Carbon Footprint of Tonsillectomy

# Abstract

## Introduction

Healthcare is responsible for 5.4% of greenhouse gas emissions in the UK. Emissions in surgery is a relatively unexplored area; in particular, this hasn’t yet been looked at as a whole in ENT in the UK.

## Aims

Quantify the amount of greenhouse gas (GHG) emission from a tonsillectomy and assess the proportion of each source’s contribution.

## Method

Operational data from tonsillectomies performed at a large university teaching hospital in the UK were gathered and converted to global warming potential using established conversion factors and data from existing healthcare-focused carbon footprint studies. The domains considered were waste, pharmaceuticals, surgical instrument decontamination, transportation, consumables use and utilities. This study used a process-based carbon footprint approach based on the “Greenhouse Gas Protocol: Product Life Cycle Accounting and Reporting Standard”.

## Results

The carbon footprint of a typical case was 41 kgCO2e which is equivalent to driving a car for approximately 150 miles. Consumables were responsible for 17% of this; 14% came from transport, 5.4% from decontamination, 4.8% from pharmaceuticals and 4% from waste. However, the largest GHG was from utilities, of which heating, ventilation and air conditioning was the overwhelming contributor.

## Conclusion

While the largest sources of GHG emissions require hospital-wide initiatives, there are aspects of consumables and waste streams we can improve on in ENT surgery. These include the use of disposable vs reusable instruments as well as increased availability and use of recycling waste streams in theatres. Additionally, this study provides a template that can be applied to other ENT procedures.

# Key Words

Carbon Footprint, Life Cycle Assessment, Tonsillectomy, Emissions, Green Surgery

# Key Points

* The largest source of carbon emissions from a tonsillectomy was heating ventilation and air conditioning in large part because it ran 24 hours a day unnecessarily.
* The second largest is consumables and therefore surgeons should opt to use reusable items when possible.
* The 3rd largest is transport of staff and patients which can be reduced through using active transport.
* The inhaled anaesthetic gas Sevoflurane had a large contribution to total emission and can be greatly reduced through optimal use and the use of vapour capture technology.
* A significant proportion is from waste disposal which could be reduced through appropriate use of waste streams.

# Background

Human-directed climate change is one of the largest threats we face to our health and well-being. The solution is a dramatic reduction in global greenhouse gas (GHG) production. This includes a reduction in healthcare emissions which are responsible for 4.4% of the total globally and 5.4% of the UK total. The NHS has already set the goal of a net-zero emission from direct sources by 2040 (1,2). To reach this goal emissions will have to be cut from all areas, especially surgery which is a particularly large consumer of resources (3). In order to reduce surgery's contribution, the impact needs to be quantified across a variety of procedures.

The environmental impact of an activity can be quantified in different ways however the most comprehensive is through life-cycle assessment (4). Life-cycle assessment identifies the potential environmental impacts throughout a product's life from raw material acquisition to leaving the factory (“cradle-to-gate”) or it’s disposal (“cradle-to-grave”) (4) . A subset of life-cycle assessment is a product greenhouse gas inventory which only focuses on the global warming potential (GWP). Different GHGs are included and because each has a different GWP they expressed in terms of kilograms of carbon dioxide equivalent (kgCO2e). As the lifetime of different GHGs in the atmosphere varies, the GWP is typically calculated over 100 years.

Carbon footprint investigations can and have been performed at different levels including national, hospital, department and procedure (1,3,5–7). Analysis at each level allows for the most effective changes to be implemented at each level. At the level of procedure, carbon footprint calculations have already been performed for skin cancer excision, cataract removal, plastic surgery and hysterectomies (3). No such impact has been quantified for tonsillectomy. Tonsillectomy was chosen due to the high volume of surgeries and therefore potential for large GHG emission reduction.

This study used a “cradle-to-grave” product greenhouse gas inventory to calculate the GWP of an adult tonsillectomy with the aim of identifying “hot spots” than can be targeted to reduce the carbon footprint.

# Methods

## Study setting

This study was performed at a large university teaching hospital in the UK. In 2021 48 adult tonsillectomies were performed.

## Ethical considerations

National Health Service Research and Ethics Committee approval was not required for this study.

## Calculation of carbon footprint

This study used a process-based carbon footprint approach based on the “Greenhouse Gas Protocol: Product Life Cycle Accounting and Reporting Standard” (8). A “cradle-to-grave” inventory analysis was used. The GHGs included were carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbons, and hydrofluorocarbons. The GWP potential of the GHGs was calculated over 100 years. Sources of data included UK government conversion factors (9), primary process activity data and previously published studies concerning anaesthetics, surgical consumables and surgical instrument decontamination. The functional unit was the completion of a tonsillectomy.

## Boundaries

A process diagram for a tonsillectomy procedure including the inventory boundary used is given in Figure 1. Not considered in this assessment were: the production and disposal of the infrastructure (machines, means of transportation), the need for repeat operations, preoperative assessment and post-operative care, staff training or any supportive services not explicitly mentioned (e.g., administration). In addition, attributable processes reasonably thought to contribute less than 1% of GHG emissions were excluded. However, the sum of the neglected materials was not reasonably expected to surpass 5%. Excluded components included: cleaning materials, saline, linen, laundry, printing paper, printing ink, patient transportation sheets, anaesthetic drug tray, face masks, scrub caps, tonsil swabs, central venous catheter, marking pen, suture, disposable diathermy, and disposable suction.

## Data sources and assumptions

### Waste

Two waste streams were identified as being using during a tonsillectomy: infectious and dry mixed recycling. The total waste for each steam was calculated by taking the difference in weight of all bags before and after the operation (including preparation). Conversion factors were then applied (9) (10).

### Pharmaceuticals

The mean amount of pharmaceuticals used was calculated from the anaesthetic records of the first 7 tonsillectomy patients from March 2021. Drug emissions were mostly taken from a chemical synthesis emission study (11) however morphine was taken from a study based on opium processing (12) and sevoflurane from a study comparing inhaled anaesthetic gases (13). Sevoflurane was derived from hexachloroacetone and mixed with 100% oxygen at a flow rate of 1 L/min with no use of vapour capture technology. Sevoflurane quantity is expressed in terms of the amount required to maintain anaesthesia for an average 70kg adult patient for 1 hour (MAC-h). The MAC-h for a typical tonsillectomy was calculated using the median anaesthetic duration at the author’s hospital (38 minutes). Due to unavailable data for diclofenac or ketolorac, a paracetamol study was used (14).

### Surgical instrument decontamination

To calculate the impact of surgical instrument decontamination data from a study at the Royal Sussex County Hospital was used (15). Information regarding the typical usage of trays and individually wrapped items was gathered from the author's experience and communication with colleagues. As the data in the study did not include transportation this was calculated separately. The distance between our hospital and the central decontamination facility was calculated using route distance with Google Maps (16). Information about the weight of the HGV used and typical loading capacity was provided by the facility manager. Carbon emission data for the HGV transport was taken from government conversion factors (9).

### Transportation

To calculate patient travel emissions, all patients that had a tonsillectomy between January 2021 and February 2022 were identified (n=48). The distance between their home postcode and the hospital, including return distance, was calculated using route distance with Google Maps (16). An estimated GWP was then calculated using the mean travel distance and the average petrol passenger car GWP data (9).

To quantify the impact of staff travel, a survey was conducted in a tonsillectomy list theatre (n = 13) which gathered the distance, the mode of transport and when relevant the engine type and size. The related conversion factors were then applied (9). The proportion of staff travel attributable to a tonsillectomy was calculated based on nine hours of operating time per day and from the median time for tonsillectomy (89 minutes). Five members of staff were directly required for a tonsillectomy: surgeon, scrub nurse, scrub runner, operating department practitioner and anaesthetist.

### Consumables

The consumables used in a standard tonsillectomy were taken from the author's personal experience and communication with colleagues. Their associated GWP was taken from existing literature using the HealthcareLCA database search (17). Where values included waste disposal that component was excluded because waste is dealt with separately within this study. Different sources were used for disposable surgical gowns, surgical face masks (18); non-sterile gloves, sterile surgical gloves (19); reusable scrub suits (20) and surgical drapes (21).

### Utilities

To estimate the impact of utilities, data was taken from meters on an individual theatre for the heating, ventilation, and air conditioning (HVAC) and lighting (7). The portion attributed to a tonsillectomy was derived from 24-hour usage and typical proportion of time spent on a tonsillectomy in an operating day. The energy use from plugs was estimated based on the sum of power consumption of the devices in the theatre (computers, diathermy machine, anaesthetic machine etc) over the median time of a tonsillectomy. Power consumption was gathered from manufacturer specification documents. The conversion factor for the energy consumption was calculated for the specific mix of grid electricity and natural gas generators used at the hospital campus (9).

# Results

## Summary

The carbon footprint of a typical tonsillectomy procedure at our hospital was found to be 41 kgCO2e which is equivalent to driving an average petrol car for approximately 150 miles (9). The largest proportion of emissions came from utilities followed by consumables and then patient and staff transport (figure 2).

## Waste

Infectious waste had a far greater GWP than the dry mixed recycling (1.48 vs 0.17 KgCO2e).

## Pharmaceuticals

The most significant pharmaceutical source of emissions was sevoflurane which had a GWP two orders of magnitude greater than any other drug (table 1).

## Surgical instruments decontamination

One medium surgical tray was identified as being used in a tonsillectomy, the GWP from this was 1.9 kgCO2. The GWP from return transport to the decontamination facility was 0.12 kgCO2e. Therefore, the total GWP from surgical instrument decontamination was 2 kgCO2e.

## Transport

The mean distance travelled by a patient was 15.2km, (95% CI 12.1 to 18.2). Two extreme outliers of 217km and 137km were excluded. The mean GWP of a patient travelling to the hospital for tonsillectomy was 2.6 kgCO2e. This was less than the GWP attributable to staff travel (3.2 kgCO2e).

## Consumables

Within consumables, the largest source of GHG emissions was the use of sterile surgical gloves (table 2).

## Utilities

By far the greatest source of GHG emissions within utilities was the HVAC system (table 3).

## Tables and Figures

Figure . Flow chart of product system and system inventory boundary for a tonsillectomy procedure

Figure . The greenhouse gas emission of tonsillectomy by source, HVAC = Heating, Ventilation and Air Conditioning

Table 1. Summary of GHG emissions from pharmaceuticals

Table 2. Summary of GHG from consumables

Table 3. Summary of GHG from utilities

# Discussion

In recent years much work has been done around improving sustainability in surgery. This work has been incorporated into a “Green Theatre Checklist” that makes recommendations on how emissions can be minimised (22). So that these recommendations are implemented in the most effective way it is important that individual surgeries have their emissions assessed so that specific “hot spots” can be targeted. Variance in “hot spots” has already been demonstrated. For example, a recent review found that the largest source of GHG emissions can vary from electricity to consumables procurement and the overall emissions can range from 6 to 814 kgCO2e (3). In this study we identified the “hot spots” within a tonsillectomy procedure that should be targeted as a priority.

The smallest source of emissions in this study was waste disposal. Although the smallest it is far greater than the <0.01% previously mentioned in the literature (23) and therefore may be an important area for improvement. The emissions from waste depend largely on the waste stream and can vary from 21 kgCO2e/ tonne for recycling to 1074 kgCO2e/ tonne for clinical waste. Therefore, emissions can be improved with waste stream optimisation through auditing of waste practices and staff education. It could be further reduced by decreasing the number of consumables used.

To reduce the number of consumables, and therefore reduce emissions both from procurement and disposal, reusable equipment should be chosen over the disposable alternative (22). However, to change to reusable items there needs to be an increase in the capacity of decontamination facilities. The main barriers within the current Health Board are staff training and the size of the facility which limits the amount of equipment. However, there is a move towards using reusable instruments and phasing out the use of disposable tonsillectomy instruments.

The GHG emissions from decontamination are already significant at 13% of the total for tonsillectomy and would likely rise with a change to more reusables. This is a difficult area to improve at the site of study as previous recommendations such as running the sterilisation machines at 100% capacity and limiting the use of individually wrapped instruments are already being implemented (15). However, there is still potential to reduce emissions by changing the disposable sterile wrapping used to a reusable alternative such as aluminium cases (15).

The fifth largest source of emissions from a tonsillectomy was the pharmaceuticals used, with sevoflurane being the primary contributor. The GWP of sevoflurane varies greatly depending upon the flow rate, method of gas synthesis, use of vapour capture technology and whether oxygen or nitrous oxide is used as a vehicle. The GWP can be as high as 44 kgCO2e/MAC‑h under certain conditions however at the site of study sevoflurane had a value of 3 kgCO2e/MAC‑h (13). This could still be optimised further at the QEUH by using a lower flow rate of 0.5 L/min and vapour capture technology which can recycle approximately 70% of the gas used (13). Together these changes would reduce the GWP from 3 kgCO2e/MAC-h to 1 kgCO2e/MAC-h. Alternatively changing to total intravenous anaesthesia would reduce GHG emission however 1% of propofol is excreted unchanged into the environment where it has high bioaccumulation and toxicity to aquatic organisms. Therefore, consideration should be given to the use of total intravenous anaesthesia or optimised sevoflurane because they do not differ significantly in GHG emissions but may in wider environmental impact (13).

The third largest source of emission pertains to the transport of patients and staff. The transport used by patients is difficult to influence as personal transport is often the most appropriate. With regards to staff transport NHS hospitals have influence and are required to have a green travel plan (1). Numerou schemes exist such as the cycle scheme which facilitates staff cycling through a salary sacrifice. Continuation and expansion of schemes such as this are a key part of reducing staff transport emissions.

The largest “hot spot” was the heating, cooling and ventilation of the operating suite. The most appropriate changes will be specific to different hospitals. At the site of the study, the operating theatre’s HVAC system run at an “in-use” capacity 24 hours a day. As outlined in “Health Technical Memorandum 03-01 Part A” this is not necessary (24). Energy consumption could therefore be greatly reduced by turning the HVAC system off when the theatre is not in use and using appropriate setbacks.

Most of the limitations of this study stem from the use of secondary data sources from other hospitals to estimate carbon emissions at the site of the study. Additionally, limitations exist in assessing the impact of pharmaceuticals, as most of the data only calculated emissions for the active substance within drugs and the boundaries of the assessment varied. Furthermore, none of the data sources accounted for drug wastage which in the case of propofol has been shown to be high at 32% (25). As with any life cycle analysis or GHG accounting the study is limited by the extent of the system boundary. It does not take into account pre-operative or post-operative care and therefore underestimates the true GHG emissions and may also leave some “hot spots” hidden. Despite these limitations, it is still possible to identify large areas of emissions that can be targeted.

The breakdown of GHG emissions provided by this study allows prioritisation of areas to target. This prioritization accelerates progress toward net-zero emissions. Additionally, by providing a clear number for each component of emissions staff can better see the implications of their actions which aids behaviour change. Furthermore, data provided from this study may empower staff to petition for changes to hospital policy. Outside of the immediate impact on the emission of tonsillectomy this research can be used as a framework for other operations and different hospitals. Comparison of these results would lead to the identification of areas of discrepancies that can be improved.

## Conclusion

To reduce the carbon footprint of surgery it is important to identify “hot spots” to target. The GHG emissions of a tonsillectomy at the site of study are primarily driven by patient and staff transport, consumables procurement, HVAC, sevoflurane and surgical instrument decontamination. Of these, HVAC and sevoflurane emissions are most amenable to change and therefore initiatives to reduce these should be a priority.

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