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Preventing Ocular Surface Disease in the Pediatric Intensive Care Unit

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Abstract

Problem: Ocular surface disease in the Pediatric Intensive Care Unit is a significant problem in intubated patients due to altered eye protective mechanics, leading to exposure of the eye surface and dry eye. The purpose of this quality improvement project was to evaluate how an eye care protocol affected the frequency of artificial tear ointment administration.

Method: A descriptive, cohort design utilizing a retrospective chart review with convenience sampling of intubated children in the PICU from two cohorts was used. Comparisons were made between the preintervention cohort in 2020 and postintervention cohort in 2021.

Results: A total of 96 (*N*=96) intubated patients were identified, with 53 (*N*=53) in the 2020 cohort and 43 (*N*=43) in the 2021 cohort. The mean number of ointment applications for patients with an artificial tear ointment order was 33.15 (*SD*=60.91) in the 2020 cohort and 28.56 (*SD*=48.95) in the 2021 cohort. A Chi-square test of independence demonstrated a statistically significant increase in ointment orders between the 2020 and 2021 cohorts ($x^2(1)=3.9$, $p=.046$). Based on a two-sided Fischer's exact test, the increase in consults seen between the 2020 and 2021 cohorts was significant ($p=.002$) A two-sided Fischer's exact test, demonstrated the increase in ointment ordering for patients who received neuromuscular blockade between the 2020 and 2021 cohorts was statistically significant ($p=.012$)

Implications for Practice: While the frequency of eye care did not have a significant increase after initiation of the protocol, there were clinically significant improvements in ophthalmology consults and the frequency of ointment ordering

Preventing Ocular Surface Disease in the Pediatric Intensive Care Unit

Children who are intubated in the pediatric intensive care unit (PICU) may be at risk for ocular surface disease (OSD). Ocular surface disease describes a range of eye disorders relating to the eyelid, conjunctiva, cornea, tear film, lacrimal glands, and meibomian glands (Craig et al., 2017). Specifically, in the PICU, ineffective protective mechanisms lead to exposure keratopathy. As a result, dryness and insult may result in infection or permanent damage. Exposure keratopathy, a subtype of OSD, can be commonly found in intubated patients and is the leading cause of eye injury in this population (Kousha, Kousha, & Paddle, 2018). Sedatives and neuromuscular blockades relax the facial muscles, resulting in lagophthalmos (incomplete eye closure) and a decreased blink reflex. Fluid overload and positive pressure ventilation can cause edema of the conjunctiva, known as chemosis, resulting in lagophthalmos. Lastly, patient positioning, such as the prone position, can place pressure on the eye or displace the eyelid (Hearne, Hearne, Montgomery, & Lightman, 2018).

Within the PICU population, OSD is a significant problem. In the PICU, disease pathologies of the eye are not life-threatening; therefore, they are not a clinical priority, and the burden of disease with its lasting effects can be substantial. While OSD is preventable, it is frequently underdiagnosed and improperly treated (Bird, Stingly, Stawicki, & Wojda, 2018). Among intubated patients in the PICU, 15% were found to have a corneal injury on arrival, possibly from intubation, and a third of patients developed OSD during their PICU stay (Niemi et al., 2020). Intensive care units (ICU) in general, who provide eye care interventions have demonstrated a lower incidence of exposure keratopathy and significant corneal injuries (Hearne et al., 2018).

In a large Midwestern, urban pediatric tertiary hospital with a PICU, in 2018-2019, there were three patients who sustained significant corneal abrasions and subsequent visual impairment caused by exposure keratopathy. There was not an eye care protocol for intubated patients in the PICU at that time. Since then, when providers place orders for neuromuscular blockade infusions, the options now offer an infusion or infusion bundle with eye ointment as needed. Despite this order, there is a lack of identification and awareness of preventative eye care for intubated patients resulting in increased risk for OSD.

There is an opportunity for OSD prevention in PICU patients who are intubated. The purpose of this quality improvement initiative was to prevent OSD in intubated patients in the PICU. The aim of this project was to increase the frequency of eye care in intubated patients by 10% in a three-month period. The primary outcome measure of interest was the frequency of eye ointment application. Secondary outcome measures included neuromuscular blockade infusion and rate of ophthalmology consults. The Iowa Model for Evidence-Based Practice was the framework to guide this study. The study question was: In intubated patients in the PICU, how did the implementation of a routine, regular eye care protocol affect the frequency of ophthalmology consults?

Review of the Literature

Data on OSD and eye care protocols in the ICU is more limited when compared to other disease pathologies and organ systems studied in acutely ill patients. Most ICU research focuses on improving life-saving measures, and the smaller research pool on ocular health demonstrates a need for more investigation into the implementation of eye care protocols in ICUs. A literature search in PubMed and Medline using the keywords

ocular surface disease, *exposure keratopathy,* and *intensive care unit.* The Boolean operator AND was used. PubMed yielded 221 results and Medline 340 results. Articles between 2010 and 2020 were considered. Further inclusion criteria were publications pertaining to ICU, inpatient diagnosis and management, PICU, and dry eye disease. Exclusion criteria were single-patient case studies, editorial articles, and outpatient settings. A total of nine studies were selected for review. In addition, a search of the American Academy of Ophthalmology (AAO) preferred practice guidelines was performed, and one guideline was reviewed. The DEWS II Report by the Tear Film and Ocular Surface Society (TFOS), a leader in dry eye disease research, was used. A total of 11 publications were selected for this review.

The key concepts sought in the publications were recognition and prevention of OSD. OSD is a broad term encompassing various disease processes of the ocular surface. The wide variety of diseases affecting the ocular surface are not all applicable or typical for the ICU patient population. The most common ocular surface disease found throughout this literature review for ICU patients was exposure keratopathy. Contributory factors of exposure keratopathy for intensive care unit patients include dry eye and lagophthalmos (Akpek et al., 2018; Demirel, Cumurcu, Fırat, Aydogan, & Doğanay, 2014; Jammal et al., 2012; Kuruvilla et al., 2015; McCall, Hussin, Gregory, Dutton, & Richardson, 2016; Niemi et al., 2020; Selvan, Pujari, Sachan, Gupta, & Sharma, 2020). Dry eye disease can be considered a separate type of disease process, especially in the outpatient setting, but for this review, dry eye is a risk factor for exposure keratopathy (Hearne et al., 2018). Lagophthalmos is incomplete eyelid closure, which leaves the conjunctiva or cornea exposed. Niemi et al. (2020) found lagophthalmos was an

independent risk factor for corneal injury. Exploring this topic led to an understanding of how to develop the eye care protocol for the hospital setting.

Lagophthalmos was found to be a significant risk factor for exposure keratopathy by six research studies (Demirel et al., 2014; Jammal et al., 2012; Kuruvilla et al., 2015; McCall et al., 2016; Niemi et al., 2020; Selvan et al., 2020). One study demonstrated 58% of patients with lagophthalmos had a grade two corneal exposure, and children had slightly higher exposure keratopathy pathologies (Selvan, Pujari, Sachan, Gupta, & Sharma, 2020). They also found exposure keratopathy was directly correlated with the degree of lagophthalmos (Selvan et al., 2020). Ocular surface disease was found in 56% of patients with lagophthalmos and in 100% of patients on initial assessment (Selvan et al., 2020; McCall et al., 2016). Furthermore, Jammal et al. (2012) found chemosis contributed to lagophthalmos and exacerbated the exposure of the corneal surface. In addition, the use of sedative and neuromuscular blockade infusions relax the facial muscles and exacerbate lagophthalmos. Kousha et al. (2018) found eyelid closure was an essential factor in mitigating exposure keratopathy. Complete eyelid closure can be achieved by manual repositioning or taping the eyelids so there is no exposure of the conjunctiva or cornea.

Dry eye, defined as a loss of tear film homeostasis, is an important concept to explore when planning interventions to reduce exposure keratopathy (Craig et al., 2017). The physiologic response to lagophthalmos, chemosis, or other processes leaving the ocular surface exposed is a dry eye. The ocular defense mechanisms which keep the eye moist are disturbed and interrupt the tear film formation (Akpek et al., 2018). The exposure of the ocular surface to room air results in the evaporation of moisture from the

eye. An inability to maintain an adequate tear film causes irritation, inflammation, and may contribute to exposure keratopathy (Craig et al., 2017). Even when complete eyelid closure is achieved with taping methods, the blink mechanism is impaired, which reduces the ability to distribute tears over the ocular surface; hence, artificial tears are used to prevent and treat dry eye. However, an ointment is more effective at maintaining moisture than drops due to increased contact time with the ocular surface (Apkek et al., 2018; Craig et al., 2017). Moreover, several medical management therapies used in the ICU can contribute to dry eye. Diuretics, antihistamines, anticholinergics, vasoconstrictors, corticosteroids, and continuous renal replacement therapy are associated with aqueous deficient dry eye. Also, some common conditions in the ICU, such as lymphoma, systemic inflammation, stem cell transplant with or without graft versus host disease, are risk factors for dry eye syndromes (Craig et al., 2017). While there are many causes for dry eye, the risk increases in an unconscious ICU patient.

Eye care protocols were found to be common in the ICU. Studies implementing an eye care protocol established there to be a reduction in exposure keratopathy and corneal injuries (Demirel et al., 2014; Kousha et al., 2018; McCall et al., 2016; Niemi et al., 2020). In fact, McCall et al. (2016) found the incidence of eye care improved from 19% to 96% after introducing an eye care protocol. They found adherence to the eye care protocol decreased abnormalities from 39% to 11% (McCall et al., 2016). Even when patients had ointment application without complete eyelid closure, the rates of corneal injury did not increase; therefore, artificial tear ointment was recommended as a method for preventing OSD (McCall et al., 2016). Niemi et al. (2020) found OSD was present in

15% of intubated patients admitted to the PICU, with 32.2% of patients developing OSD while intubated, but after extubation, only 8.6% of patients had mild OSD.

Exposure Keratopathy was associated with morbidity and mortality. Kurvilla et al. (2015) noted that prolonged ventilation and ICU stay increased the risk for exposure keratopathy. Kousha at al. (2018) found a correlation between the degree of organ dysfunction and the risk of exposure keratopathy. Lastly, Kurvilla et al. (2015) discovered that 51% of patients with exposure keratopathy died. For clinicians, understanding the severity of illness as a risk for ocular injuries may be an essential factor in the prevention of OSD.

Current practice guidelines recommend monitoring of the ocular surface in ICU patients. Treatment recommendations in regard to maintaining an adequate moisture barrier for the eye are presented in a stepwise approach. Initial steps include lid hygiene and preservative-free ocular lubricants as artificial tears (Apkek et al., 2018). The use of preservative-free artificial tear ointment is a safe and effective method to maintain moisture on the ocular surface. A second-tier treatment includes prevention of tear evaporation with moisture chamber goggles or similar modalities. Beyond these listed interventions, the involvement of an ophthalmologist for expert opinion and additional therapies is recommended (Apkek et al., 2018).

There are gaps in the literature of OSD for the pediatric population because most studies were done in adult ICUs. Only two studies included in this review occurred in the PICU setting, and another two studies were a combined ICU (Demirel et al., 2014; Niemi et al., 2020; McCall et al., 2016; Selvan et al., 2020). Interestingly, Selvan et al., (2020) found 56% of children had corneal exposure compared to 43% of adults, but more study

is needed. Regardless, no studies included long-term follow-up for continued assessment of visual acuity changes related to OSD.

In summary, while the physiology and causality of exposure keratopathy is understood, there is still an opportunity for improvement in minimizing this complication. There is some evidence demonstrating the use of eye care protocols to mitigate vision loss associated with ocular surface injuries sustained while intubated. Most research exists in adult ICUs, and therefore, a focus on PICU eye care protocols is needed. The strengths of this review were in the large studies obtained (Demirel et al., 2014; Kousha et al., 2018; Kurivilla et al., 2015; Niemi et al., 2020). Limitations of this literature review consisted of cohort and observation studies and no randomized control trials. The Iowa Model of Evidence-Based Practice will be used as a theoretical framework to guide this quality improvement project to improve eye care in the PICU. Education for staff was a common theme among the studies that included eye care protocols. The protocols were in flowchart format for easy visualization and compliance. Artificial tear ointment was the lubricating method used in these studies and is proven to be effective at preventing exposure keratopathy in intubated patients (Jammal et al., 2012).

The evidence-based framework to guide this project was the Iowa Model of Evidence-Based Practice. This theoretical framework assisted in identifying the problem focus trigger of OSD. In addition, OSD has become a priority for the PICU. This literature review contained relevant research and related literature (i.e., AAO practice guideline) to provide a sufficient research-based pilot change in practice. An eye care protocol was piloted in the PICU.

Method

Design

This was a descriptive, cohort design utilizing a retrospective medical record review. Reviews occurred of PICU patients from January 15th, 2020 to April 15th, 2020 for baseline data on PICU eye care practice. Then, a three-month pilot study from January 15th, 2021 to April 15th, 2021 was conducted after the initiation of an eye care protocol in the PICU.

Setting

The setting was a large, Midwestern, urban PICU in a 402-bed quaternary care pediatric hospital. This hospital serves over 3 million residents, however there are many children referred from out of state. Approximately 275,000 patient visits occur each year, and over 3,400 people are employed (About St. Louis Children's Hospital, 2020). The 40-bed PICU has 145 FTEs. Patients range in age from two-days through approximately 25-years of age.

Sample

A convenience sample of intubated children in the PICU from two cohorts was used (i.e., 2020 and 2021). The inclusion criteria were admission to the PICU and intubation with mechanical ventilation for greater than 12-hours. Exclusion criteria included patients not admitted to the PICU, intubated less than 12-hours, significant eye trauma, and those meeting criteria for brain death.

Approval

Approval for this pilot project was obtained by the PICU Nurse Manager, Nurse Practitioner Lead, and the quality and safety Physician. Additional approvals were obtained from the Doctor of Nursing Practice Committee, graduate school, and the

university's Institutional Review Board (IRB). There was minimal risk to patients as all data was deidentified. Benefits included prevention of OSD.

Data Collection/Analysis

Data was deidentified and stored on a password-protected computer and removable drive owned by the primary investigator. The data was coded as 20-1, 20-2, 20-3, etcetera, for those reviewed from 2020, and 21-1, 21-2, 21-3, etcetera, for those reviewed in 2021. While no demographic data was collected, outcome data measures obtained including artificial tear ointment administration, neuromuscular blockade infusion, and the number of ophthalmology consults were recorded. Inferential statistics of t-test and chi-square were utilized.

Procedures

After a literature review and consultation with clinical experts, the first step in the preliminary phase of this project was to develop the eye care protocol, which helped guide eye care practice in the PICU (Appendix A). The next step was to have the ordering process for neuromuscular blockade infusions in the electronic health record (EHR) changed to align with the eye care protocol. The implementation phase of this project first involved education to the bedside nurses and providers of the eye care protocol. Information dissemination occurred informally via signs posted around the unit, video posted on the PICU teams app, and presented at a virtual staff nurse meeting. This project's implementation phase consisted of posting a copy of the eye care protocol algorithm at each bedside for the staff nurses' reference. Data collection occurred for the first three months following the implementation of the eye care protocol. Due to limited access to ocular tools, such as fluorescein stain, blue light, and slit lamps, bedside

recognition of signs and symptoms indicating impaired corneal integrity were used to prompt an ophthalmology consult. After a discussion with the ophthalmology service, a set of recommendations were incorporated into the eye care protocol for what constitutes concerning assessment findings which should trigger an ophthalmology consult.

Results

A total of 96 (N = 96) intubated patients who met the inclusion criteria were identified in the 2020 and 2021 cohorts. Of these, 53 intubated patients were in the 2020 cohort (n=53) and 43 intubated patients were in the 2021 cohort (n=43). In the 2020 cohort, 37.7% (n=20) had eye ointment ordered; whereas, in the 2021 cohort 58% (n=25) had eye ointment ordered. A Chi-square test of independence demonstrated a statistically significant increase between the 2020 cohort orders and 2021 cohort orders ($x^2(1)=3.9$, p=.046). Despite an order, the mean number of ointment applications for patients after an artificial tear ointment order was placed was 33.15 (SD=60.91) in the 2020 cohort and 28.56 (SD=48.95) in the 2021 cohort. Based on a two-tailed Wilcox signed rank test, the results were not statistically significant (V=92.5, z=-0.1, p= .920).

Ophthalmology consults were ordered on 7.5% (n=4) in the 2020 cohort and 23.2% (n=10) of patients in the 2021 cohort (Appendix B). Based on a two-sided Fischer's exact test, the increase in consults between the 2020 and 2021 cohorts was significant (p=.002). For patients who had ophthalmology consults, the mean number of ointment applications increased from 74 (SD=126.03) in the 2020 cohort to 102 (SD=94.11) in the 2021 cohort. Based on a paired samples t-test, the difference in the two means was not statistically significant ($t(3)=0.28$, p=.798).

Neuromuscular blockade was induced on 39.6% (*n*=21) of patients in the 2020 cohort and 58% (*n*=25) in the 2021 cohort. Of those patients who received neuromuscular blockade, ointment was ordered for 47.6% (*n*=10) in 2020 and 60% (*n*=15) in 2021. Based on a two-sided Fischer's exact test, the increase in ointment ordering for patients who received neuromuscular blockade between the 2020 and 2021 cohorts was statistically significant (*p*=.012). The mean number of eye ointment applications for patients who received neuromuscular blockade increased from 9.24 (*SD*=20.39) in the 2020 cohort to 19.38 (*SD*=49.42) in the 2021 cohort. The difference between the two means was not statistically significant based on a paired samples t-test (*t*(20)= -0.84, *p*=.412).

Discussion

The development and implementation of an eye care protocol in the PICU was associated with an increased number of ophthalmology consults. The increase was both clinically and statistically significant. While an increase in consults could indicate a greater incidence of corneal injuries, another reason for the increase could be attributed to heightened awareness of OSD and recognition of clinical signs of a compromised ocular surface which would prompt an ophthalmology consult. Implications of increased ophthalmology consults include improved eye care and early interventions directed by specialists, less patients with visual acuity impairments after discharge, and reduced financial burden related to outpatient follow-up.

The occurrence of ointment orders for intubated patients increased from 37.7% in the 2020 cohort to 58% of in the 2021 cohort, demonstrating clinically and statistically significant improvement in patients who had eye ointment ordered (*p*=.046). Ointment

orders for patients who received neuromuscular blockade also exhibited a significant increase. While ointment orders showed a clinically significant increase, the mean ointment applications did not increase after implementation of an eye care protocol. There is still room to improve the frequency of ointment applications and ointment orders. When examining the outcomes, notably, the ordering of artificial tear ointment for intubated patients is less than 60%, even after introducing the eye care protocol. Reasons for this phenomenon could include uncertainty in using eye ointment in patients who had spontaneous eye opening. Despite education on the evidence-based frequency of ointment administration and no exclusion for patients with spontaneous eye opening in the eye care protocol, some nurses reported feeling the administration of eye ointment in patients with spontaneous eye opening was irritating and disturbed the visual field. Another potential reason for low administration rates is ocular health is of low priority in the context of critical care and other compromised organ systems. Of note, the requested changes to the neuromuscular blockade infusion order bundle were unable to be implemented into the EHR due to system-wide constraints related to precedence of COVID-19 EHR changes. Presumably, if the neuromuscular blockade order changes were implemented, all patients with neuromuscular blockade would receive scheduled eye ointment.

A strength of this study was the homogeneity of the two cohorts. Limitations of this study include non-randomized design, single-center study, small sample size, and uncontrolled variables. The data was not controlled for artificial tear ointment order specifics, such as, if it was a scheduled frequency or only ordered as need per nurse discretion; nor was it controlled for length of intubation. Recommendations for further

study on OSD in the PICU include adjusting the neuromuscular blockade infusion bundle in the EHR as previously planned and to include artificial tear ointment in the ventilator order so all intubated patients automatically receive an eye ointment order.

Conclusion

In summary, the implementation of a PICU eye care protocol demonstrated clinically significant increases in ophthalmology consults and artificial tear ointment ordering. The results indicated the eye care protocol was an effective instrument for improving eye care practices. More changes to the EHR order process are a strategic next step in finding greater improvements for eye ointment ordering and administration adherence of intubated patients. While the improvement in ointment applications was not significant, the increase in ophthalmology consults and orders demonstrates early progress in eye care practices and symptom recognition of a compromised ocular surface.

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Appendix A

Figure 1. PICU Eye Care Protocol

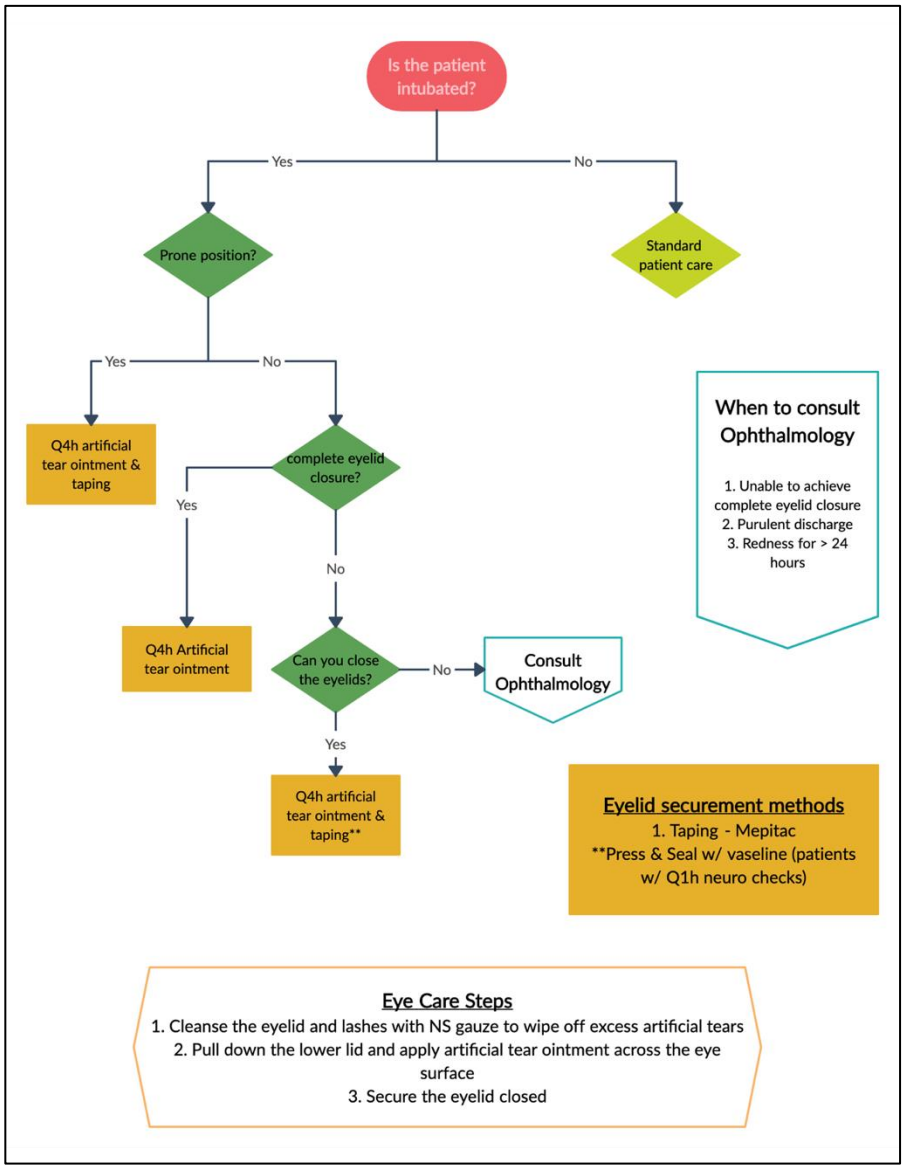

Figure 1. The PICU Eye Care Protocol was developed in algorithm format for ease of use at the bed side. Adapted from Kousha at al. (2018); McCall et al. (2016); Niemi et al. (2020).

Appendix B

Figure 2. Ophthalmology Consults

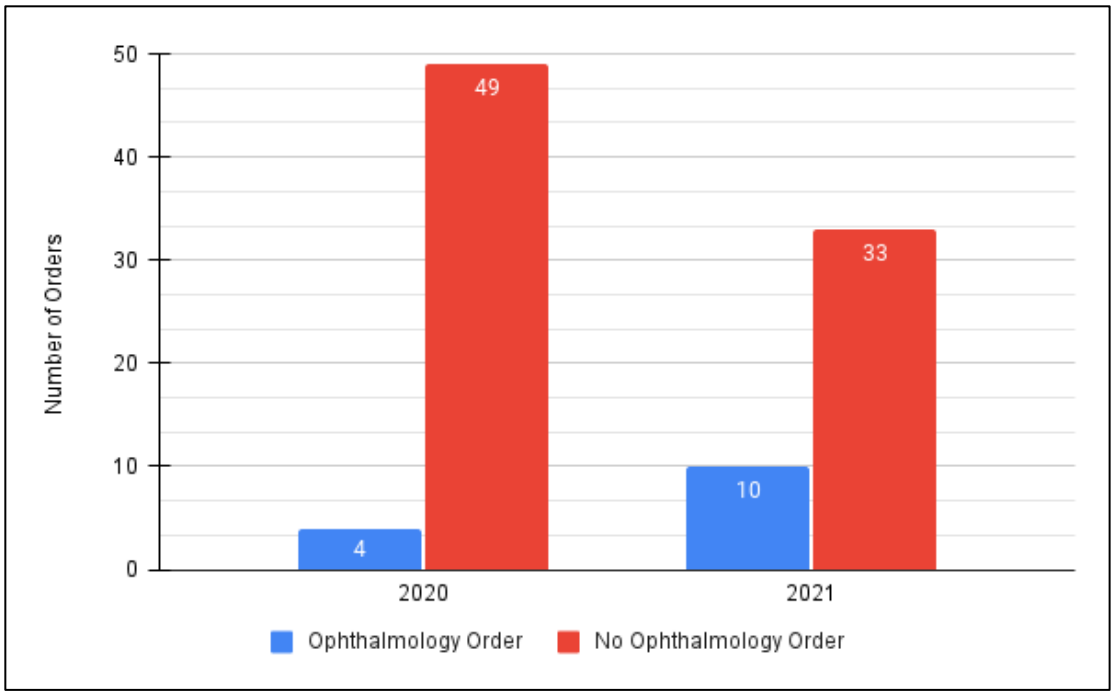

Figure 2. Comparing the difference in ophthalmology consult orders (blue) between 2020 and 2021, while also examining the ratio of patients with and without ophthalmology consult orders.