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ORIGINAL RESEARCH ARTICLE

A randomised controlled trial comparing quality of recovery between desflurane and isoflurane inhalation anaesthesia in patients undergoing ophthalmological surgery at a tertiary hospital in South Africa (DIQoR trial)

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Abstract

Background: The patient's experience of their postoperative recovery is an important perioperative outcome, with the 15-item quality of recovery scale (QoR-15) recommended as a standardised outcomes measure. Desflurane has a faster emergence from anaesthesia compared with other volatile anaesthetics, but it is uncertain whether this translates to better subjective quality of recovery. The hypothesis for this study is that patients receiving desflurane for maintenance of anaesthesia would have better postoperative quality of recovery than patients receiving isoflurane.

Methods: Male and female adult patients undergoing ophthalmological surgery under general anaesthesia were randomly allocated to receive desflurane or isoflurane for maintenance of anaesthesia. The primary outcome was to compare postoperative QoR-15 scores. Secondary outcomes included comparing preoperative QoR-15 scores, volatile agent consumption, and time spent in the recovery room.

Results: Data from 164 patients were analysed (80 desflurane, 84 isoflurane). Median (Q1, Q3) postoperative QoR-15 scores were not significantly different (desflurane: 145 [141, 148], isoflurane: 144 [139, 147], 95% confidence interval 0–3, P=0.176, minimal clinically important difference=8). Median (Q1, Q3) volatile agent consumption was 15.4 (12.5, 19.3) ml hr^{-1} in the desflurane group, and 7.4 (5.9, 9.7) ml hr^{-1} in the isoflurane group. Median (Q1, Q3) time spent in the recovery room was significantly shorter in the desflurane group (desflurane: 18 [13, 23]; isoflurane: 25 [19, 32], 95% confidence interval −10 to 5, P<0.001).

Conclusions: This study found no difference in quality of recovery between patients who received desflurane or isoflurane for maintenance of general anaesthesia during ophthalmological surgery. A shorter time in the recovery room was not associated with improved QoR-15 scores.

Clinical trial registration: NCT04188314.

Keywords: anaesthesia; inhalation; desflurane; quality of recovery; patient-reported outcome measures; perioperative care

Recovery after surgery and anaesthesia has traditionally been assessed with objective measures including time to awakening, time to regaining airway reflexes, duration of stay in the recovery room, hospital, or both, and incidence of adverse events such as pain and postoperative nausea and vomiting. Increasingly, the patient's experience of their postoperative recovery is being recognised as an important outcome.[1–6]

The 15-item quality of recovery scale (QoR-15) has been validated to give a patient-centred global measure of overall health status in the short term after surgery and anaesthesia.[7,8] This continuous composite score allows for

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comparison between intervention groups in research.[9] With a score ranging from 0 to 150, the minimal clinically important difference (MCID) for the QoR-15 is 8, and the patient acceptable symptom state score is 118.[9] The QoR-15 has been classified into four categories of recovery: excellent (136–150), good (122–135), moderate (90–121), and poor (0–89) recovery.[10] The Standardised Endpoints for Perioperative Medicine, Core Outcomes Measures in Perioperative and Anaesthetic Care (StEP-COMPAC) group recommends the QoR-15 to assess patient comfort after surgery.[2] This score has recently been translated and validated in isiZulu in South Africa.[11]

Factors previously shown to impact quality of recovery include type and severity of surgery,[7,12–14] duration of anaesthesia,[7,8,11,13–15] time spent in the recovery room,[7,12] and sex.[7,12,14,16]

The volatile anaesthetic agent desflurane has a rapid onset and offset of action, faster time to awakening, faster time to regaining airway reflexes, minimal metabolism, and a clearer sensorium after surgery.[17] This has been found in studies comparing desflurane with sevoflurane, isoflurane, and propofol.[18–23] One study comparing desflurane with sevoflurane for gynaecological day case surgery found that 29 of 31 patients in the desflurane group returned to normal activities the day after surgery, compared with only 15 of 29 in the sevoflurane group.[20] However, desflurane is more expensive than other volatile anaesthetics and concerns have been raised about its high global warming potential (GWP).[24–30] The overall climate impact from volatile anaesthetic agents is minimal however,[31] especially when radiative forcing based on current atmospheric concentrations is considered.[32] For economic and environmentally responsible use, desflurane should be used with a minimal or basal flow anaesthetic technique.[33,34]

Isoflurane is still commonly used in the public healthcare sector in South Africa, and the main agent used for maintenance of anaesthesia at Dr George Mukhari Academic Hospital (DGMAH). When desflurane was introduced at DGMAH, many anaesthetists were impressed with the comparatively rapid emergence they witnessed. The question arose whether there would be a difference from the patient's perspective. Patient-reported outcomes measures (PROMS) had never been evaluated before at DGMAH, a resource-constrained facility, with a focus mostly on service delivery and surgical volume.

The hypothesis for this study is that patients receiving desflurane for maintenance of anaesthesia would have better postoperative quality of recovery than patients receiving isoflurane, arising from desflurane's more favourable pharmacokinetic and pharmacodynamic properties.

The primary aim of the study is to determine whether there is a clinically significant difference in quality of recovery between patients in the sample population who received desflurane or isoflurane for maintenance of general anaesthesia by evaluating the postoperative QoR-15 scores and change from baseline preoperative scores. Secondary aims were to examine volatile agent consumption and cost at minimal to basal fresh gas flow (FGF), and time spent in the recovery room.

Methods

The study was registered with ClinicalTrials.gov (NCT04 188314, registration date 5 December 2019), approved by the Sefako Makgatho Health Sciences University Research Ethics Committee (SMUREC/M/240/2019:PG), and was conducted at DGMAH, a tertiary hospital in South Africa, between February 2020 and February 2022.

The English QoR-15 questionnaire was translated into Setswana and Afrikaans by professional translators and back-translated into English by a panel of three first-language speakers blinded to the original English version. The final translations were approved by all members of the panel.

Patients aged 18–80 yr, of American Society of Anesthesiologists (ASA) physical status class 1 and 2, who presented for ophthalmological surgery under general anaesthesia were considered for inclusion. Institutional practice for ophthalmological surgery under general anaesthesia is that patients are admitted the day before their procedure and kept overnight after their procedure. On average 180 patients undergo general anaesthesia for ophthalmological surgery at DGMAH every 6 months but the COVID-19 pandemic had a severe impact on this service, with very few cases done from March 2020 until February 2021.

Exclusion criteria were inability to give informed consent, ASA physical status 3 and above, patients with severe medical or surgical conditions who were expected to have prolonged admissions or critical care admissions, contraindications to laryngeal airway mask use, uncontrolled psychiatric conditions, known adverse reaction with inhalation anaesthetic agents, suspected or known malignant hyperthermia, and incomplete data collection forms.

Written, informed consent to participate in the study was obtained before surgery. Patients were assisted by the principal investigator to complete a preoperative QoR-15 questionnaire during the preoperative visit the day before surgery, which ascertained a baseline and familiarised patients with the assessment tool. The morning after surgery, participants were assisted in completing QoR-15 questionnaires by a research assistant blinded to allocation groups who visited the patients in the ward before discharge. Most of the patients were seen by a research assistant dedicated to the project, however during the COVID-19 pandemic two blinded trainee anaesthetists occasionally assisted with the postoperative follow-ups.

Participants were randomly assigned by the statistician to maintenance of anaesthesia with either isoflurane (control, standard of care) or desflurane (intervention) by using a computer-generated block randomisation sequence, with random block sizes. Allocation was concealed until the day of surgery using sequentially numbered sealed opaque envelopes, which were handed to the treating anaesthetist by the principal investigator at the start of the case. Participants were blinded to randomisation results. Unblinding of participants was not deemed necessary, because it was considered that adverse events would be similar between the two groups and treating anaesthetists were not blinded and could manage any adverse events with full knowledge of the agent the patient was receiving.

In both groups, standard monitoring was applied pre-induction. Anaesthetic management was according to a treatment plan (Table 1) that was deemed feasible by anaesthesia providers in the department of anaesthesiology at DGMAH, in terms of acceptability, practicality, and implementation. As per institutional protocol, patients undergoing general anaesthesia for ophthalmological surgery do not receive regional eye blocks, only systemic analgesia. All participants received monitoring of end-tidal concentration of carbon dioxide, oxygen, and anaesthetic agent.

Any adverse events were immediately reported to the principal investigator and recorded on the case report form

Table 1 Anaesthesia treatment protocol. FGF, fresh gas flow; FiO2, fraction of inspired oxygen; LMA, laryngeal mask airway; MAC, minimum alveolar concentration; NMBA, neuromuscular blocking agent; PONV, postoperative nausea and vomiting.

Induction of anaesthesia	• Fentanyl 1.5–3 μg kg^{-1} pre-induction. • Lidocaine 40 mg pre-induction. • Propofol 2–2.5 mg kg^{-1} until induction of anaesthesia. • Dexamethasone 8 mg after induction of anaesthesia. • Mask ventilation with oxygen 100%, 6 L min^{-1} until airway is placed.
Airway management	• Secure airway with an LMA, sized according to patient weight. • Place device after i.v. induction and before opening vaporiser.
Use of NMBA (optional)	• Rocuronium 0.15 mg kg^{-1} OR cisatracurium 0.05 mg kg^{-1}. • Top-up doses as required, every 30–40 min.
Maintenance desflurane	• Reduce FGF to 2 L min^{-1}, set desflurane vaporiser to 12%. • Maintain until MAC multiple of 1.0 attained. • Reduce FGF to 0.2–0.5 L min^{-1}; aim to keep FGF as low as possible (maintenance flow). • If basal flow (0.2 L min^{-1}) reached, keep FiO_2 at 1.0 to fulfil basal oxygen requirement. • Adjust vaporiser setting to maintain MAC multiple of 1.0. • If bellows collapse, or if MAC multiple falls below 1.0, increase FGF to 2 L min^{-1} and set vaporiser to 12%. Maintain until bellows are full or MAC multiple is 1.0, then return to maintenance flow. • Record the maintenance flow used for the majority of the case.
Maintenance isoflurane	• Reduce FGF to 2 L min^{-1}, set isoflurane vaporiser to attain an MAC multiple of 1.0. • Reduce FGF to 0.2–0.5 L min^{-1}; aim to keep FGF as low as possible (maintenance flow). • If basal flow (0.2 L min^{-1}) reached, keep FiO2 at 1.0 to fulfil basal oxygen requirement. • Adjust vaporiser setting to maintain MAC multiple of 1.0. • If bellows collapse, or if MAC multiple falls below 1.0, increase the FGF to 2 L min−1 and adjust the vaporiser as required. Maintain until bellows are full or MAC multiple is 1.0, then return to maintenance flow. • Record the maintenance flow used for the majority of the case.
PONV prophylaxis or treatment (optional)	• Metoclopramide 10 mg OR ondansetron 4 mg i.v.
Analgesia (optional)	• Tramadol 50–100 mg i.v. 30 min before end of procedure.
Additional troubleshooting (optional)	• If too light a plane of anaesthesia, administer bolus of propofol 0.5–1 mg kg^{-1}. • If intraoperative tachycardia or hypertension, administer bolus of fentanyl 50–100 μg.
End of anaesthesia	• Ensure reversal of neuromuscular blocking agent, if used. • Close vaporiser, increase FGF to 6 L min^{-1}. • Remove LMA in theatre when clinically appropriate. • Take patient to recovery room when able to protect own airway. • Discharge to the ward when patient achieves modified Aldrete score of at least 9.

(see definitions Table 2). Emergency equipment and drugs were immediately available.

All data were recorded by hand on pre-printed case report forms. Sequential study numbers were recorded on all documents relating to a particular participant. All forms were checked for completeness at the end of the procedure and source documents were referred to in case of missing data. Data from the hand-written forms were captured electronically using REDCap[35] installed on a Safe Surgery SA[36] server.

Postoperative QoR15 scores were calculated from the data as the primary outcome measure. Secondary outcome measures included the preoperative QoR15 score, volatile agent consumption, and time spent in the recovery room (see definition Table 3). Volatile agent consumption was recorded from the GE Aisys anaesthetic workstation at the end of the procedure (automatically calculated by the device based on direct measurement of volatile agent consumption by infrared absorption spectroscopy which is input into a proprietary formula).

The null hypothesis for this study is that there is no clinically or statistically significant difference in mean postoperative QoR-15 scores of patients receiving isoflurane or desflurane for maintenance of anaesthesia.

The sample size calculation was based on an estimation of the difference in mean postoperative QoR-15 scores between groups, with the MCID of 8 used as the threshold for clinical significance, assuming normal distribution and a standard deviation of 18.5.[9] Using these estimates, a 1:1 randomisation, two-tailed alpha 0.05, and 1-beta 0.8, a sample size of 85 per group was calculated to provide 80% power with respect to the primary outcome.

Standard descriptive statistics were used to summarise patient characteristics. Continuous data were inspected for normality before analysis (Shapiro–Wilk), summarised with median and 25th–75th centiles (Q1, Q3), and evaluated for differences with the Wilcoxon Rank Sum Test and the Wilcoxon Signed Rank test, as appropriate. Hodges–Lehman median difference and 95% confidence interval (CI) of the median difference (95% CI) are reported where appropriate. Categorical data were summarised by frequency count and percentage calculations and evaluated for differences with the Fisher exact test. Quantile regression, suitable for skewed data, was used to identify confounders that may impact on postoperative quality of recovery scores. A two-tailed P-value <0.05 was taken to indicate statistical significance.

Table 2 Adverse events. Data are shown as number (percentage). *Fisher's exact test. †Bronchospasm defined as an acute reversible reflex spasm of the bronchioles. Incidents occurred at induction, after laryngeal mask airway was placed, before vapour was started. ‡Laryngospasm defined as sudden sustained closure of vocal cords in response to airway irritation. Incidents occurred at induction, two before the vapour was started, and one spasm occurred after isoflurane was started. ¶Bradycardia defined as a heart rate below 60 beats min^{-1}. Incidents were related to surgical traction on the ocular muscles, and responded to single doses of atropine or glycopyrrolate. §Hypotension defined as a mean arterial pressure below 60 mm Hg. All cases responded to single doses of ephedrine 15 mg. ‖Hypoxia defined as pulse oximeter reading <90%. All episodes of hypoxia in the recovery room lasted <10 min and responded to 2 L min^{-1} nasal prong oxygen. #Desflurane group had one episode of prolonged recovery (patient remained somnolent and responded to naloxone 40 μg, time in recovery room was 41 min); isoflurane group had one episode of pain needing a dose of fentanyl 25 μg after surgery.

	Desflurane *n*=80	Isoflurane *n*=84	*P*-value*
Bronchospasm†	2 (2.5)	0 (0)	0.236
Laryngospasm‡	1 (1.3)	2 (2.4)	1.000
Intraoperative bradycardia¶	0 (0)	3 (3.6)	0.246
Intraoperative hypotension§	2 (2.5)	2 (2.4)	1.000
Postoperative nausea and vomiting in recovery room	1 (1.3)	0 (0)	0.488
Hypoxia in recovery room‖	3 (3.8)	3 (3.6)	1.000
Other#	1 (1.3)	1 (1.2)	1.000

Data were exported from REDCap into Excel for Microsoft 365 (Version 2209), Microsoft Corporation, Redmond, WA, USA, and analysed using R, version 4.2.0 (2022-04-22 ucrt), R Foundation for Statistical Computing, Vienna, Austria.

Results

We randomly allocated 175 eligible participants to receive desflurane (*n*=86) or isoflurane (*n*=89); data from 164 participants were included in the analysis (desflurane 80, isoflurane 84) (Fig. 1). The patients' baseline characteristics were similar between the two groups (Table 4).

Anaesthetic management was similar between the two groups, except for the median dose of ondansetron which was slightly higher in the isoflurane group (Table 3). The median number of antiemetics received per patient in each group was 2 (1, 2) (95% CI 0 to 0, *P*=0.170).

The QoR-15 questionnaires were completed mostly in English, with two patients completing the questionnaire in Setswana. Because of impaired vision, most of the patients needed assistance to complete the questionnaires. Scoring for both the preoperative and postoperative questionnaires was complete with no missing data. Smoking pack-years was omitted on three data collection forms; it was considered that this would not influence the final result so these cases were not excluded from analysis.

The overall median preoperative QoR-15 score was 145 (136, 148) and the postoperative QoR-15 score was 145 (139, 148) (95% CI -2.5 to 0.5, *P*=0.294). The median preoperative QoR-15 score in the desflurane group was 146 (138, 148) and in the isoflurane group 143 (133, 148) (95% CI 0 to 4, *P*=0.045). The median postoperative QoR-15 score in the desflurane group was 145 (141, 148) and in the isoflurane group 144 (139, 147)

Table 3 Characteristics of anaesthetic management. Data are shown as median (Q1, Q3) and number (percentage). NMBA, neuromuscular blocking agent. *Hodges Lehman 95% Confidence Interval of the median difference. †Wilcoxon rank sum test; Fisher's exact test. ‡Time from intravenous induction until time that patient is pushed out of theatre. ¶Time from opening until closing vaporiser. §Time from arrival in the recovery room until the time patient achieved an Aldrete score of 9. ‖Maintenance fresh gas flow used for the majority of the case, as reported by anaesthesia provider.

	Desflurane *n*=80	Isoflurane *n*=84	95% CI*	*P*-value†
Duration of anaesthesia‡ (min)	72 (58, 88)	80 (60, 98)	-15 to 3	0.171
Vapour duration¶ (min)	59 (44, 77)	64 (47, 88)	-14 to 4	0.324
Time in recovery room§ (min)	18 (13, 23)	25 (19, 32)	-10 to -5	**<0.001**
Reported maintenance fresh gas flow‖ (L min^{-1})	0.3 (0.25, 0.35)	0.5 (0.35, 0.5)	-0.2 to -0.1	**<0.001**
Propofol total dose (mg kg^{-1})	2.7 (2.4, 3.2)	2.5 (2.1, 3.1)	-0.0 to 0.3	0.118
Fentanyl total dose (μg kg^{-1})	2.7 (1.8, 3.1)	2.5 (1.7, 3.1)	-0.2 to 0.3	0.670
Lidocaine dose (mg kg^{-1})	0.6 (0.5, 0.7)	0.6 (0.5, 0.7)	0 to 0	0.772
NMBA used	47 (49)	49 (52)	—	1.000
Rocuronium used	39 (49)	44 (52)	—	0.755
Rocuronium total dose (mg kg^{-1})	0.15 (0.13, 0.18)	0.15 (0.14, 0.24)	-0.04 to 0.00	0.120
Cisatracurium used	8 (10)	5 (6)	—	0.395
Cisatracurium total dose (mg kg^{-1})	0.05 (0.03, 0.06)	0.05 (0.05, 0.06)	-0.02 to 0.02	0.833
NMBA reversal given	38 (48)	38 (45)	—	0.876
Neostigmine dose (μg kg^{-1})	34 (30, 40)	36 (28, 40)	-4 to 4	0.971
Atropine dose (μg kg^{-1})	7 (6, 8)	6 (5, 6)	-1 to 5	0.200
Glycopyrrolate dose (μg kg^{-1})	5 (5, 6)	6 (5, 7)	-1 to 0	0.399
Tramadol given	63 (79)	62 (74)	—	0.470
Tramadol dose (mg kg^{-1})	1.4 (1.2, 1.7)	1.5 (1.2, 1.7)	-0.1 to 0.1	0.700
Dexamethasone dose (mg kg^{-1})	0.11 (0.10, 0.13)	0.12 (0.10, 0.13)	-0.01 to 0.01	0.772
Metoclopramide given	49 (61)	44 (52)	—	0.273
Metoclopramide dose (mg kg^{-1})	0.14 (0.13, 0.17)	0.15 (0.13, 0.17)	-0.01 to 0.01	0.796
Ondansetron given	13 (16)	12 (14)	—	0.829
Ondansetron dose (mg kg^{-1})	0.06 (0.05, 0.08)	0.08 (0.07, 0.11)	-0.04 to 0.00	**0.030**

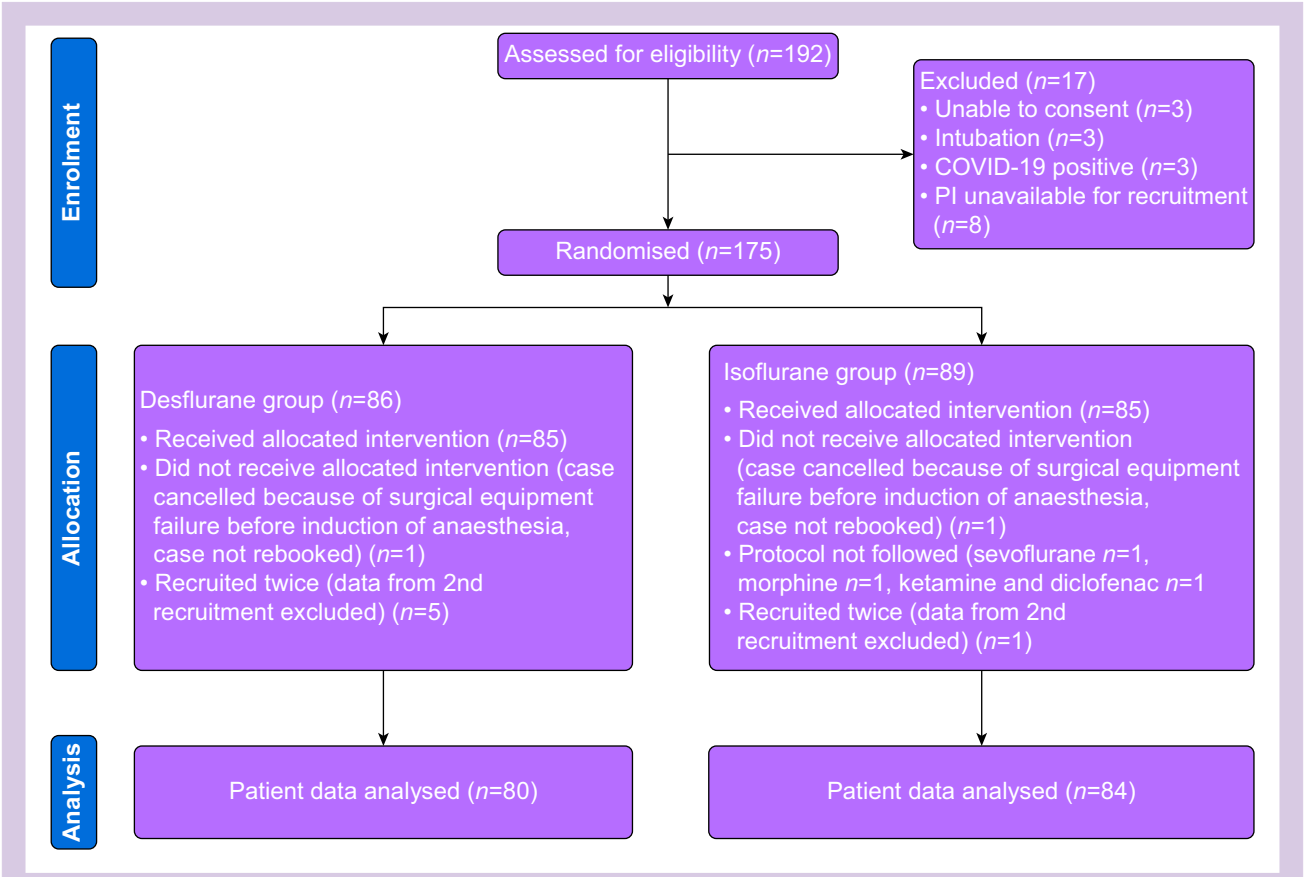

Fig 1. CONSORT diagram. CONSORT, Consolidated Standards of Reporting Trials.

Table 4 Patient characteristics. Data are shown as median (Q1, Q3) and number (percentage). ASA, American Society of Anaesthesiologist; BMI, body mass index; PONV, postoperative nausea and vomiting; HIV, human immunodeficiency virus. *Missing data for pack-years: n=3, desflurane=2, isoflurane=1.

	Desflurane n=80	Isoflurane n=84
Age (yr)	36 (27, 50)	42 (28, 56)
Sex, female/male	33 (41)/47 (59)	27 (32)/57 (68)
Weight (kg)	70 (60, 80)	65 (60, 80)
Height (cm)	169 (165, 178)	170 (166, 177)
BMI (kg m^{-2})	23.6 (21, 27)	22.7 (20, 27)
Physical status, ASA 1/ASA 2	41 (51)/39 (49)	41 (49)/43 (51)
Smoking history		
Non-smoker	59 (74)	58 (69)
Current smoker	19 (24)	22 (26)
Ex-smoker	2 (2.5)	4 (4.8)
Pack years*	3 (1.9,5)	5 (2,6)
PONV risk factors		
Female sex	33 (41)	27 (32)
Previous PONV	1 (1.3)	1 (1.2)
Motion sickness	1 (1.3)	2 (2.4)
Non-smoker	59 (74)	58 (69)
Comorbidities		
Hypertension	10 (13)	20 (24)
Diabetes	4 (5)	6 (7.1)
Respiratory disease	2 (2.5)	2 (2.4)
HIV	17 (21)	10 (12)
Other	5 (6.3)	4 (4.8)

(95% CI 0 to 3, P=0.176); this difference does not meet the threshold for clinical or statistical difference. The change in scores from preoperative to postoperative questionnaires was not clinically or statistically significant in either group (desflurane=-1, 95% CI -2.5 to 1.5, P=0.626; isoflurane=+1, 95% CI -6 to 1.5, P=0.314) (Fig. 2).

The distribution of patients according to category of recovery[10] was similar between the two groups, with most patients reporting excellent quality of recovery (desflurane=69 [86%]; isoflurane=65 [77%], 95% CI 0.8 to 4.6, P=0.161). In the postoperative questionnaires, 23 (13.5%) patients scored the highest score (150), which is below the 15% suggested cut-off for a ceiling effect.[37] There was no evidence of a floor effect. None of the individual scores was normally distributed. Among the postoperative questions, all the questions had a median score of 10, except 'moderate pain', which had a median score of 9 (8, 10). Quantile regression did not reveal any variables to be confounders impacting on postoperative quality of recovery, including duration of anaesthesia, time spent in the recovery room, age, sex, postoperative nausea and vomiting prophylaxis, and analgesia.

Twelve patients had postoperative QoR scores below the acceptable symptom state score of 118. All but one of these patients scored less on their postoperative scores than their

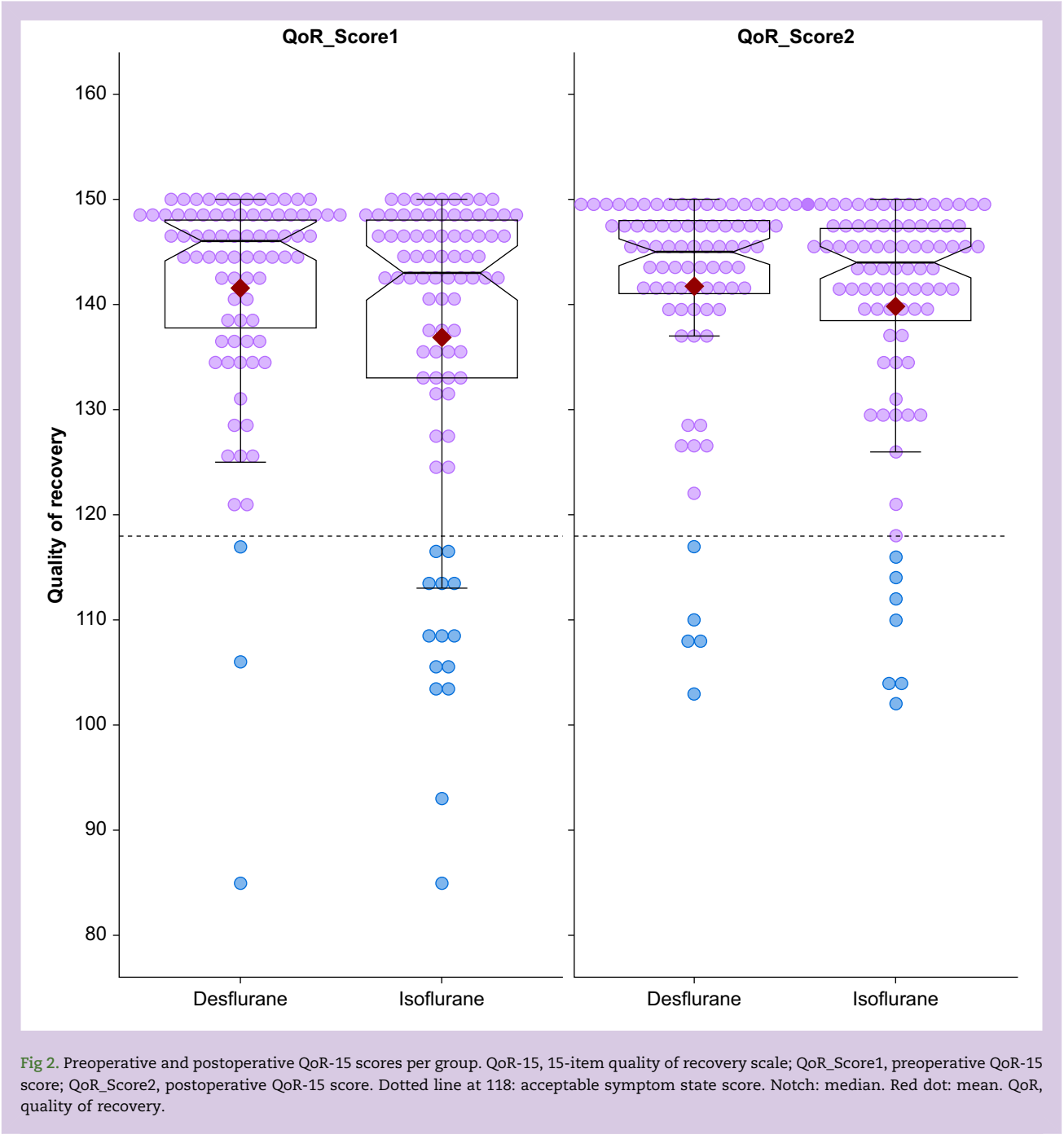

Fig 2. Preoperative and postoperative QoR-15 scores per group. QoR-15, 15-item quality of recovery scale; QoR_Score1, preoperative QoR-15 score; QoR_Score2, postoperative QoR-15 score. Dotted line at 118: acceptable symptom state score. Notch: median. Red dot: mean. QoR, quality of recovery.

preoperative scores (range of decrease 1 to 40). For this subgroup, the overall median preoperative QoR-15 score was 137 (127, 146) and the median postoperative QoR-15 score was 109 (104, 113) (95% CI 15 to 33, P=0.004). The three questions with the lowest median for these patients were moderate pain (2 [1, 7.3]), return to normal activities (6 [4.8, 7]), and feeling worried (6.5 [3.8, 10]).

Five participants in the desflurane group returned postoperative QoR-15 scores that were less than 118 (median 108 [108, 110]), however there was insufficient evidence to conclude that the scores were significantly lower than their median preoperative scores (136 [134, 138], P=0.103). Seven patients in the isoflurane group returned postoperative QoR-15 scores <118, with the median preoperative QoR-15 score 142 (126, 147) and the median postoperative QoR-15 score 110 (104, 113) (95% CI 12 to 38, P=0.023).

No serious adverse events occurred, with an equal number of mild adverse events between the two groups (Table 2).

Volatile agent consumption is dependent on FGF. In the desflurane group, the median reported maintenance FGF was 0.30 (0.25, 0.35) L min^{-1}, and in the isoflurane group it was 0.50 (0.35, 0.50) L min^{-1}. The median volatile agent consumption was 15.4 (12.5, 19.3) ml h^{-1} in the desflurane group, and 7.4 (5.9, 9.7) ml h^{-1} in the isoflurane group. The lowest desflurane volatile agent consumption per hour was 6.5 ml hr^{-1} during the longest case that lasted 279 min with a reported maintenance FGF of 0.2 L min^{-1}. Desflurane consumption was 10 ml h^{-1} or less in nine (11%) cases. The total cost for desflurane usage in the study was ZAR 105.54 (USD 5.59) per hour and for isoflurane usage it was ZAR 11.61 (USD 0.61) per hour (Table 5).

The time spent in the recovery room was significantly shorter in the desflurane group (Table 3), but quantile regression did not show this to be a confounder for QoR-15 scores.

Discussion

This study did not demonstrate a clinically or statistically significant difference in the primary outcome of subjective quality of recovery between patients receiving desflurane or isoflurane for maintenance of general anaesthesia during ophthalmological surgery. The change from preoperative to postoperative QoR-15 scores was similar between the two groups with no significant difference in postoperative QoR-15 scores between the two groups. The majority of patients in both groups reported excellent postoperative quality of recovery.

This was a single-centre trial focused on patients undergoing ophthalmological surgery, and the analysis was per-protocol. Efforts were made to include adult male and female patients of all ages of similar physical status, undergoing a surgical procedure of similar duration and severity, for which a standardised anaesthetic treatment protocol could be developed where the main difference between the groups would be the vapour for maintenance of anaesthesia. The treatment protocol allowed for pragmatic changes according to the discretion of the treating anaesthetist, and allowing for availability of medications in a resource-constrained hospital. We did not find that any of the small differences in the treatment protocol were confounders for the postoperative QoR-15 scores.

This study complements other research into PROMS, a developing field in perioperative research.[3] This study also contributes to the ongoing debate about the usefulness of desflurane in the context of the concerns around its environmental impact.

Real-world data are given regarding volatile agent consumption and current cost of both desflurane and isoflurane using minimal FGF for maintenance of anaesthesia. Ryksen and Diedericks[38] in their 2012 paper mathematically calculated the cost of inhalation anaesthesia at low flow rates, using a FGF of 1 L min^{-1}. This FGF is more than three times higher than the median reported FGF used in our desflurane group. Ryksen and Diedericks[38] emphasise the point that higher flow rates are associated with increased cost of inhalation anaesthesia. It would therefore make sense to limit FGF as much as possible for all agents, especially for expensive agents such as desflurane. The practice at DGMAH is to use desflurane with a basal maintenance FGF of 0.2 L min^{-1} with the aim of consuming no more than 10 ml hr^{-1}. This consumption limit was achieved in 11% of cases in this study, where flow rates up to 0.5 L min^{-1} were allowed. This study shows that inhalation anaesthesia with basal to minimal maintenance FGF is feasible, and leads to economical volatile agent consumption.

The study presents a complete data set for preoperative and postoperative QoR-15 scores including related variables that could be feasibly collected in the study setting. A preoperative baseline score is not required to use or interpret the postoperative QoR-15 score, but it gives useful additional information, and it allows the patient to become familiar with the questionnaire. Lower preoperative QoR-15 scores may be predictive of lower postoperative QoR-15 scores,[39] but this was not found in our patient population. Female sex was not

Table 5 Volatile agent consumption and cost. *Total millilitres used (ml)/total hours of vapour time (h). †Calculations based on the public sector cost of desflurane and isoflurane at the time of writing the article. Cost given in South African Rands (ZAR) and United States dollars (USD); conversion rate as at the time of submission of the article. ‡Cost per millilitre×volatile agent consumption.

	Desflurane		Isoflurane	
Total millilitres used (ml)	1494		774	
Total minutes of vapour time (min)	5837		6027	
Total hours of vapour time (h)	97.28		100.45	
Volatile agent consumption* (ml h^{-1})	15.36		7.71	
	ZAR	USD	ZAR	USD
Cost per bottle†	1649.32 per 240 ml	87.34 per 240 ml	376.76 per 250 ml	19.96 per 250 ml
Cost per ml	6.87	0.36	1.51	0.08
Actual cost per hour‡	105.54	5.59	11.61	0.61
Cost per hour at 10 ml h^{-1}	68.72	3.64	15.07	0.80

associated with lower QoR-15 scores, which is consistent with findings from two other South African studies,[11,39] but contrary to findings from other quality of recovery studies.[7,12,14,16] This may be because of differences in cultural and socioeconomic backgrounds. The time spent in the recovery room was significantly shorter in the desflurane group, but contrary to expectations based on previous studies,[7,12] this was not associated with better quality of recovery scores in our study. A longer duration of anaesthesia was also not associated with worse quality of recovery scores.

This study had a few limitations. The type of ophthalmological procedure was not recorded, but all procedures were invasive enough to require general anaesthesia. The study protocol did not account for the postoperative ward prescription, which in our setting is the responsibility of the treating surgeon. As they were visually impaired, most patients needed assistance to complete the QoR-15 questionnaires, which may introduce an element of response bias. The QoR-15 can be used as a self-administered tool, and it has been used with telephonic follow-ups and with in-person assistance.[7,9,11,14]

The COVID-19 pandemic impacted the study in various ways. The recruitment period was prolonged from 6 months to 2 yr because elective eye surgery was postponed for long periods of time and there was a shift to doing more cases under regional rather than general anaesthesia during this period. The workplace disruption during the pandemic meant that the same research assistant could not assist all patients, which may have led to response bias.

To comply with local ethics committee requirements, the English QoR-15 was translated into Afrikaans and Setswana, but the trial methodology did not allow for validation of either translation. Future studies to validate the translations will increase the accessibility of this valuable patient-reported outcomes measure in a multilingual population.

It is hoped that future interventional trials will continue to use the QoR-15 as an outcome measure in order to get input from the patient's perspective. Future studies could evaluate the impact of desflurane, used with a basal to minimal maintenance FGF as described in this study, in a more heterogenous surgical patient population.

Conclusion

This study did not find a difference in subjective quality of recovery between patients who received desflurane or those who received isoflurane for maintenance of general anaesthesia during ophthalmological surgery. Real-world data are given regarding volatile consumption and current cost of both desflurane and isoflurane using minimal maintenance FGF. The time spent in the recovery room was significantly shorter in the desflurane group, but this did not impact postoperative QoR-15 scores.

Author's contributions

Study concept and design, data interpretation, critical revision: CS, HK

Data collection, data analysis, writing of the first draft of the manuscript: CS

Declarations of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bjao.2023.100246.

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