REVIEW/UPDATE

Factors contributing to the carbon footprint of cataract surgery

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The healthcare sector is a significant greenhouse gas emitter. Cataract surgery is a procedure that results in a large amount of carbon dioxide (CO_2) emissions. We sought to review the literature for factors contributing to the carbon footprint of this procedure. The literature, although limited, varies greatly by region. The carbon footprint of cataract surgery ranged from approximately 6 kg CO_2 equivalents in a center in India to 181.9 kg CO_2 equivalents in a center in the United Kingdom. Factors contributing to the carbon footprint of cataract surgery included the procurement of materials, energy use, and the emissions associated with travel. Factors facilitating a lower carbon footprint include the reuse of surgical materials and more efficient autoclave settings. Potential areas for improvement to consider include the reduction in packaging material, the reuse of materials, and potentially reducing travel emissions by performing simultaneous bilateral cataract surgery.

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There has been emerging evidence that anthropogenic climate change has the potential to influence human health because of increased adverse weather events worldwide and heat waves in northern communities.[1,2] These adverse events can influence human health by means of immediate harm, as well as long-term displacement and food insecurity.[3] In addition, air pollutants are associated with ophthalmic disease, as ozone (O_3), fine particulate matter, and sulfur dioxide (SO_2) molecules are risk factors for dry eye disease in China, with similar findings regarding ozone levels in South Korea.[4,5] At the molecular level in mice, extended ozone exposure led to corneal lesions and damaged conjunctival goblet cells and, in human, cultured conjunctival epithelial cells, led to the activation of nuclear factor κB and nuclear factor κB–mediated inflammatory processes, which contribute to ocular inflammation.[6]

Despite our intentions as healthcare providers, the healthcare sector is a large contributor to greenhouse gas (GHG) emissions that, in turn, contribute to these ecological events.[7] Medical services in Canada alone contribute about 5% to 6% of the global healthcare GHG emissions, which is a disproportionate value because Canada accounts for less than 5% of the global population.[8] Similarly, the United States contributes approximately 8% of the global healthcare footprint.[9]

A large contributor to the global healthcare sector, and specifically in Canada, is cataract surgery.[10] Cataracts are a leading cause of treatable blindness worldwide, and the surgical volumes of this procedure have increased significantly over the past 2 decades.[11] Although cataract surgery has evolved to be incredibly efficient, the large surgical volume inevitably results in a large amount of waste and a high carbon footprint, typically characterized as the amount of GHG emissions emitted during the life cycle of a product or service.[12,13]

Assessing the life cycle of a product identifies the emitted GHGs at each step of the product's life, which includes all stages, from its development and manufacturing from raw materials to distribution, consumption, and disposal.[13] Selecting the specific GHG depends on the practice that is being assessed, although carbon dioxide (CO_2) is the most common GHG reported and the most predominant GHG emitted from the healthcare sector.[13,14] All GHGs, such as methane and nitrous oxides, as well as CO_2, can be converted to CO_2 equivalents, a quantifiable value demonstrating the carbon footprint of a product or service. In terms of quantifying the carbon footprint of a service, both indirect and direct emissions must be considered.[13] Indirect emissions include aspects of a service such as emissions associated with the transport of goods and disposal of products used during the service. Direct emissions are those related to the direct use of energy during the procedure and would include the energy used to power the building and the energy associated with travel to and from the service provider. These individual indirect and direct processes typically have emission factors publicly available, which, when applied to

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the amount used and disposed of, can convert each process to a CO_2 equivalent value.[14] When these values are summed together, this can quantify the carbon footprint associated with a practice.

To ensure the sustainability of cataract surgery, it is important to understand the carbon footprint and waste accumulation of cataract surgery and to identify the main contributors. Determining the carbon footprint and major contributors may provide a basis to help mitigate these drivers of high emissions. In this review of the literature, we sought to determine the carbon footprint of cataract surgery and to discuss which protocols and regulations have the greatest influence on the carbon footprint of cataract surgeries.

METHODS

We conducted a comprehensive literature review using search engines, including PubMed, Google Scholar, and MEDLINE. We used the following key words with each search engine: carbon footprint OR sustainability OR emissions OR waste accumulation OR environmental impact AND phacoemulsification OR cataract surgery OR cataract extraction OR intraocular lens implantation. In PubMed, this search resulted in a total of 158 papers; 4 were review papers and were removed, regardless of relevance. The remaining 154 papers were reviewed for relevance. In Google Scholar, this search resulted in a total of 174 papers; 33 were review papers and were removed, regardless of relevance. The titles and abstracts of the remaining 141 were reviewed for relevance. In MEDLINE, this search resulted in a total of 44 papers; 5 were review papers and were removed, regardless of relevance. The titles and abstracts of the remaining 39 papers were reviewed for relevance.

RESULTS

After reviewing the papers resulting from these searches, we narrowed by titles and abstracts and reduced the relevant literature to 5 papers, which truly assessed the carbon footprint and/or waste accumulation of cataract surgery. We also included 2 papers that only looked at the waste accumulation of some or all of a cataract procedure. One paper was unavailable after consistent efforts to obtain it; therefore, we reviewed a total of 6 papers. Results of each study are summarized in Supplemental Table 1 (available at http://links.lww.com/JRS/A869).

Based on this literature review, the carbon footprint of cataract surgery varies greatly and ranges from approximately 6 kg CO_2 equivalents to 181.9 kg CO_2 equivalents. There is consensus among these papers that the largest contributor to the carbon footprint of cataract surgery is the procurement of pharmaceuticals, medical equipment, and disposable items.

DISCUSSION

The Aravind Eye Center (https://aravind.org/our-story/) is a high-volume eyecare system composed of 14 different hospitals, where surgeons completed over 300 000 cataract surgeries in the 2019-2020 year.[15] Thiel et al., through their investigation, concluded that the carbon footprint of 1 single cataract surgery in this center was approximately 6 kg CO_2 equivalents, which was exceptionally low compared with other studies.[16] Although this may sound promising for the future sustainability of cataract surgery, it is important to highlight the factors that facilitated such a low carbon footprint and to determine whether these practices may be scaled to other centers.

First, the guidelines in place at the Aravind Eye Care System differ from those in other centers in that the operating rooms host 2 operating tables.[16] The ophthalmic surgeon will operate on one patient, whereas another patient is being prepared for the surgery, lying on the other operating table. Once the first surgery is complete, the surgeon turns their chair and moves the single microscope, applies sanitizer to their gloves, and performs the next procedure.[15,17,18] Surgical gowns are not routinely changed after each surgery, and various pieces of medical equipment are reused.[15,18] To increase efficiency and turnover, the Aravind center has implemented a modified sterilization protocol with respect to their reusable medical equipment. A high-speed sterilizer is used on short cycles (17 minutes) to sterilize equipment between procedures and has the capacity to sterilize 16 trays of equipment at once.[18] This cycle is composed of 10 minutes of exposure to 134°C and 30 pounds of pressure and takes 7 minutes for this pressure buildup.[18] Taken together, these practices reduce the carbon footprint of cataract surgery for 2 reasons: (1) this greatly increases the efficiency of operating rooms because the surgeon can operate on more patients in a single day, therefore reducing the total emissions and energy use per surgery, and (2) the amount of waste and energy per surgery is significantly reduced because gloves are sanitized and changed every 10 operations, and autoclave settings are fast and highly efficient.[16,18] Although other centers may be hesitant to implement these practices, it should be noted that the rate of endophthalmitis postcataract surgery in Aravind Eye Center was relatively low, estimated to be around 0.02% of phacoemulsification cases, which was comparable with rates in Europe and the United States, which have reported rates between 0.04% and 0.07%.[18–22] In fact, new protocols were implemented because of COVID-19, whereby each patient was gowned, gloves were changed between cases, and only 1 patient was present in each operating room.[15] However, the authors determined that these new protocols implemented did not result in significantly lower rates of postoperative endophthalmitis. Therefore, the protocols in place at the Aravind Eye Care System allow for a highly sustainable and safe model of care. This model allows for the significant reduction in GHG emissions because of cataract surgery and may explain why Aravind sees an exceptionally lower carbon footprint compared with the United Kingdom and Malaysia. However, practices such as these may be less feasible in other nations, where guidelines may be stricter on changing gloves and gowns, single-patient operating rooms, and longer autoclave protocols.

The carbon footprint reported for cataract surgery in centers outside of India ranges from 55 kg CO_2 equivalents reported by a South African center to 181.8 kg CO_2 equivalents reported by the University Hospital of Wales in Cardiff, United Kingdom (see Supplemental Table 1, available at http://links.lww.com/JRS/A869, for further details).[23,24] The authors of these investigations make no note about special protocols in place, such as those in India, so it was assumed that surgeons were operating on a single patient in 1 room, and all materials were changed between surgeries. These practices may explain the high carbon footprint of a single cataract procedure because building energy use and waste accumulation was higher per operating procedure. Furthermore, Morris et al. determined that much of the carbon footprint for cataract procedures in Cardiff can be attributed to the supply chains of medical equipment, which is almost double that of pharmaceuticals. This may provide insight into the areas where emissions can be reduced; innovations with the reuse of surgical equipment may be necessary in the future. For example, the reuse of a phacoemulsification tip resulted in no postoperative complications for patients, although the authors still suggest using a new tip per surgery.[25] However, this may be an aspect of cataract surgery that can facilitate a lower carbon footprint; finding ways to reuse materials in a safe way may reduce waste accumulation, and ophthalmologists should collaborate with device manufacturers to develop these reusable materials. Similarly, ophthalmologists can encourage intraocular lens manufacturers to reduce packaging waste.

Based on the study in Cardiff, United Kingdom, the intraocular lens (IOL) commonly used weighed only 1 g, whereas the packaging weighed 64 g, including a lengthy paper booklet that may or may not be read. Considering that many operating rooms do not have recycling bins, this packaging should, at the very least, be minimized, as it may be excessive and leads to greater waste accumulation. One solution to lowering the immediate carbon footprint of cataract surgery is incorporating carbon offsets into practice. If IOL manufacturers buy carbon offsets, the emissions associated with cataract surgery can be reduced. However, buying carbon offsets should not be a long-term goal for sustainable change because the emissions are just shifted to another activity. Instead, carbon offsets can be incorporated temporarily by IOL manufacturers to reduce the footprint as cataract surgery volumes increase, but using this critical time to truly assess and implement ways to directly reducing waste and emissions associated with the production of IOLs and other products.[26] Although surgeons do not typically have much control of emissions associated with IOLs, they may have more control over waste protocols in operating rooms and can help to reduce emissions there. For example, waste was not effectively sorted in the operating room from the study conducted in Malaysia, where 50% of general waste (not including sharps, face drapes, and solutions) was recyclable material but was, in fact, not recycled.[27] The majority of this nonrecycled waste was the intraocular lens packaging. The authors estimate that if this material was recycled, this would reduce the carbon footprint of general waste at their center by 6200 tonnes CO_2 equivalents every year. Although the authors of this study did not quantify the carbon footprint of an entire cataract surgery, practices such as lack of recycling and high levels of waste inevitably contribute to a high carbon footprint and should be addressed to improve the sustainability of cataract surgery. Furthermore, the amounts of unused pharmaceuticals cannot go unnoticed because they contribute greatly to the carbon footprint of cataract procedures in the United States, potentially contributing between 23 000 and 105 000 metric tons of CO_2 equivalents per year.[28] To contextualize these figures and according to U.S. government data as of March 2022, this is equivalent to the emissions associated with approximately 22 624 gasoline-powered cars being driven for 1 year or equivalent to 20 430 homes' electricity use for 1 year.[29] Addressing practices to ensure that high volumes of pharmaceuticals do not go to waste may reduce the environmental impact of cataract procedures. Another practice that may reduce the carbon footprint of cataract surgery is the inclusion of renewable energy. If surgical facilities incorporate solar energy into their infrastructure, overtime, the emissions associated with energy consumed by the building and powered devices will decline, contributing to a lower footprint.[30]

Although various centers have attempted to quantify the carbon footprint of cataract procedures, there is difficulty in generalizing these results across centers and countries. Based on this lack of generalizability, we suggest that a study should be conducted in Canada because many factors may differ and thus result in a different carbon footprint in Canadian ophthalmic operating rooms. Studies must incorporate the travel data for the patients and staff into the overall footprint of these surgeries, and much of these data is based on assumptions. For example, in New Zealand, the travel emissions were estimated using the average car, which was a 2010 Toyota Corolla with a 1.6 L engine.[31] These travel data may differ from those in Canada, where the most common car likely differs. Given the large geographical area and low population density of rural Ontario and Canada, travel may play a larger role in the carbon footprint of healthcare delivery than in other countries. For example, a recent study in eastern Canada investigated that the reduction in carbon emissions was associated with travel for patients with head and neck cancer to a closer outreach clinic compared with a further regional center.[32] Through survey analysis of 107 patients over a 3-month period, the median distance patients traveled to the closer outreach clinic was 29 km; however, the mean distance traveled to the regional center was 327 km. Most patients lived within a 50 km distance of the outreach clinic, and the reduction in emissions associated with this outreach clinic can be extrapolated to just under 47 000 g CO_2 emissions.[32] Perhaps a similar approach with the strategic placement of outreach clinics should be implemented with cataract procedures, considering that they are a high-volume procedure and have great potential for emission reductions.

In addition, the capacity of ophthalmologists to perform high-volume cataract procedures should also be considered; in 2013, the ratio of ophthalmologists to patients was less than ideal in 4 provinces and the 3 territories in Canada, and there exists great variability in the ratio across Canada.[33] This ratio is also expected to decrease by 2030, which may lead to less accessible care because ophthalmologists may become unavailable, potentially resulting in further travel for patients.[33] One short-term potential solution to mitigate both the high carbon footprint and lack of accessible eyecare is to encourage simultaneous bilateral cataract procedures in patients who require it. Considering that travel emissions account for a large portion of the carbon footprint of cataract surgery, reducing travel time by performing sequential bilateral cataract surgery can reduce emissions and foster a more cost-effective and efficient cataract surgery practice.[34] However, implementing sequential bilateral cataract surgery to reduce emissions may be limited by barriers associated with compensation for surgeons, as payment plans can influence patterns of practice. For example, for ophthalmologists practicing in the United States, compensation through Medicare for the second-eye surgery in sequential bilateral cataract surgery is 50% of that for the first eye, which may discourage wide acceptance of this procedure within the ophthalmology community.[35] Payment plans may need to be altered to increase compensation for ophthalmologists for performing procedures resulting in lower emissions. In addition, tax incentives may need to be implemented for surgical facilities that become more sustainable by performing more procedures with lower emissions, incorporating recycling, and using more renewable sources of energy. These sustainable practices, adjusted payment plans, and potential tax incentives may need to be overseen by surgical facility managers or hospital administrators as opposed to ophthalmologists because eye surgeons are typically busy with surgery and clinics and may not necessarily have the time to fully transition to sustainable models of care without support.

Cataract surgery is a high-volume procedure involving the removal of a patient's crystalline lens and replacing it with an artificial intraocular lens. This procedure has evolved to become highly efficient and is typically completed in minutes. However, practices within cataract surgical suites can lead to high waste and high carbon output and are contributing to the high GHG emissions of the healthcare sector. Future studies should be performed to characterize the carbon footprint of cataract surgeries because practices and operating guidelines influencing this differ between regions. Best practices should be discussed between centers where the carbon footprint is low and those where the output is high, and studies should aim to determine ways in which the carbon footprint can be lowered and waste reduced, while maintaining high patient safety within regional health guidelines. Specifically, we believe that more studies should be conducted in Canada because this is a region that is understudied within this field.

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