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ORIGINAL RESEARCH

Oculocardiac Reflex During Strabismus Surgery: Conjunctival Incision versus Standardized Rectus Muscle Traction

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Video abstract

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Background: Extraocular muscle (EOM) tension during strabismus surgery produces trigemino-vagal bradycardia as a form of the oculocardiac reflex (OCR). Surface pain in the eye can cause bradycardia in premature infant eye examinations, so we evaluated the effect on the heart rate of different aspects of strabismus surgery.
Methods: Electrocardiograph heart rate (H.R.) was monitored during outpatient strabismus surgery without anticholinergic or local anesthetic. The impact of limbus-based conjunctival incision was compared to 200 gram, 10-second tension on rectus muscles.
Results: The 239 patients aged 0.6 to 83 years (16±20) during the limbal conjunctival incision had median change in H.R. from 100 bpm to 103 bpm, while initial rectus tension changed from 102 bpm to 75 bpm. Compared to median (and interquartile range) %HR with incision of 100% (100%, 101%) the corresponding first rectus tension 82% (65%, 98%) and subsequent rectus tension 80% (65%, 92%) were significantly greater (Kruskal–Wallis X2(2) = 251, $p < 0.001$) independent of gender, race, iris color, neurologic deficit, use of fentanyl or dexmedetomidine. Younger patients had greater percent heart rate drop with muscle tension but not conjunctival incision.
Conclusion: Despite uninhibited pain receptors and general anesthesia in children and adults, conjunctival incision produced essentially no OCR compared to EOM rectus tension.
Clinical Trials Registry: Clinical trial registration NCT04353960.
Data Access: https://www.abcd-vision.org/references/OCR%20Incision%202025.pdf.

Précis: During strabismus surgery without anticholinergic or local anesthetic, rectus muscle tension of 10-seconds and 200 grams produced a median heart rate drop of 18% however the preceding conjunctival incision elicited no change.

Keywords: oculocardiac reflex, trigeminovagal reflex, bradycardia, pain, strabismus surgery

Introduction

The oculocardiac reflex (OCR) is a vagal bradycardia elicited by stimulation the trigeminal nerve in the region of the eye.[1] Typically, OCR is induced by traction on an extraocular muscle, however it can be due to various other stimuli (Figure 1). OCR can be reduced by retrobulbar block,[2] topical anesthesia and even by direct application of cold water.[3]

Incision of the conjunctiva has been associated with OCR. Rahimi Varposhti et al in a manuscript translated into English, described an "incision (cutting) phase" and a "release phase" with substantial bradycardia in each however only the "cutting" phase was inhibited by topical tetracaine.[4]

The oculocardiac reflex represents one of the trigemino-vagal reflexes that can be elicited by many stimuli or procedures in the region innervated by the trigeminal nerve[5] such as otorhinolaryngology surgery.[6] The oculocardiac

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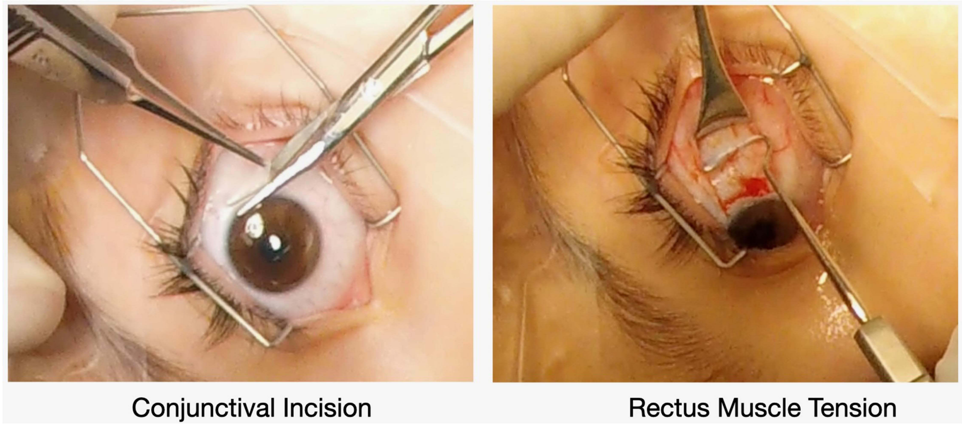

Figure 1 Images of trigeminal nerve stimulation by limbus-based conjunctival incision and lateral rectus 200-gram, 10-second muscle tension.

reflex is typically elicited by procedures in the orbit such as orbital fracture repair,[7] retinal detachment[8] or strabismus surgery,[9] but has also been reported with LASIK[10] and cataract surgery.[11] A profound oculocardiac reflex can be elicited when Alfonso lid speculum and scleral depression is utilized for retinopathy of prematurity staging examinations.[12] We have also noticed bradycardia in about 6% of our premature infants associated with instillation of topical tetracaine 0.5% drops (Figure 2) intended to reduce stress just before the retinal exams.[13]

Methods

This prospective observational study is part of the Alaska Oculocardiac Reflex study with Institutional Review from Providence Alaska Medical Center (Alaska Oculocardiac Reflex Study, 1992-2026). De-identified data is collected during routine anesthesia and strabismus surgery for which written consent had been waived. The study complies with the Declaration of Helsinki and the Health Insurance Portability and Accountability Act and has clinical trial registration NCT04353960. De-Identified data can be accessed: https://www.abcd-vision.org/references/OCR%20Incision%202025.pdf.

Patients undergoing strabismus surgery had electrocardiograph monitoring during quantified extraocular rectus tension and also during the initial conjunctival/Tenon's capsule incision (Figure 1 and Video abstract: https://vimeo.com/1145540010?fl=

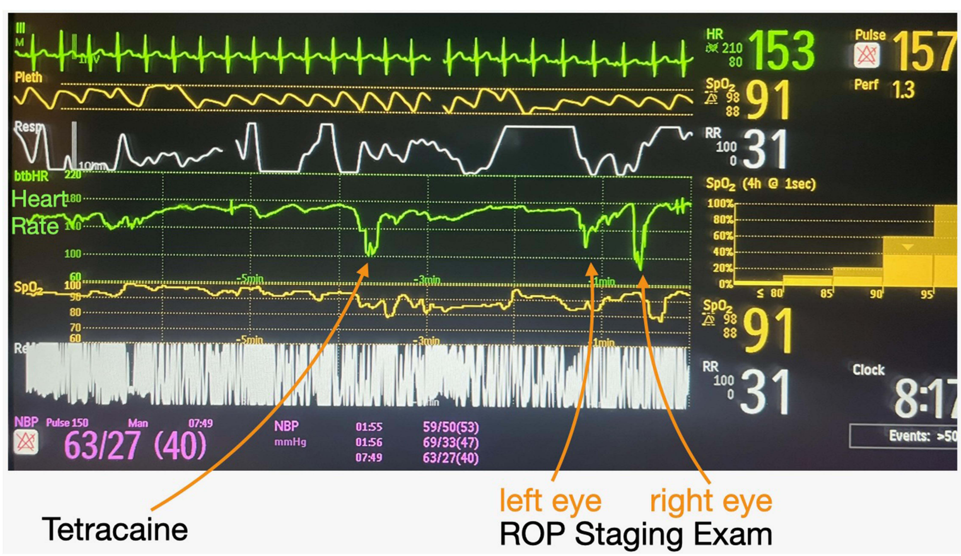

Figure 2 Vital signs highlighting electrocardiograph and heart rate over the course of retinopathy of prematurity staging examination for a premature infant in the neonatal intensive care unit. Alphonso lid speculum scleral depressed indirect ophthalmoscopy exam right eye and left eye noted to the right. Two minutes before an additional bradycardia event was associated with gentle instillation of tetracaine drops.

tlandfe=ec). No topical or subconjunctival or retrobulbar anesthetic was given. The order of patients consecutive, actual patients with various strabismus types, ages and medical conditions. The inferior rectus is tested most often since it can be easily accessed through a medial, a lateral or an inferior approach and it typically has the greatest bradycardia with uniform tension.[1] Since oculocardiac reflex was elicited by 10-second, square wave tension on gently isolated rectus muscle, these cases could be compared to prior identically elicited cases. In cases with two or more muscles operated, the first and second oculocardiac reflex with identical 10-second, 200 gram square wave tension is reported.

Data was assessed for normality of distribution. Non-normal distributions were compared with non-parametric tests Mann–Whitney and Kruskal–Wallis. Proportions were compared with Chi square.

Sample Size Calculation: Prior oculocardiac reflex elicited by 10-second, square wave, 200 gram tension without anticholinergic medication in 2531 cases had mean 80% ± 21% and a median of 85% (IQR 30) with kurtosis 0.95 and skewness −1.07.[14] With alpha 0.05, and Power 80%, the sample size needed to detect a 4% difference in percent oculocardiac reflex due to different afferent stimuli would be about 200 (n = 197).

Results

The heart rate response to two aspects of strabismus surgery were monitored in 254 patients. Descriptive statistics for age and weight and for percent heart rate change in response to conjunctival incision and extraocular muscle tension as well as actual heart rate before and after stimuli are given in Table 1. Excluded from the main data set were 7 cases given anticholinergic and one with cardiac pacemaker. Six re-operative cases had the subsequent case excluded from the main database, but these observations were compared to determine consistency in effect over time. One case done under topical anesthesia was excluded, therefore 239 cases were analyzed.

There were 114 female and 125 male patients. Age ranged from 0.6 to 83 years with mean 15.8±20 years. In total, 140 patients were under age ten years while 48 were age 20 and older. Patient weight ranged from 4.7 to 149 kilograms with mean 40±32. Of patients with recorded race/ethnicity, 6 were Asian, 20 were Black, 102 were White, 14 were Hispanic, 19 were Alaska Native, 1 was Middle Eastern and 7 were Pacific Islanders. Recorded iris color was brown in 86, blue in 53, green in 6, hazel in 1 and pink in 2.

Thirty-three different anesthesia providers primarily cared for the patients and chose anesthetic protocols, encouraged not to routinely employ intravenous anticholinergics. Some patients received midazolam pre-operatively. Most had laryngeal mask airway general inhalational sevoflurane anesthesia however three had total intravenous anesthesia (TIVA). During the procedure, the opioid fentanyl was used 175 cases and hydromorphone hydrochloride was used 9 times. Dexmedetomidine was administered intravenously to 58 patients; 49 cases had both fentanyl and dexmedetomidine.

Of the 239 patients, 32 had some form of neurologic impairment including 3 with Down Syndrome, 5 with other syndromes, 3 with autism, 5 with epilepsy, 3 with cerebral infarction, and two with hydrocephalus.

Table 1 Descriptive Statistics for 239 Oculocardiac Reflex (OCR) Patients Including Standard Deviation (S.D.), Interquartile Ranges (IQR), Minimum (Min) and Maximum (Max). Percent Heart Rate Change and Actual Heart Rate (HR) for Conjunctival Incision (Incise) and First and Second Rectus Muscle Tension (OCR-1 and OCR-2)

			Heart Rate Change Percent			Trigeminal Stimulus Heart Rate (beats per minute)					
n = 239	AGE/y	Weight/Kg	Incise HR%	%OCR-1	%OCR-2	Pre-incise	Incise HR	Pre-OCR1	HR OCR1	Pre-OCR-2	HR OCR2
Mean	16	42	100%	77%	77%	99	100	101	78	109	84
S.D	20	33	9%	23%	21%	26	27	26	31	25	32
Median	8	25	100%	82%	80%	100	103	102	75	112	82
IQR-1	3	16	100%	65%	65%	75	75	78	62	93	65
IQR-3	18	66	101%	98%	92%	119	120	120	97	126	106
Min	1	7	62%	9%	17%	48	44	51	10	48	11
Max	83	149	214%	122%	110%	160	160	160	160	158	158

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For symmetric cases, the surgeon routinely starts with left eye and finishes with the right eye. A 4–0 silk traction suture is used in most cases, then a limbus-based conjunctival flap is created with Wescott scissors (Figure 1 and Video abstract: https://vimeo.com/1145540010?fl=tlandfe=ec). For the initial muscle-tension oculocardiac reflex from gently-isolated, thin Jameson hook, 10-second, 200 gram, square wave tension, the left inferior rectus was pulled in 198 cases, the left medial rectus in one and the left superior rectus in 6. The right inferior rectus was pulled during 29 cases, the right lateral in one, and the right superior rectus in four. The onset of bradycardia over the ten-second, square-wave tension was described as "gradual" in 128 cases while the onset was described as "rapid" in 53 cases.

From induction of inhalational anesthesia to conjunctival incision was 14 ± 1 minutes and from incision to first rectus muscle tension was 1–2 minutes. A second rectus muscle identical tension oculocardiac reflex was measured in 168 of the 239 cases. The second followed the first rectus tension by 12±1 minutes. A total of 74 of the two-muscle cases were noted to have gradual onset bradycardia while 23 were described as rapid onset.

Utilizing Shapiro–Wilk to determine whether the distribution of data is normal, percent heart rate change for conjunctival incision was not normal (W stat 0.39), as was first tension percent heart rate change (W-stat 0.93) and second extraocular muscle tension OCR (W-stat 0.93). Oculocardiac reflex as a percent change (median; IQR1, IQR3: 100%,100%, 101%) for conjunctival incision was much less of a change compared to extraocular rectus muscle tension OCR-1 (77%, 65%, 98%) (Mann–Whitney z = 13.5, p < 0.001). The distributions of conjunctival incision compared to first and second rectus muscle tension were markedly different (Figure 3, Kruskal–Wallis $X^2(2) = 251$, $p < 0.001$).

The recent n = 239 cases were compared to 2531 from identically elicited rectus muscle tension and without anticholinergic. The former median percent OCR of 85% did not differ from the current median 82% (Mann–Whitney z = 1.3, p = 0.19).

Various factors are known to influence muscle tension oculocardiac reflex in a cohort with sufficient sample size.[14,15] Single variable factors in this study that did not influence first %OCR (Mann–Whitney) were gender (z = 0.79, p = 0.43), use of fentanyl (z = 1.6, p = 0.11), use of dexmedetomidine (z = 1.3, p = 0.20) and neurologic impairment (z = 1.6, p = 0.11). Rapid onset cases (marked reduction in heart rate and prolongation of R-R interval within the first few seconds of square-wave tension) had more oculocardiac reflex than gradual onset (z = 8.8, p < 0.001). Multiple variables (Kruskal–Wallis) without effect were iris color ($X^2(5) = 6.5$, p = 0.26), race ($X^2(6) = 7.4$, p = 0.28), anesthetist ($X^2(33) = 41$, p = 0.17) and intravenous opioid ($X^2(2) = 2.6$, p = 0.28). Age was positively correlated to %OCR due to the first rectus muscle tension (Pearson r(237) = 0.26, p < 0.001).

For our cohort, change in heart rate due to inferior rectus tension (n = 228, median 82.4%) did not differ from superior rectus (n = 10, median 81.8%, Mann–Whitney z = 0.66, p = 0.51). However, percent oculocardiac reflex due to

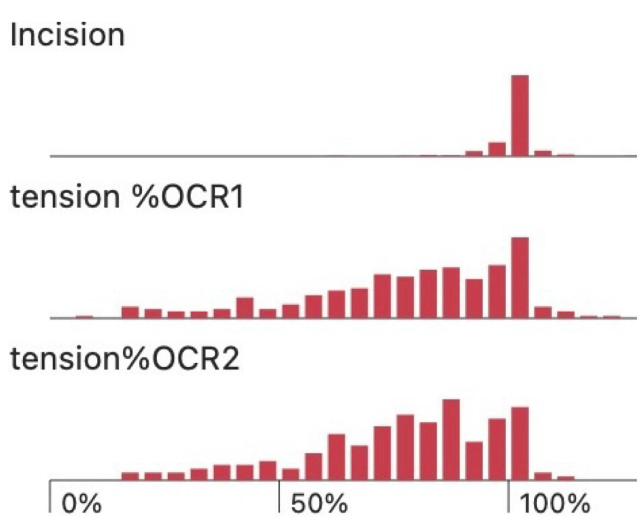

Figure 3 Compared frequency of percent heart rate change due to conjunctival incision, and first and second rectus muscle tension (%OCR).

tension on the left eye inferior rectus (n = 195, median 82%) was more bradycardia than right eye inferior rectus (n = 27, median 94%, Mann–Whitney z = 2.1, p = 0.04).

These same factors were compared to the minimal heart rate change observed when elicited by conjunctival incision. Corresponding p-values accompany the following factors: sex (p = 0.20), iris color (p = 0.78), race (p = 0.87), anesthetist (p = 0.11), dexmedetomidine (p = 0.13), fentanyl (p = 0.87), any opioid (0.99) and onset of bradycardia for the same patient with muscle tension (p = 0.17). Due to an outlier, the impact of neurologic condition on change in heart rate due to conjunctival incision nearly reached a significant difference (Mann–Whitney z = 1.76, p = 0.08).

Heart rate change due to conjunctival incision did not correlate with age (r(194) = 0.005, p = 0.95) or with heart rate change due to first rectus muscle tension (r(194) = −0.06, p = 0.40).

When oculocardiac reflex is defined as the proportion of cases with greater than 10% heart rate change, our 3% of those elicited by conjunctival incision was much less than the 64% due to the initial rectus muscle tension (Figure 4, Chi-square z = 14, p < 0.001).

One teenaged patient under sevoflurane, fentanyl and dexmedetomidine had marked tachycardia (increase in heart rate of 114% from 72 bpm to 154 bpm) associated with re-operative conjunctival incision followed 3 minutes later by rapid bradycardia from 99 bpm to 43 bpm elicited by the first rectus muscle tension. That same patient with a neurologic condition had had two prior strabismus surgeries years before the first of which was noted to have substantial (>50% drop) oculocardiac reflex.

Actual heart rate before and after conjunctival incision and rectus muscle tension are shown in Table 1. There was a trend toward higher pre-stimulus heart rate, however muscle tension 1 was not statistically greater than conjunctival incision (Mann–Whitney z = 0.64, p = 0.52). The increasing pre-heart rate trend did reach significance when the second rectus muscle tension was included (Figure 5; Kruskal–Wallis $X^2(2) = 14.8$, p < 0.001).

For the six re-operative cases, heart rate response to conjunctival incision and heart rate response to uniformly delivered extraocular rectus muscle tension were compared by Bland Altman Analysis (Figure 6). The mean difference for incision was similar to first muscle tension (−0.01 versus 0.01). The standard deviation of the difference for incision 0.02 was much less than 0.24 for muscle tension.

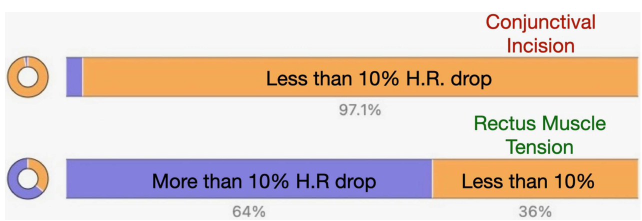

Figure 4 Portion of heart rate change greater than 10% due to conjunctival incision and rectus muscle tension.

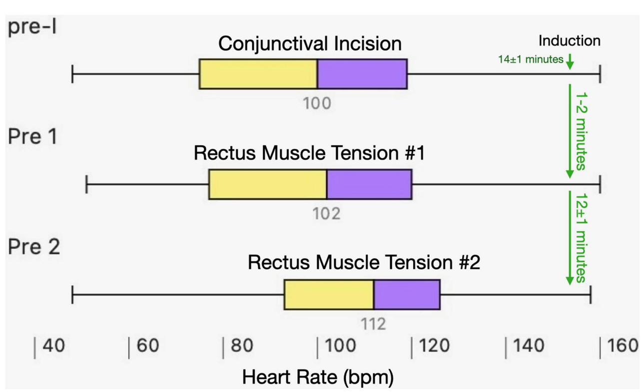

Figure 5 Actual heart rate (beats per minute) before (pre) each trigeminal stimulus conjunctival incision and first and second rectus muscle tension over average operative time course (green arrows to right side).

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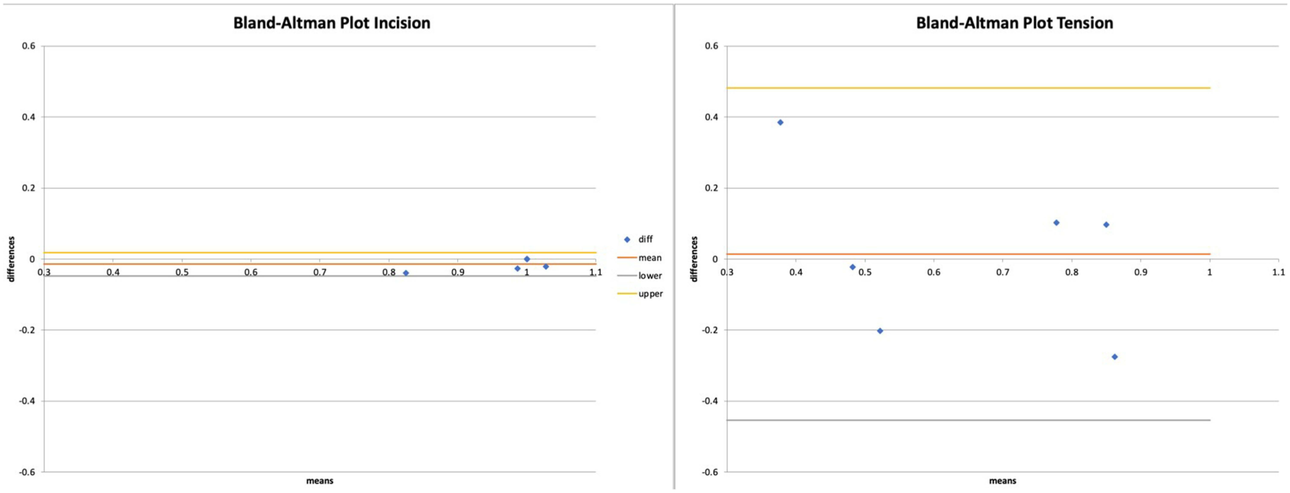

Figure 6 Bland Altman Plot of percent heart rate change due to conjunctival incision (left) and rectus muscle tension (right) for 6 patients with re-operations during the study period.

Discussion

Under carefully controlled conditions, we were able to monitor heart rate change with the two trigeminal nerve stimuli on each patient, but not in random order. The conjunctival incision always preceded the carefully quantified, extraocular rectus muscle tension. Under these conditions, the bradycardia produced by rectus muscle tension was consistently greater than the minimal change produced by our typical conjunctival incision. There was a gradual trend of increasing pre-stimulus heart rate from conjunctival incision to first rectus muscle tension, and even more to second rectus muscle tension. Younger patients and the surgeon-preferred first left eye had more percent heart rate change. Different types of conjunctival incision (Cul de sac, Swan, etc) might have a different degree of heart rate response. Alteration of the method and/or timing of conjunctival incision might influence subsequent rectus muscle tension somewhat.

Other studies covered in a comprehensive review of oculocardiac reflex[1] have also reported a substantial heart rate change with conjunctival manipulation. The frequency of OCR due to conjunctival manipulation was less than muscle manipulation appearing in 7 compared to 30,[16] 7 compared to 38[17] and 1 compared to 4.[18] Our findings differ from Rahimi Varposhti et al who found significant heart rate change due to their "cutting" phase of the procedure[4] Unlike their study of 70 subjects randomized to a placebo group, we did not compare with and without topical anesthesia on our "conjunctival incision" phase. We previously found that topical anesthesia with topical antibiotic-steroid ointment did not offer any substantial comfort advantage during recovery from strabismus surgery.[19] For the anesthesiologist, the heart rate response to conjunctival incision did not rule out more profound bradycardia during extraocular muscle tension in our study.

In premature infants for whom lid-speculum, bright light scleral depressed examination can produce profound, and prolonged bradycardia and oxygen desaturation, we have observed bradycardia from instillation of topical anesthetic drops which initially produce brief pain.[12,13] Perhaps, the gradually increasing pre-stimulus heart rate over the course of our strabismus surgery is related to similar pain fiber activation. On the other hand, the percent oculocardiac reflex elicited by the first rectus muscle tension did not differ from the second, identical magnitude rectus muscle stimulus, despite an initially higher pre-tension heart rate ten to 15 minutes later. Topical anesthesia, after initial instillation, may offer some comfort advantage during the type of retinal examination targeting retinopathy of prematurity.[13] The oculocardiac reflex is age-dependent with younger strabismus patients having slightly more percent bradycardia and exam induced bradycardia rare in adults.[20] Even younger premature infants have a much more profound bradycardia with retinal examination.

Prior studies have noted increased bradycardia associated with fast-acting opoids[21] and with dexmedetomidine.[22] This current study found a less significant trend partly due to difference in sample size.

Strengths of this study are sample size of consecutive patients with standardized rectus muscle tension without anticholinergic medication, and standard conjunctival incision. Weaknesses include non-randomized order of heart rate (always conjunctiva first) and various anesthetics agents at the preference of the anesthesiologists.

Conclusion

Despite a significant pain signal produced by conjunctival incision without topical anesthesia, we found that trigeminal afferent to the oculocardiac reflex to be minimal and consistently weaker than quantified extraocular rectus muscle tension.

Abbreviations

EOM, extraocular muscle; HR, heart rate; IQR, interquartile range; max, maximum; min, minimum; OCR, oculocardiac reflex; SD, standard deviation; TIVA; total intravenous anesthesia.

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Disclosure

Dr. Arnold coordinates the Alaska Blind Child Discovery which has received discounted vision screening technology from several vendors. Dr. Arnold is board member and patent holder for PDI Check. The authors report no other conflicts of interest in this work.

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