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ORIGINAL RESEARCH

Estimation of the Economic and Environmental Impact of Single-Use Instruments in Routine Cataract Surgery

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Purpose: To estimate the economic and environmental impact of single-use instruments (SUIs) to perform standard cataract surgery in six ophthalmology centers located in Europe and in the United States.

Setting: Online survey and interview.

Design: Comparative cost analysis based on an online survey with follow-up questionnaire and interview. The carbon footprint calculation was made by ClimatePartner.

Methods: Annual costs of reusable instruments (RUIs) were calculated based on data provided by the centers. Annual costs of SUIs were estimated based on the average-selling price of a single-use cataract set of 5 instruments and the reported annual volume of cataract surgery. The calculation carbon footprint of a cataract instrument covered the whole life cycle from production to end-of-life.

Results: Annual costs for SUIs were found inferior or similar to the annual costs for RUIs for 4 out of the 6 centers included in this study. The centers where SUIs were demonstrated to be the most cost-effective were also associated with the highest costs of sterilization per instrument. The carbon footprint of 5-years usage of a cataract instrument was found to be 5478.2 kg $CO_{2\ eq}$ for SUIs without recycling, 4639.9 kg $CO_{2\ eq}$ for SUIs with recycling and 20.6 kg $CO_{2\ eq}$ for RUIs.

Conclusion: The study demonstrated that SUIs can be an alternative solution to using RUIs in multispecialty hospitals associated with high sterilization costs.

Keywords: cost analysis, cataract surgery, surgical instruments, reusable instruments, single-use instruments, environmental impact, carbon footprint

Introduction

Both reusable instruments (RUIs) and single-use instruments (SUIs) are used for surgical procedures, and each type of instrument offers advantages and disadvantages, which have been well documented in cost effectiveness, as well as quality studies.[1–5] While RUIs were usually associated with a higher quality, lower cost, and a lower environmental impact, SUIs are commonly considered safer for the patients and easier to use.[1–5]

A surgeon-based survey has been conducted to compare ease of use, handling, defects and complication rates between SUIs and RUIs in cataract surgery.[6] Results of this survey revealed that SUIs in cataract surgery were an acceptable and safe alternative to RUIs.[6] A more recent joint survey sponsored by the ASCRS and the ESCRS showed that 10% of surgeons currently prefer SUIs.[7] Moreover, it was shown that SUIs can present several advantages including instrument performance, liability reduction patient and staff safety, patient desirability or preference, cost savings to hospital/facility, reduced staff processing requirements (eg cleaning and sterilization) and improved operating room efficiency.[7]

Recent improvements in the manufacturing of SUIs have led to a significant increase in quality, as well as a decrease in their costs, making these instruments more cost competitive compared to RUIs. However, very few data are available regarding the cost comparison of RUIs versus SUIs for cataract surgery. The primary reason is likely due to the

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complexity of calculating the real cost of RUIs, involving not only direct costs such as repairing and sterilizing but also more hidden indirect costs such as administration costs, cost of interrupted surgeries, cost of transportation/storage, additional needed single use, costs due to infection risks and other opportunity costs.[1,4,5]

In addition to the economic impact, the environmental impact of cataract surgery is at the heart of the concerns of medical centers, particularly those based in Europe.[8] Cataract surgery represents around 70% of all eye surgeries and is one of the most frequently performed surgeries globally. Therefore, this procedure can generate high volumes of surgical waste, along with a carbon footprint due to procurement of materials, energy use, and the emissions associated with transportation.[9] Moreover, in most settings, cataract surgery is performed in one eye at a time, which increases the carbon footprint as the patient must return for a second time to undergo cataract surgery on their other eye. With the probable generalization of bilateral cataract surgeries, the carbon footprint may probably decrease.[9]

The aim of this study was to compare the annual costs of SUIs compared to RUIs for standard cataract surgeries, as well as to assess the carbon footprint of these SUIs.

Material and Methods

Since no data from patients have been collected in this survey and in accordance with the EU General Data Protection Regulation, no ethics approval was required to conduct this study.

Estimation of Annual Costs of SUIs and RUIs

An independent consultant (Medevise Consulting, Strasbourg, France) was contracted to conduct this study to determine if there is an advantage to using only SUIs in cataract surgery. An online survey was sent to the American Society of Cataract & Refractive Surgery (ASCRS) user database to collect data about the volume of cataract surgery per year, their use of RUIs and their sterilization process. Respondents could respond anonymously or agree to provide their contact details for follow-up. Questions also included general information as well as the type and quantity of instrumentation. From this, six centers, representing a cross-section of standard settings for cataract surgery in the US and Europe (Table 1), agreed to provide additional details for this study, utilizing a questionnaire and interview (Annex 1).

The total costs for RUIs were calculated based on the data reported by each center including the annual sterilization cost, amortization over 4 years (average based on number of years of amortization used by the 6 centers) and the annual

Table 1 Comparison Costs Between Calculated of Annual Use of Reusable Instruments versus Single-Use Instruments

	US Centers		EU Centers			
Center #	**Center 1**	**Center 2**	**Center 3**	**Center 4**	**Center 5**	**Center 6**
Setting (Hospital, clinic, or standalone surgery center)	Standalone surgery center, Eastern US	Two surgery centers as part of an ophthalmology group, southern US	12 private eye clinics in Northwestern Germany	University/private multi-specialties hospital in Germany	Dedicated eye hospital within public university hospital in the Netherlands	Private, multi-specialty hospital in Ireland
Annual Cataract Surgery Volume	3,000	8,400	6,000	8,750	3,500	3,000
Sterilization costs per instrument	0.93 €	1.21 €	1.16 €	€8.30	3.00 €	1.41 €
Frequency of replacement for reusable instruments	100% of stock replaced twice per year	5% of stock replaced each year	5% of stock replaced each year	35% of stock replaced each year	10% of stock replaced each year	16% of stock replaced each year
Estimated Annual costs for RUIs	151,397 €	240,257 €	250,700 €	508,750 €	435,153 €	202,931 €
Estimated Annual costs for SUIs*	154,642 €	541,248 €	420,000 €	350,000 €	245,000 €	210,000 €
Difference in annual instrument cost if changing to SUIs	**+ 3,245 €**	**+ 300,991 €**	**+ €169,300**	**- €158,750**	**- €190,153**	**+ €7,069**

Notes: *These prices represent the average-selling prices for one SUI manufacturers cataract set of 5 instruments including a speculum, a rhexis forceps, a fixation forceps, a manipulator/chopper and scissors.

replacement cost (**Equation 1–4**). Indirect costs (including opportunity and turnover costs) have been reported as zero or minimal and thus have not been included in the equation to calculate the annual total costs.

$$\text{Annual Sterilization Cost(ASC)} = \text{Number of trays sterilized per} \times \text{ sterilization cost per tray}$$

Equation 1. Calculation of the annual sterilization cost

$$\text{Amortization Cost Over4years(4YAC)} = (\text{Number of tray in stock} \times \text{ Cost per tray}) \div 4$$

Equation 2. Calculation of the amortization cost over 4 years

$$\text{Annual Replacement Cost(ARC)} = \text{Cost per tray} \times \text{ Replacement Rate}$$

Equation 3. Calculation of the annual replacement cost

$$\text{Annual Total Costs} = \text{ASC} + \text{4YAC} + \text{ARC}$$

Equation 4. Calculation of the annual total costs

The total costs for SUIs for each center were estimated based on the average costs of a standard set of 5 SUIs (a speculum, a rhexis forceps, a fixation forceps, a manipulator/chopper and scissors) sold by a manufacturer of single-use instruments (HASA Optix, Brussels, Belgium) multiplied by the annual volume of cataract surgery. All estimated costs reported in USD for the centers located in the United States were converted to EUR. To do so, a conversion rate of 1 USD to 0.92 EUR was used. Finally, the difference between the annual costs of RUIs and the estimated costs for SUIs were calculated. The median value of the difference obtained for each center was also calculated.

Estimation of the Carbon Footprint

The CO_2 impact of SUIs with and without recycling and of RUIs has been assessed in this study. The footprint of the whole lifecycle of 5-years usage of a cataract instrument, including raw material, packaging, inbound logistics, production process, outbound logistics and overhead emissions was calculated by a specialist consultant (ClimatePartner Netherlands B.V). To make this calculation, several assumptions have been made. Raw materials, packaging and supply chain processes for the cataract set have been provided by the SUI manufacturer. However, due to supply chain complexities and unavailability and/or reliability of certain data, several assumptions were made, especially for outbound logistics. Inbound logistics include all incoming raw materials and packaging to the factory in China and the transport to the manufacturer in Brussels, Belgium. Outbound logistics have been calculated for a typical client in Lund, Sweden located at 1000 km from the manufacturer warehouse in Belgium. It was also assumed that the centers passed all materials (used instruments and packaging) into the recycling process. Therefore, the end-of-life result was assumed to be 0.00 kg CO_2eq. If the product would go to incineration and packaging materials were calculated as average end-of-life, the footprint result of the product would be 4.36 kg CO_2e. Finally, water consumption and gamma sterilization of the finished products were not considered since these data were not available. For both SUI groups (with or without recycling), it was considered that 1,265 instruments were used in 5-years usage. For RUIs, it was considered that the instrument was sterilized 1,266 times using autoclave steam sterilization.

Results

Comparison of the Annual Costs of RUIs versus SUIs

The characteristics of each center, the comparison of reported RUIs costs, as well as the estimated costs of replacement by SUIs are reported in Table 1. The annual volume of cataract surgery ranged from 3,000 to 8,750 according to the center. The difference in the annual cost for sterilization of the RUIs was found to vary widely between centers. SUIs were found to be more cost-effective than RUIs for centers 4 and 5, which represent the centers with the highest sterilization costs. When the annual cost is broken down into a sterilization per instrument there is again a wide range, from 0.93 € to 8.30 €. Overall, the estimated costs were higher for RUIs compared to SUIs in 2 centers (centers 4 and 5), lower in 2 centers (centers 2 and 3) and similar in 2 centers (centers 1 and 6) (Table 1). The median of the difference in annual costs between SUIs and RUIs was 5,157 €.

Table 2 Calculation of the Carbon Footprint of 5-Years Usage of SUIs with or Without Recycling and RUIs

	SUIs Without Recycling	SUIs With Recycling	RUIs
Raw Materials	821.7	92.8	2.1
Packaging	109.6	92.8	0.2
Inbound logistics	2465.2	2459.1	2.3
Production process	1150.4	1113.6	14.0
Outbound logistics	493.0	510.4	0.4
Overhead emissions	438.3	371.2	1.6
End-of-life	0	0	0
Total	5478.2	4639.9	20.6

Estimation of the Carbon Footprint of SUIs

The carbon footprint of the whole life cycle was found to be 5478.2 kg $CO_{2\ eq}$ for SUIs without recycling, 4639.9 kg $CO_{2\ eq}$ for SUIs with recycling and 20.6 kg $CO_{2\ eq}$ for RUIs (Table 2).

Discussion

In this study, the economic and environmental impact of the use of SUIs have been estimated. Annual costs of RUIs versus SUIs were compared in different clinical settings from standalone surgery centers to multi-specialties hospitals, in the US and Europe. Results found that SUI annual costs are lower or similar compared with RUIs in 4 of the 6 medical centers studied (if replaced with a standard set of 5 single-use instruments). The cost of sterilization is a determinant factor even though it is the overall gathering of costs which needs to be considered. According to the interviews realized following the survey, the centers where SUIs were demonstrated to be the most cost-effective also have the highest cost of sterilization per instrument. Sterilization costs were found to be highest in the centers which did not have an internal sterilization system and required an external service to sterilize their instruments. Interestingly, the annual volume cataract surgery did not seem to affect the sterilization cost per surgery, in these examples.

In this study, we also found that the carbon footprint was 5478.2 kg $CO_{2\ eq}$ for SUIs without recycling, 4639.9 kg $CO_{2\ eq}$ for SUIs with recycling and 20.6 kg $CO_{2\ eq}$ for RUIs. However, several strategies could be used to reduce the carbon footprint of SUIs. First, the use of green energy and recycled materials should be preferred. Second, a stock of SUIs at the medical center and deliveries of instruments limited to 3–4 times per year should be considered to limit the carbon footprint.

This study presents some limitations. First, only 6 centers have been assessed in this study, and the results presented may vary in other centers. However, the selected centers represent typical settings for cataract surgery in the US and Europe. Second, the estimated costs for SUIs were based on an average-selling price in these two markets, therefore, these costs may be different in some settings. For the calculation of the carbon footprint, we have assumed that the instruments are meant to be recuperated and the raw material recycled, which is not always the case according to the centers. Therefore, this calculation is only valuable if a recycling program exists. Finally, gamma sterilization of the finished products was not considered in the carbon footprint calculations since these data were not available.

Conclusion

The study demonstrates that RUIs are more cost-effective than SUIs, except in multi-specialty centers with high sterilization costs. For these centers, SUIs represent the most cost-effective solutions. The environmental analysis demonstrated a lower carbon footprint for RUIs compared to SUIs.

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Disclosure

Vincent Qin received personal fees as a consultant for Thea Pharma, Glaukos, HASA Optix, Mona, Rosa, Bayer, EyeD Pharma, Horus Pharma, Deceuninck Medical, Physiol, Ophtalmoservice, Simovision, Alcon, a speaker for Thea Pharma, Glaukos, Bayer, a scientific board member for HASA Optix, Mona and Rosa, and a shareholder of Bubbly Contact and Gratiago. Sandro Di Simplicio Cherubini is a key opinion leader for Alcon, BVI, Oculus, Samsara and HASA Optix, and received personal fees as honorarium from Alcon BVI and Oculus. The authors report no other conflicts of interest in this work.

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