The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 19, a comparative study of the cost and carbon footprint of local anaesthesia techniques for cataract surgery

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Synopsis:

Increasing usage of topical anaesthesia for cataract surgery in the NHS could substantially reduce the cost and carbon footprint of services.

ABSTRACT

Background: Understanding the financial and environmental impact of pathways is important for designing sustainable services. This study aimed to compare cost and carbon footprints of sub-Tenon's and topical anaesthesia for cataract surgery, benchmark minimum topical anaesthesia utilisation rates, and quantify increased topical anaesthesia usage benefits in the United Kingdom National Health Service (NHS).

Methods: The cost and carbon footprint of products and staffing for topical and sub-Tenon's anaesthesia for cataract surgery were calculated and applied to National Ophthalmology Database audit data. A mainly process-based approach was used to estimate carbon dioxide equivalents (CO2e) associated with product production, usage, and waste disposal.

Results: The typical CO2e per case was 0.71kg for topical anaesthesia and 1.19kg for sub-Tenon's anaesthesia. Around a third of the CO2e was generated by usage of unnecessary equipment and wasteful practices. The typical cost per case was £14.60–£17.14 for topical anaesthesia, £27.74 for sub-Tenon's anaesthesia performed by an operating department practitioner and £56.15 for sub-Tenon's anaesthesia performed by a consultant anaesthetist. It is estimated that around 25 000 NHS cataract cases could annually be converted from sub-Tenon's to topical anaesthesia, which would reduce the CO2e emissions of cataract services by 12 000kg while saving £265 000 on product usage and between £63 500 and £773 750 on staffing costs.

Conclusions: Topical anaesthesia is a cheaper and more environmentally sustainable alternative to sub-Tenon's anaesthesia for cataract surgery. Increasing the usage of topical anaesthesia in cataract services could contribute towards the NHS aspiration of becoming "net zero" by 2040.

KEY MESSAGES

What is already known on this topic:

- Topical anaesthesia is commonly used for cataract surgery and is associated with lower anaesthetic related complication rates than sub-Tenon's anaesthesia, but sub-Tenon's anaesthesia was still used in around 45.9% of NHS cataract cases between 2010 and 2019.

What this study adds:

- Increasing topical anaesthesia usage would reduce the cost and carbon footprint of NHS cataract services.
- It is estimated that around 85% of NHS cataract operations could feasibly be performed using topical anaesthesia without compromising surgical training.

How this study might affect research, practice or policy:

- Aiming to perform at least 85% of cataract cases using topical anaesthesia is an achievable minimum benchmark and would substantially contribute towards the NHS's "Net Zero" aspiration while reducing costs.

INTRODUCTION

Ophthalmology is the highest volume outpatient specialty in England and is likely responsible for a significant part of the cost and carbon footprint of the National Health Service (NHS) [1]. Over the coming decade ophthalmic services in the United Kingdom (UK) are expected to grow, with projections forecasting a 52% increase in cataract cases between 2015 and 2035 [2]. To ensure that existing eye care provision and future service expansion is affordable and environmentally sustainable, a better understanding of the cost and carbon footprint of common clinical pathways is needed [3].

Topical and sub-Tenon's anaesthesia are commonly used anaesthetic techniques for cataract surgery [4]. Although topical anaesthesia is growing in popularity and is associated with lower anaesthetic related complication rates than sub-Tenon's anaesthesia, sub-Tenon's anaesthesia was still performed in around 45.9% of NHS cataract cases between 2010 and 2019 [4]. Topical anaesthesia requires less equipment and technical expertise than sub-Tenon's anaesthesia, so there would be potential environmental and financial benefits of increasing its usage. Since around 608 000 cataract operations were performed in England during the 2022 NHS year, the cumulative impact of changes in cataract anaesthetic practices could contribute substantially to achieving the NHS aspiration of becoming "Net Zero" by 2040 [5,6].

The aim of this study was to compare the direct costs and carbon footprint of topical and sub-Tenon's anaesthesia for cataract surgery and quantify the potential benefits of increasing topical anaesthesia usage. Because this study was comparative in nature, components of topical and sub-Tenon's anaesthesia pathways that are the same regardless

of the anaesthetic technique, such as building use and staff travel, were not included in analyses. An estimate of the number of NHS cataract operations that could feasibly be converted from sub-Tenon's to topical anaesthesia was generated using Royal College of Ophthalmologists (RCOphth) National Ophthalmology Database (NOD) National Cataract Audit data and represent an aspirational but achievable goal for improving the sustainability of services.

METHODS

Product inventories

Products typically used for topical and sub-Tenon's anaesthesia were identified by observation of cataract theatre lists during September 2023 at Leeds Teaching Hospitals NHS Trust. Three cases using topical and three using sub-Tenon's anaesthetic were observed. Details of the products and their primary packaging were recorded, including additional intraoperative and postoperative products. Waste disposal behaviours were established by setting up empty waste disposal containers prior to the procedure and then reviewing the waste collected after completion. Products taken home by patients were assumed to be disposed of via domestic waste.

Product inventories were checked by clinicians applying the anaesthetic. Since our sample demonstrated no variation in product usage or waste disposal behaviours and the clinicians applying the anaesthetic agreed the product inventory, no further cases were observed.

The material composition of products and packaging were determined using manufacturer information and studies detailing similar items [7]. Products and packaging were deconstructed into discrete material types and weighed using a Sartorius Analytic lab balance (Sartorius, Göttingen, Germany) sensitive to 0.0001g. If products could not be deconstructed, the material composition was estimated based on similar items in the literature [7].

Optimized topical and sub-Tenon's inventories were developed using guidance presented in Health Technical Memorandum documentation produced by NHS England in consultation with ophthalmologists [8]. The inventories describe the minimum product requirement for topical and sub-Tenon's anaesthesia with streamlined waste disposal practices. Products included and choice of waste disposal method were confined to resources available locally (e.g., there is currently no option to recycle waste in operating theatres, so this could not be integrated into the pathway). The feasibility of the optimized inventories was confirmed by an ophthalmologist applying the anaesthetic using only the products listed.

Staffing costs

Grades of staff performing anaesthesia were determined through observation of theatre lists and discussion with managers and ophthalmologists. Both topical and sub-Tenon's anaesthesia are performed locally by nurses or operating department practitioners (ODPs) on the band 5 and band 6 pay scale. However, it was advised by management that performing sub-Tenons' anaesthesia would be a designated band 6 activity. In addition, ophthalmologists reported that in some local hospitals, sub-Tenon's anaesthesia is routinely performed by consultant anaesthetists. Staffing costs for topical anaesthesia are therefore

calculated for band 5 and 6 ODPs, and staffing costs for sub-Tenon's anaesthesia are calculated for band 6 ODPs and consultant anaesthetists.

Annual salaries were obtained from documents and online sources detailing NHS pay scales [9,10]. When staffing pay was dependent on experience, a midpoint value was used.

A 4-hour theatre session is equivalent to 1 programmed activity (PA) of a 10 PA per week consultant job plan [11,12]. To estimate staffing costs per theatre session, weekly pay was calculated by dividing annual salaries by 44 (assuming a 52-week year with 8 weeks allocated for annual leave, study leave and sick leave), which was then divided by 10 to calculate pay per PA [13–15]. It was assumed that 6 cataract operations are performed per theatre session, as this is the median number of cases on NHS training lists [11].

Procurement, decontamination and waste disposal costs

Product costs were obtained from the procurement team and included delivery. If only part of a product was used per case (e.g., for surgical tape), the cost was divided by the number of cases it could be expected to be used for. The cost per case of reusable equipment was estimated by dividing the product cost by the expected number of uses during its lifespan. Information on reusable equipment lifespan was not available locally, so estimates are based on similar items in the literature [7]. There was no opportunity to observe waste disposal of reusable equipment, so this was extrapolated from equivalent single-use items.

Decontamination costs of reusable equipment was obtained from a local decontamination service provider (B. Braun Sterilog Limited, Sheffield, UK). Waste disposal costs were obtained from hospital waste compliance managers and, except for sharps and medicinally contaminated infectious waste, included transportation to the disposal site.

Costs were commercially sensitive so are presented in aggregated form.

Carbon footprint of products

Product production

CO2e estimates for product and packaging production was generated using emission factors encompassing "cradle to factory gate" activities, which typically includes raw material extraction, transportation of materials to factory sites, material processing and product manufacturing.

The primary source of emission factors was The Inventory of Carbon and Energy (ICE) database (version 3), as it reflects UK production practices [16]. If emission factors were unavailable on the ICE database, the Ecoinvent v3.6 database and other published studies were used [7,17]. When no process-based emission factors were available, spend-based emission factors from the Small World Consulting Carbon Factors Dataset v5.3 were used [18]. If only a small proportion of the cost of a product was attributed to a component requiring spend-based emission factors, an estimated attributable cost was calculated for the component based on weight. The system boundaries of all emission factors used are presented elsewhere [7].

Product usage

The system boundary for product usage included decontamination of reusable sub-Tenon's sets with a washer and an autoclave and transportation of reusable sets to and from the decontamination centre.

Details regarding washers and autoclaves were obtained from B. Braun Sterilog, who were also consulted regarding the methodology for estimating decontamination CO2e. The main decontamination machines used locally are 15 DIN capacity Belimed WD390 washers and 24 sterilizing unit capacity Belimed 9-6-18 HS2 autoclaves with 1 400 litre volume. Washer CO2e per cycle was estimated from a study of similar 15 DIN capacity washers with roughly equivalent size and configuration [19]. The autoclave CO2e per cycle was estimated using data for 18 sterilizing unit capacity autoclaves with a 1 250 litre volume [19]. To account for the 12% larger volume of the autoclaves in the present study, the per cycle CO2e was multiplied by 1.12. Estimates of typical numbers of sub-Tenon's sets processed per cycle and maximum number of sets possible to process per cycle were obtained from B. Braun Sterilog management.

The distance between the hospital and the decontamination site was calculated using Google Maps (Google, California, US). UK Government Greenhouse Gas conversion factors were used to calculate transportation CO2e throughout the study [20].

Waste disposal

Information regarding local waste disposal streams were obtained from hospital waste compliance managers. The CO2e associated with processing waste was estimated using emission factors reported for another NHS hospital [21].

Hotspot analysis

A hotspot analysis was used to identify carbon intensive components of the anaesthesia pathways.

For the product production hotspot analysis, products were grouped into 4 categories: packaging (including containers, lids, ampoules and protective covers), medical equipment, pharmaceuticals and personal protective equipment (PPE). Packaging production had its own category and was not included in the CO2e of other categories.

National Ophthalmology Database data

The number of NHS cataract cases that could be feasibly converted from sub-Tenon's to topical anaesthesia was estimated using data from the RCOphth NOD. Detailed information regarding the RCOphth NOD is published elsewhere [4].

The anaesthetic technique used for NHS cataract operations performed in England during the 2022 NHS year (01/04/2022 to 31/03/2023) was extracted from the National Cataract Audit. Operations using general anaesthesia or with incomplete information were excluded, as were organisations with <50 operations performed using topical or sub-Tenon anaesthesia. It is accepted that very high proportions of cataract operations can be performed under topical anaesthesia by experienced surgeons in centres only accepting

lower complexity cases [4]. To estimate the proportion of cataract operations that could be performed under topical anaesthesia in a typical NHS service that provides surgical training, only NHS centres with at least 11% of cases performed by trainees were used in line with the minimum training expectations set nationally [22].

The proportion of cases using topical and sub-Tenon's anaesthesia was calculated for each centre. Centres were then ranked according to topical anaesthesia usage. The number of sub-Tenon's cases that could be converted to topical anaesthesia if all centres performed at least as much topical anaesthesia as the centre on the 75th percentile was calculated as an achievable but aspirational target.

Ethical approval

Service evaluations of this type are exempt from ethical approval as per NHS Health Research Authority guidance [23]. The study was conducted in accordance with the declaration of Helsinki and the UK's Data Protection Act.

RESULTS

Product inventories, emission factors, expected lifespan of reusable equipment, transportation distances and local waste disposal processes are shown in the supplementary materials.

Costs

The typical staffing and product cost per case of topical anaesthesia was £14.60 for cases performed by band 5 ODPs and £17.14 for cases performed by band 6 ODPs. Staffing costs contributed 80% or more of the anaesthesia cost.

The typical staffing and product cost per case of sub-Tenon's anaesthesia (using a single use sub-Tenon's set) was £27.74 for cases performed by a band 6 ODP and £56.15 for cases performed by consultant anaesthetists. Staffing costs contributed 51-76% of the anaesthesia cost. Reusable sub-Tenon's sets cost £0.15 more than single use sets, mostly because of the decontamination cost.

Optimizing product inventories saved £0.90 per case for topical anaesthesia and £2.83 per case for sub-Tenon's anaesthesia. A breakdown of the costs is show in table 1.

Table 1. Cost of product inventories and staff

Product inventory	**Cost per case for typical practice (£)**	**Cost per case for optimized practice (£)**
Topical anaesthesia	2.99	2.09
Sub-Tenon's anaesthesia*	13.59	10.76
Staffing	**Cost per case (£)**	
Band 5 ODP	11.61	
Band 6 ODP	14.15	
Consultant anaesthetist	42.56	

*Values assume that the single use sub-Tenon's set was used
ODP = operating department practitioner

Carbon footprint of products

The typical total CO2e per case associated with product production and waste disposal was 0.71kg for topical anaesthesia and 1.19kg for sub-Tenon's anaesthesia. Optimizing product inventories reduced the CO2e by 0.22kg for topical anaesthesia and 0.42kg for sub-Tenon's anaesthesia. Of the changes made during product inventory optimization, reductions in pharmaceutical product usage and unnecessary PPE had the greatest impact on CO2e. The single most impactful change during product inventory optimization was using only one type of topical anaesthetic drop rather than two, which reduced the CO2e by 0.16kg.

Pharmaceuticals contributed over half of CO2e in all cases. The second greatest contributor of CO2e for sub-Tenon's anaesthesia was medical equipment, followed by packaging. Waste disposal related activities were responsible for less than 5% of CO2e in all cases. A CO2e hotspot analysis of product production and waste disposal is shown in table 2.

Single use vs reusable sub-Tenon's set CO2e

The washers used for decontaminating reusable sub-Tenon's sets typically process one three-tiered load carriage per cycle containing 16 sets per tier. Optimizing the loading process by substituting the three-tiered load carriage with four-tiered racks increases the maximum washer capacity from 48 to 64 sets per cycle. Autoclaves used locally typically process two 3-tiered load carriages per cycle containing 16 re-usable sub-Tenon's sets per

tier. Optimizing loading process by using an alternative basket increases the maximum autoclave capacity from 96 to 120 sets per cycle.

The total CO2e associated with sub-Tenon's sets was 0.18kg for single use sets, 0.26kg for reusable sets processed using typical decontamination practices and 0.21kg for reusable sets processed using optimal loading practices (table 3). For all reusable sets, over 80% of total CO2e emissions per case were related to the decontamination process.

Table 2. CO2e hotspot analysis of product production and waste disposal

Product inventory	Product and packaging production CO2e by category (g) (% of total)				Waste disposal CO2e by activity (g) (% of total)		Total CO2e (g)
	Packaging	Medical equipment	Pharmaceuticals	PPE	Transportation to disposal site	Processing waste	
Topical anaesthesia (typical inventory)	23.00 (3.23)	33.49 (4.70)	602.58 (84.58)	44.56 (6.25)	0.08 (0.01)	8.71 (1.22)	712.41
Topical anaesthesia (optimized inventory)	18.79 (3.85)	17.48 (3.58)	444.28 (90.97)	0.00 (0.00)	0.11 (0.02)	7.75 (1.59)	488.41
Sub-Tenon's anaesthesia (typical inventory*)	150.85 (12.71)	253.86 (21.40)	607.06 (51.17)	124.57 (10.50)	0.44 (0.04)	49.65 (4.19)	1186.44
Sub-Tenon's anaesthesia (optimized inventory*)	107.73 (14.07)	153.88 (20.09)	444.28 (58.02)	22.28 (2.91)	0.44 (0.06)	37.19 (4.86)	765.80

*Values assume that the single use sub-Tenon's set was used
PPE = personal protective equipment

Table 3. CO2e hotspot analysis: single use vs reusable sub-Tenon's sets

Activity	Single use sub-Tenon's set CO2e per case (g) (% of total)	Reusable sub-Tenon's set CO2e per case (g) (% of total)	
		Typical loading practices	Optimal loading practices
Production of set	161.17 (87.56)	35.42 (13.71)	35.42 (16.82)
Transporting set to and from decontamination site	N/A	0.17 (0.066)	0.17 (0.08)
Decontamination process	N/A	219.43 (84.93)	171.65 (81.51)
Waste disposal*	22.90 (12.44)	3.36 (1.40)	3.36 (1.59)
Total	184.08	258.38	210.60

*Values are based on typical waste disposal practices and include transportation to waste disposal site

National Ophthalmology Database data

There were 58 NHS centres with at least 11% of cataract cases performed by trainees in the 2022 NHS year on the NOD. The percentage of cataract cases performed using topical anaesthesia at each of these 58 centres is shown in figure 1, with the centre on the 75th percentile using topical anaesthesia in 83.2% of cases. In total, 70 904 cataract operations were performed using topical anaesthesia and 44 261 cataract operations were performed using sub-Tenon's anaesthesia. If all 58 NHS centres used topical anaesthesia at least as much as the centre on the 75th percentile, roughly 25 000 NHS cataract cases could be converted from sub-Tenon's to topical anaesthesia annually. Converting 25 000 cataract cases from sub-Tenon's to topical anaesthesia would save the NHS £265 000 and 12 000kg of CO2e in products each year assuming typical product usage. Since topical anaesthesia can be performed by a band 5 ODP and sub-Tenon's is typically performed by a band 6 ODP or consultant anaesthetist, a further £63 500–£773 750 could annually be saved in staffing costs.

DISCUSSION

As ophthalmic services grow to accommodate demographic change, the already high cost and carbon footprint of eye care is set to rise [1,2]. To ensure that ophthalmic services are growing in an affordable and environmentally sustainable way it is important to understand the cost and carbon footprint of common clinical pathways [3].

This study aimed to compare the cost and carbon footprint of the products and staffing involved in topical and sub-Tenon's anaesthesia for cataract surgery, the most common NHS

operation [6]. Sub-Tenon's anaesthesia was between £10.60 and £41.55 more expensive than topical anaesthesia per case, and the products used for sub-Tenon's anaesthesia produced approximately 1.7 times more CO2e emissions than topical anaesthesia.

Our analysis of 58 NHS centres offering cataract surgical training demonstrated significant variation in UK cataract anaesthetic practices. Some NHS hospitals use sub-Tenons anaesthesia for nearly all cataract operations; others use almost exclusively topical anaesthesia. There is no clear clinical rationale for this variation in practice and topical anaesthesia was found to be cheaper and more environmentally sustainable. In addition, studies suggest that topical anaesthesia is associated with lower anaesthetic related complication rates [4]. Based on the NHS centre on the 75th percentile in our analysis, we propose that all NHS hospitals with trainees should aspire to use topical anaesthesia for at least 85% of cataract operations. Centres not contributing to training should aspire to a higher proportion of topical usage.

The optimized inventories reflect the financial and environmental benefits of tackling wasteful behaviours commonly encountered in clinical practice. It was found that for both topical and sub-Tenon's anaesthesia typically around one third of the CO2e and 5%–10% of the cost was generated by products not needed for the procedure and inappropriate waste disposal.

Pharmaceutical product production was one of the most carbon intensive components of both anaesthesia pathways, and so it was unsurprising that the most impactful intervention during product inventory optimization was the reduction from two types of anaesthetic

drops to one. As well as avoiding products with a large carbon footprint, CO2e can be reduced by exchanging products for more sustainable alternatives. For example, it was typical practice in the cases observed to use gauze made of cotton to wipe excess eye drops. However, cotton production is over five times more carbon intensive than paper and paper-based tissues would be equally acceptable [16].

Surprisingly, reusable sub-Tenon's sets were more expensive and had a greater carbon footprint than single use alternatives, mostly owing to the decontamination process. While there is evidence in favour of the environmental benefits of reusable surgical sets, previous studies indicate that decontamination processes become less efficient when sets contain fewer instruments [19,24]. Our findings suggest that in our context the environmental benefits of reusing very small surgical sets—the total weight of the instruments in the sub-Tenon's sets is less than 20 grams—may be limited, even after optimising loading processes.

Waste disposal activities were responsible for only a small proportion of CO2e, partly because the disposal site for most products was only 4km away from the hospital. There was no option to recycle waste in operating theatres, which is reflective of practice in many NHS hospitals and may represent an opportunity for improvement locally and nationally.

Staffing accounted for most of the total cost of anaesthesia and so is an important target for strategies looking to save money. Trusts should be encouraged to train ODPs to apply sub-Tenon's anaesthesia rather than using consultant anaesthetists, as this reduced the total cost per case by more than half. In addition, it was typical practice for band 5 or 6 ODPs to

perform topical anaesthesia, but it would be less costly to use band 3 staff who routinely apply eyedrops for other ophthalmic procedures.

Our study provides an example of how addressing inefficiencies in high volume ophthalmic services can have a large impact when leveraged on a national scale. Although the choice of whether to use sub-Tenon's or topical anaesthesia for cataract surgery may appear small, the cumulative effect of this decision across the whole NHS is not insignificant.

Author contribution: JB and JM conceived the study idea and design. With input from JB, JM developed the research protocol, collected and analysed cost and CO2e data, and drafted the manuscript. MG and PD provided NOD data and contributed to its use and analysis. All authors reviewed and commented on the final manuscript.

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Figure Legends:

Figure 1. Percentage of cataract operations performed using topical anaesthesia at the 58 NHS centres on the NOD with at least 11% of operations performed by trainee surgeons (n = 115 165 cataract operations).