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Culture and sensitivity pattern of aerobic bacterial isolates in diabetic foot infections during 2018–2022 in Asian countries: a literature review study

Thomas E.C.J. Huwae, PhD[a], Irene Ratridewi, PhD[b,*], Yulanda M. Lena, MD[c], Dewi Retnoningsih, MD[c], Panji Sananta, PhD[a], Syaifullah Asmiragani, MD[a]

Background: The most prevalent consequence of diabetes mellitus is diabetic foot infections (DFIs). Prior to the final treatment established by the culture findings, the early identification of infections may be used as a prescription for an empirical therapy. This study examines the microbiological profile and antimicrobial susceptibility profile of the bacteria that cause DFI.

Methods: This research aims to determine the culture and sensitivity trend of aerobic bacterial isolates of DFI in Asian nations over a 5-year period. The article was searched using PubMed and Google Scholar with the keywords 'Diabetic Foot Infections', 'Antibiotic', 'Microbiological Profile', and their combinations. The author uses publications from 2018 to 2022 in Indonesian and English to select the appropriate journal.

Results: The author identified 11 relevant articles with microbiological profiles and sensitivity patterns in DFI. A total of 3097 isolates were found in 2498 patients with DFI. Gram-negative bacteria were the leading source of infection ($n = 1737$; 56%). Totally, 1148 (or 37%) of all isolates were aerobic Gram-positive cocci. *Staphylococcus aureus* was the most commonly isolated aerobe ($n = 608$, 20%), followed by *Pseudomonas aeruginosa* ($n = 451$, 15%). Gram-positive bacteria showed good susceptibility to trimethoprim-sulfamethoxazole, chloramphenicol, doxycycline, vancomycin, and linezolid. Gram-negative bacteria displayed excellent susceptibility to aminoglycosides, piperacillin-tazobactam, and carbapenems.

Conclusions: Gram-negative microorganisms were the most prevalent cause of DFI. This study's findings will facilitate the development of future empirical therapeutic guidelines for the treatment of DFI.

Keywords: antibiotic, diabetic foot infection, microbiological profile

Background

Diabetic foot infections (DFIs) are the most common complication of diabetes. Soft tissue infections or osteomyelitis are the two types of infections that could arise. The International Working Group on the Diabetic Foot (IWGDF) and the Infectious Diseases Society of America (IDSA) adopt the following grading system: grade 1 (uninfected), grade 2 (mild infection), grade 3 (moderate infection), and grade 4 (severe infection)[1–4].

Gram-positive bacteria, such as *Staphylococcus aureus*, *Streptococcus pyogenes*, and *Enterococcus* spp., and Gram-negative rods, such as *Enterobacter* spp., *Pseudomonas aeruginosa*, and *Pseudomonas fluorescens*, are the most frequent microorganisms responsible for DFI[1–13].

The first management and therapy for DFI is empiric antibiotic therapy, depending on the pattern of antibiotic sensitivity of the infection, followed by wound care and surgery. In addition to a variety of other considerations, empiric treatment should be based on the clinician's best estimate of the likely causative bacteria and their local antibiotic susceptibilities (e.g. drug allergies, recent hospitalization, patient co-morbidities, the likelihood of adverse events or potential drug interactions, and the availability and cost of various agents). This research aims to determine the

HIGHLIGHTS

- Diabetic foot infections (DFIs) are the most prevalent complication among diabetes mellitus patients.
- Gram-negative bacteria were the leading cause of DFIs.
- Culture and sensitivity patterns of bacteria are required for future DFI therapy.

Departments of [a]Orthopaedics and Traumatology, [b]Pediatrics and [c]Clinical Microbiology, Faculty of Medicine, Universitas Brawijaya – Dr. Saiful Anwar General Hospital, Malang, East Java, Indonesia

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**Corresponding author. Address: Department of Pediatrics, Faculty of Medicine, Universitas Brawijaya – Dr. Saiful Anwar General Hospital, Malang 65111, East Java, Indonesia. E-mail address: irene24.fk@ub.ac.id (I. Ratridewi).*

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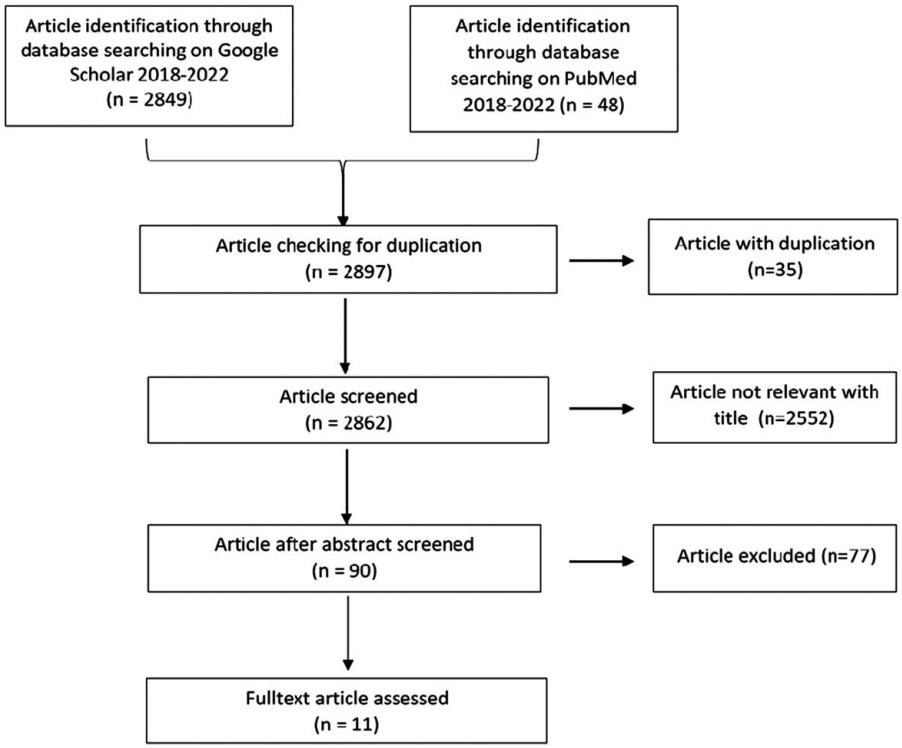

Figure 1. Flow diagram of the search strategy.

Table 1

Summary of the relevant article

Author	Isolates	Antibiotics
Sekhar *et al.* [1]	1. *Staphylococcus aureus*	1. Doxicycline
	2. *Pseudomonas aeruginosa*	2. Meropenem
Wu *et al.* [10]	1. *Staphylococcus aureus*	1. Vancomycin, Linezolid
	2. *Pseudomonas aeruginosa*	2. Fluoroquinolone, Aminoglycoside Carbapenem
Li *et al.* [9]	1. *Staphylococcus aureus*	1. Vancomycin, Linezolid, Piperacillin-tazobactam
	2. *Pseudomonas aeruginosa*	2. Carbapenem, Aminoglycoside
Rahmawati *et al.* [4]	1. *Enterococcus faecalis*	1. Vancomycin, Ampicillin Sulbactam
	2. *Klebsiella pneumoniae*	2. Meropenem
Donastin *et al.* [3]	1. *Staphylococcus aureus*	Carbapenem
	2. Klebsiella pneumoniae	
Ahmadishooli *et al.* [5]	1. *Escherichia coli*	1. Vancomycin
	2. *Enterococcus* spp.	2. Meropenem, Ciprofoxacin
Goh *et al.* [11]	1. *Staphylococcus aureus*	1. Vancomycin
	2. *Pseudomonas aeruginosa*	2. Meropenem, Amikacin
Salim *et al.* [12]	1. *Staphylococcus aureus*	1. Vancomycin, Tigecycline, Linezolid
	2. *Klebsiella pneumoniae*	2. Carbapenem
Sannathimma *et al.* [14]	1. *Staphylococcus aureus*	1. Doxicycline, TMP-SMX, Vancomycin, Linezolid
	2. *Pseudomonas aeruginosa*	2. Carbapenem, Aminoglycoside
Degloorkan *et al.* [8]	1. *Staphylococcus aureus*	1. Rifampicin, Cefoperazone, Tigecycline
	2. *Morganella morganii*, *Proteus mirabilis*	2. Fluoroquinolone, Carbapenem
Aydin *et al.* [7]	1. *Staphylococcus aureus*	1. Vancomycin, Teicoplanin, Linezolid, TMP-SMX
	2. *Klebsiella pneumoniae*	2. Meropenem, Amikacin, Piperacillin-tazobactam

culture and sensitivity trend of aerobic bacterial isolates of DFI in Asian nations over a 5-year period. A literature study is necessary to examine the microbiological profile and antibiotic susceptibility pattern of the bacteria causing DFI[2].

Methods

The following strategy was used terms on Google Scholar and PubMed search engine was 'diabetic foot infections', 'antibiotic', 'microbiological Profile', and its combination. After searching those keywords, the author uses publications from 2018 to 2022 in Indonesian and English to select the appropriate journal. Journals were reviewed based in the title and abstract and followed inclusion criteria. The inclusion criteria were studied on patients with DFI, and microbiological cultures and sensitivity tests were performed. The journal search strategy is shown in Figure 1. This research aims to identify the culture and sensitivity trend of aerobic bacterial isolates from DFI in Asian nations over a 5-year period.

Results and discussions

The author identified 11 relevant articles with a microbiological profile and sensitivity pattern in DFI (Table 1). All of the studies come from Asian countries: three studies from Indonesia, two studies from India, one study from Malaysia, two studies from China, one study from Oman, one study from Turkey, and one study from Iran. Five studies classified patients according to IDSA/IWGDF, or Wagner, and six studies did not classify patients.

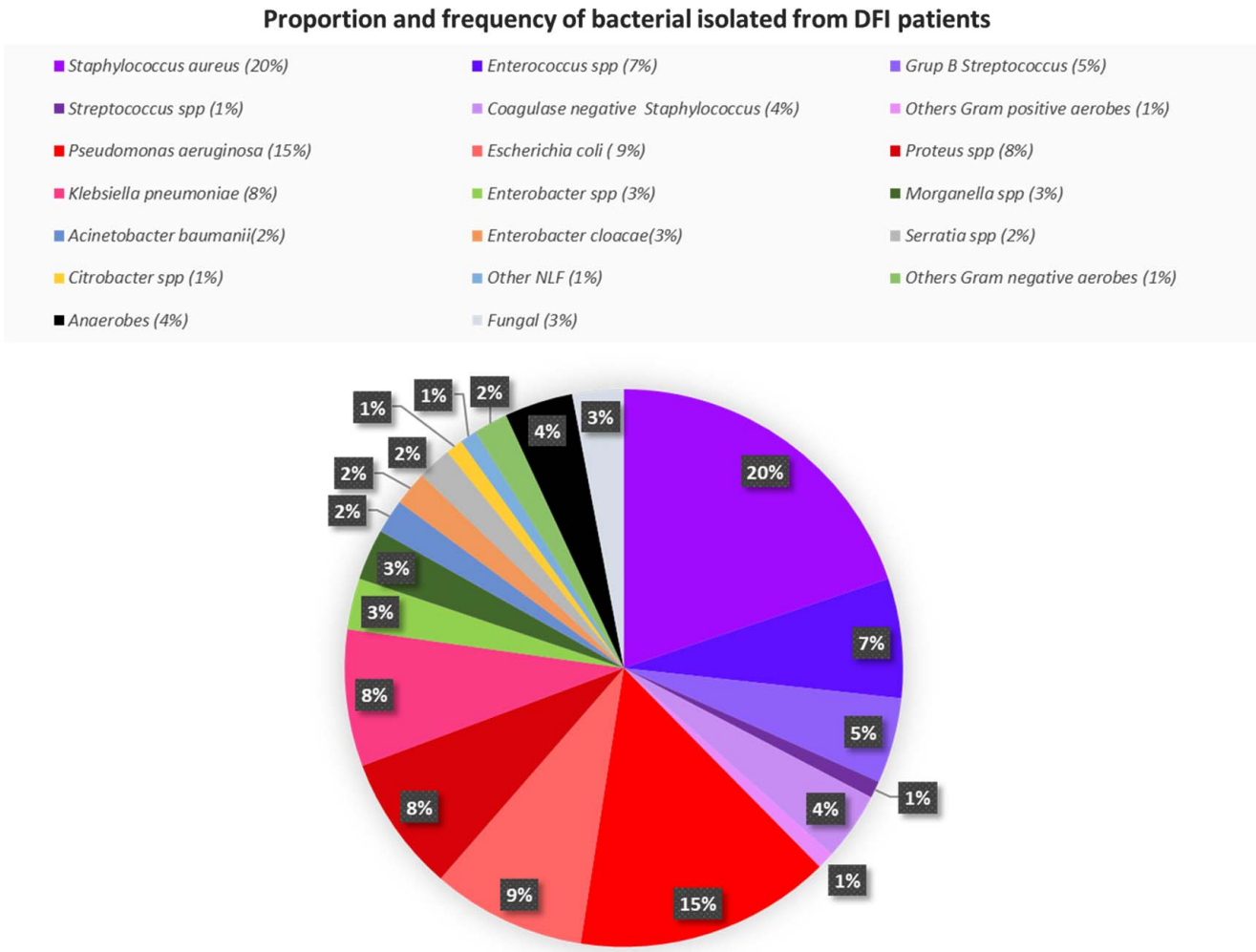

Figure 2. Proportion and frequency of bacterial isolated from diabetic foot infection patients.

A total of 3097 isolates were found in 2498 patients with DFI. Gram-negative bacteria were the leading source of infection ($n = 1737$; 56%). Totally, 1148 (or 37%) of all isolates were aerobic Gram-positive cocci. *S. aureus*, however, was the most frequently isolated aerobe ($n = 608$; 19.6%), followed by *P. aeruginosa* ($n = 451$; 14.5%) (Fig. 2).

S. aureus, a Gram-positive bacterium (Fig. 3), exhibited high susceptibility to oxacillin (100%), chloramphenicol (100%), teicoplanin (100%), vancomycin (100%), tigecycline (100%), and linezolid (100%), and good susceptibility to trimethoprim/sulfamethoxazole (87%), gentamycin (84%), clindamycin (78%), and doxycycline (74%).

While methicillin-resistant *S. aureus* showed high-level susceptibility to linezolid (100%), tigecycline (100%) and doxycycline (100%), vancomycin (93%), and trimethoprim/sulfamethoxazole (83%). On the other hand, group B *Streptococcus* and *Enterococcus* spp. showed high susceptibility to chloramphenicol (100%), teicoplanin (100%), doxycycline (100%), gentamycin (99%), linezolid (90–95%), tigecycline (80–100%), and vancomycin (96%). Multiple global studies have documented a rise in *S. aureus* and *Enterococcus faecalis* vancomycin resistance. In order to prevent the future emergence of vancomycin-resistant strains, the prudent use of these medications is strongly recommended. In this investigation, we found that trimethoprim-sulfamethoxazole, chloramphenicol, and doxycycline are suitable for the empirical treatment of Gram-positive isolates[6].

Gram-negative bacteria demonstrated excellent susceptibility to imipenem (84–94%), meropenem (61–99%), piperacillin-tazobactam (63–88%), and amikacin (50–86%). Carbapenems, cephalosporins, aminoglycosides, piperacillin/tazobactam, and fluoroquinolone have shown high-level susceptibility to *P. aeruginosa*. The similar good susceptibility of these treatments has been documented by numerous studies[6]. The high rate of susceptibility may be attributable to the restricted use of these drugs due to their expensive cost, increased risk of adverse effects, and stringent usage restrictions. *Enterobacteriaceae* and *Acinetobacter baumannii* showed low-level susceptibility to cephalosporins. This is due to the widespread use of these medications for treatment and prevention as well as the creation of resistant strains. Compared to Gram-positive organisms, Gram-negative organisms are known to develop resistance to several antibiotics more quickly. These results indicate that aminoglycosides, piperacillin-tazobactam, and carbapenems are suitable for

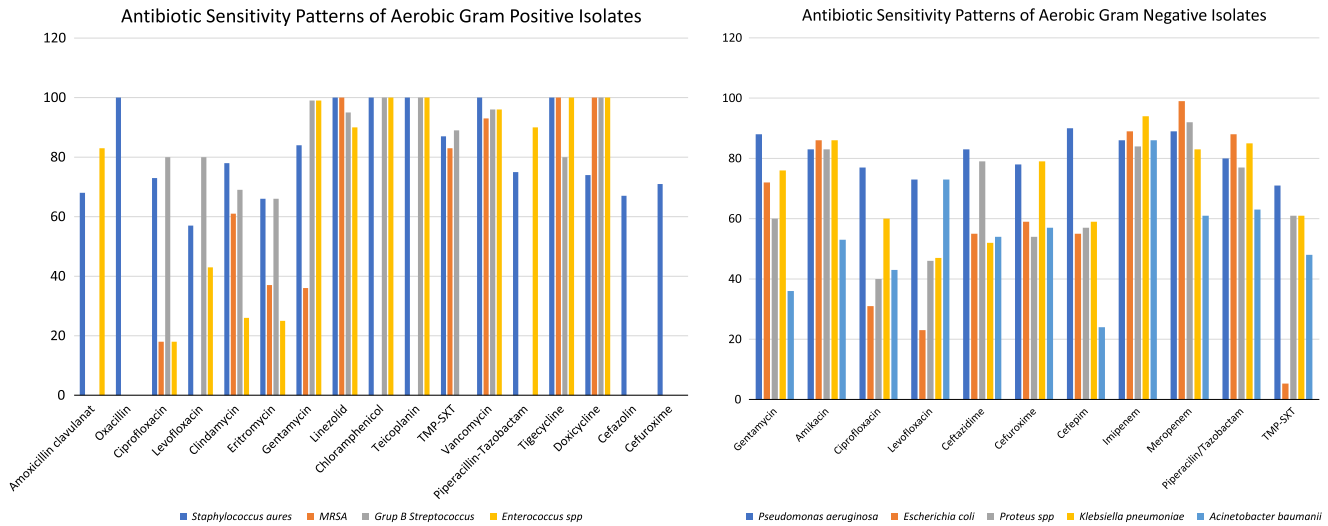

Figure 3. Antibiotic sensitivity patterns of aerobic gram-positive and negative isolates.

the empirical treatment of Gram-negative bacterial infections in DFI.

Conclusions

Gram-negative bacteria were the most common cause of DFI. We have shown that trimethoprim-sulfamethoxazole and doxycycline are suitable for the empirical treatment of Gram-positive bacterial infections, while aminoglycosides and carbapenems are suitable for Gram-negative bacterial infections in DFI.

Ethical approval

This study does not need ethical review.

Consent

This study does not need inform consent.

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This study did not receive any specific grant from funding agencies, commercial, or not-forprofit sectors.

Conflicts of interest disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contribution

T.E.C.J.H.: conceptualization, writing original draft preparation, supervision, validation. I.R.: writing the paper and editing, data interpretation, data collecting, validation. Y.M.L.: writing the paper and editing, data interpretation, validation, visualization. D.R.: writing the paper and editing, data interpretation, validation, visualization. P.S.: writing the paper and editing, methodology, data interpretation. S.A.: writing the paper and editing, supervision, validation.

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Guarantor

Irene Ratridewi, Department of Pediatrics, Faculty of Medicine, Universitas Brawijaya – Dr. Saiful Anwar General Hospital, Jl. Jaksa Agung Suprapto No. 2, Klojen, Malang 65112, East Java, Indonesia. E-mail address: irene24.fk@ub.ac.id

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