Risk factors and management of pulmonary infection in elderly patients with heart failure
A retrospective analysis
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Abstract
Pulmonary infection is common in patients with heart failure, yet the risk factors remain unclear. We aimed to evaluate the clinical characteristics and risk factors of pulmonary infection in elderly patients with heart failure, to provide reference to the prevention of pulmonary infection.

This study was a retrospective study design. We included elderly heart failure patient admitted to our hospital from April 1, 2018 to August 31, 2020. The characteristics and clinical data of pulmonary infection and no infection patients were assessed. Logistic regression analyses were conducted to identify the risk factors of pulmonary infections in patients with heart failure.

A total of 201 patients were included. The incidence of pulmonary infection in patients with heart failure was 23.88%. There were significant differences in the age, diabetes, New York Heart Association (NYHA) grade, left ventricular ejection fraction (LVEF), C-reactive protein (CRP) between infection and no infection group (all \( P < .05 \)), and there were not differences in the sex, body mass index, alcohol drinking, smoking, hypertension, hyperlipidemia, length of hospital stay between 2 groups (all \( P > .05 \)). Logistic regression analyses indicated that age \( \geq 70 \) years, diabetes, NYHA grade III, LVEF \( \leq 55\% \), and CRP \( \geq 10 \text{mg/L} \) were the independent risk factors of pulmonary infections in patients with heart failure (all \( P < .05 \)). Pseudomonas aeruginosa (34.48%), Staphylococcus aureus (19.57%), and Klebsiella pneumoniae (15.22%) were the most common 3 pathogens in patients with pulmonary infection.

Heart failure patients with age \( \geq 70 \) years, diabetes, NYHA grade III, LVEF \( \leq 55\% \), and CRP \( \geq 10 \text{mg/L} \) have higher risks of pulmonary infections, preventive measures targeted on those risk factors are needed to reduce pulmonary infections.

Abbreviations: CRP = C-reactive protein, LVEF = left ventricular ejection fractions, NYHA = New York Heart Association.
Keywords: bacteria, heart failure, nursing care, prevention, pulmonary infection, treatment

1. Introduction
Heart failure is mainly a clinical syndrome caused by ventricular insufficiency, which is associated with decreased cardiac output.[1] Studies[2,3] have shown that infection is the most important cause of heart failure. Elderly people are very prone to infection due to their weakened body immunity.[4] Pulmonary infection is the main cause of death from heart failure in the elderly.[5] It has been reported that heart failure patients with pulmonary infection have 2.5 times risk of death of those patients without pulmonary infection.[6] Therefore, early diagnosis and prevention of pulmonary infection in elderly patients with heart failure is the key to treatment.

Heart failure is a common clinical manifestation of most organic heart diseases that progress to the end stage.[7] It is mostly caused by the loss of ventricular pumping ability due to changes in cardiac structure and function.[8] In contemporary society with an increasingly aging population, heart failure occurs greatly.[9] The rate of heart failure shows an upward trend year by year.[10] Patients with heart failure are often accompanied by secondary conditions such as pulmonary circulatory congestion and pulmonary edema, which can lead to dyspnea, gas exchange disorders, and other consequences, creating certain conditions for pathogens to invade and colonize the lungs.[11,12] Therefore, patients with heart failure may have higher risk of pulmonary infection. Besides, pulmonary infection and insufficient oxygen uptake can increase pulmonary artery pressure, decrease the body’s metabolic function, and further increase the burden on the
heart. Presently, the potential influencing factors of pulmonary infection in patients with heart failure remain unclear. Therefore, we aimed to identify the risk factors of pulmonary infection in elderly patients with heart failure, to provide evidences to the treatment and nursing care of heart failure, thereby improving the prognosis of patients with heart failure.

2. Methods

We aimed to report this study in comply with Strengthening the Reporting of Observational studies in Epidemiology statement. Our study had been checked and approved by the ethical commissions of our hospital (SZC0018093), and all the included patients had signed the written informed consents.

2.1. Patients

We retrospectively analyzed the relevant clinical data of elderly heart failure patient admitted to the department of cardiac surgery, Wuhan Asia Heart Hospital (Wuhan, China) from April 1, 2018 to August 31, 2020. The inclusion criteria were: ① The clinical manifestations and echocardiographic examination results met the relevant diagnostic criteria for heart failure; ② The patients were ≥60 years old; ③ All patients received standardized anti-heart failure and anti-infective treatment of Ceftriaxone 2g/day for 2 days; ④ All patients were informed and willing to participate in this study. The exclusion criteria of this study are: ① Patients with cardiogenic shock, acute and chronic organophosphate poisoning, pneumonia lung tumors, and autoimmune diseases at the timing of hospital admission; ② Patients with chronic lung diseases, lung malignant tumors, severe metabolic acidosis with a pH of 7.20 to 7.25 and bicarbonate 7 to 14 mmol/L, liver dysfunction (Child-Pugh level C) and kidney dysfunction (Creatinine >177 μmol/L), and patients who had used immunosuppressive drugs within 3 months before enrollment. ③ The patients who did not agree to take part in this study.

2.2. Diagnostic criteria for pulmonary infection

Patients need to meet ≥2 of the following criteria to be diagnosed with pulmonary infection: ① body temperature >38°C, duration of 4 to 6 days; ② white blood cell count >10 × 10^9/L; ③ 3 consecutive sputum examinations showed the presence of pathogenic bacteria, and increased thick sputum; ④ computed tomography examination of the lungs showed the presence of inflammatory lesions.

2.3. Data collection

Our study was a retrospective study design, we retrospectively collected the data from the medical records and we all conducted follow-up until the discharge of patients. We calculated on the sample size following formula for the rate comparison of two groups based on the incidence of pulmonary infection reported in previous study, a sample size of 186 would be enough for the detection of group differences. We collected the following personal characteristics and clinical data of included patients, including sex, age, body mass index, alcohol drinking, smoking, hypertension, diabetes, hyperlipidemia, New York Heart Association (NYHA) grade, intubation, death in hospital, and length of hospital stay. The detection method of C-reactive protein (CRP) was as following: we took fasting venous blood from the patient in the morning, separated the serum, and detected by immunoturbidimetry. Left ventricular ejection fractions (LVEFs) were measured with a Philips heart color ultrasound detector (Philips ×300, German) after the patient was admitted to the hospital. Two authors used a unified form to gather patient-related information, which they then checked against each other to make sure it was accurate, to reduce the risk of biases.

2.4. Pathogen detection of pulmonary infection

We collected respiratory secretions specimens of patients in the infection group and used the MINGXI automatic microbial identification system (XD200, Shanghai, China) to detect the distribution of pathogens.

2.5. Data analysis

In this study, SPSS 19.0 software was used for related data processing (SPSS Inc, Chicago, IL). We have checked the normality of the analyzed data before choosing parametric analysis. Measurement data were expressed as mean ± standard deviation; comparisons between groups were examined by t test. Count data were expressed by percentage, and comparison between groups was examined by χ² test. Logistic regression analyses were conducted to identify the risk factors of pulmonary infections in patients with heart failure. In this study, P < .05 was regarded as the group difference had statistical significance.

3. Results

3.1. The characteristics of included patients

A total of 201 patients with heart failure were included, of whom 48 had been diagnosed with pulmonary infection; the incidence of pulmonary infection in patients with heart failure was 23.88%. As indicated in Table 1, there were significant differences in the age, diabetes, NYHA grade, LVEF, and CRP between infection and no infection group (all P < .05), and there were no differences in the gender, body mass index, alcohol drinking, smoking, hypertension, hyperlipidemia, intubation, death in hospital, and length of hospital stay between 2 groups (all P > .05).

3.2. The risk factors of pulmonary infections in patients with heart failure

The variable assignment of multivariate logistic regression was presented in supplementary file 1, http://links.lww.com/MD/G407. As presented in Table 2, logistic regression analyses indicated that age ≥70 years, diabetes, NYHA grade III, LVEF ≤55%, and CRP ≥10 mg/L were the independent risk factors of pulmonary infections in patients with heart failure (all P < .05).

3.3. Pathogen distributions in elderly patients with pulmonary infection

Of the 48 patients with pulmonary infection, we have detected cases of pathogens; we could not identify the pathogens of the other two cases. As showed in Table 3, Pseudomonas aeruginosa (34.48%), Staphylococcus aureus (19.57%), and Klebsiella pneumoniae (15.22%) were the most common 3 pathogens in patients with pulmonary infection.
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Table 1
The characteristics of included patients.

| Variables                | Infection group (n = 48) | No-infection group (n = 153) | \( \chi^2 \) | P       |
|--------------------------|--------------------------|-----------------------------|--------------|---------|
| Age, y                   | 75.84 ± 8.11             | 68.95 ± 8.46                | 1.746        | .027    |
| Male                     | 30 (62.50%)              | 98 (64.05%)                 | 1.052        | .081    |
| Bmi, kg/m²               | 23.33 ± 1.03             | 22.9 ± 1.83                 | 1.024        | .106    |
| Alcohol drinking         | 31 (64.59%)              | 90 (58.82%)                 | 1.242        | .085    |
| Smoking                  | 22 (45.83%)              | 77 (50.33%)                 | 1.337        | .094    |
| Hypertension             | 27 (56.25%)              | 82 (53.59%)                 | 1.601        | .067    |
| Diabetes                 | 32 (66.67%)              | 40 (26.14%)                 | 1.841        | .009    |
| Hyperlipidemia           | 17 (35.42%)              | 51 (33.33%)                 | 1.197        | .094    |
| NYHA grade               |                          |                             |              |         |
| II                       | 6 (12.50%)               | 38 (24.84%)                 | 1.182        | .003    |
| III                      | 12 (25%)                 | 104 (67.97%)                | 1.182        | .003    |
| IV                       | 30 (62.50%)              | 11 (7.19%)                  | 1.211        | .052    |
| LVEF (%)                 | 49.05 ± 12.34            | 61.28 ± 10.83               | 6.204        | .014    |
| CRP, mg/L                | 18.54 ± 5.49             | 6.44 ± 2.06                 | 1.028        | .009    |
| Intubation               | 4 (8.33%)                | 10 (6.54%)                  | 1.211        | .052    |
| Death in hospital        | 1 (2.08%)                | 3 (1.96%)                   | 1.059        | .088    |
| Length of hospital stay, days | 10.13 ± 3.51             | 9.58 ± 3.97                 | 1.112        | .075    |

BMI = body mass index, CRP = C-reactive protein, LVEF = left ventricular ejection fraction.

Table 2
Logistic regression analysis on the risk factors of pulmonary infections in patients with heart failure.

| Variables                | \( \beta \) | SE     | OR    | 95% CI     | P       |
|--------------------------|------------|--------|-------|------------|---------|
| Age ≥70 y                | 0.135      | 0.129  | 2.049 | 1.121–3.208| .042    |
| Diabetes                 | 0.132      | 0.115  | 2.129 | 1.093–4.042| .025    |
| NYHA grade ≥III          | 0.108      | 0.099  | 2.455 | 1.264–4.085| .017    |
| LVEF <55%                | 0.172      | 0.173  | 3.806 | 1.184–6.102| .023    |
| CRP ≥10 mg/L             | 0.141      | 0.102  | 1.934 | 1.016–3.774| .041    |

CI = confidence interval, CRP = C-reactive protein, LVEF = left ventricular ejection fraction, OR = odds ratio, SE = standard error.

4. Discussions

With the increase of cardiovascular diseases and the aging of the population, the incidence of heart failure has gradually increased, of which 62.18% are elderly patients with heart failure.\(^{[18]}\) Pulmonary infection can increase pulmonary circulatory resistance, increase the afterload of ventricular contraction, and aggravate heart failure. It is the main cause of death in elderly patients with heart failure.\(^{[19]}\) Therefore, it is very important to judge whether elderly patients with heart failure are complicated by pulmonary infection.\(^{[20]}\) At present, the diagnosis of heart failure combined with lung infection is mainly through imaging examination and bacterial culture.\(^{[21]}\) Compared with imaging studies, bacterial culture can confirm whether there is pulmonary infection.\(^{[22]}\) The results of our study have showed that the incidence of pulmonary infection in patients with heart failure is 23.88%, and age ≥70 years, diabetes, NYHA grade III, LVEF ≤55%, and CRP ≥10 mg/L are the independent risk factors of pulmonary infections in patients with heart failure, which may provide reliable evidences to the management of heart failure.

In elderly patients with heart failure, the left ventricular myocardial contractility is weakened and the ejection ability is reduced, which often leads to pulmonary hypertension, pulmonary edema, and pulmonary congestion.\(^{[23]}\) Besides, in elderly patients, various functions of the body are reduced, bronchial glands and mucosal atrophy, and airway barrier function is weakened.\(^{[24,25]}\) Decreased alveolar elasticity and decreased mobility of the mucocilia in the trachea, all of which lead to a decline in immune function and a decrease in cough reflex sensitivity in the elderly, which makes the elderly heart failure more likely to merge with lung infection.\(^{[26,27]}\) Inflammatory factors stimulate pulmonary small blood vessels during lung infection, causing vasculitis, resulting in thickening of the vessel wall and narrowing of the official cavity.\(^{[28]}\) Meanwhile, inflammatory exudation increases the pressure in the alveoli, of which lead to varying degrees of pulmonary hypertension and increase the afterload of ventricular contraction.\(^{[29]}\) However, elderly patients often lack specific symptoms and signs due to the decline of the body’s stress ability, which brings difficulties to clinical diagnosis.\(^{[30]}\) Meanwhile, patients with heart failure often have different degrees of pulmonary edema.\(^{[31]}\) It is difficult

Table 3
The pathogen distributions in elderly patients with heart failure.

| Pathogens                  | Cases | Percent |
|----------------------------|-------|---------|
| Gram-positive bacteria      | 14    | 30.44%  |
| Staphylococcus aureus       | 9     | 19.57%  |
| Staphylococcus haemolyticus | 3     | 6.52%   |
| Staphylococcus epidermidis  | 2     | 4.35%   |
| Gram-negative bacteria      | 29    | 63.04%  |
| Pseudomonas aeruginosa      | 10    | 24.48%  |
| Klebsiella pneumoniae       | 7     | 15.22%  |
| Acinetobacter baumannii     | 6     | 13.04%  |
| Enterobacter cloace         | 4     | 8.69%   |
| Enterobacter aerogenes      | 2     | 4.35%   |
| Fungus                     | 3     | 6.52%   |
| Candida albicans            | 3     | 6.52%   |
to diagnose the lungs through clinical lung auscultation.[32] Therefore, it is difficult to determine whether it is complicated with lung infection. In the process of clinical treatment, doctors also rely on clinical experience to use antibiotics, which is prone to bacterial resistance.[33] Therefore, early identification of risk factors for pulmonary infection is of great significance.

Elderly heart failure combined with pulmonary infection is a common condition in clinical settings.[34] The severity and prognosis of heart failure and lung infection are also closely related.[35] For patients with pulmonary infection, clinicians generally adopt empirical antibiotic treatment, but it is often accompanied by the overuse of antibiotics and the production of drug-resistant bacteria, and it brings unnecessary economic burden to patients, so understand that the distribution of pathogenic bacteria in patients with pulmonary infection is of great significance for guiding the choice of clinical treatment strategies.[36] The pulmonary infections of patients with heart failure are mainly Staphylococcus aureus, Klebsiella pneumoniae, and Pseudomonas aeruginosa, which are consistent with the results of previous related studies,[37,38] suggesting that the sputum of patients with heart failure and lung infection needs to be cultured. Therefore, the use of antibiotics in the treatment of elderly patients with heart failure and pulmonary infection should mainly inhibit Gram-negative bacteria. And we should use medicines reasonably according to the specific pathogenic bacteria infection to effectively control pulmonary infection.

Elderly patients with heart failure complicated with lung infection should take relevant preventive measures. Strictly monitor the sputum and bacteria culture of patients during treatment, and instruct them to eat more foods with high calories, high protein, and high vitamins, instruct patients who stay in bed for rest to properly raise the head of the bed and encourage their family members to help them get out of bed.[39,40] Besides, back pat, expectoration, turn over times is beneficial to the prevention of pulmonary infection.[41] And patients should be carried out oral care regularly, rinse mouth with 0.9% sodium chloride or 0.3% soda after meals to inhibit the growth of fungi.[42] Patients with a history of smoking are advised to quit smoking, and patients with diabetes should strengthen blood sugar management and correct their wrong lifestyle.[43,44] Those measures may be effective to the prevention of pulmonary infection in patients with heart failure.

Several limitations in this study must be considered. First, the sample size is small, it may lack sufficient power to detect the potential group differences, it will need more such studies with more participants to validate the findings. Secondly, our study is a retrospective design, we have failed to show the severity of pulmonary infection limited by collected data, many other factors that may influence the occurrence of pulmonary infection cannot be included for analysis. Therefore, we think that it may be underpowered to build a model to predict infection in heart failure population. Besides, together with the prediction model, a nomogram will be useful for the ease of clinical utility. Future studies with prospective design and more potentially associated factors for pulmonary infection is of great significance.

5. Conclusions
To sum up, the pulmonary infection in patients with heart failure is very common, and the main pathogenic bacteria in elderly patients with pulmonary infection are Gram-negative bacteria, anti-Gram-negative bacteria should be used for antibiotic treatment when the pathogen infection is unknown. Besides, we have found that age ≥70 years, diabetes, NYHA grade III, LVEF ≤55%, and CRP ≥10 mg/l are the independent risk factors of pulmonary infections in patients with heart failure. Clinically, early prevention and intervention measures should be taken for these risk factors to reduce pulmonary infections.

Author contributions
Q Y designed research; Q P, Q Y conducted research; Q P analyzed data; Q P and Q Y wrote the first draft of manuscript; Q Y had primary responsibility for final content. All authors read and approved the final manuscript.

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References
[1] Remawi BN, Gadoud A, Murphy IMJ, Preston N. Palliative care needs-assessment and measurement tools used in patients with heart failure: a systematic mixed-studies review with narrative synthesis. Heart Fail Rev 2021;26:137–53.
[2] Bader F, Manla Y, Atallah B, Starling RC. Heart failure and COVID-19. Heart Fail Rev 2021;26:6–10.
[3] Malangu B, Lanier GM, Frishman WH. Nonpharmacologic treatment for heart failure: a review of implantable carotid baroreceptor stimulators as a therapeutic option. Cardiol Rev 2021;29:48–53.
[4] Baral R, Loudon B, Frenneaux MP, Vassiliou VS. Ventricular-vascular coupling in heart failure with preserved ejection fraction: a systematic review and meta-analysis. Heart Lung 2021;50:121–8.
[5] Grassi G, Quarti-Trevano F, Eser MD. Sympathetic activation in congestive heart failure: an updated overview. Heart Fail Rev 2021;26:173–82.
[6] Fan Z, Jiang H. Etiological characteristics and risk factors of nosocomial pulmonary infection in elderly patients with coronary heart disease complicated with heart failure. Chin J Prevent Med 2020;24:35–9.
[7] Fukuta H, Goto T, Wakaami K, Kamiya T, Oike N. Effect of beta-blockers on heart failure severity in patients with heart failure with preserved ejection fraction: a meta-analysis of randomized controlled trials. Heart Fail Rev 2021;26:165–71.
[8] Tello K, Seeger W, Naeije R, et al. Right heart failure in pulmonary hypertension: Diagnosis and new perspectives on vascular and direct right ventricular treatment. Br J Pharmacol 2021;178:90–107.
[9] Zhang Z, Cao L, Chen R, et al. Electronic healthcare records and external outcome data for hospitalized patients with heart failure. Sci Data 2021;8:46.
[10] Altibri AM, Prous G, Agarwal M, et al. Readmission-free period and inhospital mortality at the time of first readmission in acute heart failure patients-NRD-based analysis of 40,000 heart failure readmissions. Heart Fail Rev 2021;26:57–64.
[11] Hinton RB, Ware SM. Heart failure in pediatric patients with congenital heart disease. Circ Res 2017;120:978–94.
[12] Hsu PY, Waters DD. Heart failure in persons living with HIV infection. Curr Opin HIV AIDS 2017;12:534–9.
[13] Correale M, Tarantino N, Petrucci R, et al. Liver disease and heart failure: back and forth. Eur J Intern Med 2018;48:25–34.
[14] Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: The Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC). Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. Eur J Heart Fail 2016;18:891–975.

[15] China HMoDiagnosis standards for nosocomial infections. Chin J Med 2010;36:495–506.

[16] Sakpal TV. Sample size estimation in clinical trial. Perspect Clin Res 2010;1:67–9.

[17] Jincheng H, Lijun Z. Clinical analysis of atrial natriuretic peptide A gene polymorphism and inflammatory markers in patients with acute left heart failure and pulmonary infection Journal of Microcirculation 2019;11:3:53-56+67.

[18] Costanzo MR. The cardiorenal syndrome in heart failure. Heart Fail Clin 2020;16:81–97.

[19] Zhu ZW, Tang JJ, Chai XP, et al. Comparison of heart failure and COVID-19 in chest CT features and clinical characteristics. Zhonghua Xin Xue Guan Bing Za Zhi 2020;48:467–71.

[20] Asano R, Newton PJ, Currrow DC, et al. Rationale for targeted self-management strategies for breathlessness in heart failure. Heart Fail Rev 2021;26:71–9.

[21] Nishimura M, Bhatia H, Ma J, et al. The impact of substance abuse on heart failure hospitalizations. Am J Med 2020;133:207-213 e201.

[22] Bergsten TM, Nicholas A, Donnino M, Wang B, Fang Y, Natarajan S. Predicting adults likely to develop heart failure using readily available clinical information: an analysis of heart failure incidence using the NHFES. Prev Med 2020;130:105878.

[23] Sulo G, Sulo E, Jorgensen T, et al. Ischemic heart failure as a complication of incident acute myocardial infarction: timing and time trends: a national analysis including 78,814 Danish patients during 2000-2009. Scand J Public Health 2020;48:294–5.

[24] DeFilippis EM, Reza N, Donald E, Givertz MM, Lindenfeld J, Jessup M. Ischemic heart failure as a complication of cardiovascular disease. Eur J Clin Invest 2020;50:e13382.

[25] Sulo G, Sulo E, Jorgensen T, et al. Ischemic heart failure as a complication of incident acute myocardial infarction: timing and time trends: a national analysis including 78,814 Danish patients during 2000-2009. Scand J Public Health 2020;48:294–5.

[26] Garcia AM, Beatty JT, Nakano SJ. Heart failure in single right ventricle congenital heart disease: physiological and molecular considerations. Am J Physiol Heart Circ Physiol 2020;318:H947–65.

[27] Rizzo P, Vicelli Dalla Sega F, Fortini F, Marraco L, Ravezzi M, Ferrari R. COVID-19 in the heart and the lungs: could we “Notch” the inflammatory storm? Basic Res Cardiol 2020;115:3.

[28] Marra AM, Benjamini N, Cittadini A, Bosse E, Grunig E. When pulmonary hypertension complicates heart failure. Heart Fail Clin 2020;16:53–60.

[29] Gologorsky RG, Roy S. Ultrafiltration for management of fluid overload in patients with heart failure. Artif Organs 2020;44:129–39.

[30] Anker SD, Butler J, Khan MS, et al. clinical trials in heart failure during (and after) the COVID-19 pandemic: an Expert Consensus Position Paper from the Heart Failure Association (HFA) of the European Society of Cardiology (ESC). Eur Heart J 2020;41:2109–17.

[31] Kobayashi M, Voors AA, Gireud N, et al. Heart failure etiologies and clinical factors precipitating for worsening heart failure: Findings from BIOSTAT-CHF. Eur J Intern Med 2020;71:62–9.

[32] Hernandez G, Vaquero C, Colinas L, et al. Effect of postextubation high-flow nasal cannula vs noninvasive ventilation on reintubation and postextubation respiratory failure in high-risk patients: a randomized clinical trial. JAMA 2016;316:1565–74.

[33] Koirala B, Budhathoki C, Dennison-Himmelfarb CR, Bhattarai P, Davidson PM. The self-care of heart failure index: a psychometric study. J Clin Nurs 2020;29:645–52.

[34] Brouch D, Tashnish N, Di Felice G, Longenecker CT, Al-Kindi SG. Human immunodeficiency virus infection and risk of heart failure rehospitalizations. Am J Cardiol 2019;124:1232–8.

[35] Polyzos KA, Konstantelias AA, Falagas ME. Risk factors for cardiac implantable electronic device infection: a systematic review and meta-analysis. Europace 2015;17:767–77.

[36] Demissei BG, Cleland JG, O’Connor CM, et al. Procalcitonin-based indication of bacterial infection identifies high risk acute heart failure patients. Int J Cardiol 2016;204:164–71.

[37] Cardoso JN, Del Carlo CH, Oliveira Junior MT, Ochiai ME, Kalil Filho R, Barretto ACP. Infection in patients with decompensated heart failure: in-hospital mortality and outcome. Arq Bras Cardiol 2018;110:364–70.

[38] Staub LJ, Mazzali Biscaro RR, Kaszubowski E, Maurici R. Lung ultrasound for the emergency diagnosis of pneumonia, acute heart failure, and exacerbations of chronic obstructive pulmonary disease/asthma in adults: a systematic review and meta-analysis. J Emerg Med 2019;56:33–69.

[39] Vallabhaiprasada Y, Jentzer JC, Geshke JB, et al. New-onset heart failure and mortality in hospital survivors of sepsis-related left ventricular dysfunction. Shock 2018;49:144–9.

[40] Orr NM, Boxer RS, Dolansky MA, Allen LA, Forman DE. Skilled nursing facility care for patients with heart failure: can we make it “heart failure ready”? J Card Fail 2016;22:1004–14.

[41] Dolansky MA, Capone L, Leister E, Boxer RS. Targeting heart failure rehospitalizations in a skilled nursing facility: A case report. Heart Lung 2016;45:392–6.

[42] Unroe KT, Fowler NR, Carnahan JL, et al. Improving nursing facility care through an innovative payment demonstration project: optimizing patient transfers, impacting medical quality, and improving symptoms: transforming institutional care phase 2. J Am Geriatr Soc 2018;66:1625–31.

[43] Brennan EJ. Chronic heart failure nursing: integrated multidisciplinary care. Br J Nurs 2018;27:681–8.

[44] Sezgin D, Mert H, Ozpelit E, Akdeniz B. The effect on patient outcomes of a nursing care and follow-up program for patients with heart failure: A randomized controlled trial. Int J Nurs Stud 2017;70:17–26.

[45] Guzik TJ, Mohiddin SA, Dimarco A, et al. COVID-19 and the cardiovascular system: implications for risk assessment, diagnosis, and treatment options. Cardiovasc Res 2020;116:1666–87.

[46] Olloquequi J. COVID-19 Susceptibility in chronic obstructive pulmonary disease. Eur J Clin Invest 2020;50:e13382.

[47] Scudiero F, Silverio A, Di Maio M, et al. Pulmonary embolism in COVID-19 patients: prevalence, predictors and clinical outcome. Thromb Res 2021;198:34–9.