

Performance Improvement System and Postoperative Corneal Injuries

Incidence and Risk Factors

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Background: **The authors' department conducted a performance improvement initiative aimed to reduce the rate of perioperative corneal injuries. This study reports the effects of the initiative and examines the risk factors for corneal injury.**

Method: **The rate of corneal injuries during nonophthalmologic procedures under anesthesia was compared between the two time periods: preinitiative baseline (August 1, 2005–December 31, 2005) and initiative period (January 1, 2006–April 30, 2007). To examine the risk factors for corneal injury, a nested case-control study with a 2:1 matched-set design was separately performed and included cases between January 1, 2006 and July 31, 2008.**

Results: **During the baseline period, the corneal injury rate was 1.51 per 1,000, and it decreased to 0.79 per 1,000 during the performance initiative (P = 0.008). Independent risk factors were longer anesthetics (odds ratio = 1.2, 95% confidence interval (CI) 1.1–1.3 per 30 min), lower American Society of Anesthesiologists physical status (odds ratio 0.5, 95% CI 0.3–0.8 for American Society of Anesthesiologists physical status 3–4 *vs.* 1–2), and student nurse anesthetist as a primary anesthesia provider (odds ratio 2.6, 95% CI 1.3–5.0).**

Conclusion: **Corneal injury rate in our institution was significantly reduced and remains at low levels long after initiation of perioperative eye care improvement initiative. The higher rate of corneal injuries among student nurse anesthetists highlights the importance of standardizing education and supervision among all anesthesia providers. We believe that our model of performance improvement initiative can be used to improve other perioperative outcomes.**

CORNEAL injuries that manifest with "painful eye" are the most common perioperative ocular complications. A 1992 American Society of Anesthesiologists Closed Claims Project reported that the eye injuries were responsible for 3% of all claims; of these, 35% were related to corneal injuries.[1] The mechanisms of perioperative injury are based on direct trauma of the corneal epithelium (corneal abrasion), corneal drying (exposure keratitis), or blockage of the outflow of aqueous fluid with acute rise in intraocular pressure (angle-closure glaucoma). Patients with incomplete lid closure (lagophthalmos) or those with protruding eyes (exophthalmos) may be at increased risk for perioperative corneal injuries.

In an attempt to reduce the rate of perioperative corneal injuries, we established an interdepartmental Performance Improvement (PI) initiative to advance perioperative eye care. The initiative consisted of two interventions introduced sequentially. The first phase aimed to increase awareness of the individual provider by sending an automated notification e-mail when his/her patient experienced corneal injury. In the second phase, we conducted formal teaching for all anesthesia personnel regarding factors that can lead to corneal injury, with emphasis on preventive measures. This educational content was then linked to each notification e-mail. The first part of our study reports the effects of our initiative on the rate of perioperative corneal injuries.

Identification of patient and procedural risk factors for corneal injuries could be used to modify anesthetic management to further reduce injury rates. To date, only one study has systematically examined perioperative risk factors for eye injury[2]; however, this study was done in the early 1990s, and subsequent changes in anesthesia practices may have modified risks. In the second part of this study, we conducted an investigation of risk factors for corneal injury in an attempt to identify specific modifiable risks factors.

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Materials and Methods

The current report consists of two related investigations. The first assessed the incidence of corneal injuries before and after implementing the PI initiative to reduce corneal injuries. The second consisted of a nested case control study assessing potential patient and procedural characteristics associated with corneal injury. Written/informed consent has been approved by the Institutional Review Board, Mayo Clinic, Rochester, MN, and approval was received for both investigations.

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The Effects of PI Initiative on Corneal Injury Rates

We measured the incidence of corneal injuries in patients undergoing nonophthalmologic operations and procedures. On January 1, 2006, the Department of Anesthesiology at Mayo Clinic, Rochester, Minnesota, implemented a system that allowed immediate identification of postoperative corneal injuries at two Mayo Clinic Rochester hospitals, Saint Marys and Methodist. From January 1, 2006 to June 31, 2006 (the notification period), an automated electronic notification system was implemented that informed all anesthesia providers involved with a case of corneal injury that their patient suffered an eye injury. During this epoch, all perioperative care nurses were instructed to automatically request an ophthalmology consult for every case of postoperative "painful eye" after nonophthalmologic operations. Ophthalmology consultation was performed at the bedside and consisted of visual inspection of cornea and conjunctiva with a slit lamp aided by fluorescein and Rose Bengal staining.

After examining a patient, the ophthalmologist used a short online form to immediately report the corneal injury. This report was directly linked to the electronic medical record and was automatically forwarded *via* e-mail to all personnel involved with the respective case and to the PI Chair (Dr. Martin; see slide No. 3 on Supplemental Digital Content 1, which is a modified Microsoft PowerPoint presentation used to conduct our Grand Rounds lecture regarding Corneal Injury Performance Improvement Initiative, http://links.lww.com/A1453). The purpose of this e-mail was to increase specific awareness regarding corneal injury rather than to trigger any specific response from the attending anesthesia team. All perioperative corneal injuries were simultaneously tracked and reviewed by the Anesthesia Department PI Committee.

On July 1, 2006, we initiated the second phase (education period) of the intervention (July 1, 2006 to April 30, 2007). This initiative consisted of an educational component, which consisted of a 45-min lecture delivered by both the PI Chair and an ophthalmologist (Dr. Mahr) to the Anesthesia Department consultants, residents, and fellows in one session and separately to certified nurse anesthetists (CRNA) and student nurse anesthetists (SRNA). The lecture focused on postoperative corneal injury awareness, understanding of risk factors, and methods of prevention (focusing on lid taping and eye ointment; see slides, Supplemental Digital Content 1, http://links.lww.com/A1453). Anesthesia providers were instructed to tape the eyes shut during anesthetic induction as soon as the eyelid reflex disappeared, and before airway management. Emphasis was made on assuring the full closure of the eyelids to avoid drying of the corneal surface. The routine use of eye ointment was left to the discretion of the anesthesia provider. The content of this lecture was posted on the Department of Anesthesiology internal website. A second component of the educational initiative included the addition of a hyperlink to the notification e-mail to the education materials posted on the departmental website (see slides, Supplemental Digital Content 1, http://links.lww.com/A1453).

To determine the rate of corneal injuries before the initiation of this project, we defined the baseline period as the period from August 1, 2005 to December 31, 2005. Cases of corneal injury during the baseline period were identified from the Department of Ophthalmology consultation database. The same ophthalmology consultation database was used to confirm the compliance with web-based reporting.

Risk Factors

To assess potential risk factors for corneal injury, we used a nested case-control design. The cases included in the risk factor analysis included the incidence cases identified *via* the web-based reporting system in our PI initiative during the notification and education periods (January 1, 2006 to April 30, 2007) and also cases identified during the subsequent 15-month follow-up period (May 1, 2007 to July 31, 2008). During this additional 15-month period, the practice changes initiated during the PI initiative were continued. For each corneal injury case, we used the Mayo Clinic anesthesia and surgery databases to create a pool of all individuals who underwent nonophthalmologic operations and procedures with general anesthesia within the same month and calendar year as the case. From these pools of possible controls, two controls were selected at random for each case. All medical records were reviewed by one of two abstractors (Drs. Gunn and Lee). Both abstractors reviewed the initial 20 charts to standardize data extraction and to enable the evaluators to identify and correct problems in data collection phase. All questionable issues were discussed with one of the authors (TNW).

The potential risk factors considered in the analysis included patient age, sex, body mass index, the use of dentures (changed facial characteristics that may alter techniques of airway and face mask manipulation), the use of noninvasive ventilation devices to assist in breathing (use of these devices may be associated with adjustments and accidental corneal injury), and American Society of Anesthesiologists Physical Status (ASA-PS) class. The following preexisting comorbidities were considered: diagnosis of Graves' disease (treatment of hyperthyroidism and note regarding presence of exophthalmos),[3] diabetes mellitus (diabetic patients have less sensitive cornea, produce fewer tears, and may be prone to corneal lesions),[4] and seasonal allergies (frequently associated with eye irritation).[5] The following surgical and anesthesia factors were considered: whether the surgery was performed on inpatient or outpatient basis, day of the week of surgery, location of surgery (head/neck *vs.* rest of the body), difficulty in performing tracheal intubation (yes, no), duration of anesthesia, patient position during

surgery (lateral *vs*. all other positions), the type of airway management (endotracheal tube *vs.* all other, *i.e.*, face mask, laryngeal mask airway), and whether the case was attended by trainees (resident or SRNA) or staff anesthetists (CRNA). At the Mayo Clinic, anesthesia coverage is provided by resident, SRNA, or CRNA with supervision by an attending anesthesiologist who is present during induction, emergence and all critical portions of the anesthetic. An anesthesia provider who started the case may be relieved before the end of the case. It is not possible to retrospectively determine that time at which the injury occurred (induction, during the maintenance of anesthesia, or during emergence), we examined the association between corneal injuries and primary provider with respect to both the start and end of anesthesia.

Statistical Analyses

For the investigation evaluating the effects of PI initiative on reducing the rate of corneal injury, denominators for total monthly nonophthalmologic surgical volumes were obtained from an institutional database. Monthly postanesthesia corneal injury rates were calculated by dividing the number of monthly postoperative corneal injury consults by the monthly nonophthalmologic surgical volumes. Injury rates, expressed as injuries *per* 1,000 surgeries, are summarized using point estimates and exact binomial 95% confidence intervals (CI). Data were analyzed using logistic regression to assess whether the rate of corneal injury declined over time after the initiation of the intervention. For this analysis, corneal injury was the dependent variable, and time (month following initiation) was the independent variable. To supplement the findings from this analysis, secondary analyses were performed using logistic regression to compare the rate of corneal injury across the three time periods (baseline, notification, and education). To assess whether the rate of corneal injury changed after the formal evaluation period, an additional analysis was performed to compare the rate of corneal injury during the 15-months follow-up period to that observed during the education period.

Risk factors for corneal injury were investigated by using a nested case control study. Data were analyzed by using conditional logistic regression, making use of the 2:1 matched-set study design. Findings are summarized by using odd ratios (OR) and corresponding 95% CI. Duration of anesthesia and location of surgery (head and neck *vs.* nonhead and neck) were previously shown as highly significant independent risks for perioperative corneal injury[2]; therefore, we used these two covariates as adjustors when assessing all other potential risk factors. Demographics, comorbidities, and surgical and anesthetic variables were assessed individually in a series of adjusted univariate analyses. For these analyses, a single potential risk factor variable was included as an explanatory variable in a conditional logistic regression model along with duration of anesthesia and location of surgery. Variables found to have some evidence ($P < 0.10$) of an association with corneal injury from these adjusted univariate analyses were considered for inclusion in a subsequent multivariable model. Variables identified through this process were assessed for multicollinearity before performing subsequent multivariable modeling. Given the high collinearity between the two variables defining anesthesia provider ("provider at the beginning of the case" and "provider at the end of the case"), only one of these variables (provider at the beginning of the case) was included in the multivariable model.

In our analyses, two-tailed $P < 0.05$ was considered to be statistically significant. Analyses were performed using SAS statistical software (Version 9.1; SAS Institute, Inc., Cary, NC).

Results

Evaluation of PI Initiative

Between August 1, 2005 and April 30, 2007, 113,162 nonophthalmologic operations and procedures requiring anesthesia were performed; during that period, 128 perioperative consults were requested with indication "painful eye." Of these, 88 occurred after January 1, 2006, which corresponds to the date that the web-based reporting tool was initiated. A comparison of the number of consultations between the ophthalmology consultation database and the web reporting tool showed that 83 of 88 injuries (94.3%) were captured by the web tool. The five missed consults in web-based reporting occurred during the first 2 months of implementation; after that, the compliance with reporting was 100%.

Patients submitted for ophthalmologic consultation had either exposure injury or corneal abrasion, and we found no cases of acute angle closure glaucoma. Unilateral injury was present in 95 patients (74.2%), bilateral in 17 patients (13.3%), and not noted in 16 patients (12.5%). All patients received treatment with antibiotic eye drops for 48 h, and all injuries resolved within days.

Monthly rates of corneal injuries between August 1, 2005 and July 31, 2008 show some increasing and decreasing patterns within epochs; however, these patterns did not show any temporal relationship with the admission of new trainees (fig. 1). During the baseline epoch, the rate of corneal injury was 1.51 (95% CI 1.1 to 2.1) *per* 1,000 surgeries. From logistic regression analysis, the injury rate was found to decline with time after baseline (OR = 0.94 per month, $P = 0.019$). During the notification period, the injury rate was 1.37 (95% CI 1.0 to 1.8) *per* 1,000 surgeries, and the injury rate during the 10-month education period was 0.79 (95% CI 0.6 to 1.1) *per* 1,000 surgeries. The injury rate was significantly lower during the education period compared to both the baseline ($P = 0.002$) and the notification periods ($P =$

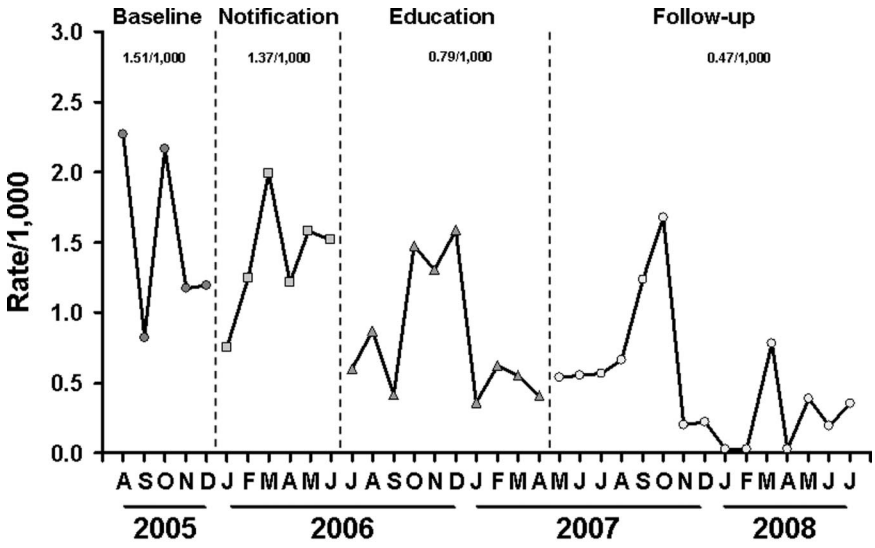

Fig. 1. The rate of corneal injuries between August 1, 2005 to July 31, 2008. Rate is expressed as number of injuries *per* 1,000 surgeries. All of the practice changes implemented as part of the performance improvement initiative were continued during the follow-up phase. *Numbers* posted below study period titles represent overall corneal injury rate for the respective period. *Letters* stand for individual months in the year (*i.e.*, in 2005: A, S, O, N, D = August, September, October, November, December).

0.008). Although the formal evaluation of the PI initiative included only data collected through April 30, 2007, the practice changes initiated during the education period have continued. During the follow-up period (May 1, 2007 to July 31, 2008), an additional 84,796 procedures were performed with an observed injury rate of 0.47 *per* 1,000 anesthetics, which was significantly lower than the rate observed during the education phase ($P = 0.018$).

Evaluation of Risk Factors

For the evaluation of risk factors we included cases of corneal injury identified *via* the web-based reporting system between January 1, 2006 and July 31, 2008. Of the 120 cases identified, there were 3 patients who did not give authorization to use their medical records for research. Therefore, the risk factor analysis includes 117 cases of corneal injury (all occurred under general anesthesia) and 234 matched controls (within the same month and calendar year, and procedure done under general anesthesia). Duration of anesthesia was 271 ± 116 min for cases and 206 ± 118 min for controls. The location of surgery was "head and neck" for 15.4% of cases and 9% of controls. From an initial logistic regression model, which included these two variables, the risk of corneal injuries was significantly increased with longer duration of surgery (OR = 1.17, 95% CI 1.09 to 1.24 per 30 min; $P < 0.001$), with some evidence of an increased risk for head and neck procedures (OR = 1.83, 95% CI 0.89 to 3.76; $P = 0.098$). Table 1 presents the results of univariate analyses assessing the association of other potential risk factors after adjusting for duration of anesthesia and location of surgery. From these analyses, the risk for corneal injury was increased in patients with Graves' disease and was lower in patients with higher ASA PS. There was no significant association between corneal injury and inpatient or outpatient status, day of the week of the procedure, body position during the procedure (lateral compared to all other positions), and type of airway management (endotracheal tube *vs.* other airway devices). When analyzing all cases between Jan 1, 2006 to July 31 2008, the type of anesthesia provider was a significant risk factor for corneal injury, with the highest risk being for cases where the primary provider was a SRNA (table 1). In our final multivariable analysis, independent risk factors for corneal injury were longer duration of anesthesia, lower ASA PS, and anesthesia provided by a SRNA (table 2).

Discussion

The most important finding of our study is that increased anesthesia provider awareness regarding perioperative corneal injury coupled with educational initiative was associated with substantial reduction of corneal injury rates. Before the implementation of the PI initiative, the incidence of perioperative corneal injuries was 1.51 *per* 1,000, and it decreased to 0.79 *per* 1,000 during the PI initiative epoch. The rate of corneal injuries continued to decrease during the follow-up epoch, and the average rate was 0.47 *per* 1,000 anesthetics for the 15 months after the completion of the PI initiative. The current PI web method, which provides timely reminders of the eye injury and offers repeated education to providers, continues to be a powerful tool for maintaining a low rate of corneal injury. Independent risk factors for corneal injury were duration of anesthesia, lower ASA PS, and anesthesia provided by SRNAs. Although the role of some of the mechanisms related to risk for corneal injury are unclear (lower ASA PS), the information that anesthesia performed by SRNA increased the risk will be used

Table 1. Adjusted Univariate Analysis of Potential Risk Factors for Corneal Injury*

	Controls (n = 234)	Cases (n = 117)	OR	95% CI	*P* Value
Age, yrs†	60.4 ± 17.7	60.7 ± 16.3	1.00	0.87–1.16	0.970
Sex					0.133
Female	116 (49.6%)	64 (54.7%)	1.00		
Male	118 (50.4%)	53 (45.3%)	0.69	0.43–1.12	
Body mass index, kg/m^2	28.8 ± 7.0	28.1 ± 5.3	0.98	0.94–1.02	0.235
Graves disease					0.032
No	233 (99.6%)	113 (96.6%)	1.00		
Yes	1 (0.4%)	4 (3.4%)	11.92	1.24–114.35	
Diabetes mellitus					0.147
No	189 (80.8%)	101 (86.3%)	1.00		
Yes	45 (19.2%)	16 (13.7%)	0.61	0.32–1.19	
Use of dentures					0.29
No	184 (78.6%)	86 (73.5%)	1.00		
Yes	50 (21.4%)	31 (26.5%)	1.20	0.87–1.67	
Use of nocturnal CPAP/BiPAP					0.41
No	206 (90.8)	110 (94.0%)	1.00		
Yes	21 (9.2)	7 (6.0%)	0.72	0.37–1.39	
Seasonal allergies					0.877
No	208 (88.9%)	100 (85.5%)	1.00		
Yes	26 (11.1%)	17 (14.5%)	1.06	0.53–2.09	
ASA physical status					0.002
1–2	113 (48.3%)	70 (59.8%)	1.00		
3–4	121 (51.7%)	47 (40.2%)	0.43	0.25–0.74	
Position during surgery					0.449
Prone/supine/sitting	209 (89.3%)	102 (87.2%)	1.00		
Lateral	25 (10.7%)	15 (12.8%)	1.32	0.64–2.73	
Endotracheal tube used§					0.988
No	21 (9.0%)	6 (5.1%)	1.00		
Yes	213 (91.0%)	111 (94.9%)	1.01	0.34–3.01	
Difficult intubation					0.103
No	216 (92.3)	107 (91.5)	1.00		
Yes	18 (7.7)	10 (8.5)	1.10	0.47–2.62	
Provider at start of surgery					0.002
CRNA	137 (58.5%)	53 (45.3%)	1.00		
Resident	45 (19.2%)	18 (15.4%)	1.09	0.54–2.20	
SRNA	52 (22.2%)	46 (39.3%)	2.97	1.57–5.61	
Provider at end of surgery					<0.001
CRNA	157 (67.1%)	70 (60.0%)	1.00		
Resident	40 (17.1%)	9 (7.7%)	0.55	0.24–1.27	
SRNA	37 (15.8%)	38 (32.5%)	2.81	1.49–5.33	
Admission category					0.251
Inpatient	178 (76.1%)	93 (79.5%)	1.00		
Outpatient	56 (23.9%)	24 (20.5%)	1.46	0.76–2.80	
Day of the week‡					0.638
Monday	42 (17.9%)	21 (17.9%)	0.85‡	0.44–1.65	
Tuesday	47 (20.1%)	29 (24.8%)			
Wednesday	41 (17.5%)	18 (15.4%)			
Thursday	54 (23.1%)	25 (21.4%)			
Friday	44 (18.8%)	23 (19.7%)			
Saturday	4 (1.7%)	0 (0.0%)			
Sunday	2 (0.9%)	1 (0.9%)			

* Analyses were performed using conditional logistic regression taking into account the 1:2 matched set study design. Each of the potential risk factors was assessed separately by adding it to a model that also included anesthesia duration and location of surgery. † Odds ratio presented for a 10-yr increase in age. ‡ Day of the week was analyzed as Monday *vs.* all other days of the week. § Endotracheal tube *vs.* all other types of airway management.

ASA = American Society of Anesthesiologists; BiPAP = bilevel positive airway pressure; CI = confidence interval; CPAP = continuous positive airway pressure; CRNA = certified nurse anesthetist; OR = odds ratio; SRNA = student in nurse anesthesia.

to direct our educational efforts to further reduce the rate of corneal injuries in our department.

The incidence of perioperative corneal injuries is infrequently studied. The last review examined 60,965 patients over a 4.5-yr period and reported an incidence of 0.56 *per* 1,000 operations,[2] a level comparable to that reached in our study between May 1, 2007 and July 31, 2008. Two decades ago, a smaller prospective study of 4,652 neurosurgical patients reported 1.7 corneal injuries *per* 1,000 operations,[6] a rate comparable to our baseline period.

Two main mechanisms of perioperative corneal injury are mechanical abrasion or exposure-induced drying of the corneal surface. The latter occurs by failing to fully

Table 2. Multivariable Analysis of Risk Factors for Corneal Injury

	OR	95% CI	*P* Value*
Anesthesia duration, min†	1.20	(1.12–1.29)	<0.001
Location of surgery			0.072
Non-head and neck	1.00		
Head and neck	2.08	(0.94–4.60)	
Graves disease			0.087
No	1.00		
Yes	7.17	(0.75–68.22)	
ASA physical status			0.009
1–2	1.00		
3–4	0.48	(0.27–0.83)	
Provider at start of surgery			0.017
CRNA	1.00		
Resident	1.15	(0.56–2.34)	
SRNA	2.58	(1.33–5.02)	

* *P*-values are from stratified logistic regression. † Odds ratio (OR) presented per 30-min increase in anesthesia duration.

ASA = American Society of Anesthesiologists; CI = confidence interval; CRNA = certified nurse anesthetist; SRNA = student nurse anesthetist.

close the eyelids during the operation. It has been shown this type of injury occurs in 44% of patient with open eyes during anesthesia.[7] Information regarding the type of injury is very important for developing preventive strategies, because it directly suggests the mechanism by which it occurred. Unfortunately, the clinical distinction on examination is subtle and somewhat arbitrary, and our ophthalmologists informally use these terms somewhat interchangeably in perioperative setting. However, this semantic issue does not affect the reported rates of corneal injuries.

We believe that the important effect of our PI initiative arises from the repeated e-mail reminders accompanied with a link to the online educational material provided at salient times associated with complication. Notification *per se* had little effect on reduction of corneal injury rate until the education initiative was co-implemented. This combination appears to provide a good tool to affect the practice modification in a voluntary and self-motivated way. Another advantage of the web-based notification tool is that this feedback closes the loop between anesthesia providers and those who diagnose downstream complications. In an academic medical setting with high turnover of trainees, these ongoing educational reminders provide an active source of continuous reeducation to the staff. Although there was no change in policy regarding eye care during the study period, the knowledge that corneal injury complications were being monitored and that each provider is identified in this monitoring system may have contributed to increased patient care and reduction of corneal injuries. With corneal injury, we have shown that closing the loop can motivate education and practice change, leading to improved outcomes. However, the observation of higher rates of injuries among SRNAs suggests that the effects of our PI initiative may not be equal among all groups of anesthesia providers.

Risk Factors

To date, only one study has systematically examined perioperative risk factors for eye injury.[2] Similarly to that study,[2] we found that longer anesthesia course represents a risk for corneal injury. This may not be surprising, because longer time under anesthesia allows for more corneal drying of an improperly closed eye. An additional contributing factor may be reduced production of tears during anesthesia.[8] In addition, any condition associated with difficulty in eye closing may increase the risk. In our study, presence of Graves disease diagnosis was associated with corneal injury, albeit only in univariate analysis.

Factors related to potential for increased manipulation around the eyes (such as difficulty in mask ventilation, difficult intubation, and use of dentures or nocturnal noninvasive ventilation devices) were not associated with increased risk for corneal injury. One can postulate that our practice of early eye taping could have contributed to the lack of association between facial manipulations and corneal injury. In the study by Roth *et al.*,[2] operative location on head and neck was an independent predictor of corneal injury; in our study, only the trend for higher injury rate was present.

The unexpected finding of our study was that the risk for corneal injury was related to the type of provider; higher rates of injury were found among the SRNAs compared to CRNAs and residents. The annual turnover rate of SRNAs (approximately 50% annually) may have resulted in an extinguishing effect (*i.e.*, the impact of the PI effort fades over time as newcomers to the anesthesia program receive less formal education). If this were true, we would anticipate some extinguishing effect among residents who also have relatively high turnover rate (approximately 33% annually); however, it was not found. In addition, the increased risk for SRNAs but not residents cannot be primarily explained by inexperience. Compared to residents, SRNAs have more prior training and experience in caring for eyes of sedated and intubated patients because of their background of working as nurses in the intensive care unit. However, eye protection practices substantially differ among the intensive care environment and operating room settings. In the current study, the cause of the injury rate discrepancies among trainee categories remains unclear. Although one may postulate that the difference may be the result of quality of teaching between the two groups, this is unlikely because CRNAs (primary teachers for SRNA) have a low rate of corneal injuries. To further reduce the rate of corneal injuries, our department is directing an effort in focused education and improved supervision initiative among SRNAs.

Unexpectedly, we found that, compared to patients with ASA PS of 3 or more, the patients with ASA PS of 2 or less had higher rates of corneal injuries. This finding may be confounded by the type of provider or duration of anesthesia (patients with lower ASA PS are assigned to SRNA or were longer cases). However, even after adjusting for duration of anesthesia, lower ASA status remained independently associated with increased rates of corneal injuries; therefore, we do not have a plausible explanation for the association between the corneal injury risk and the ASA PS.

Limitations of the Study

Although the corneal injury information was gathered prospectively, this is an observational study with all the inherent limitations related to a retrospective design. Also, Mayo Clinic is a large academic medical center with parallel physician and nurse training programs, and it may not be representative of other hospital settings. Furthermore, we cannot accurately comment on the exact proportion of patients with corneal exposure *versus* corneal abrasions, information that can be used to more closely examine the exact mechanism of corneal injury and allow us to more precisely direct preventive efforts.

In conclusion, the incidence of perioperative corneal injuries decreased after implementation of measures that both raised the awareness regarding this complication and increased educational efforts. In our institution, improvement in education and enforcement of strategies regarding eye protection among SRNAs may further reduce an already low rate of perioperative corneal injuries. Finally, we believe that our novel performance initiative, simultaneously based on improvement of communication and education, can serve as a model to advance other aspects of perioperative safety and outcomes.

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