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Review

Infection prevention and control factors associated with post-cataract surgery endophthalmitis - a review of the literature from 2010 – 2023

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S U M M A R Y

Patients undergoing cataract surgery are at risk of post-cataract surgery endophthalmitis (PCSE), a sight-threatening complication. Cataract surgery is a relatively straightforward and quick procedure often performed under local anaesthetic. It is therefore simple to scale up to reduce the currently long waiting times, but it is important to maintain patient safety when considering high throughput surgery. This literature review aimed to identify appropriate infection prevention and control (IPC) measures to support increased throughput of cataract surgery in Scotland. Database searches were conducted using Medline and Embase from 2010 to 2023. Further hand-searching was also performed. The organisms associated with PCSE and IPC factors relevant to PCSE were analyzed. A range of microorganisms was associated with PCSE, where outbreak reports were most associated with Gram-negative bacteria and fungi, whereas retrospective chart reviews were most associated with Gram-positive bacteria. IPC risk factors identified were related to the built environment and issues with sterilization. Specifically, the sources of outbreaks included failures in the ventilation system, as well as contaminated ophthalmic solutions, surgical instruments, and medications. The factors identified in this review should be considered when implementing high throughput cataract surgery to ensure that patient safety is maintained.

Introduction

With an estimated global prevalence of 17.2%, cataracts are the leading cause of blindness and the second highest cause of moderate or severe visual impairment globally. [1,2] It is the opacification of the lens which causes a loss of lens transparency. [3] The prevalence of cataracts increases with age and is associated with a plethora of negative health impacts amongst the elderly population, including a higher risk of dementia, falls, road traffic accidents, a significant reduction in quality of life, and a higher risk of mortality. [3–6].

Surgery is the most effective treatment for cataracts and is one of the commonest elective surgical procedures in the world. [3] In a small proportion of cases, however, endophthalmitis may occur. Endophthalmitis is a sight-threatening inflammation of the inner layers of the eye caused by

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intraocular colonization by micro-organisms. [7,8] Post-cataract surgery endophthalmitis (PCSE) can be classified based on the interval between surgery and infection. It is categorized as acute when infection occurs shortly after the surgery — usually within one to two weeks but may occur up to six weeks after. [9,10] Chronic cases are those that manifest several weeks or months after surgery, usually after six weeks. [10,11] The use of antiseptic agents and other interventions has led to a huge decline in the incidence of endophthalmitis over the last few decades. [12].

As a result of the disruptions caused by the COVID-19 pandemic, there have been delays and increased waiting times for elective surgeries. As cataract surgery is a straightforward day surgery, measures can be implemented to increase throughput and rapidly decrease waiting times. However, given the potential risk of PCSE, there must be assurance that patient safety is maintained. [13] Although recent reviews of the incidence and aetiology of endophthalmitis have been published, they focused on outbreaks and clusters, therefore sporadic single cases were not captured. [14,15] Therefore, a literature review was commissioned by the Scottish National Cataract Short Life Working Group (SLWG) to evaluate the scientific literature to identify appropriate infection prevention and control (IPC) measures to support increased throughput of cataract surgery in Scotland. The following research questions were considered:

i. Which organisms are associated with post-cataract surgery endophthalmitis (PCSE)?
ii. What factors related to infection prevention and control are associated with post-cataract surgery endophthalmitis?

Methods

A draft review protocol was approved by the Scottish National Cataract SLWG, commissioned to address the delays in cataract surgery in Scotland. A database search was undertaken using two comprehensive search strategies on Medline and Embase (see Appendix 1). The search strategies were developed by a single author and peer-reviewed by a Librarian. Due to time constraints, all searches were limited to articles published between 1 January 2010 and 14 April 2023. Hand-searching of reference lists and a search of online resources was carried out to identify grey literature.

Titles and abstracts were screened by a single author who also conducted the full-text screen. Evidence was critiqued by a single reviewer using the SIGN50 principles however critical analysis tools were not used. [16].

The final version of the review was approved by the SLWG following consultation.

Inclusion criteria

Studies included are case studies, case series, outbreak reports and retrospective chart reviews published in the English language regardless of the country where they were published. Retrospective chart reviews assess all cases of PCSE in a particular location over a defined period irrespective of the causative organism. Only studies reporting post-cataract surgery cases of endophthalmitis with positive microbial culture were considered.

Exclusion criteria

Studies were excluded if they reported PCSE cases with negative patient microbial cultures or endophthalmitis secondary to trauma or a procedure other than cataract surgery. Also excluded were studies focused on non-human subjects, intervention bundles, or non-infection prevention and control (IPC) factors such as prophylaxis, surgical preparation, and intra-operative surgical practice and techniques.

Conference abstracts, and papers not published in the English Language were excluded.

Results

Study selection

A total of 390 papers were identified after deduplication. After title and abstract screening, 109 were retrieved for full-text review and 42 were considered appropriate for inclusion. Seven papers identified through hand searching were included.

Study characteristics

A total of 880 patients were described in the 49 included studies. Twenty-six of the studies were case reports/series, [17–42] 11 were outbreak studies [43–53] and the remainder (n=12) were retrospective chart reviews [54–65] (Table I). Over half of the studies were published in Asia (28/49) with seven each published in Europe and North America, respectively. There were two studies from the United Kingdom [33,34], three from South America [24,42,52], and one each from Africa [30] and Oceania [37].

Organisms associated with post-cataract surgery endophthalmitis

The included studies were screened to identify organisms associated with PCSE. As shown in Table II, 40 different genera of micro-organisms were identified as associated with PCSE, including Gram-positive and Gram-negative bacteria, fungi, and amoeba. Gram-negative bacteria were identified in 23 studies, the majority being *Pseudomonas aeruginosa* [35,49–52,57,58,60,62,65]. *Stenotrophomonas maltophilia* was identified in five studies [42,53,57,60,65].

Gram-positive bacteria were identified in 16 papers, chief of which were *Staphylococcus aureus* [54,55,57,58,60,62,65] and *Staphylococcus epidermidis* [40,54,61,62,64].

Fungal endophthalmitis was described in 17 studies with *Fusarium* spp. being the most frequently reported (n = 6) [31,45–48]. Others included *Aspergillus* spp. [20,59,65], *Candida* spp. [62,65], *Curvularia* spp. [29], *Penicillium citrinum* [33], *Trichosporon* spp. [25], *Pseudozyma aphidis* [37], *Wickerhamomyces anomalus* [41] and *Acremonium* spp [59].

Other organisms identified included *Acanthamoeba culbertsoni* and *Mycobacterium* spp. [22,23] Two studies reported cases where more than one organism was isolated from a single patient. [57,58].

Figures 1 and 2 show that most of the cases in the included retrospective chart reviews were associated with Gram-positive bacteria (79.1%), the predominant being *Staphylococcus* spp., followed by Gram-negative bacteria (19.3%)

Table I
General characteristics of included studies

Study ID	Country/Territory	Study type	Number of patients	Age/mean age	Sampling
Agrawal 2022 [25]	India	Case series	10	-	Vitreous samples
Rammohan *et al.*, 2021 [22]	India	Case series	4	-	Various, vitreous or both or scleral abscess
Dave *et al.*, 2020 [19]	India	Case series	4	-	Vitreous biopsy/sample
Kannan *et al.*, 2020 [18]	India	Case series	28	66.07 ± 8.6	Various including vitreous tap, aqueous aspirate, anterior chamber membrane, vitreous biopsy, IOL, scleral swab, corneal scraping, AS exudate
Sen *et al.*, 2020 [21]	India	Case series	17	62.44 ± 9.6	Intra-ocular fluids - not specific
Hsu *et al.*, 2018 [23]	Taiwan	Case series	9	69	Either aqueous humor or vitreous fluid or both
Mesnard *et al.*, 2016 [17]	French West Indies	Case series	4	67.5	Aqueous humor
Mithal *et al.*, 2015 [20]	India	Case series	8	55.75	Corneal scrapings, vitreous biopsy, and explanted intraocular
Williams *et al.*, 2014 [42]	Argentina	Case series	3	80.7	Vitreous samples
Mattos *et al.*, 2013 [24]	Brazil	Case series	7	-	Vitreous samples
Francomacaro *et al.*, 2022 [28]	USA	Case study	1	60–69	Anterior chamber paracentesis and vitreous sample
Lam *et al.*, 2022 [39]	USA	Case study	1	60	Vitreous sample
Ledesma *et al.*, 2022 [41]	Spain	Case study	1	77	Vitreous sample
Babalola 2020 [30]	Nigeria	Case study	1	84	Vitreous sample
Dave *et al.*, 2020 [29]	India	Case study	1	50	Vitreous biopsy/sample
Shah *et al.*, 2020 [36]	India	Case study	1	39	Vitreous sample
Voon *et al.*, 2019 [37]	New Zealand	Case study	1	46	Anterior chamber and a vitreous tap
Palioura *et al.*, 2018 [27]	USA	Case study	1	62	Anterior chamber sample
Alvarez-Ramos *et al.*, 2016 [38]	Spain	Case study	1	-	Vitreous humor
Garg *et al.*, 2016 [33]	England	Case study	1	85	Anterious chamber and vitreous sample
Lodhi *et al.*, 2016 [32]	India	Case study	1	50	Aqueous humor and Vitreous sample
Arici *et al.*, 2014 [31]	Turkey	Case study	1	73	Vitreous humor, corneal scraping, aqueous humor
Amissah-Arthur *et al.*, 2013 [34]	England	Case study	1	85	AC samples and intravitreal biopsy
Khan *et al.*, 2013 [26]	India	Case study	1	50	Vitreous sample
Gupta *et al.*, 2010 [35]	USA	Case study	1	80	Vitreous sample
Javey *et al.*, 2010 [40]	USA	Case study	1	86	Vitreous humor, vitreous biopsy
Kim *et al.*, 2023 [48]	South Korea	Outbreak study	103	65.4 ±10.8	Not provided
Arasaki *et al.*, 2022 [45]	Japan	Outbreak study	2	63.4±8.5	Vitreous and IOL samples
Spilker *et al.*, 2022 [43]	Norway	Outbreak study	6	75.5	Cultures of vitreous or anterior chamber fluid or implanted intraocular lenses and lens capsules from each patient
Cheraqpour *et al.*, 2021 [49]	Iran	Outbreak study	10	69.3	Vitreous samples
Bawankar *et al.*, 2019 [50]	India	Outbreak study	13	67	AC samples for 10 patients and vitreous samples for 3 patients

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Table I (*continued*)

Study ID	Country/Territory	Study type	Number of patients	Age/mean age	Sampling
Ji *et al.*, 2015 [53]	China	Outbreak study	14	64.6	Vitreous and aqueous fluid
Buchta *et al.*, 2015 [46]	Czech Republic	Outbreak study	20	70.5	Mostly vitreous humor
Lalitha *et al.*, 2014 [44]	India	Outbreak study	13	57.7	Vitreous samples
Guerra *et al.*, 2012 [52]	Brazil	Outbreak study	26	-	Aqueous humor and vitreous samples
Ramappa *et al.*, 2012 [51]	India	Outbreak study	5	-	Vitreous samples
Gungel *et al.*, 2011 [47]	Turkey	Outbreak study	9	-	Aqueous or vitreous samples
Jiang *et al.*, 2022 [63]	China	Retrospective Study	3	-	Some eyes were sampled using vitreous humor others by aqueous humor
Malmin *et al.*, 2021 [61]	Norway	Retrospective study	6	-	Vitreous samples, anterior chamber samples, or both
Jeong *et al.*, 2017 [65]	South Korea	Retrospective study	58	70.7	Vitreous samples
Artsi *et al.*, 2016 [64]	Israel	Retrospective study	2	-	Not clearly stated
Kelkar *et al.*, 2016 [54]	India	Retrospective study	30	-	Aqueous humor and vitreous samples
Yannuzzi *et al.*, 2016 [55]	USA	Retrospective study	63	-	Vitreous sample and vitrectomy cassette
Sharma *et al.*, 2014 [59]	India	Retrospective study	16	-	Vitreous samples
Yao *et al.*, 2013 [57]	China	Retrospective study	25	-	Aqueous humor and vitreous samples
Friling *et al.*, 2012 [56]	Sweden	Retrospective study	113	-	-
Rahimi *et al.*, 2012 [62]	Iran	Retrospective study	33	65.04	AC samples and vitreous taps
Cheng *et al.*, 2010 [60]	Taiwan	Retrospective study	34	-	-
Pijl *et al.*, 2010 [58]	Netherlands	Retrospective study	166	74	Vitreous biopsy or a primary vitrectomy

Abbreviations: AC, anterior chamber; IOL, intraocular lens; -, not reported.

Table II
Endophthalmitis related organisms and their sources

Study ID	Study type	Organism[a]	Organism group	Source	Genetic relatedness	IPC factors
Mesnard *et al.*, 2016 [17]	Case series	α-hemolytic streptococcus	Gram-positive bacteria	-	-	-
Agrawal 2022 [25]	Case series	*Trichosporon* spp.	Fungi	Possible contamination of disposables with unsterile water but no credible link	-	-
Williams *et al.*, 2014 [42]	Case series	*Stenotrophomonas maltophilia*	Gram-negative bacteria	Silicon surgical-reusable tube suspected.	Not tested. Isolates from all cases exhibited a similar spectrum of antibiotic sensitivity. However, antibiotic sensitivity of S. maltophilia isolated from the suspect reusable tube was not reported.	-
Mattos *et al.*, 2013 [24]	Case series	*Ochrobactrum anthropi*	Gram-negative bacteria	Contaminated tubing of phaco-emulsification machine suspected	-	-
Kannan *et al.*, 2020 [18]	Case series	*Nocardia*	Gram-positive bacteria	Not found	-	-
Hsu *et al.*, 2018 [23]	Case series	*Mycobacterium chelonae*/ *Mycobacterium abscessus*	NTM	-	-	-
Dave *et al.*, 2020B [19]	Case series	*Enterobacter* spp.	Gram-negative bacteria	-	-	-
Mithal *et al.*, 2015 [20]	Case series	*Aspergillus terreus*	Fungi	-	-	-
Sen *et al.*, 2020 [21]	Case series	*Aspergillus niger* (5), *A. flavus, A fumigatus, A. nidulans* (2), *A. terreus* (2), *Candida* spp. (2), *Fusarium* spp. (2), unclassified dematiaceous fungi (2)	Fungi	-	-	-
Rammohan *et al.*, 2021 [22]	Case series	*Acanthamoeba culbertsoni*	Protozoa	-	-	-
Ledesma *et al.*, 2022 [41]	Case study	*Wickerhamomyces anomalus*	Fungi	-	-	-
Javey *et al.*, 2010 [40]	Case study	*Staphylococcus epidermidis*	Gram-positive bacteria	-	-	-

(*continued on next page*)

Table II (*continued*)

Study ID	Study type	Organism[a]	Organism group	Source	Genetic relatedness	IPC factors
Alvarez-Ramos *et al.*, 2016 [38]	Case study	*Rothia mucilaginosa*	Gram-positive bacteria	Possible self-contamination or contaminated eye drops but no credible link reported	-	-
Lam *et al.*, 2022 [39]	Case study	*Rothia mucilaginosa*	Gram-positive bacteria	iStent device suspected but no viable link was reported	-	-
Voon *et al.*, 2019 [37]	Case study	*Pseudozyma aphidis*	Fungi	Not found	-	-
Shah *et al.*, 2020 [36]	Case study	*Pseudomonas stutzeri*	Gram-negative bacteria	-	-	-
Gupta *et al.*, 2010 [35]	Case study	*Pseudomonas aeruginosa*	Gram-negative bacteria	-	-	-
Amissah-Arthur *et al.*, 2013 [34]	Case study	*Prevotella* spp.	Gram-negative bacteria	-	-	-
Garg *et al.*, 2016 [33]	Case study	*Penicillium citrinum*	Fungi	-	-	-
Lodhi *et al.*, 2016 [32]	Case study	*Nocardia asteroids*	Gram-positive bacteria	-	-	-
Arici *et al.*, 2014 [31]	Case study	*Fusarium solani*	Fungi	-	-	-
Babalola 2020 [30]	Case study	*Enterococcus faecium*	Gram-positive bacteria	-	-	-
Dave *et al.*, 2020 [29]	Case study	*Curvularia* spp.	Fungi	-	-	-
Francomacaro *et al.*, 2022 [28]	Case study	*Clostridium intestinale*	Gram-positive bacteria	-	-	-
Palioura *et al.*, 2018 [27]	Case study	*Candida parapsilosis*	Fungi	-	-	-
Khan *et al.*, 2013 [26]	Case study	*Burkholderia cepacia*	Gram-negative bacteria	-	-	-
Ji *et al.*, 2015 [53]	Outbreak study	*Stenotrophomonas maltophilia*	Gram-negative bacteria	Aspiration tube of a phaco emulsifier - tested positive for *S. maltophilia*	Not tested. Vitreous isolates from patients and the suspect aspiration tube had similar antibiotic sensitivity profiles.	-
Bawankar *et al.*, 2019 [50]	Outbreak study	*Pseudomonas aeruginosa*	Gram-negative bacteria	Trypan blue solution	PFGE	Contaminated medical product
Cheraqpour *et al.*, 2021 [49]	Outbreak study	*Pseudomonas aeruginosa*	Gram-negative bacteria	A contaminated phaco probe was used for all 10 patients without sterilization in between	Contaminated phaco probe tested positive for *P. aeruginosa* - no genetic testing was performed	-
Guerra *et al.*, 2012 [52]	Outbreak study	*Pseudomonas aeruginosa*	Gram-negative bacteria	-	-	-

Ramappa *et al.*, 2012 [51]	Outbreak study	*Pseudomonas aeruginosa*	Gram-negative bacteria	IOL and IOL suspension solution	ERIC-PCR	Contaminated medical product
Kim *et al.*, 2023 [48]	Outbreak study	*Fusarium* spp.	Fungi	Viscoelastics	Direct sequencing	Contaminated medical product
Gungel *et al.*, 2011 [47]	Outbreak study	*Fusarium solani*	Fungi	Contaminated BSS and/ or cefuroxime solution suspected	-	-
Arasaki *et al.*, 2022 [45]	Outbreak study	*Fusarium oxysporum*	Fungi	Not found	-	-
Buchta *et al.*, 2015 [46]	Outbreak study	*Fusarium oxysporum*	Fungi	Suspected - viscoelastic solution. Not tested because the suspected batch was exhausted before the first case presented. Endophthalmitis was reported in 62.5% (n= 32) of patients who used suspected viscoelastic compared to 0 patients on whom it was not used.	-	Contaminated medical product
Lalitha *et al.*, 2014 [44]	Outbreak study	*Burkholderia cepacia*	Gram-negative bacteria	Contaminated aesthetic eye drop	BOX-PCR	-
Spilker *et al.*, 2022 [43]	Outbreak study	*Burkholderia contaminans*	Gram-negative bacteria	Ventilation system	MLST	Built environment contamination
Artsi *et al.*, 2016 [64]	Retrospective study	*Streptococcus viridans*, *Staphylococcus epidermidis*	Gram-positive bacteria	-	-	-
Jiang *et al.*, 2022 [63]	Retrospective study	*Staphylococcus hominis* (2), *Streptococcus* spp.	Gram-positive bacteria	-	-	-
Rahimi *et al.*, 2012 [62]	Retrospective study	*Staphylococcus epidermidis* (4), *Staphylococcus aureus* (12), *Streptococcus hemolyticus* (2), *Streptococcus pneumonia*, *Pseudomonas aeruginosa* (4), *Enterobacter* spp. (4), *E. coli* (2), *Acinetobacter* spp., *Proteus vulgaris*, *Haemophilus influenza*, *Candida Albicans*	Mixed	-	-	-

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Table II (*continued*)

Study ID	Study type	Organism[a]	Organism group	Source	Genetic relatedness	IPC factors
Jeong *et al.*, 2017 [65]	Retrospective study	*Staphylococcus epidermidis* (33) *Enterococcus faecalis* (11) *Pseudomonas aeruginosa* (14)	Mixed	-	-	-
Malmin *et al.*, 2021 [61]	Retrospective study	*Staphylococcus epidermidis* (2), *Streptococcus oralis* (1), *Enterococcus faecalis* (3)	Gram-positive bacteria	-	-	-
Cheng *et al.*, 2010 [60]	Retrospective study	*Staphylococcus aureus* (9), *Enterococcus*, *Streptococcus pneumonaie*, *Paenibacillus glucanolyticus*, Coagulase negative *staphylococci*, *Pseudomonas aeruginosa* (13), *Proteus vulgaris* (2), *Stenotrophomonas maltophilia* (2), *Moraxella cataralis* (2)	Mixed	-	-	-
Sharma *et al.*, 2014 [59]	Retrospective study	*Pseudomonas* spp. (4), *Staphylococcus* spp. (2), *Streptococcus* (2), *Bacillus licheniformis*, *Acremonium* spp. (2), *Aspergillus flavus*, *A. terreus*, *A. flavipes*, *Candida* spp. (2)	Mixed	-	-	-
Pij *et al.*, 2010 [58]	Retrospective study	Gram-positive coagulase negative *Staphylococci* (89), *Staphylococcus aureus* (20), *Streptococcus pneumoniae* (12), Viridans group *Streptococci* (11), B hemolytic *Streptococcus* x9, *Enterococcus* (3), Diphtheroid Gram-positive rods (3), *Abiotrophia* spp. (2), *Gemella morbillorum*,	Mixed	-	-	-

		Peptostreptococcus spp., *Propionibacterium acnes, Proteus mirabilis* (3), *Haemophilus influenzae* (3), *P. aeruginosa* (2), *Achromobacter xylosoxidans, Acinetobacter iwoffi*, polymicrobial (4)				
Yao *et al.*, 2013 [57]	Retrospective study	Gram positive coagulase negative (8), *S. aureus* (3), *Enterococcus faecalis*, Dry *Corynebacterium, Streptococcus pyogenes, Pseudomonas maltophilia* (8), *P. paucimobilis, P. aeruginosa*, Polymicrobial (*Bacillus cereus* + *Streptococus viridians*)	Mixed	-	-	-
Friling *et al.*, 2012 [56]	Retrospective study	*Enterococc*i (42), Coagulase-negative *Staphylococci* (35), Other *Streptococci* (9), Other Gram-positive species (8), *Pseudomonas* spp. (10), *Enterobacteria* spp. (7), other Gram-negative bacteria (2)	Mixed	-	-	-
Yannuzzi *et al.*, 2016 [55]	Retrospective study	Coagulase-negative *Staphylococcus* (39), *Streptococcus* spp. (7) (*S. salivarius, S. sanguinis, S. constellatus, S. mitis* (2), *S. viridans), Staphylococcus aureus* (7), *Staphylococcus* spp. (3) (*S. warneri, S. Lugdunensis* (2), *Enterococcus* (3) *(E. faecalis* (3), *Propionibacterium* (2)	Mixed	-	-	-

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Table II (*continued*)

Study ID	Study type	Organism[a]	Organism group	Source	Genetic relatedness	IPC factors
		(*Propionibacterium acnes*, *P. granulosen*), *Pseudomonas* spp., *Serratia* spp.				
Kelkar *et al.*, 2016 [54]	Retrospective study	Coagulase negative *Staphylococcus* x8, MRSA (5), *Staphylococcus aureus* (3), *Streptococcus pneumoniae* (3), *Propionibacterium acnes*, *Staphylococcus epidermidis* (3), *Streptococcus mitis*, *E. coli* (3), *Pseudomonas* spp. (1), *Klebsiella* spp., *Sphingomonas paucimobilis*	Mixed	-	-	-

Abbreviations: ERIC PCR - enterobacterial Repetitive Intergenic Consensus Polymerase Chain Reaction; PFGE - Pulse-field gel electrophoresis; NTM – Nontuberculous Mycobacteria MLST – Multilocus sequence typing.

[a] Numbers in brackets represent the number of cases for studies reporting more than one organism. In such studies, organisms with no number in the bracket mean a single case.

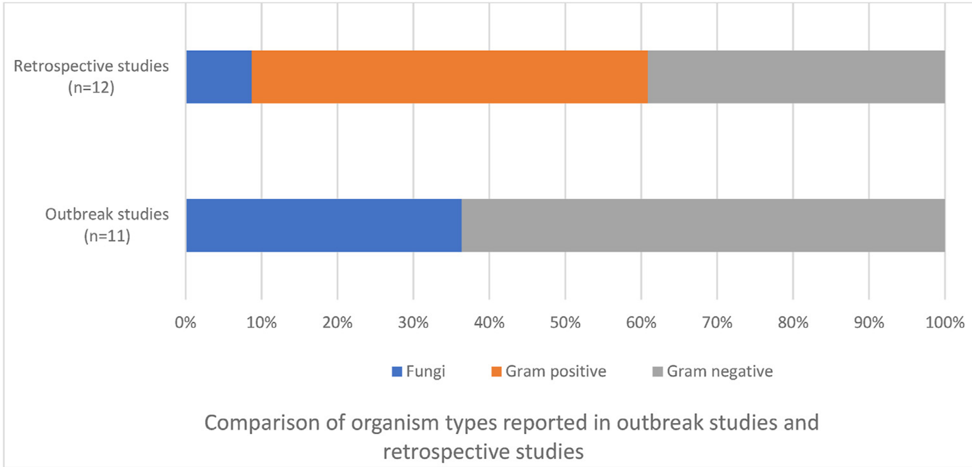

Figure 1. Comparison of organism types reported in outbreak studies and retrospective studies.

and fungi (1.6%), whereas outbreak studies were associated with either gram-negative bacteria or fungi.

IPC factors associated with post-cataract endophthalmitis

To understand the IPC factors that are associated with PCSE, sources of transmission described in the outbreak studies were analyzed. Only studies that demonstrated genetic relatedness or a strong epidemiological link were considered in the discussion about IPC factors.

To establish the source of the outbreaks, five studies employed various techniques to demonstrate genetic relatedness between the organisms isolated from patients and the environment. These included variants of repetitive element-based PCR (Rep-PCR) reported by two studies; BOX-A1R-based repetitive extragenic palindromic-PCR (BOX PCR), [44] and Enterobacterial Repetitive Intergenic Consensus Polymerase Chain Reaction (ERIC PCR). [51] Others include direct sequencing, [48] pulsed-field gel electrophoresis (PFGE) [50] and multi-locus sequence typing (MLST). [43].

The sources included contaminated ophthalmic solutions and medications (n = 4 studies), [44,48,50,51] contaminated surgical instruments (n = 1 study) [49] and the ventilation system (n = 1 study). [43] Behind some of these were IPC factors such as built environment contamination, [43] or poor sterilization practices (Table II). [48] The organisms associated with these outbreaks were either Gram-negative bacteria (*P. aeruginosa*, [49–51] and *Burkholderia* spp.), [43,44] or fungal (*Fusarium* spp.) (Table II). [48].

In one outbreak study, an epidemiological link was demonstrated between patient samples and the suspected source, even though typing was not done. It involved a single ophthalmologist who used the same phaco probe in uncomplicated cataract surgeries with IOL implantations for ten patients without sterilization between patients. All ten patients developed PCSE with vitreous samples yielding *Pseudomonas aeruginosa*, as did the phaco probe. [49].

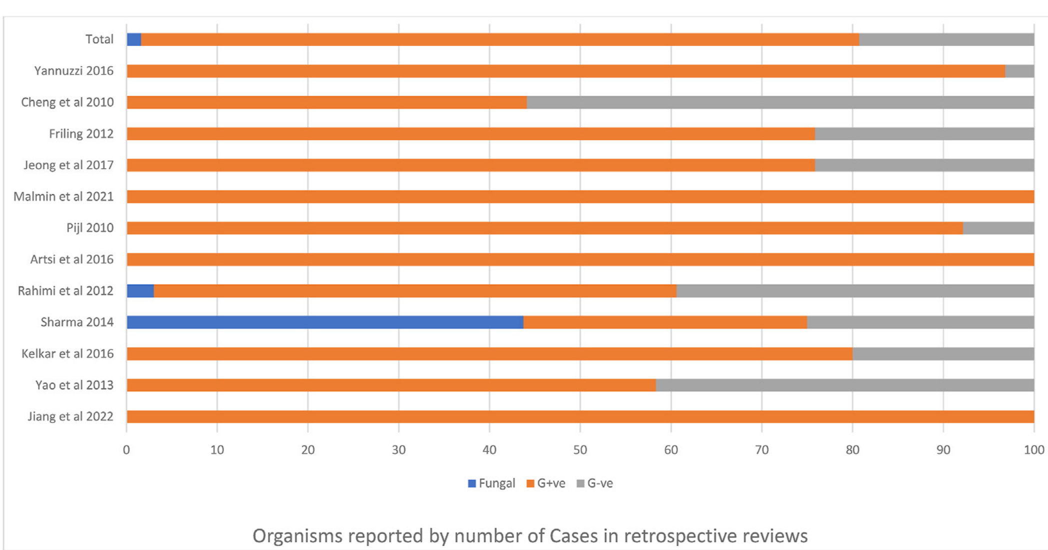

Figure 2. Organisms reported by number of Cases in retrospective reviews.

Discussion

In the studies identified for this review, the IPC risk factors for PCSE were found to include environmental contamination, ineffective sterilization procedures, or a lack thereof. Outbreaks caused by ophthalmic solutions contaminated at the batch manufacturing level were also found. These issues relating to IPC should be considered, particularly when scaling up cataract surgery, to ensure that patient safety is maintained. Moreover, this review explored the pathogens associated with PCSE. These included Gram-positive and Gram-negative bacteria and fungi. Evidence compiled by this review suggested a difference in the type of pathogen according to case type (sporadic cases versus outbreaks). Outbreak studies were associated with Gram-negative bacteria and fungi, whilst retrospective chart reviews of sporadic cases were associated with Gram-positive organisms. The knowledge that fungi and Gram-negative pathogens are often associated with outbreaks should prompt IPC teams to consider and investigate the possibility of epidemiologically linked cases and their sources to limit additional cases of PCSE.

Organisms associated with post-cataract surgery endophthalmitis

A large variety of microorganisms are associated with PCSE. *Staphylococcus* spp. was associated with the most cases (32.4%) even though *Pseudomonas* spp. were reported by more studies (32.7%). The occurrence of the various pathogens is better understood when evidence is synthesized according to study type.

Gram-positive bacteria (especially *Staphylococcus* spp. and *Streptococcus* spp.) were most implicated in retrospective chart reviews. This is not surprising since aqueous contamination with skin commensal bacterial flora is considered the main pathogenesis for endophthalmitis [8].

While Gram-positive bacteria were associated with most of the cases in retrospective chart reviews, this was not the case in outbreak studies. Outbreak studies included in this review were found to exclusively involve fungal and Gram-negative organisms. Previous reviews that solely assessed outbreak studies or did not distinguish on study type support the latter and found *Pseudomonas aeruginosa* as the most frequently isolated pathogen in outbreaks and clusters. [12,14] This review suggests that samples positive for *Fusarium* spp., *Burkholderia* spp., and *P. aeruginosa* should be viewed with concern because they are not normal flora of the skin and are more likely to be associated with contaminated instruments or solutions. This is particularly concerning regarding *Fusarium* spp., which can be aerosolized and has often been associated with outbreaks in healthcare. [66—69].

Factors related to infection prevention and control associated with post-cataract surgery endophthalmitis

Sterile ophthalmic solutions were reported to be the cause of PCSE outbreaks in four studies. [44,48,50,51] These solutions included anaesthetic eye drops, ophthalmic viscoelastic devices (OVDs), trypan blue solution, and intraocular lens (IOL) suspension solution. They were contaminated by *P. aeruginosa, B. cepacia,* and *Fusarium* spp. and were all genetically linked to the organisms isolated from patient samples. In all four studies, the contamination occurred at a manufacturing level as samples from unopened bottles yielded growth of the contaminating organisms [44,48,50,51]. A nationwide outbreak in South Korea was only resolved after the withdrawal of a particular brand of sodium hyaluronate viscoelastic materials. [48] Batchwise sampling of ophthalmic solutions may be considered as a strategy to reduce the likelihood of such outbreaks occurring.

Failures in the sterilization of surgical instruments were also reported as a probable source in one study, in which the surgeon used the same phaco probe for all 10 cases without sterilization between patients. [49].

A contaminated ventilation system was identified as the source of an outbreak of *B. contaminans* in a private single-physician clinic in Norway. [42] Seven samples from a particular air intake duct in the ventilation system yielded bacterial growth that tested positive using a *Burkholderia*-specific PCR assay, one being from pooled standing water and the other six being swabs from biofilms. Multi-locus sequence typing (MLST) analysis showed that all seven isolates had an identical allelic profile to those recovered from patient cultures. It was hypothesized that this contamination occurred due to water pooling in air intake ducts following flooding. However, air sampling was not performed to further investigate this as the transmission route.

A key limitation of the body of evidence included in this review is a potential for publication bias as many outbreak investigations are not published, hence the potential IPC factors related to PCSE may not have been identified. Another limitation is that screening and data extraction were performed by a single reviewer and there was no formal risk of bias assessment. It is however important to consider variations in symptom severity, medication effects, healthcare systems, and health-seeking behaviours across different countries that can affect this measure. Extraction of this data was challenging in certain studies, particularly retrospective chart reviews where cases of endophthalmitis following surgeries other than cataract surgeries or cases without positive microbial culture were included. Despite these limitations, this review demonstrates the differences in organisms associated with endophthalmitis outbreaks compared to those in sporadic cases, which may assist in prompt management and control of PCSE outbreaks.

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Appendix 1. Search strategy

Database search on post-cataract surgery endophthalmitis. Search performed on April 13, 2023.

Ovid MEDLINE

Line	Search term	Result number
1	*Cataract Extraction/	18984
2	(cataract$ adj4 (surg$ or operat$ or extract$ or aspirat$ or excis$ or remov$ or emulsif$ or implant$)).ti,ab,kf.	33863
3	post?cataract.ti,ab,kf.	225
4	Phacoemulsification/	11634
5	(pha?oemulsif$ or phaco or phako).ti,ab,kf.	10897
6	1 or 2 or 3 or 4 or 5	45205
7	*Endophthalmitis/	6416
8	endophthalmiti$.ti,ab,kf.	9421
9	ophthalmia.ti,ab,kf.	1989
10	7 or 8 or 9	12333
11	exp *Infection Control/	41325
12	exp *Cross Infection/	47255
13	exp *Disease Transmission, Infectious/	45086
14	exp *Decontamination/	3295
15	exp *Equipment Contamination/	7767
16	Postoperative Complications/pc [Prevention & Control]	50789
17	((infect$ or endophthalmiti$) adj3 (prevent$ or control$ or manag$)).ti,ab,kf.	130832
18	(cross infect$ or contamina$ or decontamina$ or sterili$ or disinfect$).ti,ab,kf.	380922
19	11 or 12 or 13 or 14 or 15 or 16 or 17 or 18	641568
20	6 and 10 and 19	564
21	limit 20 to english language	504
22	**limit 21 to yr="2010 -Current"**	**280**

Embase

Line	Search term	Result number
1	*cataract extraction/	20593
2	(cataract$ adj4 (surg$ or operat$ or extract$ or aspirat$ or excis$ or remov$ or emulsif$ or implant$)).ti,ab,kf.	39488
3	post?cataract.ti,ab,kf.	261
4	phacoemulsification/	17987
5	(pha?oemulsif$ or phaco or phako).ti,ab,kf.	14329
6	1 or 2 or 3 or 4 or 5	53244
7	*endophthalmitis/	6953
8	*fungal endophthalmitis/**Note:** Embase has a separate subject heading for fungal endophthalmitis, so this has been included in order to ensure that this form of the infection is captured	308
9	endophthalmiti$.ti,ab,kf.	11615
10	ophthalmia.ti,ab,kf.	1432
11	7 or 8 or 9 or 10	13697
12	exp *infection control/	38258
13	exp *cross infection/	12282
14	exp *disease transmission/	40521
15	exp *medical device contamination/	401
16	exp *"prevention and control"/	741670
17	postoperative complication/pc [Prevention]	19072
18	((infect$ or endophthalmiti$) adj3 (prevent$ or control$ or manag$)).ti,ab,kf.	168932
19	(cross infect$ or contamina$ or decontamina$ or sterili$ or disinfect$).ti,ab,kf.	444514
20	12 or 13 or 14 or 15 or 16 or 17 or 18 or 19	1338291
21	6 and 11 and 20	725
22	limit 21 to english language	620
23	22 not conference*.so,pt.	543
24	limit 23 to yr="2010 -Current"	329

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