Review

ANNALS OF MEDICINE & SURGERY

OPEN

Immunizing hearts: exploring the vaccination frontier in heart failure management

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Abstract

Heart failure (HF) is a widespread clinical condition that affects numerous individuals globally and is a leading cause of hospitalization, particularly in the elderly population. Despite efforts to manage HF using various pharmacological and nonpharmacological interventions, mortality and hospitalization rates remain alarmingly high. Preventive vaccination has emerged as a key measure endorsed by cardiology societies for reducing the morbidity and mortality associated with HF. This study undertakes an extensive review of existing literature to explore the role of vaccination in managing HF, focusing specifically on the immunological pathways involved and potential benefits offered by immunization in this context. This article highlights the role of various vaccines, including influenza, pneumococcal, and COVID-19 vaccines, in reducing HF-related hospitalization, mortality, and overall disease burden. Additionally, this article will delve into specific vaccines that have shown promise in HF management, such as influenza, pneumococcal, and COVID-19 vaccines, along with the rationale for their use, clinical trials, meta-analyses, and real-world data supporting their effectiveness in patients with HF. This article also considers potential challenges and obstacles to widespread vaccination in individuals with HF, which include vaccine hesitancy, accessibility, and adverse events related to vaccines.

Keywords: COVID-19, heart failure, immunization, influenza, pneumococcal, vaccination

Introduction

Heart failure (HF) refers to the inability of the heart to adequately pump blood to meet the body's requirements. It is a complex clinical syndrome caused by ischemic (coronary artery disease) or nonischemic conditions (valvular heart disease, hypertension, diabetes, infections, lung disease, genetic predisposition, alcohol consumption, and chemotherapy)[1,2]. Regardless of the cause, HF presents with increased shortness of breath and lower limb edema due to pulmonary and vascular congestion. HF can be categorized into four main groups: heart failure with a preserved ejection fraction (HFpEF), reduced ejection fraction (HFrEF), mildly reduced ejection fraction (HFmrEF), and HF with an improved ejection fraction[3].

HF is a global health issue that affects ~64 million individuals worldwide. This is the primary reason for hospitalization in people aged over 65 years (1–2%)[4]. Currently, it is estimated that there are around 6.2 million adults who are diagnosed with HF in the United States alone. Alarmingly, this number is projected to increase significantly, reaching ~8 million by 2030. HF-related deaths decreased to 89.5 per 100 000 in 2009 but increased to 96.9/100 000 in 2014[5]. Deaths related to HF in 2020 were 48.6% higher than in 2009[6]. The financial burden

HIGHLIGHTS

- Vaccination against respiratory infections is crucial for reducing infection risk and complications in heart failure patients, with the potential to lower mortality and hospitalizations.
- Low vaccination rates in heart failure patients result from barriers including limited knowledge, negative attitudes, and healthcare system challenges.
- Addressing these barriers through enhanced awareness, accessibility, and tailored recommendations is essential, alongside exploring specific subgroups' responses to optimize vaccination strategies.

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Annals of Medicine & Surgery (2024) 86:300–307

Received 7 August 2023; Accepted 30 October 2023

Published online 7 November 2023

http://dx.doi.org/10.1097/MS9.0000000000001486

associated with HF in 2021 amounts to ~$30.7 billion, encompassing expenses related to healthcare services, medications, and productivity loss due to missed workdays[2,7]. The risk is higher after 45 years of age ranging from 20 to 45% and trends indicate that the incidence of HFpEF is increasing whereas HFrEF is decreasing though both subtypes have similar all-cause mortality rates[6]. HF not only affects the patients' lives by causing social isolation and depression but also contributes to caregiver burden[8].

Influenza contributes to 300 000–650 000 deaths worldwide annually, with increased infection rates in patients with significant comorbidities such as HF[9]. Patients with HF are particularly at risk of decompensation due to infections and, in many cases, can develop sepsis and septic shock[10]. Respiratory infections account for at least half of all hospitalizations in patients with HF and are associated with increased 30-day and 1-year mortality[11]. Influenza is the most common cause, followed by pneumococci[12]. For patients with infection-related hospitalization, particularly respiratory infections, the main cause of readmission at 6 months is reinfection[13]. The Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF) revealed that 15.3% of hospitalizations were due to pneumonia, which increased the risk of in-hospital mortality by 60%[14].

Although previous studies have shown the beneficial effects of immunization against respiratory infections in individuals with other cardiovascular diseases such as coronary artery disease and atrial fibrillation[15–17], few studies have specifically focused on immunization in patients with HF.

This literature review sought to address this research gap by collecting and synthesizing existing evidence on the role of vaccination in patients with HF. By conducting a comprehensive review, our objective was to assess several important aspects, including the significance of vaccination in individuals diagnosed with HF, the rationale for using vaccinations against respiratory infections among those affected by HF, and how vaccination affects morbidity and mortality rates within this patient population. Additionally, we aimed to explore potential future directions or areas that require further investigation regarding vaccinations and their impact on outcomes in individuals with HF.

Review

Potential mechanisms underlying the benefits of vaccination

HF is a highly intricate and multistep condition characterized by the involvement of various physiological processes[18]. Numerous research studies, both in experimental and clinical settings, have revealed an increased expression and release of inflammatory cytokines in patients with HF[19,20]. Specifically, proinflammatory cytokines such as tumor necrosis factor-α, interleukin-1, and IL-6 have been extensively linked to the development of HF[19]. The persistent elevation of these cytokines directly correlates with the progressive deterioration of cardiac function through its impact on intracellular calcium transport and signal transduction pathways[19].

Infections such as, influenza, pneumococcal disease, and COVID-19 play a significant role in the morbidity and mortality of individuals with HF. These infections have a significant effect on the cardiovascular system[10]. Influenza results in increased metabolic demand, an increase in adrenergic activity, endothelial dysfunction, and hypercoagulability. These factors contribute to prolonged elevation of cytokine levels, which subsequently increases the risk of cardiovascular complications[21].

Similarly, pneumococcal infection induces oxidative stress and triggers inflammatory markers that can lead to thrombogenesis (formation of blood clots), destabilization of atherosclerotic plaques (hardening or narrowing of arteries due to plaque buildup), and endothelial dysfunction. Consequently, pneumococcal infections amplify the likelihood of developing HF[22].

Additionally, the SARS-CoV-2 virus that causes COVID-19 induces a condition called 'cytokine storm', which is characterized by an exaggerated release of proinflammatory cytokines from immune cells. This uncontrolled inflammatory response significantly raises the risk of HF in infected individuals[23].

Vaccination plays a crucial role in improving the outcome of patients with HF through various mechanisms. First, they trigger a targeted immune response by stimulating the production of antibodies and activating T cells, which are essential for combating infections[24]. This immune response is particularly beneficial for individuals with weakened immune systems due to HF as it enhances their ability to defend against respiratory infections and reduces the likelihood of complications. Moreover, research has shown that vaccination directly decreases the risk of cardiovascular events by mitigating systemic inflammation and endothelial dysfunction, both known factors contributing to the development and progression of HF[25,26].

Types of vaccines

Influenza

Influenza infection is caused by a negative-sense RNA virus that is responsible for the annual seasonal flu. There are two types of vaccines against this virus: egg-based and cell culture-based vaccine, which is further subdivided into inactive and recombinant vaccines[27,28]. Hemagglutinin (HA) is a protein fragment from the viral surface structure that is often present in all types of vaccine[29]. It is recommended for every person above 6 months of age. The egg-based vaccine, which has a more powerful immunologic response because of a protein-based epitope, more specific antibody generation, and a longer time period of effective protection, is recommended in patients with HF taking into account the risk of hemodynamic impairment in HF patients[27].

Pneumococcal

The gram-positive bacterium pneumococcus frequently causes pneumonia in patients with HF[30]. Depending on whether the immune system activation is protein-associated or not, vaccines against this bacterial illness are available in two forms: pneumococcal conjugated vaccine (PCV) and pneumococcal polysaccharide vaccine (PPSV). PCV20 alone or the PCV15 followed by the PPSV23 is recommended in adults[31,32].

COVID-19

The SARS-CoV-2 virus, an enveloped positive-sense single-stranded RNA virus that belongs to the coronaviridae family, is the cause of the COVID-19 pandemic[33]. The two forms of vaccination against this infection approved by the FDA are the protein subunit vaccine and the mRNA vaccine[34].

Only the bivalent vaccines from the Pfizer-BioNTech and Moderna developments, which contain the original and omicron BA.4 and BA.5, are permitted for administration to the general public in the USA[35].

Vaccination rates in HF patients

The factors affecting vaccination rates in HF can be broadly divided into two categories. The first is demographic factors, including education and awareness, socioeconomic status, and sex. The second is clinical factors, including NYHA class, hospitalization, recommendation of the vaccine from the treating physician, and adverse effects. Despite all the recommendations, the vaccination rates in HF patients remain low[11,13,36–38].

In an observational study conducted in Teresópolis, researchers investigated the vaccination status of patients with HF using three different approaches[36]. First, they examined the records of vaccine requests at the Health Department of Teresópolis and discovered that only 15.3% of the patients with indications for cardiovascular and respiratory diseases received the recommended vaccines. Second, the researchers directly asked 61 patients about their vaccination status; the researchers found that among those over 60 years of age, only 23.1% had received the influenza vaccine, and for all age groups, 24.6% had received the pneumococcal vaccine. Lastly, in the emergency department, only 35.8% of patients with decompensated chronic HF received the influenza vaccine and only 2.5% were administered the pneumococcal vaccine. The study identified a need for more recommendations from healthcare professionals and limited patient awareness about the importance of vaccination as the primary factor contributing to low vaccination rates[36].

In another study conducted by Bhatt *et al.*[11], 313 761 patients discharged from 392 hospitals were evaluated to assess influenza and pneumococcal vaccination rates. The findings showed that the overall percentage of patients receiving influenza vaccination was 68%. There was a slight decline, from 70% in 2012–2013 to 66% in 2016–2017. The overall proportion of pneumococcal vaccinations was 66%, which decreased significantly over the study period, from 71% in 2013 to 60% in 2016. These results indicate suboptimal vaccination rates for both influenza and pneumococcal vaccines in the study population over time. The study also found that people who received vaccination were more likely to have insurance and to be older, of white ethnicity, and female[11].

Another study examined the influenza vaccination rates among 8099 patients with HF in the PARADIGM-HF trial[39]. Only 21% of the participants received influenza vaccination. There were significant regional differences, with the highest rates in the Netherlands, Great Britain, and Belgium, whereas Asia had the lowest vaccination rate[39]. Various factors have been recognized as determinants of influenza immunization, such as the patient's country of registration, ethnicity, presence of an implanted defibrillator, advanced age, lower heart rate, and a previous diagnosis of diabetes mellitus.

Impact of vaccination on HF

Given that individuals with HF are particularly vulnerable to infections and their potential consequences, vaccination can be seen as an essential component of a holistic approach to managing HF. Vaccination helps reduce the risk of infections, hospitalizations, and complications, thereby complementing other essential therapies and improving the overall well-being of patients[11].

Role of influenza vaccine

According to guidelines from various organizations such as the American College of Cardiology Foundation/American Heart Association (ACC/AHA), Center for Disease Control and Prevention (CDC), WHO, and Infectious Diseases Society of America, influenza vaccination is recommended for patients with chronic heart disease, including those with HF. These guidelines emphasize the importance of influenza vaccination as a preventive measure to protect individuals with HF from the potential complications and adverse outcomes associated with influenza infection[1,27,40,41].

The effectiveness of influenza vaccines in lowering cardiovascular events among people with coronary heart disease has been supported by numerous studies[42–44]. However, evidence is still unclear as to whether influenza vaccination significantly reduces mortality and morbidity, especially in people with HF[44,45].

A meta-analysis conducted by Gupta *et al.*[46] evaluated influenza vaccination in patients with HF using nonrandomized studies. The results indicated that getting vaccinated against influenza was linked to significant reductions in both all-cause mortality (RR 0.75, 95% CI: 0.71–0.79; $P < 0.0001$) and cardiovascular-related mortality (RR 0.77, 95% CI: 0.73–0.81; $P < 0.0001$). However, it was also observed that vaccinated patients with HF had a higher risk of all-cause hospitalization compared to those who were not vaccinated, with a risk ratio of 1.24 (95% CI: 1.13–1.35; $P < 0.0001$). However, evidence supporting these findings was categorized as having very low certainty[46].

A recent meta-analysis conducted by Rodrigues *et al.*[47] found that influenza vaccination in patients with HF is associated with a significantly lower risk of all-cause mortality (HR = 0.83, 95% CI: 0.76–0.91). However, influenza vaccination was found to have no significant impact regarding decreasing cardiovascular mortality (HR = 0.92, 95% CI: 0.73–1.15) and all-cause hospitalization (HR = 1.01, 95% CI: 0.92–1.11), with high levels of heterogeneity observed ($I^2 = 94\%$ and $I^2 = 65\%$, respectively). Influenza vaccination was also linked to significantly lower risk of HF hospitalizations (HR = 0.69, 95% CI: 0.55–0.86) and recurrent HF hospitalizations (HR = 0.303, 95% CI: 0.178–0.514). The evidence backing these findings was classified as having very low certainty[47].

In 2022, a multinational randomized controlled trial conducted by Loeb *et al.*[48] aimed to investigate the impact of a standard-dose influenza vaccine on patients with HF. The study included a total of 5129 participants with an average age of 57.2 years and divided them into two groups: one group being administered the influenza vaccine and the other being administered placebo in a double-blind manner. The two main outcomes of the study—a composite of cardiovascular death, nonfatal heart attacks, nonfatal strokes, and HF requiring hospitalization—were not shown to be significantly affected by the influenza vaccine. However, the vaccine demonstrated a significant decrease in hospitalization for all causes, largely due to a lower rate of HF hospitalization. The rate of community-acquired pneumonia associated with the influenza vaccine also decreased by 42%[48].

Influenza vaccination has the potential to decrease adverse cardiovascular events, although the certainty of available evidence is currently low. Rigorous randomized controlled trials (RCTs) are required to further evaluate the ability of influenza vaccine to protect against infection, particularly in people with HF[49].

Inactivated influenza vaccine administration via intramuscular injection early in the season has been proven to be a cost-effective preventive measure for patients with cardiovascular disease. This approach significantly decreased the incidence of all-cause and cardiovascular-related hospitalization[39,50,51]. The documented benefits of the influenza vaccine cannot be overlooked, considering its minimal potential for severe harm and its relatively low-cost compared to the expenses associated with hospital care for major cardiovascular events caused by influenza[49].

Role of pneumococcal vaccines

A meta-analysis published in 2022 consisting of observational studies concluded that the pneumococcal vaccinated population has fewer cardiovascular outcomes and mortality compared to placebo[52]. Although there are trials and meta-analyses that indicate the impact of pneumococcal vaccination on cardiovascular outcomes[53], no RCTs or other studies are available to date, that specifically show the impact of pneumococcal vaccination in patients with HF.

Role of COVID-19 vaccines

There are minimal data available, and no RCTs have been conducted that evaluated the impact of the COVID-19 vaccine on HF outcomes. In a population-based cohort study in the Czech Republic in 2022, 9728 patients with HF who contracted COVID-19 (SARS-CoV-2) were evaluated. They found that the risk of intensive care hospitalization was 7.6% in unvaccinated patients, 4.8% in vaccinated patients and only 2.9% in patients who received a booster dose[54].

A recent review in 2023 found COVID-19 vaccine to be beneficial in reducing deleterious impact of COVID-19 in patients with HF[55]. It is important to note that drawing conclusions regarding the efficacy of the COVID-19 vaccine in patients with HF is premature at this stage, primarily due to the lack of RCTs.

Other vaccines

In context of vaccinations and their impact on HF, it is important to acknowledge that not all infections hold equal significance in the pathophysiology of this condition. While vaccinations like pneumococcal, influenza, and COVID-19 have gathered attention due to their potential relevance, several other infections do not share the same level of prominence in this context.

For instance, infections such as Measles, Mumps, and Rubella (MMR) predominantly affect children and do not typically have a direct association with HF in adults[56]. While it is true that certain viral infections like measles can lead to complications like myocarditis, which may, progress to HF, the incidence of such occurrences is relatively low. Consequently, there is limited research demonstrating the direct benefits of MMR vaccination in preventing HF in adult populations.

Similarly, vaccines like polio, tetanus, hepatitis A and B, HPV, shingles, rabies, and Japanese encephalitis primarily target other organ systems or are relevant to different age groups. Their implications in the pathophysiology of HF are not substantial, and there is a lack of evidence supporting their role in reducing mortality and morbidity among HF patients. Furthermore, diseases like tuberculosis have largely been eradicated from developed countries, while smallpox has been eradicated globally.

There is no conclusive proof that vaccinating the elderly against these aforementioned diseases significantly impacts the outcomes of HF. Observational studies and RCTs are notably lacking in this regard, and global health organizations like the WHO and the Centers for Disease Control and Prevention (CDC) do not currently recommend these vaccinations as standard practice for HF management.

Immunization recommendations for HF patients

Patients with HF should be immunized against influenza and pneumococcus, as recommended by various renowned cardiology societies such as the European Society of Cardiology (ESC), Center for Disease Control and Prevention (CDC), and the American College of Cardiology/American Heart Association (AHA)[1,27,40,41]. These guidelines take into account the higher susceptibility to infections and associated complications in patients with HF, while also recognizing that vaccination can potentially decrease hospitalization and mortality rates. Since there were no RCTs and the data came from extensive observational studies and population-based registries that included people with cardiovascular disease, it is noteworthy that these recommendations are based on expert consensus (Table 1).

Vaccine safety and considerations in HF patients

To date, no RCTs have been conducted on the safety of these vaccines in patients with HF. However, some studies have been published that discussed the relationship between vaccines and cardiovascular disease. In a study conducted in Turkey regarding pneumococcal vaccines (PCV13 and PPSV23), vaccine safety and benefit were a concern to the general population. Vaccine safety is a serious issue that makes patients reluctant to use these vaccines[37].

A study conducted in Denmark reported that patients who received more than one influenza vaccine were at higher risk of death and atrial fibrillation[38]. However, it is necessary to mention that when the results were adjusted for various confounding factors, the risk of death in patients with HF was reduced in vaccinated patients compared to nonvaccinated patients[38].

The COVID-19 vaccine was the subject of numerous speculations over its safety, with some believing that it raised the risk of HF, as well as the risk of venous thromboembolism and myocarditis in patients with HF[58]. However, recent studies have revealed that these side effects are associated with vaccines[59].

No study has discussed the effects of vaccines in patients with HF with comorbidities or immunosuppression. Hypertension is the most prevalent comorbidity in individuals with HF followed by other cardiovascular disorders. Vaccinations are still thought to be safe for these individuals, and they are typically recommended to take the vaccine to lower the risk of hospitalization for respiratory infections or other diseases that can be prevented by vaccination[59].

Table 1

Current guideline recommendations on respiratory vaccination in cardiovascular disease

Guidelines	Society	Recommendations
2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure[57]	American Heart Association	The 2022 AHA guidelines list influenza and pneumococcal vaccines as secondary prevention methods. It recommends annual vaccination based on the results of PARADIGM-HF study[39]
Center for disease control and prevention/ ACIP Vaccine Recommendations and Guidelines 2022–23[27,40]	Center for disease control and prevention	Recommends annual vaccination for adults with cardiovascular risk factors (excluding isolated hypertension)[27]
For adults aged 65 years or older without a previous PCV vaccination, a single dose of PCV (either PCV20 or PCV15) is recommended. PCV15 should be followed by a dose of PPSV23. Similarly, adults aged 19–64 years with certain medical conditions or risk factors should also receive a single dose of PCV, followed by PPSV23 if PCV15 is used[40]		
2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure[41]	European Society of Cardiology	Under prevention and monitoring ESC recommends the administration of influenza, pneumococcal, and COVID vaccines

AHA, American Heart Association; ACC, American College of Cardiology; HFSA, Heart Failure Society of America; HF, Heart Failure; ACIP, Advisory Committee on Immunization Practices; PCV, Pneumococcal Conjugate Vaccine; PPSV, Pneumococcal Polysaccharide Vaccine; ESC, European Society of Cardiology

Barriers and challenges to vaccination in HF patients

Patient-related barriers

Many factors affect the vaccine acceptance rate in patients like preexisting comorbidities, socioeconomic status, access to healthcare, and psychological factors (knowledge about the vaccine, attitude towards healthcare services, and perception of vaccine side effects)[37]. In one of the studies done on the barriers related to influenza vaccine uptake, it was concluded that limited vaccine knowledge and negative attitude toward healthcare services were the main factors affecting its acceptance rate[60]. Misinformation surrounding the utilization of vaccines poses a significant barrier to adequate vaccine coverage in individuals diagnosed with HF. A study conducted by Gorman *et al*.[61] on influenza vaccination showed that women were three times more likely to be vaccinated when educated by a healthcare worker.

Healthcare system-related challenges

The cost of the vaccine and access to the healthcare system are some of the important factors that affect and limit vaccination rates. In a study conducted by Schmedt *et al*.[62], it was found that only 7–13% of patients diagnosed with high-risk illness received the pneumococcal vaccine in the first 3 years. According to a self-administered, anonymous study of physicians, 25% of subspecialists and 14% of general physicians failed to strongly recommend influenza vaccine[63]. Lack of recommendations by healthcare workers has also been detrimental to vaccination rates. Lack of knowledge regarding vaccination as a preventive measure in patients with HF among healthcare workers is a major limiting factor in vaccination coverage in this debilitated population. Direct advice by medical doctors is a significant inducer of vaccination uptake, as proven in previous studies[64].

It is necessary to increase public awareness regarding the effectiveness and safety of vaccines by making educational resources available. For patients to be immunized in a timely manner, we must ensure that each patient has a designated primary care provider. To increase immunization rates, actions must be taken to increase patient access to healthcare.

Future directions

Vaccination plays a crucial role in reducing morbidity and mortality in patients with HF, making it an important aspect of healthcare management. By expanding our understanding of the impact of vaccination on patients with HF, we can develop more effective strategies to improve their outcomes and enhance their overall quality of life. Recent advances in vaccine technology have highlighted the potential of mRNA vaccines as a promising development[57]. These innovative vaccines significantly shorten the production timelines, allowing for wider population coverage in a timely manner. This is particularly crucial when considering the susceptible population of individuals with HF who face a heightened risk of hemodynamic deterioration after contracting infections such as influenza and pneumococcus[65]. Vaccination against these specific pathogens has the potential to be life-saving in individuals with HF

Given the high prevalence of HF in the general population, there is a paucity of observational studies examining the effectiveness of vaccination for influenza, pneumococcal infections, and COVID-19. Moreover, many existing studies suffer from limitations like small sample sizes and a lack of proper randomization, which impede our ability to understand the true impact of preventive vaccinations on HF patients. Additionally, this hampers our capacity to conduct thorough prospective follow-ups to accurately evaluate the outcomes.

There is a need for comprehensive research on the impact of vaccination on patients with HF. This entails the conduct of large-scale observational studies that not only ascertain vaccination rates but also stratify these rates according to key variables such as age, sex, nationality, and resource availability.

The majority of the evidence presented in this review is derived from observational studies, which introduces a potential for confounding bias that needs to be addressed by the conduction of large-scale RCTs to provide conclusive evidence regarding the role of vaccination in patients with HF. These trials will play a pivotal role in determining which vaccines are effective at

reducing hospitalization and mortality rates within this vulnerable population. Additionally, there is a need to compare different vaccine doses and timing of administration among HF patients. Understanding whether specific dosages or schedules offer improved efficacy or safety profiles can lead to optimized vaccination strategies for this patient group.

Given the significant number of individuals diagnosed with HF and undergoing multiple drug therapies, there is an urgent mandate for global health organizations to establish comprehensive guidelines pertaining to the vaccination against influenza, pneumococcal infections, and COVID-19. These guidelines are crucial, serving as essential frameworks to equip healthcare providers with directives for administering vaccinations effectively and in a timely manner.

Conclusion

The incidence of HF, particularly HFpEF, in increasing worldwide in the elderly, and is a leading cause of hospitalization. The financial burden of HF is substantial, with costs exceeding $30 billion annually in the United States alone. Respiratory infections like influenza, pneumococcal and COVID-19 infections significantly contribute to morbidity and mortality in HF patients. Vaccination can potentially mitigate the risk of cardiovascular complications in HF patients by reducing inflammation and infection rates. Despite the evident vulnerability of this population, vaccination rates remain low. Influenza and pneumococcal vaccinations have shown potential in lowering all-cause mortality and hospitalizations in these patients, though evidence remains of low certainty. Initial data on COVID-19 vaccination in HF patients suggest reduced severe outcomes. Low vaccination rates are influenced by patient-related barriers (limited knowledge and negative attitudes) and healthcare system challenges (cost and access). To mitigate risks, healthcare practitioners should prioritize vaccinations as part of comprehensive care. Public health campaigns should raise awareness, address misconceptions, and promote vaccine accessibility. Healthcare systems must ensure affordable vaccines and develop strategies to overcome barriers, fostering patient awareness, positive attitudes, and physician recommendations.

Future directions include conducting large-scale observational studies, RCTs, and evaluating different vaccine doses and schedules to optimize vaccination strategies for patients with HF. To tailor vaccination recommendations, there is a need to explore the impact of vaccination on specific subgroups of patients with HF, such as those with comorbidities or immunosuppression.

Ethical approval

Ethical approval was not required for this review.

Consent

Informed consent was not required for this review.

Sources of funding

No financial support was received for this study.

Author contribution

M.E., S.S., A.M.J., and A.S.S.: made substantial contributions to the conception and design of the work; N.P., C.S., N.N., L.M.O.T., E.V., S.M.S., E.F.S., and A.K.: are responsible for the execution, acquisition, and interpretation of data; A.M.J., A.S.S., N.P., C.S., N.N., L.M.O.T., E.V., S.M.S., and E.F.S.: are involved in drafting or writing of the manuscript; M.E., S.S., and A.K.: critically reviewed and made substantial revisions to the manuscript. All authors have agreed on the journal to which the article will be submitted and have given the final approval for the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflicts of interest disclosure

The authors report no relationships that could be construed as a conflict of interest.

Research registration unique identifying number (UIN)

This is not applicable for our review.

Guarantor

Muhammad Ehsan.

Availability of data

The data that support the findings of this study are available from the corresponding author, ME, upon reasonable request.

Provenance and peer review

Not applicable.

Acknowledgements

Not applicable.

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