

Infectious complications after cardiac implantable electronic devices insertion in the elderly patients

Agata Firkowska

II Department of Cardiology and Electrotherapy, University Clinical Centre in Gdańsk

Abstract

The use of cardiac implantable electronic devices (CIEDs) is steadily increasing alongside the aging of the global population. Although these devices significantly improve quality of life and survival in patients with arrhythmias and heart failure, they are also associated with a risk of serious infectious complications. The geriatric population is especially susceptible to CIED infections due to age-related physiological changes, immunosenescence, comorbid conditions, and polypharmacy. Infectious complications following CIED implantation present a complex clinical challenge in elderly patients. A multidisciplinary, individualized approach is critical to reducing infection rates and improving patient outcomes in this high-risk group. This review provides a comprehensive analysis of the various CIED types, the etiology and mechanisms underlying CIED-related infections, and the risk factors specific to the elderly population. *Geriatrics* 2025;19:147-152. doi: 10.53139/G.20251924

Keywords: CIED, cardiology, infections, elderly, pacemaker

Introduction

According to the *World Population Prospects 2024*, by the end of the 2070s, the global population of adults aged 65 and over is projected to reach 2.2 billion, overtaking the number of children younger than 18. Additionally, by the mid-2030s, the count of people aged 80 and above is projected to exceed 265 million – overtaking the number of newborns under one year old [1]. As global populations age and life expectancy increases, the demand for cardiac implantable electronic devices (CIEDs) in the geriatric population continues to grow. Currently, more than 80% of pacemakers are implanted in patients over the age of 65, with the most frequent indications being high-degree atrioventricular (AV) block and sinus node dysfunction [2,3].

While these procedures significantly improve outcomes in patients with arrhythmias and heart failure, infectious complications remain among the most serious and challenging adverse events. Cardiac implantable electronic device (CIED) infections are associated with substantial morbidity and mortality, prolonged hospital stays, the need for device removal, and a substantial decline in functional status – particularly in elderly patients. The in-hospital or 30-day mortality rate is estimated at 5-8%, with significantly higher rates observed in patients with major comorbidities such as heart failure, chronic kidney disease, or those on chronic corticosteroid therapy. Mortality is notably elevated in cases of

CIED-related endocarditis compared to localized pocket infections. Patients who experience a CIED infection have a 1.5 to 2.4 times higher long-term mortality risk compared to those without infection [4].

This review will explore the available CIED types, etiology and mechanisms of infection, risk factors in the elderly, and strategies for prevention of CIED-related infections with a particular emphasis on the need for individualized approaches in this high-risk population.

CIED types and technical aspects of implantation

CIEDs (Cardiac Implantable Electronic Devices) are medical devices inserted in patients with heart conditions such as heart failure, bradyarrhythmias or structural heart disease to regulate heart rate, correct abnormal heart rhythms, improve heart muscle function and prevent sudden cardiac death.

The main types of CIEDs include:

- permanent pacemakers (PPMs),
- implantable cardioverter defibrillators (ICDs),
- cardiac resynchronization therapy (CRT), available as CRT-P (pacemaker) or CRT-D (defibrillator).

The implantation of cardiac implantable electronic devices (CIEDs) involves a series of critical technical steps aimed at ensuring optimal device function and minimizing procedural complications. Device pocket is generally performed left-sided as it corresponds to the

nondominant side in the majority of patients and typically allows for more straightforward lead placement. The subcutaneous or subpectoral placement can be chosen. Venous access is typically achieved via the subclavian or axillary vein, often under ultrasound/fluoroscopy guidance to reduce the risk of complications such as pneumothorax or arterial puncture [5]. Depending on the type of device and the medical indications, one to three leads are inserted intravenously into the heart and into the appropriate cardiac chambers – commonly the right atrium, right ventricle and for cardiac resynchronization therapy (CRT), the coronary sinus [6]. Once the leads are connected to the generator, the device is programmed according to the clinical indication.

Etiology and mechanisms of CIED related infections

There are two major mechanisms of CIED infections (CIEDI) development:

1) Direct contamination during the procedure

Infection occurs during implantation procedure itself – whether during the primary implantation, generator replacement, or system upgrade – and results from direct contamination of leads or pulse generator by microorganisms colonizing the patient's skin, via the air in the operating room or the hands of the medical staff handling the device [4]. In such cases, the infection typically manifests first in the device pocket.

2) Hematogenous spread

Bacteria from distant infectious sites such as thrombophlebitis, osteomyelitis or pneumonia enter the bloodstream causing bacteremia. This pathway results in direct lead colonization, which may progress to systemic infection. In this case, patients typically present with generalized signs of infection, while the device pocket may appear clinically unremarkable [7,8].

CIED infections present with a broad spectrum of clinical manifestations, ranging from asymptomatic cases to severe presentations such as septic shock. There can be distinguished:

- generator pocket infections – the majority of CIED infections (approximately 60%) are pocket infections, typically presenting with erythema, tenderness, local warmth, and, in some cases, skin erosion with device exposure (figure 1). However, infection can extend along the intravascular portion of the leads, progressing to intravascular

infection, which may manifest as bacteriemia or lead-associated endocarditis.[9] Lead involvement is associated with higher rates of complications and mortality [10],

- systemic infections – manifesting with a wide range of symptoms from non-specific signs such as fever, chills, and unintentional weight loss, to more severe presentations like septic shock, typically accompanied by persistent bacteremia and positive blood cultures. This condition may arise either through hematogenous spread from a localised pocket infection or as a result of secondary lead colonization (figure 2) following bacteremia originating from a distant infectious source [10],
- lead-related infective endocarditis (LRIE) – endocarditis is present in 25-29% of CIEDI cases [11-13]. Diagnosis is based on a combination of clinical, microbiological, and imaging findings, often guided by the Modified Duke Criteria. Lead-related infective endocarditis (LRIE) represents the most severe and life-threatening complication associated with cardiac implantable electronic devices. LRIE carries a significant risk of mortality and may present independently or alongside pocket infection, often involving vegetations on the intracardiac leads or the tricuspid valve [14].



Figure 1. Pocket infection with device exposure

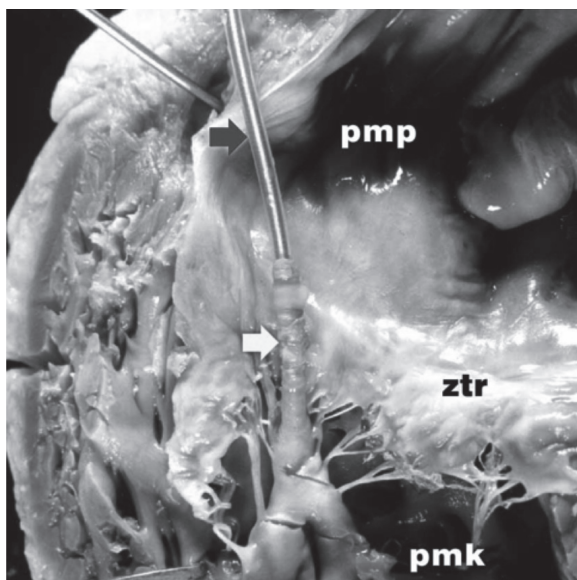


Figure 2. Lead colonization

According to „European Heart Rhythm Association (EHRA) international consensus document” the vast majority (70%–90%) of CIED-related infections are caused by Gram-positive bacteria, with *Staphylococcus aureus* (30,8%) and coagulase-negative staphylococci (37,6%), mainly *Staphylococcus epidermidis*, being the

most common pathogens. Nearly half of all staphylococcal infections have been reported to be caused by methicillin-resistant staphylococci. The percentage distribution of pathogens responsible for CIEDI is shown in figure 3. Gram-negative bacteria are less common, causing under 10% of all infections [4]. When they do occur, they are most often caused by organisms such as *Pseudomonas aeruginosa*, *Klebsiella* spp. or *Escherichia coli* [15]. Gram (-) CIEDI tend to appear more frequently in patients with a history of prior CIED infections or significant comorbidities [15,16]. In terms of Gram-negative CIED infections, hematogenous spread from a distant infection sites is rare, however it can occasionally happen – particularly following transient bacteremia originating from the urinary tract or abdominal cavity [17]. Urinary tract infections (UTIs) are common in the elderly people with *E. coli* accounting for the majority of them and causing asymptomatic bacteremia [18]. Based on these observations, it can be concluded that elderly patients, burdened with multiple underlying conditions and infection risk factors, have higher susceptibility to suffer from CIED infections due to Gram (-) bacteria.

Risk factors for CIED infections in geriatric population

Elderly people are at higher risk of developing infections in general, including those associated with

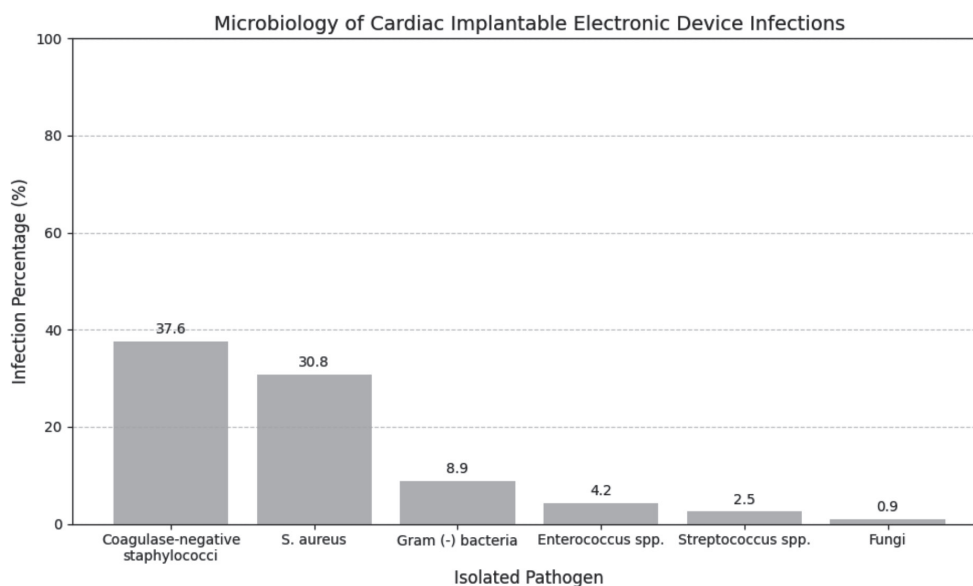


Figure 3. Percentage distribution of etiological agents in CIED infections [4]

cardiac implantable electronic device (CIED) procedures [19,20]. In retrospective cohort study, which enrolled patients who had undergone CIED procedures at two heart centers in Turkey between January 2011 and May 2023, infection rates were relatively higher in the patient group aged ≥ 75 years [19].

Along with aging, the human immune system undergoes progressive functional decline – defined as immunosenescence. This complex, multifactorial process is characterized by changes in various aspects of different immune components, leading to diminished immune surveillance, impaired pathogen clearance, and a blunted response to new antigens [20]. As a result, older population exhibits increased vulnerability to infections, malignancies, and poorer vaccine responses. Immunosenescence plays a role in the heightened risk of infectious complications observed in elderly patients in general, as well as in the context of invasive procedures such as cardiac implantable electronic device (CIED) implantation.

Another common and significant risk factor concerning the elderly population of patients is presence of comorbid diseases [2]. Older patients are often burdened with multiple comorbidities, such as:

- end-stage renal disease,
- diabetes mellitus,
- chronic obstructive pulmonary disease,
- heart failure (NYHA class ≥ 2),
- malnutrition and hypoalbuminemia [19],
- skin disorders.

These conditions further compromise immune function and wound healing [9]. End-stage renal disease is considered as a highest-risk factor.

What is more, due to multiple chronic conditions that require complex pharmacological treatment, older people are vulnerable to polypharmacy. This increases the likelihood of drug – drug interactions, adverse drug effects, all of which can compromise the immune response and wound healing (immunosuppressive agents, corticosteroids, antidiabetic drugs) [21]. Moreover, medications such as anticoagulants or antiplatelet agents raise the risk of hematoma formation in the device pocket, which is a well-established predictor of pocket infection. What is relevant, ‘bridging’ anticoagulation strategy with low-molecular-weight heparin (LMWH) increases the risk of pocket haematoma and is no longer recommended in clinical practice [4].

Due to the fact, that patients with CIED live longer, it is more likely they will need to undergo reinterventions,

including generator replacements due to low battery or upgrade procedures. Each of reintervention increases the cumulative infection risk [4].

Advanced age is often associated with reduced skin elasticity and a significant loss of subcutaneous tissue and fat redistribution, also in the prepectoral region where these devices are commonly placed. As a result, the generator and transvenous leads may lie closer to the skin surface, increasing the risk of chronic mechanical pressure, progressive skin erosion, and eventual device exposure. These conditions create a favorable environment for bacterial colonization and infection, which can lead to serious complications, including device-related endocarditis and sepsis [22,23].

CRP level as a CIED infection predictor

Research projects have demonstrated that increased CRP levels at the time of cardiac device implantation may be associated with a greater risk of complications, including infectious ones, requiring TLR (transvenous lead removal) during the 6 months after the initial procedure [24]. CRP levels generally rise with advancing age and the presence of multiple comorbidities [25]. As a result, elderly patients, who are usually associated with multimorbidity, are more prone to elevated CRP values at the time of CIED implantation, potentially increasing their risk of post-procedural infection. What is more, elevated pre-procedural CRP level appears to be an indicator of CIED infection severity and is correlated with long-term outcomes in patients [26]. In such scenarios, careful planning the optimal timing for implantation, that is until inflammatory markers return to normal range, may help reduce complication rates.

Prevention strategies

A reliable prevention strategy is essential for reducing cardiac implantable electronic device (CIED) infections, particularly in elderly patients at higher risk due to comorbidities, frailty, or procedural history. In this vulnerable population, careful patient selection, meticulous surgical technique, and consideration of alternative implantation strategies are essential to minimize the likelihood of erosion and infection. Strategies include:

- Preoperative optimization – managing comorbidities (diabetes, malnutrition), skin decolonization, no infection symptoms [4,10].
- Antibiotic prophylaxis – administered ideally within 60 minutes before incision, significantly reduces infection risk (first-generation cephalosporin like

cefazolin); vancomycin is reserved for patients with cephalosporin allergies or high MRSA prevalence; vancomycin requires prolonged infusion period (around 60 minutes) and should be initiated 90 to 120 minutes before incision [4,10,27].

- Aseptic technique and surgical expertise [10].
- Minimizing procedure time and avoiding reinterventions.
- Avoiding bridging anticoagulation [4].

What is more, it has been shown that antibiotic prophylaxis in high-risk individuals was associated with a significant reduction of infective endocarditis after invasive dental procedures (particularly extractions and oral surgical procedures) [10].

Conclusion

As the global population continues to age, the number of elderly patients receiving CIEDs is expected to increase significantly. While these devices offer substantial clinical benefits, infectious complications

remain a major concern in this group of patients. Age-related immune decline, comorbidities, polypharmacy, and anatomical changes all contribute to elevated infection risk. Thus, it can be said that it is not age itself that affects the risk but the co-morbidities and physiological changes that come with age. Prioritizing prevention is key to the optimal management of CDIs. Tailored approaches of geriatric patients are vital for optimizing care and minimizing complications.

Conflict of interest

None

Correspondence address

✉ Agata Firkowska

II Department of Cardiology and Electrotherapy

University Clinical Centre

Smoluchowskiego St. 17, 80-211 Gdańsk

☎ (+48 58) 584 47 60

✉ agata.firkowska@gmail.com

References

1. United Nations Department of Economic and Social Affairs, Population Division (2024). World Population Prospects 2024: Summary of Results (UN DESA/POP/2024/TR/NO. 9).
2. European Society of Cardiology (ESC) Task Force on Cardiac Pacing and Cardiac Resynchronization Therapy, with the special contribution of the European Heart Rhythm Association (EHRA). 2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy. *Eur Heart J*. 2021;42(35):3427-520.
3. Lim WY, Prabhu S, Schilling RJ. Implantable Cardiac Electronic Devices in the Elderly Population. *Arrhythm Electrophysiol Rev*. 2019;8(2):143-6. doi: 10.15420/aer.2019.3.4. PMID: 31114690; PMCID: PMC6528033.
4. Blomström-Lundqvist C, Traykov V, Erba P, et al. European Heart Rhythm Association (EHRA) international consensus document on how to prevent, diagnose, and treat cardiac implantable electronic device infections—endorsed by the Heart Rhythm Society (HRS), the Asia Pacific Heart Rhythm Society (APHRS), the Latin American Heart Rhythm Society (LAHRS), International Society for Cardiovascular Infectious Diseases (ISCVID) and the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS), *EP Europace*, 2020;22(4):515-49.
5. Puette JA, Malek R, Ahmed I, et al. Pacemaker Insertion. [Updated 2024 Oct 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025.
6. Rao A, Bennett S. Cardiac implantable electronic devices: an overview for primary care. *Br J Gen Pract*. 2022;72(721):402-4. doi: 10.3399/bjgp22X720461. PMID: 35902258; PMCID: PMC9343029.
7. Ślawiński G, Kempa M, Lewicka EK, et al. Implantable cardiac electronic device infections: single center study. *Eur J Transl Clin Med*. 2018;1(1):57-62. Doi: 10.31373/ejtc/92167.
8. Ślawiński G, Kempa M, Przybylski A. Prevention of Cardiac Implantable Electronic Device Infections: A Review. *Rev. Cardiovasc. Med*. 2023;24(6):176.
9. Tarakji KG, Ellis CR, Defaye P, Kennergren C. Cardiac Implantable Electronic Device Infection in Patients at Risk. *Arrhythm Electrophysiol Rev*. 2016;5(1):65-71. doi: 10.15420/aer.2015.27.2. PMID: 27403296; PMCID: PMC4939310.
10. Matteucci A, Pignalberi C, Pandozi C, et al. Prevention and Risk Assessment of Cardiac Device Infections in Clinical Practice. *J. Clin. Med*. 2024;13:2707.
11. Krahm, A, Longtin, Y, Philippon, F. et al. Prevention of Arrhythmia Device Infection Trial: The PADIT Trial. *JACC*. 2018;72(24):3098-109.
12. Thomas Olsen, Ole Dan Jørgensen, Jens Cosedis Nielsen, et al. Incidence of device-related infection in 97 750 patients: clinical data from the complete Danish device-cohort (1982–2018), *European Heart Journal*, 2019;40(23):1862-9.
13. Vance G Fowler, David T Durack, et al. The 2023 Duke-International Society for Cardiovascular Infectious Diseases Criteria for Infective Endocarditis: Updating the Modified Duke Criteria, *Clinical Infectious Diseases*, 2023;77(4):518-26.

14. Polewczyk A, Jacheć W, Polewczyk M, et al. Outcomes of patients with definite and possible infective endocarditis related to a cardiac implantable electronic device. *Pol Arch Intern Med.* 2024;134:16775.
15. Schinas G, Koros R, Ntalakouras I, et al. Gram-Negative Bacterial Infections in Cardiac Implantable Electronic Devices: Insights from a Retrospective Analysis of Multidrug-Resistant and Non-Multidrug-Resistant Isolates. *Pathogens.* 2025;14(3):215.
16. Pascale R, Toschi A, Aslan AT, et al. Risk factors for gram-negative bacterial infection of cardiovascular implantable electronic devices: Multicentre observational study (CarDINe Study). *Int J Antimicrob Agents.* 2023;61(3).
17. Palmeri, N, Kramer, D, Karchmer, A. et al. A Review of Cardiac Implantable Electronic Device Infections for the Practicing Electrophysiologist. *J Am Coll Cardiol EP.* 2021;7(6):811-24.
18. Rodriguez-Mañas L. Urinary tract infections in the elderly: a review of disease characteristics and current treatment options. *Drugs Context.* 2020;9:4-13.
19. Güzel T, Aktan A, Kılıç R, et al. Aging and cardiac implantable electronic device complications: is the procedure safe in older patients? *Aging Clin Exp Res.* 2023;35(11):2445-52.
20. Lee KA, Flores RR, Jang IH, et al. Immune Senescence, Immunosenescence and Aging. *Front Aging.* 2022;3:900028.
21. Varghese D, Ishida C, Patel P, et al. Polypharmacy. [Updated 2024 Feb 12]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan.
22. Vandenberk B, Murray K, Rizkallah J. Risk Mitigation of Pacemaker Pocket Erosion in Thin Patients. *CJC Open.* 2022;4(6):585-7.
23. Rudolph R, Curtis G. Soft Tissue and Skin Reinforcement with Acellular Dermal Matrix to Protect Implanted Cardioverters/Defibrillators and Pacemakers. *Plast Reconstr Surg Glob Open.* 2018;6(7):e1866.
24. Sławiński G, Kempa M, Lewicka E, et al. Elevated C-reactive protein levels during cardiac implantations may increase the risk of early complications requiring transvenous lead removal: a preliminary report. *Pol Arch Intern Med.* 2018;128(2):138-40. doi: 10.20452/pamw.4217. Epub 2018 Feb 28. PMID: 29511152.
25. Cesari M, Onder G, Zamboni V, et al. C-reactive protein and lipid parameters in older persons aged 80 years and older. *J Nutr Health Aging.* 2009;13(7):587-93.
26. Bulat Z, Arslan S, Gecit MH, et al. investigating long-term outcomes and predictors of primary outcomes in patients treated for cardiac implantable electronic device infections. *Europace.* 2024;26(Suppl 1):euae102.503.
27. Pandozi C, Matteucci A, Pignalberi C, et al. Antibiotic Prophylaxis and Treatment for Cardiac Device Infections. *Antibiotics.* 2024;13(10):991.