Post-traumatic endophthalmitis prophylaxis: a systematic review and meta-analysis

Joshua M. Van Swol\textsuperscript{1*}, Walter K. Myers\textsuperscript{1}, Jonathan A. Beall\textsuperscript{2}, Miriam M. Atteya\textsuperscript{1} and Jeffrey P. Blice\textsuperscript{3}

Abstract

Purpose: The goal of this study is to determine if certain aspects of endophthalmitis prophylaxis strategies are superior to others.

Design: This investigation is a systematic review and meta-analysis.

Methods: All studies specifying a type of prophylaxis strategy and resulting rates of endophthalmitis were included. Time course, method of administration, and antibiotic regimen, and confounding factors were collected and included for meta-regression.

Results: Time courses greater than 24 h did not significantly improve outcomes. Likewise, intraocular and/or intravenous antibiotic administration methods did not significantly outperform oral administration. No antibiotic regimens performed differently from vancomycin/\(\geq 3\)rd generation cephalosporin except for ciprofloxacin monotherapy which yielded significantly worse outcomes.

Conclusions: Future antibiotic strategies should strongly consider the risks of antibiotic treatment > 24 h and administration methods other than the oral antibiotic forms. In addition, providers should be wary of using ciprofloxacin monotherapy for endophthalmitis prophylaxis when treating open globe injuries.

Keywords: Open globe, Post-traumatic, Endophthalmitis, Meta-analysis, Systematic review, Prophylaxis

Introduction

While treatment strategies have improved, endophthalmitis remains a serious ophthalmologic disease. Endophthalmitis, a purulent inflammatory condition of the eye, can result in catastrophic complications such as reduced visual acuity, blindness, and can even necessitate an enucleation in refractory cases [1]. For this reason, it is considered one of the leading causes of monocular vision loss [2]. Endophthalmitis can occur due to a systemic infection reaching the eyes, known as endogenous endophthalmitis, but most commonly occurs through trauma, surgery, or corneal infections, otherwise called exogenous endophthalmitis [3]. Traumatic endophthalmitis risk factors include intraocular foreign bodies, rural trauma, wound size, lens rupture, and delayed repair [2]. However, a consensus on the most favorable prophylaxis management remains unreached [4]. Finding an optimum prophylaxis regimen could reduce the ocular morbidity related to endophthalmitis. The aim of this study is to evaluate different prophylactic approaches in the literature too discover factors correlated with a lower incidence of endophthalmitis. In this investigation, a comprehensive systematic review was performed to search for studies using standard endophthalmitis prophylaxis protocols after open globe injuries (OGIs) and a meta-regression was performed to evaluate different treatment factors.
Materials and methods

Search criteria
This study was done according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [5]. Detailed search strategies were developed for the following three databases: PubMed (U.S. National Library of Medicine, National Institutes of Health), Cochrane Library (Wiley), and CINAHL (EBSCO). Databases were searched from date of inception through May 18, 2022. The search strategy included the keywords: “endophthalmitis,” “traumatic,” and “open globe.” The PubMed search strategy was reformatted to be used in the two other databases. Additional file 1: Appendix A details the search strategy and results for each database. References of relevant articles were searched to verify the search strategy as well as to include any articles not captured by the search. The review management software Covidence (Veritas Health Innovation Ltd, Melbourne, Australia) was used for study selection.

Selection criteria
All studies that specified uniform endophthalmitis prophylaxis strategies for patients with OGIs were included. Double- or single-blinded randomized controlled trials and randomized comparison trials, non-randomized controlled trials, and prospective or retrospective observational studies were considered for inclusion. Exclusion criteria included unspecified prophylaxis treatment, starting samples other than OGIs, non-uniform prophylaxis, and prophylaxis not well documented. The remaining exclusion criteria included non-English language, review articles, non-human studies, case reports with less than five patients, duplicates, and inaccessible articles. Two reviewers (J.M.V and M.M.A.) independently screened titles and abstracts to identify all articles that met the inclusion criteria; then full texts of these articles were read to assess which articles would be included in the final analysis. A third reviewer (W.K.M.) resolved any conflicts between reviewers. The Oxford Center for Evidence-Based Medicine criteria was used to critically evaluate the level of evidence of all articles included [6]. The Cochrane Handbook for Systematic Reviews of Interventions version 6.0 was used to assess risk of bias [7]. To evaluate the risk of bias for each study the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool was used for each aspect outlined in Fig. 1, bias was graded as low, high, or unclear. J.M.V and M.M.A. independently performed a risk of bias assessment on all studies and compared results for consistency of assessment; disagreements were resolved through discussion with W.K.M.

Data extraction
Two authors (J.M.V and M.M.A) performed data extraction independently and compared results for accuracy. Extracted data included all information reported in Table 1, the study name, patient demographics, country of origin, total number of patients receiving prophylaxis, prophylaxis management protocol, and the total number of patients in each group who developed endophthalmitis.

Data analysis
Mixed effects meta-regression models were constructed to investigate the effect of prophylactic regimens, treatment duration, and treatment administration on the rate of endophthalmitis. Summary statistics shown in Supplemental Tables 1, 2 and 3 based on variables shown in Table 2 demonstrated that there were combinations of days, administrations, and regimens that were not observed in the data. The three individual models were constructed in lieu of a model which contained all covariates of interest due to the number of unobserved combinations of the covariates. IOFB will be included in each of these models to control for potential confounding. Analyses were completed using the rma function from the metafor R package and R v.4.0.3 [23, 24].

Results

Search results and study characteristics
The literature search yielded 1823 studies and 16 studies [8–22, 25] were included in the final analysis. A total of 1229 studies were excluded due to meeting exclusion criteria or lacking the necessary factors for inclusion. A diagram outlining the full search process is included in Fig. 1. One included study was a randomized controlled trial [25], 5 were cohort studies [13, 14, 17–19], and 10 were case series [8–12, 15–22], which were level 1b, 2b and 4, respectively according to the Oxford Level of Evidence [26]. Critical appraisal of studies indicated an acceptably low risk of bias for most studies (Fig. 2). Potential sources of bias were most pronounced in bias due to selection of participants into the study. This was most often due to strict exclusion criteria. Our studies were published between 1994 and 2019 and were from 10 different countries. A total of 8,582 patients and 9,543 eyes were included from all the studies. A total of 358 patients from all included studies developed endophthalmitis.

Effect of prophylactic regimens
Our search strategy yielded the following groups of antibiotic regimens for meta-analysis: ≥ 3rd generation cephalosporin (ceftazidime or cefepime) + vancomycin (regimen 1), 1st generation cephalosporin (cefalotin
or cefazolin) + aminoglycoside (gentamicin or netilmicin) (regimen 2), ciprofloxacin monotherapy (regimen 3), and unspecified cephalosporin monotherapy (regimen 4). Table 3 shows the results for the regimen model. The parameter estimates for this model show that, relative to treatment regimen 1, regimens 2 and 4 do not significantly alter the odds of outcome (p-values: 0.532 and 0.621, and CI's (confidence intervals): -0.579–1.121 and -0.698–1.170, respectively). The parameter estimate for regimen 3 indicates that, relative to regimen 1, there is a significant increase in the odds of outcome (p-value: 0.000 and CI: 0.597–2.348). Specifically, the parameter estimate for regimen 3 is 1.472, which indicates that the odds of outcome for patients' treatment under regimen 3 relative to regimen 1 is 4.36 (exp (1.472)), which represents a greater than fourfold increase in the odds of outcome. IOFB was not a significant predictor of outcome.

**Effect of treatment duration**

Table 4 shows the results for the days model. The parameter estimates for this model show that, relative to 1 day of treatment, treatment durations of 2, 3 and 5 days do not significantly alter the odds of outcome (p-values: 0.139, 0.470, and 0.486, CI's: -2.724–0.379, -0.708–1.536, and -0.739–1.555, respectively). IOFB was not a significant predictor of outcome.

**Effect of treatment administration**

In the included studies, we found oral (type 1), intravenous (IV) (type 2), and IV plus intraocular (type 3) antibiotic administration utilized. Table 5 shows the results
Table 1  Included Studies Characteristics

| Study (ref) | Place | OLE | Study Design | Patients (No.) | Eyes (No.) | Female (%) | Age (Yr.) | Median | SD | Range |
|-------------|-------|-----|--------------|----------------|------------|------------|-----------|--------|----|--------|
| Abouammoh et al, 2018 [8] | SA | 4 | R | 994 | 994 | 12.5 | 25.7 | 8.6 | 0.75–70 |
| Al-Mezaine et al, 2010 [9] | SA | 4 | R | 629 | 629 | 12.6 | 25 | 14.8 | - |
| Andreoli et al, 2009 [10] | USA | 4 | R | 558 | 558 | 19.2 | 40.1 | - | 1–95 |
| Dehghani et al, 2018 [11] | Iran | 4 | R | 918 | 918 | 13.6 | 35.3 | 15.8 | - |
| Duch-Samper et al, 1997 [12] | Spain | 4 | R | 403 | 403 | - | - | - | - |
| Du Toit et al, 2017 [25] | Russia | 2b | P | 300 | 300 | 23.3 | - | - | - |
| Gupta et al, 2010 [13] | India | 2b | P | 174 | 174 | 48 | 21.6 | - | - |
| Huang et al, 2016 [14] | USA | 2b | R | 224 | 224 | 18.8 | 35 | 22 | - |
| Mansouri et al, 2009 [15] | Iran | 4 | R | 2340 | 2340 | 18.6 | 22.4 | 16.7 | - |
| Nakayama et al, 2019 [16] | Brazil | 4 | R | 453 | 453 | 42.3 | 15.6 | - | - |
| Narang et al, 2003 [17] | India | 2b | P | 70 | 70 | - | - | - | - |
| Rafati et al, 2013 [18] | Iran | 2b | P | 111 | 111 | 17.1 | 22.7 | 12.7 | - |
| Soheilian et al, 2007 [19] | Iran | 2b | P | 346 | 346 | 13.6 | - | - | - |
| Soliman et al, 2008 [20] | Egypt | 4 | P | 147 | 153 | 20 | 22 | - | 0.17–76 |
| Verbraeken et al, 2008 [21] | Egypt | 4 | P | 1255 | 1255 | 26.5 | 46 | 19.9 | 2–98 |
| Verbraeken et al, 1994 [22] | Belgium | 4 | P | 615 | 615 | - | - | - | - |

When necessary, data reported in two separate cohorts were combined into a single group for this data table

Abbreviations: OLE Oxford Centre for Evidence-Based Medicine Level of Evidence, No. Number, Yr. Year, SD Standard Deviation, SA Saudi Arabia, USA United States of America, R Retrospective, P Prospective

Table 2  Endophthalmitis Rate and Contributing Factors in the Included Studies

| Study (ref) | Antibiotic(s) | Route | Treatment Duration (days) | Endophthalmitis (%) | IOFB (%) | Presentation < 24 h (%) | Lens Injury (%) |
|-------------|---------------|-------|---------------------------|---------------------|----------|-------------------------|-----------------|
| Abouammoh et al, 2018 [8] | V/C | IV | 5 | 3.74 | 13.3 | 88.1 | - |
| | V/C | IV/IO | 5 | 1.70 | 19.3 | 89.8 | - |
| Al-Mezaine et al, 2010 [9] | V/C | IV | 5 | 3.50 | 1.9 | 88.2 | 28.9 |
| Andreoli et al, 2009 [10] | V/C | IV | 2 | 0.90 | 17.0 | - | - |
| Dehghani et al, 2018 [11] | C/A | IV | 1 | 2.02 | 16.1 | - | - |
| | Cip | Oral | 3 | 3.66 | 20.5 | - | - |
| Duch-Samper et al, 1997 [12] | C/A | IV | 3 | 4.22 | - | - | - |
| Du Toit et al, 2017 [25] | C | IV | 3 | 2.00 | 0 | - | - |
| | C | Oral | 3 | 2.67 | 0 | - | - |
| Gupta et al, 2010 [13] | Cip | IV | 5 | 11.49 | 5.7 | - | - |
| Huang et al, 2016 [14] | V/C | IV | 2 | 0.89 | 20.1 | - | 25.9 |
| Mansouri et al, 2009 [15] | C/A | IV | 3 | 5.00 | 24.0 | - | - |
| Nakayama et al, 2019 [16] | C/A | - | - | 6.62 | - | - | - |
| Narang et al, 2003 [17] | Cip | IV | 3 | 18.42 | 21.1 | - | 75.0 |
| | V/C | IV/IO | 3 | 6.25 | 25.0 | - | 14.4 |
| Rafati et al, 2013 [18] | C/A | IV | 5 | 4.50 | 18.9 | - | 30.5 |
| Soheilian et al, 2007 [19] | C/A | IV | 5 | 4.79 | 15.0 | - | - |
| | C/A | IV/IO | 5 | 0.56 | 15.1 | - | - |
| Soliman et al, 2008 [20] | V/C | IV/IO | 5 | 6.54 | 14.4 | - | - |
| Tabatabaei et al, 2016 [21] | V/C | IV | 3 | 2.14 | 4.30 | - | - |
| | V/C | Oral | 3 | 2.16 | - | - | - |
| Verbraeken et al, 1994 [22] | C/A | IV | 1 | 4.07 | 37.7 | - | - |

Abbreviations: IOFB Intraocular foreign body, h hour(s), V Vancomycin, C Cephalosporin, A Aminoglycoside, Cip Ciprofloxacin, IV Intravenous, IO Intraocular
for the administration model. The parameter estimates for this model show that, relative to administration type 1, administration types 2 and 3 do not significantly alter the odds of outcome ($p$-values: 0.831 and 0.942, CI’s: -1.194–1.485, -1.626–1.510, respectively). Again, IOFB was not a significant predictor of outcome.

### Discussion

#### Duration of antibiotic administration

Prophylaxis of varying durations is used for prevention of endophthalmitis. The American College of Surgeons and the Surgical infection society found that antimicrobials should be discontinued after skin closure for most procedures; however, this has not been well studied for OGI repair [27]. The risks of prolonged prophylactic regimens are also unclear but prior studies have shown that antibiotics are a leading cause of adverse drug events and emergency department visits [28]. Our analysis was not able to conclude that durations of prophylaxis longer than 1 day achieved statistically better results. Studies with larger samples of patients may be needed to more conclusively elucidate this relationship. However, if longer durations were of little value, then the risks of antibiotic administration > 24 h could outweigh the theoretical benefit.

#### Method of antibiotic administration

Although their penetration of the blood-retinal barrier is poor, systemic antibiotics are generally used for endophthalmitis prophylaxis after OGI though there is little agreement on the route of administration [29]. When possible, using oral instead of IV antibiotics can reduce adverse drug-related events and decrease costs [30, 31]. Further, various studies recommend intravitreal antibiotics for high-risk scenarios cases [32–35] though robust clinical evidence for this is lacking. Our results did not find a statistically significant difference in outcomes when IV antibiotics were administered instead of the oral forms. Similarly, we did not find prophylaxis protocols that included the use of intraocular antimicrobials in severe cases to achieve statistically superior results.
Due to the relatively small numbers of total patients in studies evaluating oral antibiotic and intraocular microbial strategies, more studies investigating these methods are needed for meta-analysis to evaluate this aspect of endophthalmitis prophylaxis more definitively. However, if this lack of superiority is found to be true, then oral antibiotics alone could be a reasonable prophylaxis protocol for OGI.

**Prophylactic antibiotic regimen**

We compared common antibiotic regimens used to prevent endophthalmitis following OGI. While the success of most regimens did not significantly differ, using ciprofloxacin monotherapy was shown to be significantly less successful than utilizing ≥ 3rd generation cephalosporins with vancomycin. Based on these results, using any of the studied regimens besides ciprofloxacin monotherapy for endophthalmitis prophylaxis is a reasonable approach. However, the choice of an antibiotic regimen for post-traumatic endophthalmitis prophylaxis must consider microbial coverage as a function of spectrum and intraocular bioavailability, along with patient-specific characteristics. As intraocular penetration, antibiotic coverage and patient specific side effects are beyond the scope of this study, future studies can compare the risks and benefits among the three regimens found to have similar efficacy in this study.

While other regimens were used in the literature including levofloxacin and moxifloxacin, unfortunately, there was an insufficient number to allow for inclusion in the meta-analysis. Indeed, previous reviews have recommended levofloxacin and moxifloxacin for prophylaxis of OGIs due to their wide coverage and high intraocular bioavailability in the uninflamed eye [36–38]. Yet, neither of these medications are as active as ciprofloxacin against pseudomonas [29, 39, 40].

**Timing of treatment**

Time to treatment has been described as a major factor in endophthalmitis development following ocular trauma and could be more important than prophylactic regimen [9]. Indeed, Dehghani et al. [11] report no significant difference in endophthalmitis risk between antibiotic regimens when presentation following ocular trauma is delayed. Unfortunately, we could not include timing of treatment in our analysis due to the variability in how studies reported this variable; however, data was extracted, reported in Table 6, and reviewed in this section. Thus, please note that Table 6 is merely a review of literature and it not part of the meta-analysis in this study.

Tabatabaei et al. [21] report a trend towards increased time between trauma and surgery for those who developed endophthalmitis (16 ± 3 [Mean ± SD; hours]) with respect to all study participants (13 ± 5). Other authors report timing of treatment categorically for patients who do and do not develop post-traumatic endophthalmitis (Table 6). Huang et al. [14] found a significant increase in the development of endophthalmitis when the interval between injury and presentation was greater than 48 h. Al-Mezaine et al. [9] report a similar finding when presentation is greater than 24 h. However, Andreoli et al. [10] did not find that presenting later than 5 h put patients at a higher risk. When considering the interval between injury and surgical repair, delays greater than 48 h were shown to be significant but waiting 12 h to perform the surgery was not. Collectively, these studies designate delayed treatment as a key element in endophthalmitis development.

**Other influencing factors**

In addition to time to presentation and treatment, the success of endophthalmitis prophylaxis is linked to other

| Author(s)            | Variable(s)                                      | Endophthalmitis | P-value   |
|----------------------|--------------------------------------------------|-----------------|-----------|
| Al-Mezaine et al. 2010 [9] | Interval between trauma and presentation ≤ 24 h (n = 555) | 7 (1.26%)       | 0.008*    |
|                      | Interval between trauma and presentation > 24 h (n = 74)   | 5 (6.76%)       |           |
| Andreoli et al. 2009 [10] | Time from injury to presentation ≤ 5 h (n = 229)       | 4 (1.75%)       | 0.19      |
|                      | Time from injury to presentation > 5 h (n = 229)        | 1 (0.4%)        |           |
|                      | Time from injury to surgical repair ≤ 12 h (n = 229)    | 1 (0.5%)        | 0.65      |
|                      | Time from injury to surgical repair > 12 h (n = 229)    | 4 (1.4%)        |           |
| Huang et al. 2016 [14] | Time from injury to presentation > 48 h (n = 15)        | 4 (26.7%)       | 0.0002*   |
|                      | Time from injury to presentation < 48 h (n = 207)       | 1 (0.483%)      |           |
|                      | Time from injury to globe repair > 48 h (n = 17)        | 4 (23.5%)       | 0.0003*   |
|                      | Time from injury to globe repair < 48 h (n = 205)       | 1 (0.488%)      |           |

Abbreviations: h hour(s), d day(s)

* Statistically significant at 5% level of significance
influencing factors. Variables such as lens disruption, wound cleanliness, rural setting, and intraocular foreign bodies could all contribute to a worse prognosis, even with a standardized prophylactic regimen. Both Sabaci et al. [41] and Thompson et al. [42] found an increased prevalence of endophthalmitis among patients with lens disruption. Additionally, cleanliness of the wound as well as the rural setting are associated with increased risk, primarily due to the presence of more virulent bacteria such as Bacillus [4]. Unfortunately, the frequency of IOFB was the only risk factor reported frequently enough to consider in our analysis and we found that it was not significantly different among any of the comparison groups. Notably, some studies combine other risk factors with delayed treatment to discover particularly high-risk groups. For example, Al-Mezaine et al. [9] report an increased endophthalmitis risk when patients who presented 24 h after injury also had a rural address or intraocular foreign body.

Limitations
This meta-analysis included 9 retrospective and 7 prospective studies. The majority of these are either case series or cohort studies, with one randomized control trial [25] that studied the effect of just two different antibiotic prophylaxis regimens. As confounders are a major concern with trauma cases in which randomization and controlling are difficult to perform, outcomes may not be representative of the intended investigations. Although these studies came from 9 countries, only articles in the English language were included in the present paper. Additionally, our analysis is limited to the existing literature, which means that our sample may not represent the true population of open globe injuries. Moreover, some methods of endophthalmitis prophylaxis were much more commonly done, which left smaller sample sizes available from which to compare strategies that differed from the conventional approach; this phenomenon yielded less certainty to the negative findings of our study. Finally, the variability in how factors were reported in each article did not allow for analysis of some variables, which could be confounding factors.

Conclusion
Post-traumatic endophthalmitis is an uncommon complication of open globe injury that often has poor outcomes. Although open globe injuries are a common ocular emergency, prophylactic strategies to prevent endophthalmitis are non-uniform across practices, a reflection of the overall lack of large multicenter randomized control trials. This study aimed to address this gap by utilizing data extracted from systematic review and employing meta-analysis to elucidate significant differences. We addressed the time course, route, and choice of antibiotics while highlighting prognostic factors that should be considered when evaluating patients with ocular trauma. In our meta-analysis, we found ciprofloxacin monotherapy to perform significantly worse than other antibiotics. No specific time course or route of antibiotic administration was significantly associated with better outcomes. However, in our systematic review, we found that in many studies, earlier OGI presentation and treatment was significantly associated with better outcomes. These findings can help guide future studies and treatment protocols utilized for endophthalmitis prophylaxis in open globe injuries.

Abbreviations
OGI: Open globe injury; IOFB: Intraocular foreign body; IV: Intravenous.

Supplementary Information
The online version contains supplementary material available at https://doi.org/10.1186/s12348-022-00317-y.

Additional file 1: Appendix A. Search Strategies.

Additional file 2: Supplemental Table 1. 2x2 Table of Treatment Durations and Administrations.

Additional file 3: Supplemental Table 2. 2x2 Table of Treatment Durations and Regimens.

Additional file 4: Supplemental Table 3. 2x2 Table of Treatment Regimens and Administrations.

Acknowledgements
None.

Disclaimer
Views expressed in the submitted article represent the views of the authors and not an official position of an organization or donor.

Financial support
None.

Other contributors
None.

Authors’ contributions
Van Swol – Systematic review, writing all manuscript sections, data extraction, paper submission, directed project. Myers – Discussion and results writing. Beall – Performing statistics, writing the statistical methods section. Atteya – Systematic review, data extraction, discussion writing. Blice – Providing expert information and editing all sections of the manuscript. The author(s) read and approved the final manuscript.

Funding
None.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.
References

1. Sadegi MA, Hassan M, Agarwal A et al (2015) Endogenous endophthalmitis: diagnosis, management, and prognosis. J Ophthalmic Inflamm Infect 5(1):32. https://doi.org/10.1186/s12348-015-0063-y

2. Ozek S, Ozmen MC (2017) Traumatic endophthalmitis. In: Yan H (ed) Mechanical ocular trauma: current consensus and controversy. Gateway East, Singapore: Springer Singapore, pp 69–92

3. Durand ML (2013) Endophthalmitis. Clin Microbiol Infect 19(3):227–234. https://doi.org/10.1111/cmi.12118

4. Lorch A, Sobrin L (2013) Prophylactic antibiotics in posttraumatic infectious endophthalmitis. Int Ophthal Clin 53(4):167–176. https://doi.org/10.1097/I0N.0b013e3182a12a1b

5. Panic N, Leoncini E, de Velbis G et al (2013) Evaluation of the endorsement of the preferred reporting items for systematic review and meta-analysis (PRISMA) statement on the quality of published systematic review and meta-analyses. PLoS ONE 8(12):e83138. https://doi.org/10.1371/journal.pone.0083138

6. Howick J (2011) The Oxford 2011 Levels of Evidence. http://www.cebm.net/index.aspx?o=5653

7. Higgins JPT (2008) Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.1. The Cochrane Collaboration. http://www.cochrane-handbook.org

8. Abouammmoh MA, Al-Mousa A, Gogandi M et al (2018) Prophylactic intravitreal antibiotics reduce the risk of post-traumatic endophthalmitis after repair of open globe injuries. Acta Ophthalmol 96(3):e361–e365. https://doi.org/10.1111/aao.13531

9. Al-Mezaine HS, Osman EA, Kangave D, Abu El-Asrar AM (2010) Risk factors for culture-positive endophthalmitis after repair of open globe injuries. Eur J Ophthal 20(1):201–208. https://doi.org/10.1177/11206721100200128

10. Andreoli CM, Andreoli MT, Kloek CE et al (2009) Low rate of endophthalmitis in a large series of open globe injuries. Am J Ophthal 147(4):601–608 e2. https://doi.org/10.1016/j.ajo.2008.10.023

11. Dehghani A, Rafieimanzelat AM, Ghadiri K et al (2018) Post-traumatic endophthalmitis prophylaxis with oral ciprofloxacin in comparison to intravenous cefazolin/gentamicin. J Res Med Sci 23:98. https://doi.org/10.4103/jrms.JRMS_384_18

12. Duch-Samper AM, Menezo JL, Hurtado-Sarrojo M (1997) Endophthalmitis following penetrating eye injuries. Acta Ophthalmol Scand 75(1):104–106. https://doi.org/10.1111/j.1600-0420.1997.tb00263.x

13. Gupta A, Srinivasan R, Babu KR, Setia S (2010) Comparison of the clinical presentation and visual outcome in open globe injuries in adults and children over 30 months. Eur J Ophthal 20(3):590–595. https://doi.org/10.1177/11206721100200309

14. Huang JM, Pansick AD, Blomquist PH (2016) Use of intravenous vancomycin and ceftazime in preventing endophthalmitis after open globe injury. J Ocul Pharmacol Ther 32(7):437–441. https://doi.org/10.1089/jop.2016.0051

15. Mansouri M, Faghhi H, Hajizadeh F et al (2009) Epidemiology of open-globe injuries in Iran: analysis of 2,340 cases in 5 years (report no. 1). Retina 29(8):1141–1149. https://doi.org/10.1097/IAE.0b013e318a395ac

16. Nakayama LF, Bergamo VC, de Moraes NSB (2019) Six-year epidemiological analysis of post traumatic endophthalmitis in a Brazilian hospital. Int J Retina Vitreous 5:43. https://doi.org/10.1186/s40942-019-0193-8

17. Narang S, Gupta V, Gupta A et al (2003) Role of prophylactic intravitreal antibiotics in open globe injuries. Indian J Ophthal 51(1):39–44

18. Rafati N, Azarmina M, Zaeri F et al (2013) Rate of post-traumatic endophthalmitis with or without injection of balanced salt solution. J Ophthalmic Vis Res 8(3):237–243

19. Soheilian M, Rafati N, Mohabbi MR et al (2007) Prophylaxis of acute posttraumatic bacterial endophthalmitis: a multicenter, randomized clinical trial of intravitreal antibiotic injection, report 2. Arch Ophthal 125(4):460–465. https://doi.org/10.1001/archopht.125.4.460

20. Soliman MM, Maky TA (2008) Pattern of ocular trauma in Egypt. Graefes Arch Clin Exp Ophthal 246(2):205–212. https://doi.org/10.1007/s00417-007-0720-4

21. Tabatabaei SA, Soleimani M, Behrooz MJ, Sheibani K (2016) Systemic oral antibiotics as a prophylactic measure to prevent endophthalmitis in patients with open globe injuries in comparison with intravenous antibiotics. Retina 36(2):360–365. https://doi.org/10.1097/iae.0b013e3180007227

22. Verbraeken H, Rysselaeere M (1994) Post-traumatic endophthalmitis. Eur J Ophthalmitis 4(1):1–5

23. R Core Team (2016) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. https://www.R-project.org/

24. Viechtbauer W (2010) Conducting meta-analyses in R with the metafor package. J Stat Softw 36(3):1–48

25. Du Toit N, Mustak S, Cook C (2017) Randomised controlled trial of prophylactic antibiotic treatment for the prevention of endophthalmitis after open globe injury at Groote Schuur Hospital. Br J Ophthal 101(7):862–7. https://doi.org/10.1111/bjo.13973

26. J H. The Oxford 2011 Levels of Evidence. http://www.cebm.net/index.aspx?o=5653

27. Ban KA, Minei JP, Laonga C et al (2017) Executive summary of the American College of Surgeons/Surgical Infection Society Surgical Site Infection Guidelines-2016 update. Surg infect (Larchmt) 18(4):379–382. https://doi.org/10.1089/sur.2016.214

28. Fleming-Dutra KE, Hersh AL, Shapiro DJ et al (2016) Prevalence of inappropriate antibiotic prescriptions among US ambulatory care visits, 2010–2011. JAMA 315(17):1864–1873. https://doi.org/10.1001/jama.2016.4151

29. Bhagat N, Nagori S, Zarbin M (2011) Post-traumatic infectious endophthalmitis. Surv Ophthalmol 56(3):214–251. https://doi.org/10.1016/j.survophthal.2010.09.002

30. Cyriac JM, James E (2014) Switch over from intravenous to oral therapy: a concise overview. J Pharmacol Pharmacother 5(2):83–87. https://doi.org/10.4103/0976-500X.130042

31. Beique L, Zvoran R (2015) Addressing concerns about changing the route of antimicrobial administration from intravenous to oral in adult inpatients. Can J Hosp Pharm 68(4):318–326. https://doi.org/10.4121/cjhpv6894.1472

32. Meredith TA (1999) Posttraumatic endophthalmitis. Arch Ophthal 117(4):520–521. https://doi.org/10.1001/archopht.117.4.520

33. Peyman GA, Carroll CP Riahard M (1980) Prevention and management of traumatic endophthalmitis. Ophthalmology 87(4):320–324. https://doi.org/10.1016/16420080(80)5240-8

34. Reynolds DS, Flynn HW Jr (1997) Endophthalmitis after penetrating ocular trauma. Curr Opin Ophthal 8(3):32–38. https://doi.org/10.1097/00055735-199706000-00006

35. Seal DV, Kirkness CM (1992) Criteria for intravitreal antibiotics during surgical removal of intraocular foreign bodies. Eye (Lond) 6(Pt 5):465–468. https://doi.org/10.1038/eye.1992.98

36. Hariprasad SM, Shah GK, Mieler WF et al (2006) Vitreous and aqueous penetration of orally administered moxifloxacin in humans. Arch Ophthal 124(2):178–182. https://doi.org/10.1001/archopht.124.1.178
37. Herbert EN, Pearce IA, McGalliard J et al (2002) Vitreous penetration of levofloxacin in the uninflamed phakic human eye. Br J Ophthalmol 86(4):387–389. https://doi.org/10.1136/bjo.86.4.387

38. Peragine C, Walker SAN, Walker S, Palmay L (2019) Fluoroquinolone antibiotic prophylaxis to prevent post-traumatic bacterial infectious endophthalmitis: using Monte Carlo simulation to evaluate the probability of success. J Ocul Pharmacol Ther 35(6):366–371. https://doi.org/10.1089/jop.2019.0013

39. Ahmed Y, Schimel AM, Pathengay A et al (2012) Endophthalmitis following open-globe injuries. Eye (Lond) 26(2):212–217. https://doi.org/10.1038/eye.2011.313

40. Gokce G, Sobaci G, O zg onul C (2015) Post-traumatic endophthalmitis: a mini-review. Semin Ophthalmol 30(5–6):470–474. https://doi.org/10.3109/08820538.2013.877939

41. Sabaci G, Bayer A, Mutlu FM et al (2002) Endophthalmitis after deadly-weapon-related open-globe injuries: risk factors, value of prophylactic antibiotics, and visual outcomes. Am J Ophthalmol 133(1):62–69. https://doi.org/10.1016/s0002-9394(01)01320-4

42. Thompson WS, Rubsamen PE, Flynn HW Jr et al (1995) Endophthalmitis after penetrating trauma. Risk factors and visual acuity outcomes. Ophthalmology 102(11):1696–1701. https://doi.org/10.1016/s0161-6420(95)30807-x

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.