Oculocardiac and Oculorespiratory Reflex during Strabismus Surgery under General Anesthesia with Laryngeal Mask Airway for Maintaining Spontaneous Respiration: A Retrospective Study

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Research article

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Abstract

Background: The oculocardiac reflex (OCR) is defined as a 10–20% reduction in heart rate (HR) from the baseline value or dysrhythmia, and the oculorespiratory reflex (ORR) manifests as shallow respiratory movement and bradypnea caused by manipulation of the eye. The aim of this study was to elucidate whether the specific muscle operated on has an effect on OCR and ORR, as well as whether the depth of anesthesia influences the OCR and ORR in patients undergoing strabismus surgery with laryngeal mask airway (LMA) to maintain spontaneous respiration.

Methods: The medical records of patients who underwent strabismus surgery on lateral rectus (LR) and medial rectus (MR) muscles from January 2017 to December 2017 were reviewed. For anesthesia induction, propofol was administered and the LMA was inserted. Anesthesia was maintained with sevoflurane and spontaneous respiration.

Results: The incidences of OCR during LR and MR operations were not significantly different between pediatric and adult patients (29% vs 27% and 15% vs 16%, respectively, $p < 0.05$). The incidence of ORR, as indexed by tidal volume (TV), was higher during MR surgery than during LR surgery in pediatric patients (29.3% vs 10.1%, $p < 0.05$). The change in HR during muscle traction and bispectral index (BIS) showed a negative correlation in pediatric patients, but this was not statistically significant. The change in TV during muscle traction and BIS was significantly correlated, in both pediatric and adult patients ($r2 = 0.034$ and 0.058, respectively, $p < 0.05$), while the change in respiratory rate (RR) during muscle traction and BIS did not show a significant correlation in either group.

Conclusions: The incidence rate of OCR did not differ between LR and MR surgeries, and the depth of anesthesia did not correlate with HR changes during muscle traction. Young age and MR surgery may be risk factors for ORR. However, MV did not decrease because of the increased RR during muscle traction. Thus, maintenance of spontaneous respiration with an LMA is safe during strabismus surgery under general anesthesia for both pediatric and adult patients.

Background

The oculocardiac reflex (OCR) is evoked by the parasympathetic stimulation induced by manipulation of the eye or extraocular muscles; thus, it typically occurs during strabismus surgery [1]. The afferent pathway of the OCR is the ophthalmic branch of the trigeminal nerve to the vagus nuclei, while the efferent pathway runs from the vagus nerve to the heart [2, 3]. The OCR is defined as a 10–20% reduction in heart rate (HR) from the baseline value or dysrhythmia [1, 2, 4]. The incidence of OCR ranged from 14% to 90% in previously published studies, depending on the definition used [1, 5–7]. Most cases of OCR resolve without treatment, but some patients exhibit cardiac arrest and, in very rare cases, sudden death [8, 9]. The OCR is known to occur more often in pediatric patients, and in those undergoing surgery on medial rectus (MR) muscles, but it is less prevalent in pediatric patients when deeper anesthesia is induced [5, 7, 10–12].

The oculorespiratory reflex (ORR) manifests as shallow respiratory movement, bradypnea, and respiratory arrest caused by pressure in, or manipulation of, the eye [13, 14]. The afferent pathway of the ORR is identical to that of the OCR, but the efferent pathway has not yet been fully elucidated [13]. However, the exact definition, incidence, and risk factors of ORR have not yet been clearly described. Because most strabismus surgeries are performed under general anesthesia with mechanical ventilation that requires neuromuscular blocking agents (e.g., rocuronium), very little clinical research has been done on ORR.

Most strabismus surgeries are performed on an outpatient basis. Therefore, anesthesia using the laryngeal mask airway (LMA) to maintain spontaneous respiration has been suggested in strabismus surgery [10]. However, there have been few studies on OCR and ORR during strabismus surgery in relation to the depth of anesthesia, especially in terms of the specific muscle undergoing surgery. Therefore, we designed this retrospective study to elucidate whether the OCR and ORR are affected by the specific muscle operated on, as well as to determine whether the depth of anesthesia influences the OCR and ORR in both pediatric and adult patients undergoing strabismus surgery with an LMA to maintain spontaneous respiration.

Methods

Study population and Ethical Approval

The study protocol was approved by the Institutional Review Board of Seoul St. Mary's Hospital, The Catholic University of Korea (approval no. KC17RESI0365). The medical records of patients with an American Society of Anesthesiologists (ASA) physical status of I or II, and who underwent strabismus surgery on the lateral rectus (LR) and MR muscles from January 2017 to December 2017, were reviewed. Patients were excluded if they underwent strabismus surgery on the oblique muscles, had bronchial asthma, chronic obstructive pulmonary disease, sleep apnea, or heart disease, or had no OCR and ORR data. Data on sex, age, body weight, the muscles operated on, HR, tidal volume (TV), respiratory rate (RR), minute ventilation (MV), and muscle traction time were collected. We defined patients under 15 years old as children.

Anesthetic management

Patients were allowed to eat and drink until 8 hours before surgery. Intravenous (IV) access was established with a 20–24-gauge angio catheter at the day surgery center (DSC). For pediatric patients who refused to enter the operating room (OR) alone, 0.05–0.1 mg midazolam IV was administered at the DSC; otherwise, no premedication was administered. Basic monitoring, including echocardiography, non-invasive sphygmomanometry, pulse oximetry, and bispectral index (BIS), was performed in the OR. For anesthesia induction, 1.5–2 mg/kg propofol was administered and the LMA (LMA® Flexible™ Airway; Teleflex, Westmeath, Ireland) was inserted when patients were fully sedated. Anesthesia was maintained with sevoflurane 2.0–2.5 vol%; spontaneous respiration was maintained with pressure between 5–10 cmH_2O using 50% N_2O and 50% O_2, with end-tidal carbon dioxide of 30–40 mmHg. Fentanyl 0.1 μg/kg was administered at the anesthesiologist's discretion. Surgery was performed by a single surgeon. At the end of surgery, sevoflurane was discontinued and the LMA was removed. Patients were then transferred to the post-anesthesia care unit, and then to the DSC for discharge.

Data collection and statistical analysis

The lowest HR, TV, RR, and MV were recorded during hooking of the rectus muscle; all parameters were recorded at the moment of traction release. Changes in HR, TV, RR, and MV were calculated as the lowest value during LR or MR traction divided by the baseline value. OCR was defined as a more than 20% reduction in HR from the baseline value. Baseline HR was defined as the initial HR after entering the OR. ORR was defined as a more than 20% reduction in TV, RR, and MV from the baseline values. The baseline values of the respiratory parameters were defined as the highest values between LMA insertion and surgical incision.

All data were analyzed using SPSS software (ver. 20.0; IBM Corp., Armonk, NY, USA). For demographic data, $\chi 2$ or Fisher's exact tests and t-tests were used. The incidence rates of OCR and ORR were compared between the LR and MR muscles using $\chi 2$ tests. Linear logistic regression was performed to analyze changes in HR, TV, RR, and BIS during muscle traction. Changes in HR, TV, RR, MV, during muscle hooking and after detachment, were compared between LR and MR surgeries using repeated-measures ANOVA with "group" and "time point" as the independent variables. The interaction term was calculated and the Bonferroni correction was applied. Data are presented as means ± standard deviations, or as numbers and percentages. A *p*-value <0.05 was considered to indicate statistical significance.

Results

In total, 141 patients were included (89 children and 52 adults) in this study. The pediatric patients underwent 69 LR and 58 MR operations, while the adult patients underwent 44 LR and 42 MR operations. The mean muscle traction time was 161 ± 50.0 s in children and 156.1 ± 42.5 s in adults (Table 1).

The incidences of OCR during LR and MR operations were not significantly different between pediatric and adult patients (29% vs 27% and 15% vs 16%, respectively). The overall incidence of ORR in terms of TV was 12.2%; the incidence of ORR in terms of TV was significantly higher during MR surgery (29.3%) than during LR surgery (10.1%) in children ($p < 0.05$), while there was no significant difference in adult patients. The incidence of ORR, in terms of RR and MV, did not show a significant difference between LR and MR surgeries in either pediatric or adult patients (Table 2).

The change in HR during muscle traction and BIS showed a negative correlation in pediatric patients, but this was not statistically significant (Fig. 1a & 1b). The change in TV during muscle traction and BIS was significantly correlated, in both pediatric and adult patients ($r^2 = 0.034$ and 0.058, respectively, $p < 0.05$) (Fig. 1c & 1d), while the change in RR during muscle traction and BIS did not show a significant correlation in either group. The change in MV during muscle traction was correlated with BIS in pediatric patients ($r^2 = 0.043$, $p < 0.05$), but not in adult patients (Fig. 1g & 1h). The change in HR during muscle traction and after muscle release did not show a significant difference in either the LR and MR (Fig. 2a). The changes in RR and MV during muscle traction were significantly greater during LR surgery than during MR surgery (36.1 ± 33.3% vs. 19.4 ± 33.1% and 53.2 ± 48.5% vs 23.4 ± 32.0%, respectively, $p < 0.05$); however, after post hoc correction, the differences were not significant (Fig. 2c & 2d).

Discussion

Strabismus surgery is one of the most common ophthalmologic surgeries performed under general anesthesia, especially in pediatric patients. To the best of our knowledge, this is the first study to investigate the incidence rates of OCR and ORR in relation to the depth of anesthesia; moreover, it is the first study to compare the incidence rates of OCR and ORR during LR and MR strabismus surgeries in patients undergoing general anesthesia using an LMA with spontaneous respiration. This study showed that the incidence of OCR was not significantly different between LR and MR surgeries, in either pediatric or adult patients; in addition, it was not correlated with the depth of anesthesia. In pediatric patients, the incidence of ORR in terms of TV was higher during MR surgery than during LR surgery. Changes in TV during rectus muscle traction were correlated with the depth of anesthesia, while changes in RR during rectus muscle traction were not correlated with the depth of anesthesia in either pediatric or adult patients. The HR, TV, RR, and MV returned to the baseline values immediately after muscle traction release without any intervention.

OCR is an important phenomenon during strabismus surgery; thus, both anesthesiologists and ophthalmic surgeons closely monitor potential signs of OCR to prevent its occurrence. Retrobulbar block, premedication with anticholinergics, and gentle tension of muscle traction have been suggested to reduce the rate of OCR [11, 15, 16]. OCR is known to occur more frequently during MR surgery than during LR surgery, due to differences in the afferent pathways involved; it occurs less frequently under deeper anesthesia [5, 7, 11, 12, 17]. In our study, LR and MR did not show differences in the incidence of OCR, in either pediatric or adult patients; moreover, changes in HR during muscle traction were not associated with the depth of anesthesia. Changes in HR during muscle traction were negatively correlated with the depth of anesthesia in pediatric patients, as in previous studies; however, this correlation was not statistically significant. We presume that this discrepancy with previous results was due to spontaneous respiration. Notably, respiration modulates sympathetic nerve activity, and more rapid RR is associated with a higher level of sympathetic activity [18]. Additionally, negative intrathoracic pressure during spontaneous inspiration causes a slight increase in HR because of vagal withdrawal and hyperinflated lungs, which may occur during mechanical ventilation and leads to bradycardia due to vagal overstimulation [19]. In contrast to the findings of previous studies involving general anesthesia with mechanical ventilation, the patients in our study maintained their spontaneous respiration; the resulting sympathetic stimulation offset the parasympathetic reflex that occurred during extraocular muscle manipulation.

ORR has not been well characterized for anesthesiologists or ophthalmologic surgeons, as most existing studies were experimental in nature. While the efferent pathway for ORR has not been clearly elucidated, it appears to be independent of the vagus nerve, because IV atropine enhances ORR; moreover, as in the OCR, the afferent pathway stimulates the pneumotaxic respiratory center to send a signal to the medullary respiratory area through the phrenic nerve and other respiratory nerves [13]. ORR is known to be prevented by retrobulbar block [14].

Allison et al. [10] reported that ORR occurred in a manner that led to reduced TV, without changes in RR, in pediatric patients who underwent strabismus surgery with LMA maintenance of spontaneous respiration. In the present study, the overall incidence of ORR in terms of TV was 12.2%; in pediatric patients; the incidence rate was greater during MR surgery than during LR surgery, which might be a result of the different afferent pathways involved [17]. However, the overall incidence rates of ORR, in terms of RR and MV, were below 5% and did not differ between the LR and MR surgeries. Among the respiratory parameters, only TV decreased with greater depth of anesthesia, in both pediatric and adult patients, although the correlations were marginal. This suggests that the depth of anesthesia is not closely correlated with the incidence of ORR. We propose that young age and MR surgery are risk factors for OCR during strabismus surgery, but additional studies are needed to confirm this hypothesis.

As shown in Fig. 2, the changes in RR and MV seemed to be greater during LR surgeries than during MR surgeries, while changes in TV did not differ between the surgeries. However, the changes did not show significance after post hoc correction, indicating that changes in RR and MV during muscle traction did not differ between the LR and MR surgeries. In this study, sevoflurane was used for anesthetic maintenance [10, 20–23]; its effect on respiration has not yet been fully elucidated. We note that the increase in RR (by ~20%) was greater than the magnitude of change in TV (~10%) during muscle traction. Because RR showed greater increases relative to baseline values in most patients, those who developed ORR in terms of TV did not show ORR in terms of MV. We assume that general anesthesia using the LMA to maintain spontaneous respiration can be safely applied in both pediatric and adult patients because. in patients who developed ORR in terms of TV. respiration in terms of MV was maintained at or above baseline due to increased RR. However, further prospective studies should be performed to clarify the relationship between ORR and the depth of anesthesia, as well as how the risk of ORR varies according to the specific muscle undergoing operation.

This study showed that HR, TV, RR, and MV returned to baseline, or near-baseline, values immediately after muscle traction release, regardless of the development of OCR or ORR. This indicates that OCR and ORR were inherently limited, suggesting that maintenance of spontaneous respiration using an LMA is a safe anesthetic management approach during strabismus surgery.

Conclusions

The incidence rate of OCR did not differ between LR and MR surgeries, and the depth of anesthesia did not correlate with HR changes during muscle traction. In pediatric patients, the incidence of ORR, in terms of TV, was higher during MR surgery than during LR surgery. Young age and MR surgery may be risk factors for ORR. However, MV did not decrease because of the increased RR during muscle traction. Thus, maintenance of spontaneous respiration with an LMA is safe during strabismus surgery under general anesthesia for both pediatric and adult patients.

Abbreviations

OCR: oculocardiac reflex; HR: heart rate; ORR: oculorespiratory reflex; LMA: laryngeal mask airway; LR: lateral rectus; MR: medial rectus; TV: tidal volume; BIS: bispectral index; RR: respiratory rate; ASA: American Society of Anesthesiologists; MV: minute ventilation; IV: intravenous; DSC: day surgery center; OR: operating room.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Seoul St. Mary's Hospital, The Catholic University of Korea (approval no. KC17RESI0365).

Consent to participate:

not applicable.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest or financial ties to disclose.

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Not applicable.

Author’s contributions

SYS participated in study design, data acquisition, statistical analysis, data interpretation, revised and drafted the manuscript. MJK participated in data interpretation and drafted the manuscript. JJ participated in study design, data acquisition, statistical analysis, data interpretation, revised and drafted the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Patient data description.

	Pediatrics			Adults		
Total (n)	89			52		
Gender (male/female)	41	/	43	26	/	26
Age (yrs)	6.6	±	2.8	39.2	±	16.6
Body weight (kg)	26.6	±	10.9	63.7	±	7.7
Number of operated muscles (LR/MR)	69	/	58	44	/	42
Baseline heart rate (bpm)	97.7	±	15.1	72.6	±	11.6
Baseline tidal volume (ml/kg)	4.0	±	1.5	4.4	±	1.2
Baseline respiratory rate (breaths/min)	24.3	±	6.7	17.7	±	7.1
Baseline minute volume (L/min)	2.6	±	1.0	4.0	±	1.5
Baseline BIS	82.3	±	17.5	97.5	±	1.0
Muscle traction time (sec)	161.0	±	50.0	156.1	±	42.5

Categorical variables are shown as numbers and other variables are shown as means ± standard deviations. LR, lateral rectus muscle; MR, medial rectus muscle; BIS, bispectral index.

Table 2. Incidence of oculocardiac reflex and oculorespiratory reflex

	Lateral rectus m.	Medial rectus m.	*P value*
OCR (n, %)			
Total	44, 38.9	43, 43.0	0.737
Pediatrics	29, 42.0	27, 46.6	0.546
Adults	15, 34.1	16, 38.1	0.709
ORR (n, %)			
TV			
Total	8, 7.1	18, 18.0	0.312
Pediatrics	7, 10.1	17, 29.3	0.008*
Adults	1, 2.3	1, 2.4	0.722
RR			
Total	1, 0.9	2, 2.0	0.192
Pediatrics	1, 1.4	1, 1.7	0.532
Adults	0, 0	1, 2.4	0.307
MV			
Total	3, 2.7	7, 7.0	0.217
Pediatrics	2, 2.9	6, 10.3	0.106
Adults	1, 2.3	1, 2.4	0.722

Variables are shown as numbers and percentages. OCR, oculocardiac reflex; ORR, oculorespiratory reflex; TV, tidal volume; RR, respiratory rate; MV, minute ventilation. * P value < 0.05.

Figures

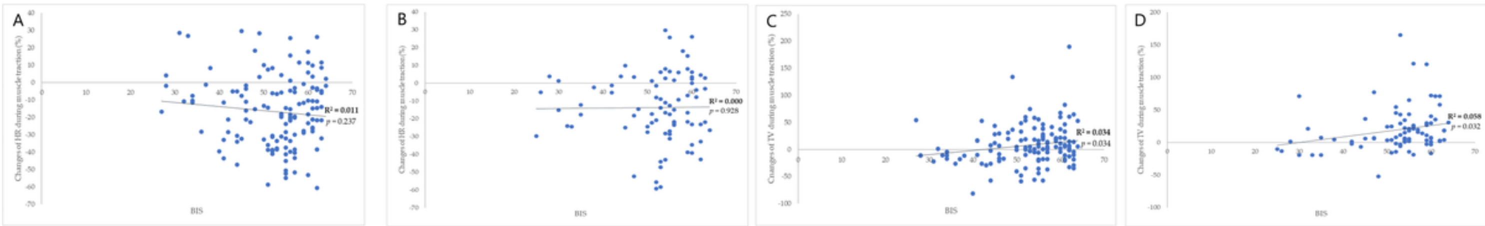

Figure 1

Relationship between BIS and changes in HR, TV, RR, and MV during muscle traction BIS, bispectral index; HR, heart rate; TV, tidal volume; RR, respiratory rate; MV, minute volume. a, c, e, and g are the results for the pediatric patients; b, d, f, and h are the results for the adult patients.

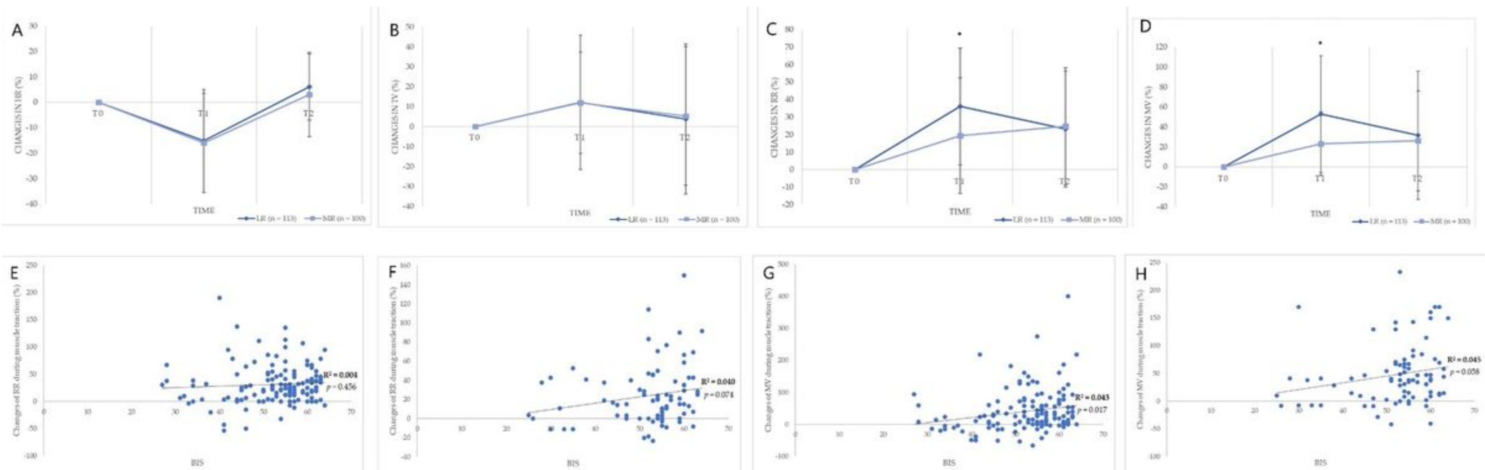

Figure 2

Changes in HR, TV, RR, and MV over time. HR, heart rate; TV, tidal volume; RR, respiratory rate; MV, minute volume; T0, baseline value; T1, during rectus muscle traction; T2, immediately after rectus muscle release. * p value < 0.05 for intergroup comparison, † Bonferroni correction for multiple comparisons; adjusted p value for multiple testing, p < 0.025.