

Morphometric Characterization of Bacteria Associated with Bacteremia

Subjects: **Microbiology**

Contributor: Ladees Al Hafi , Evangelyn C. Alocilja

Among the leading causes of bacteremia are *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus*. *E. coli* and *K. pneumoniae* are increasingly exhibiting resistance to last-resort antibiotics, such as carbapenems. Rapid and accurate identification of these pathogens is critical for timely treatment and infection control. This paper aimed to develop a computer-aided bacterial morphometric technique for identifying and classifying wild-type *E. coli*, *K. pneumoniae*, and *S. aureus* in a field guide fashion. A 3D laser scanning confocal microscope was used to gather key parameters of each organism: length (L, μm), circular diameter (CD, μm), volume (V, μm^3), surface area-to-cross-sectional area ratio (SA/CSA, unitless), surface uniformity ratio (Str), and surface texture ratio (Sdr). Microscope images and measurement results showed that *S. aureus* was spherical with the shortest length (1.08 μm) and smallest volume (0.52 μm^3). *E. coli* and *K. pneumoniae* were rod-shaped with lengths $>2.0 \mu\text{m}$ and volumes $>1.0 \mu\text{m}^3$. Carbapenem-resistant (CR) strains exhibited larger volumes than their wild-type counterparts. Surface parameters further differentiated strains: wild-type *E. coli* had a greater surface texture or a less smooth surface (larger Sdr) than *K. pneumoniae* (lower Sdr) did. CR *E. coli* had more surface uniformity (lower Str) than CR *K. pneumoniae* did. A dichotomous key based on shape, circular diameter, volume, length, and surface characteristics was developed to classify the species using a series of paired, contrasting features. This morphometric analysis can aid researchers in quickly identifying bacteria, leading to faster diagnosis of life-threatening diseases and improved treatment decisions.

bacteremia

antimicrobial resistance (AMR)

diagnostics

dichotomous

morphometrics

size

surface roughness

E. coli

K. pneumoniae

S. aureus

Bacteremia is the presence of viable bacteria in circulating blood, and it is associated with significant morbidity and mortality [1]. Various factors, including microbial infection, medical procedures, or the use of medical devices, can cause bacteremia [1]. In a surveillance study between 2002 and 2020, *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus* were the top three causes of bacteremia in Taiwan [2]. Sepsis can develop from bacteremia if the body's immune system is unable to control the infection [2]. It can rapidly progress to organ failure and can lead to shock and death if not treated quickly [2]. Rapid and accurate identification of the causative bacteria is crucial for effective treatment. Current methods of identification include culture (colony morphology and biochemical tests), staining (Gram-positive and Gram-negative stains), genomics (polymerase chain reaction, microarrays, and ribotyping), and other advanced techniques (mass spectrometry and flow cytometry). However, these techniques are time-consuming and expensive. Bacterial identification based on morphology is gaining popularity [3]. It is rapid, reduces costs, and yields intuitive results [3][4]. Modern morphometry utilizes advanced computer-assisted image analysis software to interface an image with geometric software that measures specific

biological features [4]. It is a quantitative analysis of the size and shape of geometric features of cells, cell organelles, and/or biomarkers [4]. Bacterial morphometry allows for a systematic approach to bacterial identification, progressing from easily observable characteristics to more detailed microscopic and biochemical analyses. It functions like a field guide by providing a framework for identifying bacteria based on their characteristic shapes, arrangements, and visible growth patterns.

The emergence of bacteria with antimicrobial resistance (AMR) has further exacerbated the poor outcomes associated with bacteremia [2]. The rise in AMR makes diagnosis and treatment increasingly complex [5][6]. AMR is one of the top three major public health threats by the World Health Organization (WHO) and is the third leading cause of death after cardiovascular diseases [6]. An estimated 1.27 million deaths were attributed to antimicrobial-resistant infections in 2019 alone, while nearly 5 million deaths were somehow associated with drug-resistant infections [6]. AMR infections can lead to severe complications, especially among immunocompromised patients [7][8]. Therapeutic options for infections caused by antimicrobial-resistant bacteria are limited, resulting in prolonged illness and significant morbidity and mortality, with a high financial impact [8]. Many medical advances, such as organ transplants and cancer therapy, depend on the ability to fight infections with antimicrobials. If the ability to effectively treat those infections is lost, the ability to safely offer people many of the lifesaving and life-improving modern medical advances will be lost with it.

Beta-lactams, including penicillin, cephalosporin, monobactam, and carbapenem, are the most widely used antibiotics worldwide, and they are reserved only for human use [9]. Carbapenems are the most effective antimicrobial agents against both Gram-positive and Gram-negative bacteria, exhibiting a broad spectrum of antibacterial activity. Thus, the rise in carbapenem-resistant (CR) bacteria is concerning, as it limits treatment options and is associated with increased morbidity, mortality, and healthcare costs [6][10]. CR can induce structural and physiological changes in bacterial cells, potentially altering their morphology and growth patterns [11][12][13].

Thus, this paper aimed to develop a computer-aided bacterial morphometric technique for identifying and classifying wild-type *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus* in a field guide fashion [13]. The first classification employed shape, followed by other parameters. Bacteria have distinct shapes, such as (1) spherical or round (cocci), in clusters (e.g., *Staphylococcus*), in chains (e.g., *Streptococcus*), in pairs with pointed ends (e.g., *Streptococcus pneumoniae*), and in pairs with kidney bean shape (e.g., *Neisseria*); (2) rods (bacilli), with square ends (e.g., *Bacillus*), with rounded ends (e.g., *Salmonella*), club-shaped (e.g., *Corynebacterium*), fusiform (e.g., *Fusobacterium*), and comma-shaped (e.g., *Vibrio*); and (3) spiral (Spirochetes), relaxed coil (e.g., *Borrelia*), and tightly coiled (e.g., *Treponema*) [11].

The morphometric technique was extended to classify CR *E. coli* and CR *K. pneumoniae* since both pathogens are frequently known to develop CR, but not on *S. aureus*, because it is not commonly known to have resistance to carbapenem. By mapping morphometric traits to specific species, this guide supports faster, image-based identification and strengthens the ability to respond to the growing threats of AMR.

References

1. McNamara, J.F.; Righi, E.; Wright, H.; Hartel, G.F.; Harris, P.N.A.; Paterson, D.L. Long-term morbidity and mortality following bloodstream infection: A systematic literature review. *J. Infect.* 2018, 77, 1–8.
2. Huang, Y.-C.; Kuo, S.-C.; Fang, C.-T.; Lauderdale, T.-L. Changing epidemiology and antimicrobial resistance of bacteria causing bacteremia in Taiwan: 2002–2020. *Microbiol. Spectr.* 2024, 12, e00608–e00624.
3. Al Hafi, L.; Franco, A.J.; Kao, K.; Alocilja, E.C. Field Guide: Morphometric Visualization and Characterization of Selected Foodborne Pathogens Using Advanced Imaging Techniques. *Encyclopedia* 2025, 5, 47.
4. Wang, X.; Shi, Y.; Guo, S.; Qu, X.; Xie, F.; Duan, Z.; Hu, Y.; Fu, H.; Shi, X.; Quan, T.; et al. A Clinical Bacterial Dataset for Deep Learning in Microbiological Rapid On-Site Evaluation. *Sci. Data* 2024, 11, 608.
5. Abban, M.K.; Ayerakwa, E.A.; Mosi, L.; Isawumi, A. The burden of hospital acquired infections and antimicrobial resistance. *Heliyon* 2023, 9, e20561.
6. Salam, M.A.; Salam, A.; Al-Amin, Y.; Pawar, J.S.; Akhter, N.; Rabaan, A.A.; Alqumber, M.A.A. Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. *Healthcare* 2023, 11, 1946.
7. Abbara, S.; Guillemot, D.; Smith, D.R.; El Oualydy, S.; Kos, M.; Poret, C.; Breant, S.; Brun-Buisson, C.; Watier, L. Antimicrobial Resistance as Risk Factor for Recurrent Bacteremia after *Staphylococcus aureus*, *Escherichia coli*, or *Klebsiella* spp. *Community-Onset Bacteremia. Emerg. Infect. Dis.* 2024, 30, 974–983.
8. Elbehiry, A.; Marzouk, E.; Aldubaib, M.; Moussa, I.; Abalkhail, A.; Ibrahim, M.; Hamada, M.; Sindi, W.; Alzaben, F.; Almuzaini, A.M.; et al. *Pseudomonas* species prevalence, protein analysis, and antibiotic resistance: An evolving public health challenge. *AMB Express* 2022, 12, 53.
9. Meletis, G. Carbapenem resistance: Overview of the problem and future perspectives. *Ther. Adv. Infect. Dis.* 2016, 3, 15–21.
10. Ahmed, S.K.; Hussein, S.; Qurbani, K.; Ibrahim, R.H.; Fareeq, A.; Mahmood, K.A.; Mohamed, M.G. Antimicrobial resistance: Impacts, challenges, and future prospects. *J. Med. Surg. Public Health* 2024, 2, 100081.
11. Levinson, W.; Chin-Hong, P.; Joyce, E.A.; Nussbaum, J.; Schwartz, B. Structure of Bacterial Cells. In *Review of Medical Microbiology & Immunology: A Guide to Clinical Infectious Diseases*, 16th ed.; McGraw Hill: New York, NY, USA, 2020; Available online:

<https://accessmedicine.mhmedical.com/content.aspx?bookid=3123§ionid=261995947>
(accessed on 30 June 2025).

12. Amako, K.; Meno, Y.; Takade, A. Fine structures of the capsules of *Klebsiella pneumoniae* and *Escherichia coli* K1. *J. Bacteriol.* 1988, 170, 4960–4962.
13. Ikebe, M.; Aoki, K.; Hayashi-Nishino, M.; Furusawa, C.; Nishino, K. Bioinformatic analysis reveals the association between bacterial morphology and antibiotic resistance using light microscopy with deep learning. *Front. Microbiol.* 2024, 15, 1450804.

Retrieved from <https://encyclopedia.pub/entry/history/show/131165>