

Research Article

Antibiotic Resistance of Intraocular Pathogens from the ARMOR Study: 2009 -2022

Reem Amine^{1*}, Heleen DeCory², Daniel F Sahn³, Penny Asbell⁴

¹Department of Ophthalmology, Duke University School of Medicine, Durham, North Carolina, United States

²Trilogy Writing and Consulting GmbH, Durham, North Carolina, United States

³IHMA, Schaumburg, Illinois, United States

⁴Bioengineering Department, University of Memphis, Memphis, Tennessee, United States

*Correspondence author: Reem Amine, Department of Ophthalmology, Duke University School of Medicine, Durham, North Carolina, United States;

Email: reem.amine8@gmail.com

Abstract

Purpose: Endophthalmitis is a rare but serious complication of ocular procedures. This study analyzed *in-vitro* antibiotic resistance profiles of intraocular isolates collected over 13 years (2009-2022) as part of the Antibiotic Resistance Monitoring in Ocular Microorganisms (ARMOR) study, the U.S. multicenter surveillance study.

Methods: Presumed endophthalmitis Isolates from aqueous and vitreous humor were collected from participating ARMOR centers and sent to an independent laboratory for susceptibility testing. Minimum Inhibitory Concentrations (MICs) were determined per Clinical and Laboratory Standards Institute (CLSI) methodology.

Results: A total of 370 intraocular isolates were collected. Methicillin resistance was observed in 45% (33/73) of *Staphylococcus aureus* and 41% (93/231) of coagulase-negative *Staphylococci* (CoNS), with multidrug resistance prevalent among methicillin-resistant strains. Gram-negative isolates showed minimal resistance, with *Haemophilus influenzae* displaying no resistance to tested drugs.

Conclusion: Resistance was prevalent among *Staphylococci*, with multi-drug resistance common in MR isolates; resistance was uncommon in Gram-negative organisms. These findings provide insights to inform antibiotic selection for endophthalmitis prophylaxis and treatment.

Keywords: Antibiotic Resistance Monitoring in Ocular Microorganisms (ARMOR); Methicillin Resistance; Gram-Negative; Multi-Drug Resistance

Introduction

Endophthalmitis is a rare but serious complication of ocular surgery and intraocular injections, typically resulting from the perioperative introduction of a patient's own bacterial flora [1]. Prophylactic use of perioperative antibiotics may reduce the risk of endophthalmitis. However,

the emergence of antibiotic-resistant bacteria complicates the effectiveness of such measures [1,2]. The Antibiotic Resistance Monitoring in Ocular microorganisms (ARMOR) study is the only prospective, multicenter, nationwide surveillance program specifically designed to monitor antibiotic resistance in ocular bacterial pathogens [3,4]. In this study, we analyzed *in-vitro* antibiotic resistance profiles of intraocular isolates collected over a 13-year period (2009 to 2022) as part of the ARMOR study.

Methodology

Isolates of *Staphylococcus aureus*, Coagulase-Negative *Staphylococci* (CoNS), *Streptococcus pneumoniae*, *Pseudomonas aeruginosa* and *Haemophilus influenzae* were collected from participating centers of the ARMOR study. These isolates were sent to an independent laboratory for species confirmation and susceptibility testing. Minimum Inhibitory Concentrations (MICs) were determined for up to 16 antibiotics across 10 antibiotic classes using guidelines outlined by the Clinical and Laboratory Standards Institute (CLSI)

Citation: Amine R, et al Antibiotic Resistance of Intraocular Pathogens from the ARMOR Study: 2009 -2022. J Clin Immunol Microbiol. 2025;6(3):1-5.

<https://doi.org/10.46889/JCIM.2025.6304>

Received Date: 20-10-2025

Accepted Date: 03-11-2025

Published Date: 11-11-2025



Copyright: © 2025 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CCBY) license

(<https://creativecommons.org/licenses/by/4.0/>).

[5]. Based on CLSI interpretive criteria, isolates were categorized as susceptible, intermediate or resistant, when available [6]. *Staphylococcus* species were further classified as Methicillin-Resistant (MR) or Methicillin-Susceptible (MS) based on oxacillin resistance or susceptibility. Gentamicin breakpoints were utilized to determine resistance or susceptibility of staphylococcal isolates to tobramycin. For this analysis, bacterial pathogens isolated from intraocular specimens, specifically Aqueous Humor (AqH) and Vitreous Humor (ViH), were included.

Results

Intraocular Isolates

A total of 370 intraocular isolates were collected from 44 participating sites across 22 states (aqueous, n=96; vitreous, n=274). Among the aqueous humor isolates, there were 27 *Staphylococcus aureus* isolates, 45 coagulase-negative *Staphylococci* (CoNS) isolates, including 38 *Staphylococcus epidermidis*, 13 *Streptococcus pneumoniae* isolates, 6 *Pseudomonas aeruginosa* isolates and 5 *Haemophilus influenzae* isolates. The vitreous humor isolates included 46 *Staphylococcus aureus* isolates, 186 CoNS isolates (of which 150 were *Staphylococcus epidermidis*), 20 *Streptococcus pneumoniae* isolates, 13 *Pseudomonas aeruginosa* isolates and 9 *Haemophilus influenzae* isolates.

In-vitro Antibiotic Resistance Profiles

Oxacillin/Methicillin Resistance (MR) was identified in 45% (33/73) of *Staphylococcus aureus* isolates and 41% (93/231) of CoNS isolates (Fig. 1). Of the MR *Staphylococcus aureus* (MRSA), 85% were resistant to ciprofloxacin and azithromycin and out of MRCoNS isolates, 70% were resistant to ciprofloxacin and azithromycin (Fig. 2). Of *S. pneumoniae* isolates, 39% (13/33) were resistant to each for azithromycin and penicillin (Fig. 3). *P. aeruginosa* and *H. influenzae* isolates exhibited little to no antibiotic resistance.

Besifloxacin demonstrated significantly lower MIC₉₀ values (minimum inhibitory concentration that inhibits 90% of isolates) compared to other fluoroquinolones, particularly for MR isolates and its efficacy was comparable to vancomycin. Against *S. aureus*, the MIC₉₀ values for besifloxacin, moxifloxacin and ciprofloxacin were 2, 8 and 64, respectively, with vancomycin at 1, indicating a 4- to 32-fold lower value for besifloxacin. Similarly, for MRSA, the MIC₉₀ values were 2, 16 and 256, respectively (vancomycin= 1), showing besifloxacin's values were 8- to 128-fold lower. In the case of CoNS, the MIC₉₀ for besifloxacin was 4, compared to 32 for moxifloxacin and 64 for ciprofloxacin (vancomycin= 2), representing an 8- to 16-fold reduction. For MRCoNS, besifloxacin's MIC₉₀ was also 4, while moxifloxacin and ciprofloxacin were 64 (vancomycin= 2), demonstrating a 16-fold lower value (Table 1).

High rates of *in-vitro* concurrent multidrug resistance, defined as resistance to three or more antibiotic classes, were observed in 41% (30/73) of *S. aureus* isolates and 40% (93/231) of CoNS isolates, with particularly elevated rates among Methicillin Resistant (MR) strains (MRSA, 38.4%; MRCoNS, 29.9%) (Fig. 4).

Antibiotic	<i>S. aureus</i>	MRSA	CoNS	MRCoNS
Besifloxacin	2	2	4	4
Moxifloxacin	8	16	32	64
Gatifloxacin	8	32	32	64
Ciprofloxacin	64	256	64	64
Levofloxacin	64	256	256	256
Ofloxacin	16	128	32	>256
Vancomycin	1	1	2	2
MIC ₉₀ Minimum inhibitory concentration that inhibits 90% of isolates (µg/mL); MR: Methicillin-Resistant				

Table 1: *In-vitro* MIC₉₀ results of different antibiotics for methicillin-sensitive and methicillin-resistant staphylococcus (*S. aureus* and CoNS).

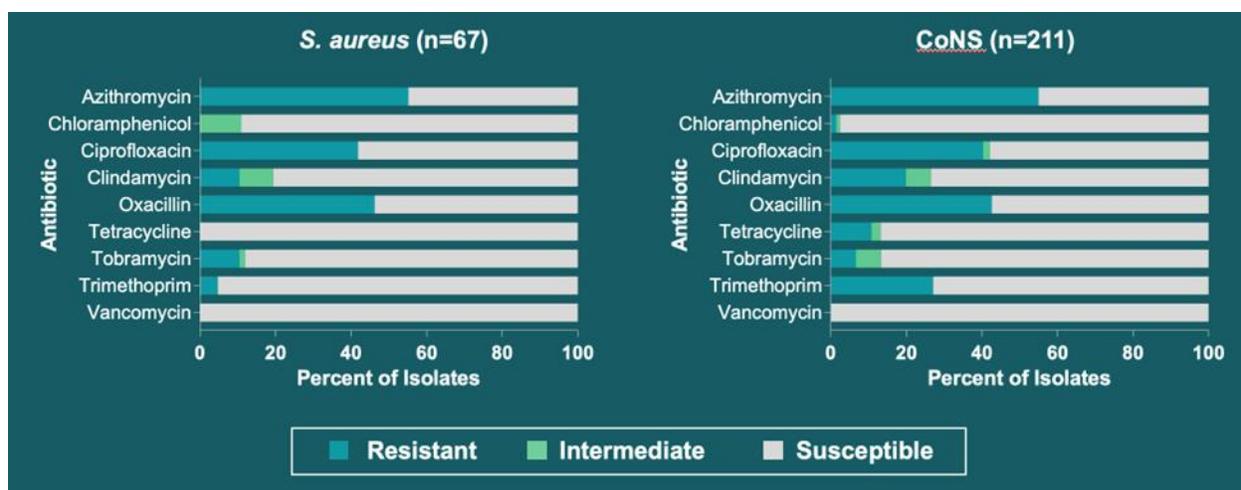


Figure 1: Oxacillin/Methicillin Resistance (MR) was identified in 45% (33/73) of *Staphylococcus aureus* isolates and 41% (93/231) of CoNS isolates.

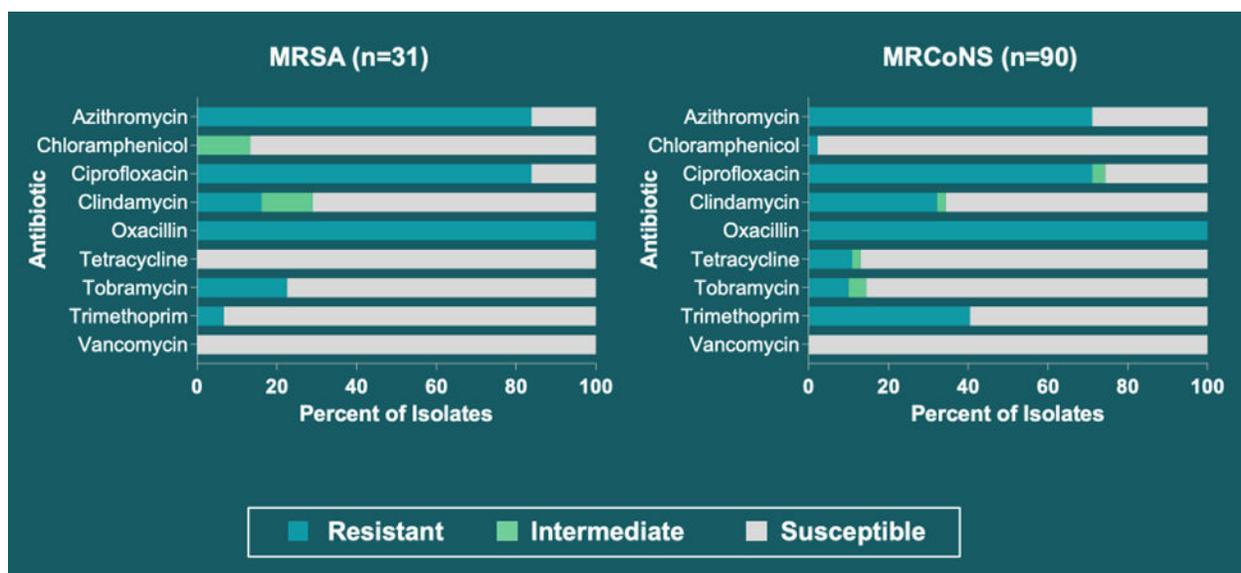


Figure 2: Resistant to ciprofloxacin and azithromycin.

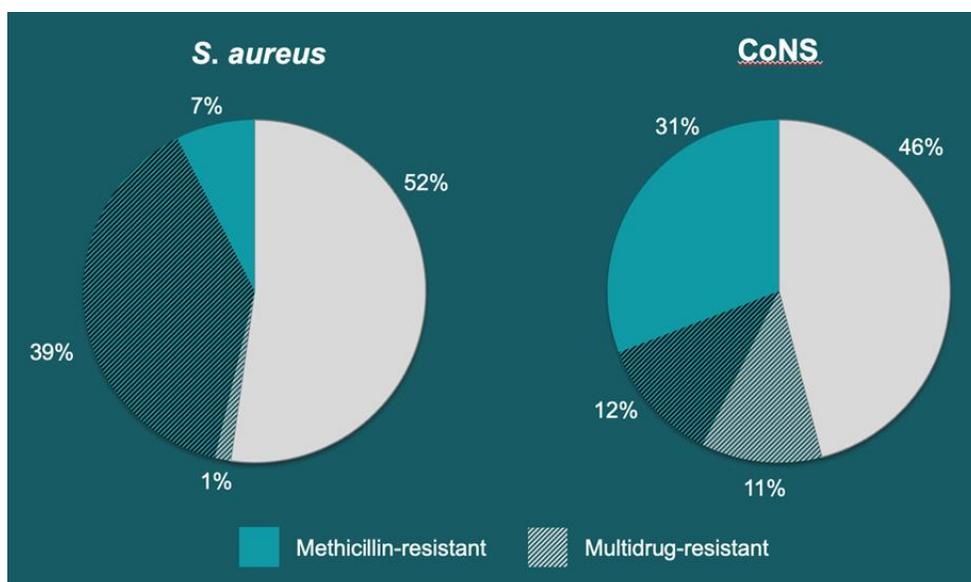


Figure 3: Resistant to each for azithromycin and penicillin.

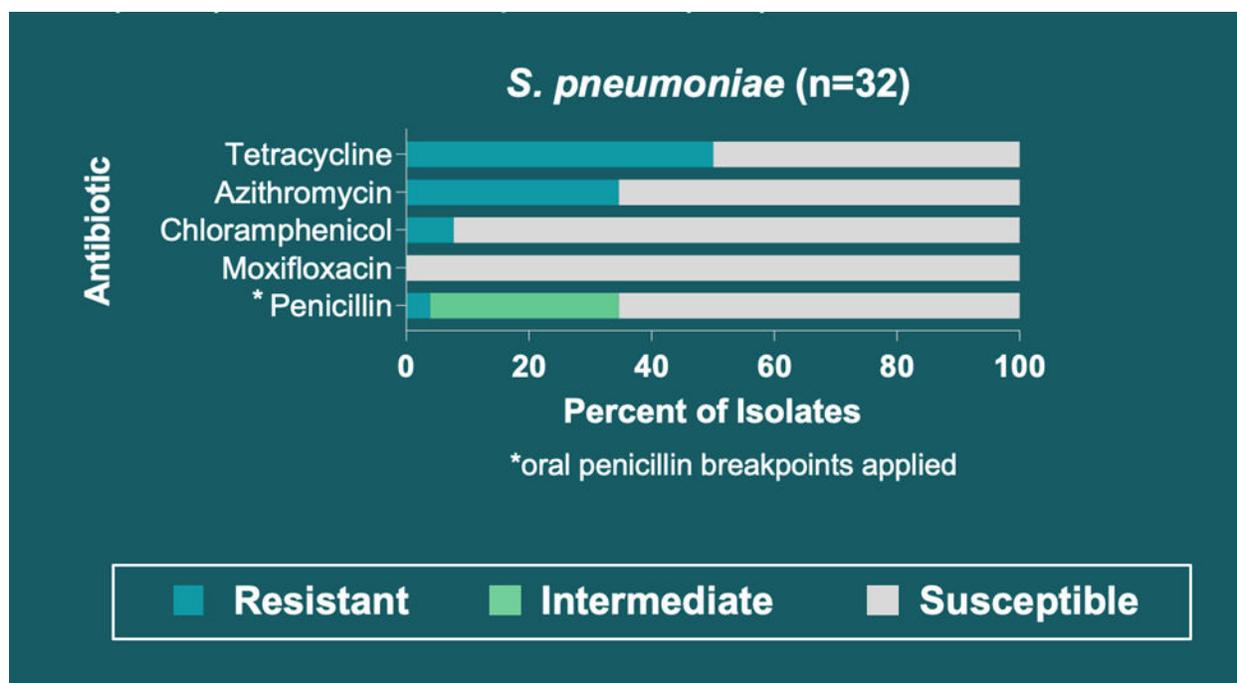


Figure 4: Resistant among Methicillin Resistant (MR) strains (MRSA, 38.4%; MRCoNS, 29.9%).

Discussion

In this analysis of presumed endophthalmitis isolates, *in-vitro* antibiotic resistance was notably prevalent among *Staphylococci*, with CoNS demonstrating the highest resistance rates. *Staphylococci*, particularly MR strains, frequently exhibited multidrug resistance. In contrast, resistance was uncommon among Gram-negative organisms. In general, the findings are consistent with those of other studies evaluating *in-vitro* antibiotic resistance among endophthalmitis isolates and prior reporting on endophthalmitis isolates collected in the ARMOR study [7]. These and other studies have shown that methicillin resistance and fluoroquinolone resistance among *Staphylococci* is particularly high. Furthermore, one study found 61% of *S. epidermidis* isolates were resistant to levofloxacin and 50% to moxifloxacin. Another study found that 34.2% of CoNS isolates were resistant to ciprofloxacin with cross-resistance observed among other fluoroquinolones. Findings from the ARMOR study provide valuable surveillance data that could guide antibiotic selection for infection prophylaxis and the treatment of intraocular following surgery. The notably high MIC₉₀ values of moxifloxacin against MRCoNS (64 mg/mL) and MRSA (16 mg/mL) in the current study warrant caution when considering its use in dropless cataract surgery via intravitreal delivery or intracameral injection as a prophylactic measure. While vancomycin remains effective against all tested *staphylococcal* isolates, its limited availability as a topical formulation and its reserved use for infections resistant to other antibiotics reduce its practicality for prophylactic purposes. For ocular surface prophylaxis, selecting an antibiotic with the highest tear C_{max} (maximum concentration) to MIC₉₀ ratio for most ocular bacteria is optimal, ensuring effective antimicrobial activity [4]. This study has some limitations that should be considered when interpreting the results. One limitation is the application of systemic breakpoints to interpret Minimum Inhibitory Concentrations (MICs). Antibiotic concentrations are more likely higher following topical ocular treatment than after systemic therapy and the application of systemic breakpoints may therefore overestimate antibiotic resistance [4]. Additionally, information on diagnosis and etiology was not collected, making it unclear what proportion of presumed endophthalmitis isolates originated from perioperative eyes versus those from intravitreal injections, other procedures or open globe injuries. In addition, these data do not provide insight into species prevalence for bacterial endophthalmitis, as ARMOR participating sites were instructed to submit a predetermined number of isolates for each bacterial species.

Conclusion

In summary, the ARMOR surveillance study provides key information on antibiotic resistance of ocular isolates and initial guidance on treatment. Clinical evaluation is, however, always needed for optimal patient care. Isolate surveillance studies can provide information on trends to help guide treatment and lead to efforts for new antibiotic discovery.

Conflict of Interest

Dr Asbell reported serving as a consultant and receiving personal fees from Alcon, Kao, Medscape, Perrigo, Santen, ScientiaCME, Senju and Shire and serving on advisory boards for Allakos, Allergan, Bausch + Lomb (a division of Bausch Health US, LLC), Dompé, Kala, Novaliq, Novartis, Regeneron Pharmaceuticals and Sun Pharmaceuticals outside the submitted work. Dr Amine has no conflicts of interest.

Funding/Support

The Antibiotic Resistance Monitoring in Ocular Microorganisms (ARMOR) study was funded by Bausch + Lomb (a division of Bausch Health US, LLC).

References

1. Gentile RC, Shukla S, Shah M. Microbiological spectrum and antibiotic sensitivity in endophthalmitis: A 25-year review. *Ophthalmology*. 2014;121(8):1634-42.
2. Schimel AM, Miller D, Flynn HW Jr. Endophthalmitis isolates and antibiotic susceptibilities: A 10-year review of culture-proven cases. *Am J Ophthalmol*. 2013;156(1):50-2.e1.
3. Asbell PA, Sanfilippo CM, Sahm DF, DeCory HH. Trends in antibiotic resistance among ocular microorganisms in the United States from 2009 to 2018. *JAMA Ophthalmol*. 2020;138(5):439-50.
4. Asbell PA, Sanfilippo CM, Mah FS. Antibiotic susceptibility of bacterial pathogens isolated from the aqueous and vitreous humour in the Antibiotic Resistance Monitoring in Ocular Microorganisms (ARMOR) Surveillance Study: 2009-2020 update. *J Glob Antimicrob Resist*. 2022;29:236-40.
5. Clinical and Laboratory Standards Institute. Documents M7-A8 through M7-A11. Wayne (PA): CLSI. 2009-2018.
6. Clinical and Laboratory Standards Institute. Document M100-S31. Wayne (PA): CLSI. 2021.
7. Asbell PA, Mah FS, Sanfilippo CM, DeCory HH. Antibiotic susceptibility of bacterial pathogens isolated from the aqueous and vitreous humor in the Antibiotic Resistance Monitoring in Ocular Microorganisms (ARMOR) surveillance study. *J Cataract Refract Surg*. 2016;42(12):1841-3.

Journal of Clinical Immunology & Microbiology



Publish your work in this journal

Journal of Clinical Immunology & Microbiology is an international, peer-reviewed, open access journal publishing original research, reports, editorials, reviews and commentaries. All aspects of immunology or microbiology research, health maintenance, preventative measures and disease treatment interventions are addressed within the journal. Immunologist or Microbiologist and other researchers are invited to submit their work in the journal. The manuscript submission system is online and journal follows a fair peer-review practices.

Submit your manuscript here: <https://athenaeumpub.com/submit-manuscript/>