices are used to their full potential in order to offset the harmful effects brought about by their development and distribution. In this section, I will discuss the use of smartphone technology in otolaryngology as a means to reduce the speciality's carbon footprint. The focus on smartphones specifically is justified by the fact that almost 85% of the world's population own a smartphone [26]. I contend that smartphones are at the forefront of successful technology of the 21st century, given their broad range of uses and widespread distribution.

One use of smartphone technology in ENT is smartphone otoscopy. Examination of the ear is an integral part of a typical otolaryngology consultation, and it is a procedure that has always demanded material equipment, from a speculum to a modern-day otoscope [27]. The need for

such equipment could be reduced, and perhaps eventually erased, with smartphone otoscopy. Modern smartphones can be used to capture high resolution images of the pinna, auditory canal and tympanic membrane [28]. Multiple studies have supported the validity and feasibility of this technology by identifying high diagnostic agreement between smartphone otoscopy and rigid otoendoscopy (see Figure 4) [27] [28]. Smartphone otoscopy would reduce ENT's carbon footprint because it would lessen the demand on materials and energy to make traditional otoscopy equipment. Of course, materials and energy are necessary to make smartphones, but as I suggested previously, smartphones are here to stay and will be made regardless of whether otolaryngologists decide to incorporate them into their practice. Therefore, they should be used to their full potential in ENT.

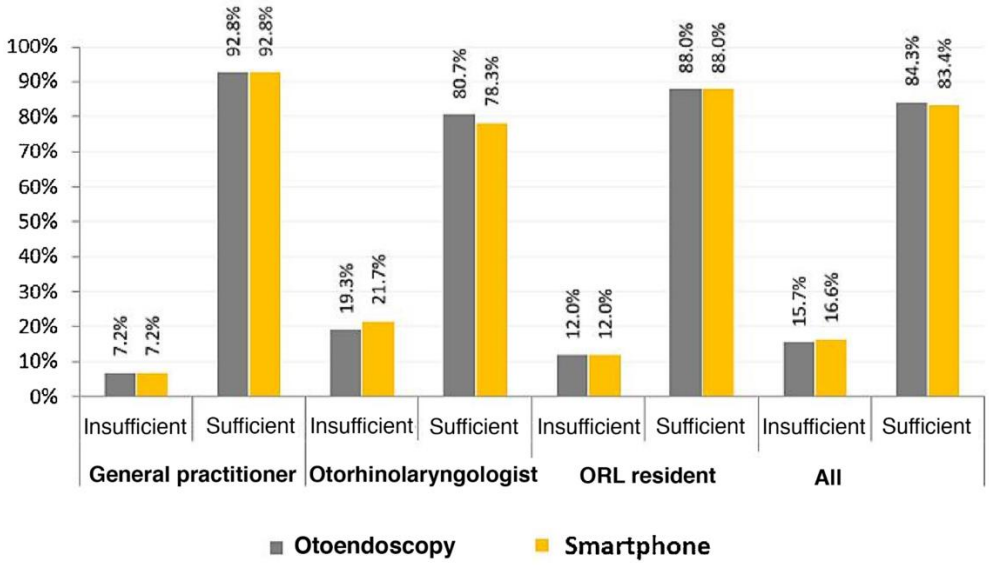

Figure 4 - Comparison between diagnostic sufficiency provided by smartphone otoscopy and otoendoscopy, taken from [27]

Thus far, my proposals regarding ENT's use of technology have centred around equipment used by otolaryngologists. It would be an oversight not to consider the use of technology by people at the centre of the speciality – its patients! ENT patients, especially those under the care of otologists, undergo varying numbers of pure tone audiometry (PTA) tests to aid diagnosis as well as monitor outcomes of treatment. What if patients could test their hearing themselves using their smartphones? There are now a number of smartphone applications that allow hearing to be tested from the comfort of patients' own homes – see Figure 5. A meta-analysis has shown these applications to be valid and feasible alternatives to PTA [29]. By reducing the need for patients to travel to clinics for hearing tests, there would be fewer transport-related carbon emissions. Studies into smartphone audiometry also promote the technology as very cost-effective [30] [31]. Therefore, it is an ideal technology to make otolaryngology more sustainable.

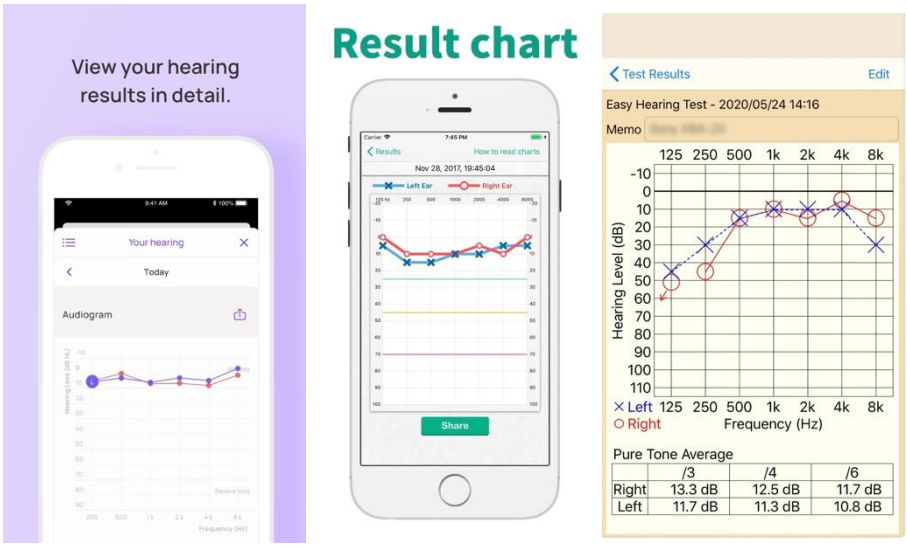

Figure 5 - A selection of screenshots taken from a search for 'hearing test' on Apple App Store[2]

I have discussed some reasons to increase the use of smartphone technology in ENT. There are further arguments in favour of this approach. First, the report 'Surgery and the NHS carbon footprint' states that it is not only energy use in operating theatres that is responsible for the current state of surgery's carbon footprint [12]. I argue that this is particularly relevant to ENT due to the high proportion of an otolaryngologist's work happening in clinics [32]. As a result, it is only right for this specialty to consider technologies for use outside of operating theatres, and smartphone technology is a perfect example of this. Furthermore, efforts to be more sustainable are centred around protecting the planet for future generations. As such, it is appropriate to empower the otolaryngologists of the future to use technology that will help to reduce ENT's carbon footprint; what better way to do this than encourage the use of a device that is already so central in the lives of young people. Overall, smartphone otoscopy and audiometry demonstrate the possibilities of utilising existing modern technology in order to make ENT more sustainable.

Creating New Technology – More Harm Than Good?

Thinking about the future of surgery typically conjures up images of modern, state-of-the-art devices, often with robotics centre-stage. Robotic surgery and other minimally invasive surgical techniques have been widely documented as beneficial to patients due to better surgical access and faster recovery [33]. ENT as a discipline may have even arisen from efforts to minimise the invasiveness of surgery [34]. Contrasting these positive outlooks, a recent systematic review revealed that greenhouse gas emissions of robotic procedures are almost 45% more than that of equivalent laparoscopic methods [35]. Robotic surgery also produces more waste than laparoscopic surgery [35]. Consequently, robotic surgery is not without cost

[2] Conducted 20/11/22 12:20 GMT.

to the environment. This reflects a broader concern that technological progress itself is a key culprit of the current climate emergency. It is known that technological progress has increased carbon emissions due to increased energy consumption and the knock-on effect on economic growth [25]. For that reason, should new technology be viewed as an obstacle to making ENT a sustainable speciality, rather than something which can be used to help reduce its carbon footprint?

Let's consider a more optimistic perspective. So-called 'green technology' is a growing area of interest in various industries [36]. It can be defined as any technology designed to reduce human impacts on the environment [36]. The range of green technology is vast, but a consistent feature is the use of renewable energy, such as solar panels and electric cars [37]. Regardless of the device, minimisation of carbon emissions is inherent to the design of these technologies [37]. Therefore, I suggest that ENT should look beyond the realms of the surgical world in order to implement new technology that is specifically designed to help reduce the speciality's carbon footprint. Here, I make two proposals as to how this might be achieved. These proposals sit at the top of The Technology Pyramid (see Figure 1). Perhaps by introducing new technologies that are designed to be green, ENT can begin to offset the environmental harm caused by certain technological advances such as robotic surgery.

Surgical headlights are widely used in ENT procedures due to the need for sufficient illumination and acuity [38]. Today, surgical headlights are typically LED which are far better for the environment than traditional incandescent bulbs [39]. Despite this, LED lighting is not the perfect green technology, and there is room for improvement. A new technology that could be useful here is thermoelectricity. A basic torch powered by body heat has already been invented [40]. The torch uses Peltier tiles which produce electricity when one side of the tile is warmed by body heat and the other is left cool by the surrounding air [41] – see Figure 6. The greater the temperature difference, the better the light. Given the heat that emanates from a focussed surgeon's head mid-procedure contrasting with the cool surroundings of a well-ventilated theatre, I would suggest that thermoelectric headlights have a future in ENT. Moreover, a randomised control trial comparing purpose-built surgical headlights to inexpensive, non-surgery-specific headlights found no significant difference in the visual acuity or colour vision provided by the devices [38]. This suggests that technology shown to work in a basic torch would work for surgical headlights, so quality of care would not be compromised.

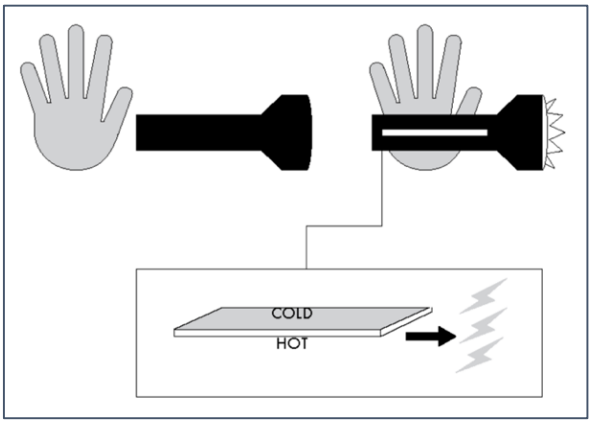

Figure 6 - Peltier tiles, taken from [42]

Since its introduction in the early 1980s, 3D printing has gained significant interest owing to its wide range of applications [43]. 3D printing is an impressive technology that works by layering materials one-by-one, directed by a computer [44]. One reason 3D printing is championed in industry is its positive environmental impacts [45]. For example, 3D printing produces little waste due to the nature of its layer-by-layer manufacturing method. 3D printing also helps to localise production, so it lowers transport-related carbon emissions [45]. Regarding surgery, the range of applications of 3D printing is vast, including anatomical models, pre-operative planning, surgical education and the creation of surgical tools. [46]. The creation of personalised implants for reconstructive procedures is another application and includes a trial procedure implanting a 3D-printed ear to treat microtia [47]. After further development, this technology could replace the use of polyethylene implants, and also used to correct nasal defects [47]. I suggest that ENT continues to advance its use of 3D printing, given the environmental benefits of this technology.

Conclusion

In this essay, I have argued for a tiered approach to ENT's use of technology to reduce its carbon footprint. The value of using simple technologies such as reusable items promoted by the Green Theatre Checklist should not be underestimated. As well as improving ENT's sustainability from its operating theatres, there are technologies for use elsewhere. I explored the use of smartphone otoscopy and audiometry as examples of how ENT can utilise existing modern technology to be more sustainable. ENT should also look to green technology from non-surgical fields for ways to reduce its carbon footprint further, and I proposed thermoelectricity and 3D printing as two examples of this. The future of ENT should be an exciting one, but I urge otolaryngologists to be modest when it comes to technology, in order for this important facet in ENT's future to help rather than hinder the speciality's sustainability.

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