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*Original Article*

# Chest CT signs and serum homocysteine levels can effectively diagnose chronic heart failure

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**Abstract:** Objective: Chronic heart failure (CHF) is a significant clinical and public health concern, and improving its diagnostic accuracy remains an urgent challenge. This study aimed to evaluate the diagnostic value of chest computed tomography (CT) signs and serum homocysteine (Hcy) levels in the preoperative diagnosis of CHF. Methods: Clinical records of 97 patients hospitalized with suspected CHF between January 2019 and December 2023 were retrospectively analyzed. The accuracy, specificity, and sensitivity of chest CT in diagnosing CHF were calculated, using color Doppler echocardiography as the gold standard. Key CT features, including pulmonary venous hypertension (PVH), atrial dilatation (AD), cardiogenic pulmonary edema (CPE), and pleural effusion (PE), were assessed. Serum Hcy levels were compared, and diagnostic performance was evaluated using a receiver operator characteristic (ROC) curves. Results: The accuracy, sensitivity, and specificity of chest CT for diagnosing CHF were 82.47%, 91.07%, and 70.73%, respectively. Among patients with diagnosed with CHF, 48 (76.19%) had PVH, 44 (69.84%) had CPE, 44 (69.84%) had PE, and 47 (74.60%) had AD. PVH, AD, CPE, and PE were strongly correlated with CHF (all $P<0.05$). The area under the curve (AUC) for CHF diagnosis was 0.831 for CT alone, 0.824 for Hcy alone, and 0.922 for the combined approach. Conclusion: Chest CT demonstrated high diagnostic efficiency for CHF, aiding clinicians in preoperative assessment and differentiation. It provides reliable identification of key CHF-related signs, including PVH, AD, CPE, and PE, all of which are strongly correlated with CHF. In addition, integrating serum Hcy levels with imaging findings enhances diagnostic accuracy.

**Keywords:** Chronic heart failure, chest computed tomography, preoperative diagnosis

## Introduction

Heart failure (HF) is a major clinical and public health concern. Due to the heterogeneity and complexity of its pathogenesis, clinical manifestations, and survival outcomes, effective treatment strategies remain limited in most cases [1]. HF is the leading cause of hospitalization and is associated with mortality risk. Globally, it affects approximately 65 million people, with an incidence of 1-2% in developed countries [2]. HF is classified into acute heart failure (AHF) and chronic heart failure (CHF), with CHF being a progressive syndrome resulting from structural or functional cardiac abnormalities. Hypertension, coronary heart disease (CHD), and dilated cardiomyopathy are common causes of CHF [3]. Patients often present with fatigue, insomnia, dyspnea, edema, depression and chest pain [4].

As aforementioned, the heterogeneity in the occurrence and presentation of CHF prevents a single test from definitively diagnosing HF. However, the frequent co-occurrence of pulmonary hypertension in CHF patients represents a potential diagnostic opportunity. Evidence suggests that pulmonary artery-related parameters are associated with survival outcome in HF patients [5]. Computed tomography (CT) is the preferred approach for obtaining comprehensive chest images and excluding pulmonary diseases [6]. Consequently, chest CT findings can aid clinicians in identifying and diagnosing CHF. Moreover, chest CT enables a more accurate characterization of the cardiac pathophysiology in HF patients [7, 8]. A study comparing chest CT, echocardiography and right ventricular catheterization reported that chest CT had high diagnostic value for identifying CHF and can help predict survival outcome in CHF patients

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**Table 1.** General information of suspected chronic heart failure patients (n=97)

| Category | N (%); mean ± sd |
|---|---|
| Sex | |
| Male | 51 (52.58) |
| Female | 46 (47.42) |
| Average age (years old) | 73.24±6.63 |
| Cardiac function classification | |
| II | 46 (47.42) |
| III | 32 (32.99) |
| IV | 19 (19.59) |
| Primary heart disease | |
| Coronary heart disease | 58 (59.79) |
| Hypertensive heart disease | 26 (26.80) |
| Rheumatic heart disease | 13 (13.40) |

with reduced ejection fraction (EF) in advanced stages [9]. Moreover, chest CT enhances the diagnostic efficacy of transthoracic echocardiography in HF [10]. Homocysteine (Hcy), a key contributor to atherosclerosis, is closely associated with cardiovascular disease [11]. Recent studies have reported elevated serum Hcy levels in CHF patients, suggesting that Hcy may serve as a risk factor for CHF [12]. However, further evidence is required to establish the combined diagnostic value of chest CT and Hcy levels in HF.

To evaluate the utility of chest CT and serum Hcy levels for the preoperative diagnosis of CHF, this study retrospectively analyzed the clinical data from 97 patients who were hospitalized with suspected CHF between January 2019 and December 2023. Key clinical signs, including pulmonary venous hypertension (PVH), atrial dilatation (AD), cardiogenic pulmonary edema (CPE), pleural effusion (PE) were assessed using chest CT. This study aimed to verify the diagnostic efficacy of chest CT and Hcy level in HF and provide reliable scientific evidence.

## Methods

### *Case selection*

Ninety-seven patients with suspected CHF who were hospitalized in the First Affiliated Hospital of Xinxiang Medical University between January 2019 and December 2023 were retrospective included in this study. This study was approved by the Ethics Committee of the First Affiliated Hospital of Xinxiang Medical University. General information is shown in **Table 1**.

Inclusion criteria: (1) Patients with suspected CHF based on clinical symptoms who required further tests (e.g., color Doppler echocardiography); (2) Patients with complete clinical data and high-quality imaging; (3) Patients with no history of severe trauma in the past two weeks; no malignant tumor or other cerebrovascular/cardiovascular diseases; no dysfunction of the liver, kidney, lungs or other organs; no hematologic or systemic immune diseases; no history of myocardial infarction or hyperthyroidism in the past six months; and no use of anti-epileptic, anti-inflammatory, or hormone drugs.

Exclusion criteria: (1) Acute coronary syndrome within past 6 months prior to admission; (2) Congenital heart disease, moderate-to-severe heart valve disease, pericardial disease, or restrictive cardiomyopathy; (3) History of post-cardiac transplantation, severe liver disease, malignant arrhythmia with hemodynamic instability, renal insufficiency, malignant disease, severe infections, or other serious wasting diseases; (4) Incomplete clinical data or poor-quality imaging.

### *Data collection*

Patient data were retrieved from electronic medical records, including demographic information (age, sex, cardiac function classification), serum biochemical markers, and imaging data (chest CT and color Doppler echocardiography). Data entry was performed using Excel software, with duplicate entries by two independent reviewers, followed by cross-checking to ensure accuracy and maintain data integrity.

### *Outcome measurement*

The primary outcome measures were chest CT findings and serum Hcy levels. Secondary outcome measures included pulmonary venous hypertension (PVH), atrial dilatation (AD), cardiogenic pulmonary edema (CPE), and pleural effusion (PE).

*Chest CT scan:* All patients underwent thoracic spiral CT scanning (GE Healthcare, Waukesha, WI, USA) with an inter-slice spacing set as 10 mm. AD was assessed using the mediastinal window, with continuous scanning performed

**Table 2.** Diagnostic results of chronic heart failure using Chest CT and Color Doppler echocardiography

| Color Doppler echocardiography result | Chest CT diagnosis results | | Total |
|---|---|---|---|
| | Chronic heart failure | Non-chronic heart failure | |
| Chronic heart failure | 51 | 12 | 63 |
| Non-chronic heart failure | 5 | 29 | 34 |
| Total | 56 | 41 | 97 |

from the lung apex downward. Vessel thickness and fluid retention were also evaluated. In addition, the degree of pulmonary edema was observed through the pulmonary window. After scanning, CT images were analyzed, and CHF-related clinical signs, including PVH, AD, CPE, and PE, were recorded.

*Color Doppler echocardiography:* All patients underwent color Doppler echocardiography (iE-elite and 7C with transducer S5-1 and X5-1; Phillips, Andover, MA, USA) to assess cardiac enlargement, systolic and diastolic function, and EF. The presence of cardiac enlargement, impaired systolic and diastolic function, and reduced EF was indicative of HF.

*Serum homocysteine (Hcy) levels:* Fasting venous blood samples were collected from all patients in the morning following hospital admission. Samples were centrifuged at 3000 rpm for 15 minutes to separate serum, and Hcy levels were measured using an enzymatic assay. Homocysteine assay kits were purchased from Ortho-Clinical Diagnostics, Inc.

*Statistical methods*

All data were analyzed using SPSS 25.0 statistical software. Categorical data were presented as the number of cases (percentage), while measured data were expressed as the mean ± standard deviation. Analysis of variance (ANOVA) was used for continuous variables, and the chi-square test was applied to categorical variables. Diagnostic sensitivity, specificity, and the area under the receiver operating characteristic (ROC) curve (AUC) were calculated based on Bayes' theorem. A two-tailed *P*-value <0.05 was considered statistically significant.

## Results

*General information*

This study included 97 patients with suspected CHF, including 51 males and 46 females, with an average age of 73.24±6.63 years old. Based on cardiac function classification, there were 46 cases of grade II, 32 cases of grade III, and 19 cases of grade IV CHF. Regarding the primary underlying heart diseases, CHD, hypertensive heart disease, and rheumatic heart disease were observed in 58, 26, and 13 cases, respectively (**Table 1**).

*Accuracy of chest CT in diagnosing CHF*

Among the 97 suspected CHF cases, CHF was confirmed in 63 patients (64.95%) by color Doppler echocardiography and in 56 patients (57.73%) by chest CT. Using color Doppler echocardiography as the gold standard, the diagnostic accuracy, sensitivity, and specificity of chest CT for CHF were calculated as 82.47%, 91.07%, and 70.73%, respectively (**Table 2**). Representative chest CT images of CHF are shown in **Figure 1**.

*Diagnostic value of PVH in CHF*

As shown in **Figure 2**, among the 63 patients diagnosed with CHF by color ultrasound, 48 patients (76.19%) exhibited pulmonary venous hypertension (PVH). In contrast, PVH was observed in 11 (32.35%) of the 34 non-CHF patients identified by color ultrasound. A Chi-square test revealed a significant difference in PVH occurrence between CHF and non-CHF patients ($P<0.0001$, $\chi^2=17.81$). Furthermore, ROC curve analysis was performed to assess the diagnostic utility of PVH for CHF. The results showed that the AUC for PVH in CHF diagnosis was 0.794 (95% CI: 0.698-0.891).

*Diagnostic value of CPE in CHF*

As shown in **Figure 3**, among the 63 patients diagnosed with CHF by color ultrasound, 44 (69.84%) had cardiogenic pulmonary edema (CPE), while CPE was present in 15 (44.12%) of the 34 non-CHF patients identified by color ultrasound. A chi-square test demonstrated

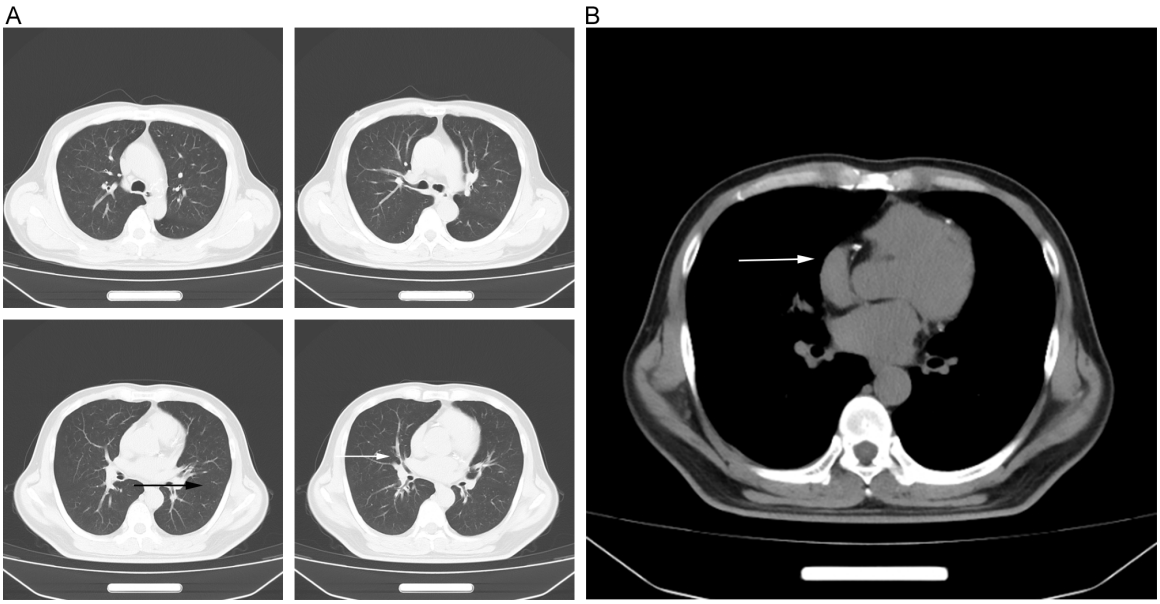


**Figure 1.** CT images from a chronic heart failure patient. A: Enlarged and blurred pulmonary hilums, thickened and blurred bronchovascular bundles (arrows), thickened smooth interlobular septa, diffuse ground-glass shadows in the lung fields; B: Mediastinal window in patients with chronic heart failure, presence of a small pericardial effusion.

a significant difference in CPE occurrence between CHF and non-CHF patients (P=0.013, $\chi^2$=6.132). Additionally, ROC curve analysis was conducted to evaluate the diagnostic value of CPE in CHF. The results showed that the AUC for PVH in CHF diagnosis was 0.731 (95% CI: 0.626-0.836).

*Diagnostic value of PE in CHF*

As shown in **Figure 4**, pulmonary edema (PE) was observed in 44 (69.84%) of the 63 CHF patients identified by color ultrasound, whereas among the 34 patients classified as non-CHF identified by color ultrasound, PE was detected in 11 (32.35%). A statistically significant difference in the incidence of PE between CHF and non-CHF patients was identified using the chi-square test (P=0.0004, $\chi^2$=12.641). Furthermore, the diagnostic performance of PE for CHF was evaluated using a receiver operating characteristic (ROC) curve. The AUC for PE in diagnosing CHF was 0.738 (95% CI: 0.634-0.841).

*Significance of AD in CHF based on chest CT*

As shown in **Figure 5**, atrial dilatation (AD) was detected in 47 (74.60%) of the 63 CHF patients identified by via color ultrasound, while AD was present in only 12 (35.29%) of the 34 non-CHF patients identified by via color ultrasound. The chi-square test revealed a statistically significant difference in AD occurrence between CHF and non-CHF patients (P=0.0002, $\chi^2$=14.321). Additionally, the ROC curve analysis of AD for CHF diagnosis showed that the AUC of PVH for CHF detection was 0.816 (95% CI: 0.723-0.908).

*Diagnostic value of CT combined with Hcy level*

According to the biochemical index detection results, the serum Hcy level in CHF patients was (30.96±7.20) μmol/L, significantly higher than (22.53±5.26) μmol/L for non-CHF patients. The diagnostic values of CT, Hcy levels, and their combined application in CHF diagnosis were assessed using ROC curve analysis.

The sensitivity and specificity of Hcy levels for CHF diagnosis were 88.24% and 68.25%, respectively. The AUC for CT alone for CHF diagnosis was 0.831, while that for Hcy levels alone was 0.824. However, the combined diagnostic approach yielded an AUC of 0.922, demonstrating significantly improved diagnostic accuracy (P<0.05). These results are illustrated in **Figure 6** and summarized in **Table 3**.

## Discussion

Heart failure (HF) occurs when the heart is too stiff to pump effectively or when the cardiac

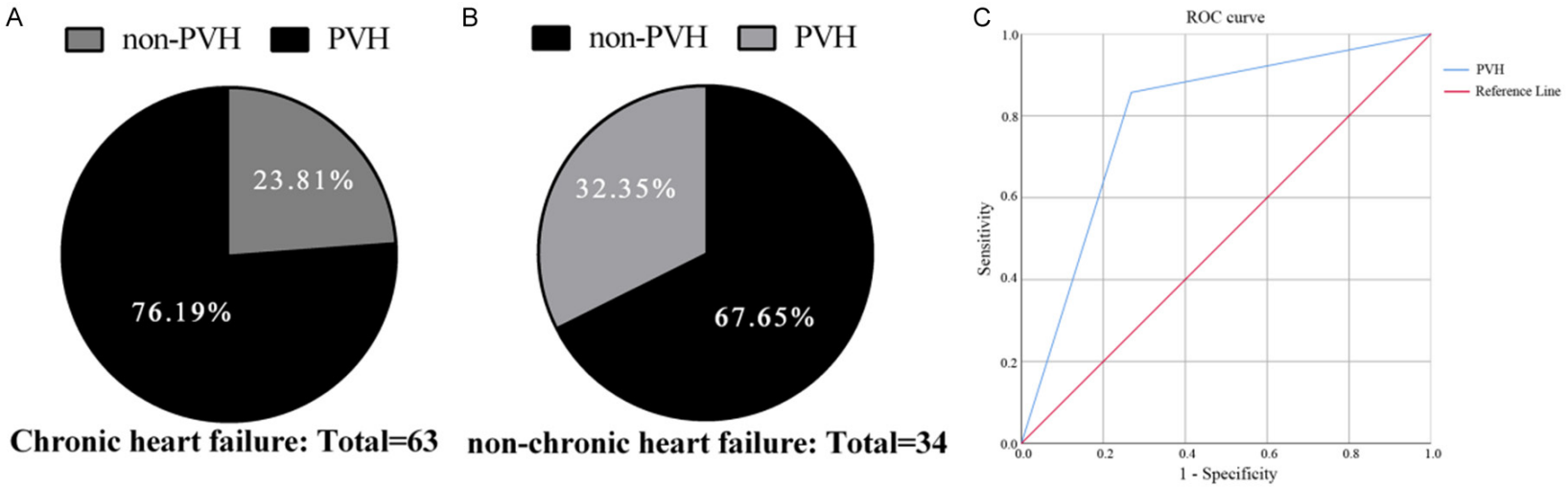


**Figure 2.** Pulmonary venous hypertension (PVH) statistics in suspected chronic heart failure (CHF) patients ($P<0.0001$, $\chi^2=17.81$). A: PVH incidence in CHF patients; B: PVH incidence in non-CHF patients; C: ROC curve for PVH for diagnosing CHF.

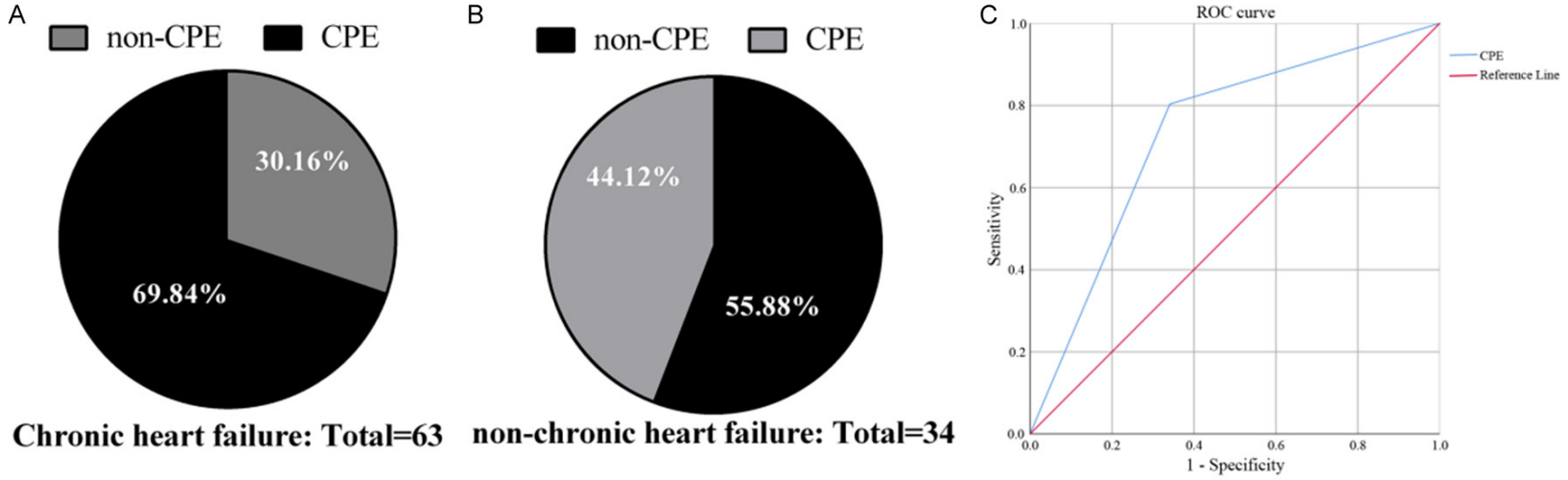


**Figure 3.** Statistics of cardiogenic pulmonary edema (CPE) for suspected chronic heart failure (CHF) patients ($P=0.013$, $\chi^2=6.132$). A: CPE incidence in CHF patients; B: CPE incidence in non-CHF patients; C: ROC curve for CPE in diagnosing CHF.

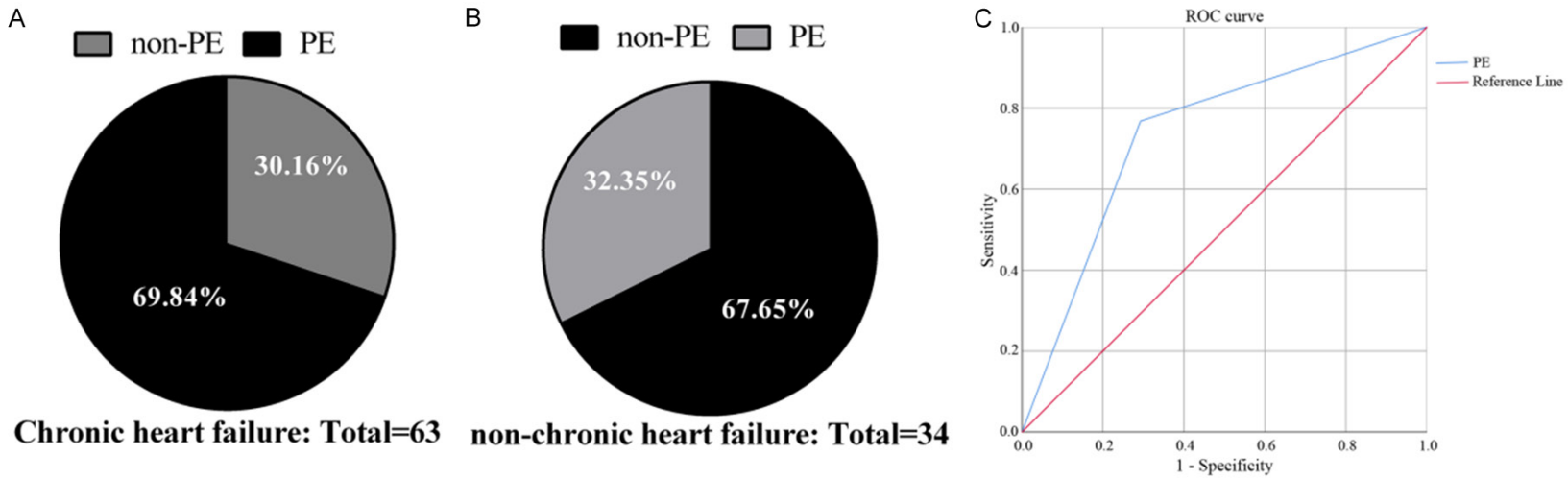


**Figure 4.** Statistics of pleural effusion (PE) in suspected chronic heart failure (CHF) patients (P=0.0004, $\chi^2$=12.641). A: PE incidence in CHF patients; B: PE incidence in non-CHF patients; C: ROC curve for PE for diagnosing CHF.

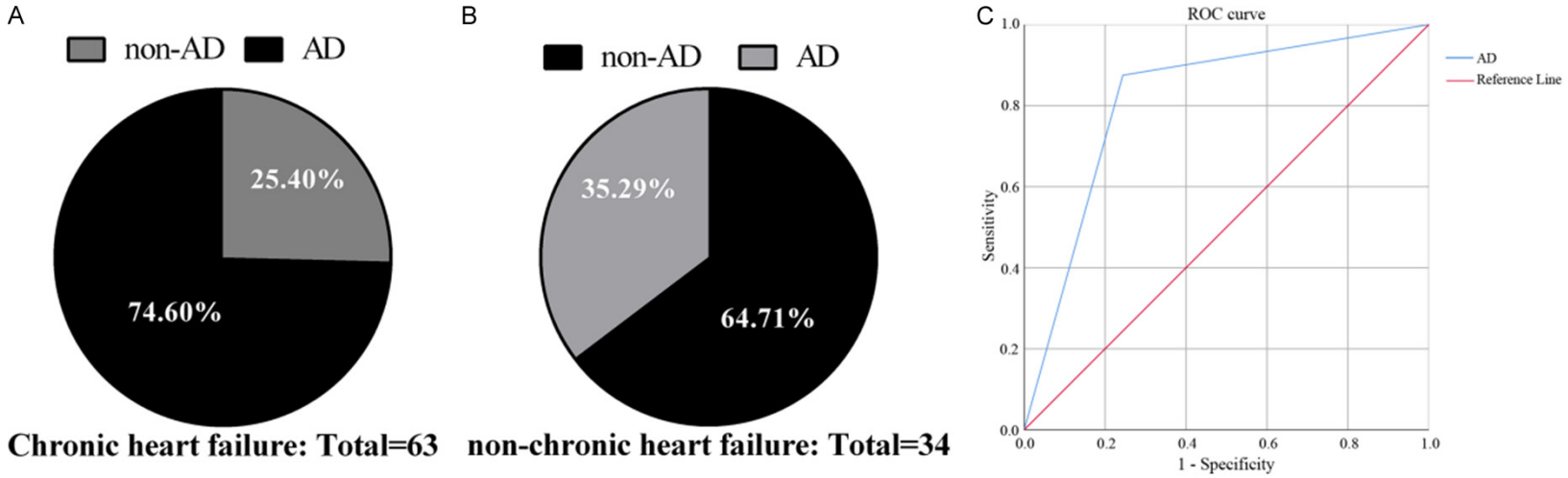


**Figure 5.** Statistics of atrial dilatation (AD) in suspected chronic heart failure (CHF) patients (P=0.0002, $\chi^2$=14.321). A: AD incidence in CHF patients; B: AD incidence in non-CHF patients; C: ROC curve for AD for diagnosing CHF.

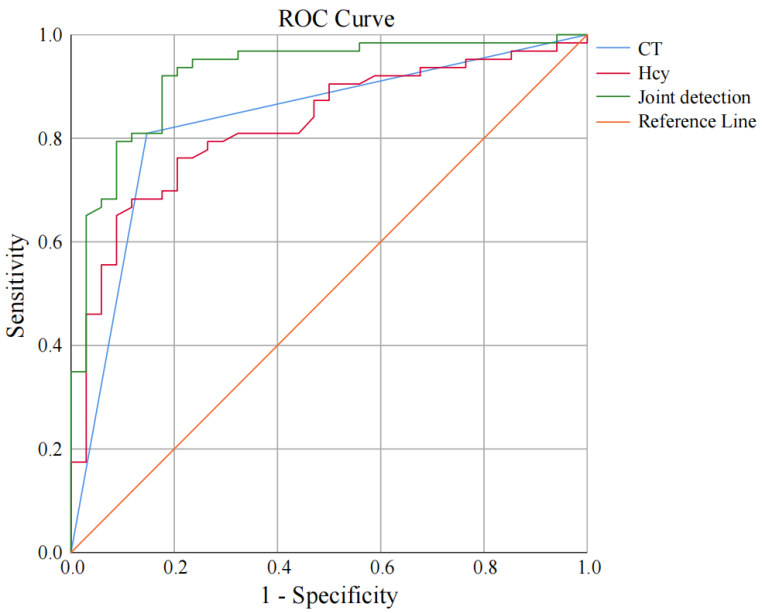


**Figure 6.** ROC analysis of CT, Hcy and their combination for diagnosing CHF. Hcy: homocysteine; CHF: chronic heart failure.

**Table 3.** Diagnostic performance of CT, Hcy, and their combination for chronic heart failure

| Variable | AUC | S.E. | P | 95% CI |
|---|---|---|---|---|
| CT | 0.831 | 0.046 | <0.0001 | 0.742-0.921 |
| Hcy | 0.824 | 0.043 | <0.0001 | 0.739-0.908 |
| Joint detection | 0.922 | 0.029 | <0.0001 | 0.865-0.979 |

Hcy: homocysteine.

muscle is weakened. Hypertension, CHD, diabetes, obesity, and smoking are all significant contributors to HF [13]. HF imposes a substantial economic burden on both patients and health care system, with treatment costs rising continuously [14]. The incidence and risk of HF increase with age [15], and diagnosing CHF remains a major challenge in the elderly population [16]. An accurate diagnosis is essential for timely and appropriate treatment strategies. Therefore, improving the diagnostic rate of CHF is an urgent clinical need.

CT enables three-dimensional visualization of organs [17]. Chest CT is a non-invasive imaging modality that facilitates the understanding of lung structure and pathophysiology, aiding in disease assessment [18]. It has considerable potential in diagnosing cardiovascular disease and is expected to improve the cost-effectiveness of disease screening in the future [19]. Predictive models based on chest CT have been shown to improve cardiovascular risk assessment, enabling timely preventive intervention and reducing the burden of cardiovascular diseases [20]. A 2017 study [21] highlighted that chest CT facilitates the identification of risk factors and improves the detection rate of cardiovascular diseases. Therefore, the use of chest CT for CHF diagnosis is a feasible approach. In this study, color Doppler echocardiography was used as the gold standard to assess the diagnostic performance of chest CT in CHF. The results revealed that chest CT has high specificity, sensitivity, and accuracy in CHF diagnosis.

Further analysis of clinical signs, including pulmonary venous hypertension (PVH), atrial dilatation (AD), cardiogenic pulmonary edema (CPE), and pleural effusion (PE), obtained based on chest CT confirmed their association with CHF. Pulmonary hypertension is a common hemodynamic alteration in HF that arises from pressure injury and chronic venous congestion due to increased left atrial pressure [22]. In CHF-induced pulmonary hypertension, the sustained high-pressure environment also impairs atrial function, leading to right AD [23]. When the right atrial stroke volume exceeds that of the left atrium, fluid accumulates in the alveoli, causing pulmonary edema [24]. Moreover, HF is a well-recognized cause of PE [25]. The above four signs, all detectable by chest CT, provide valuable insight into the pulmonary pathophysiology of HF.

However, chest CT has certain limitations. First, the risks of radiation exposure must be considered, and further studies are needed to evaluate the relationship between radiation dose and CHF diagnosis. Second, chest CT is relatively expensive, which poses financial constraints for routine screening. Thus, enhancing

the diagnostic accuracy of chest CT by integrating cost-effective biochemical markers could be a more practical approach. In this context, we evaluated serum Hcy levels, a methionine metabolite strongly associated with cardiovascular disease. Hcy-mediated endothelial cell damage can lead to structural and functional vascular abnormalities and is considered a possible etiologic factor in CHF assessment [26, 27]. Elevated Hcy levels have been widely reported to promote mast cell aggregation and are an independent risk factor for myocardial fibrosis, diastolic dysfunction, and ventricular remodeling [12]. In the present study, we found that Hcy can serve as a useful biomarker for CHF diagnosis, with its diagnostic value further enhanced when combined with chest CT.

This study still has several limitations. The primary limitation is its monocentric and retrospective design, which may limit the generalization of the findings. Additionally, the retrospective nature of data collection may lead to an underestimation of outcomes due to potentially incomplete patient records. While some data were automatically sourced from the patient management system, most required manual retrieval from various patient documents, introducing a possibility of data omission or inconsistencies. Furthermore, this study focused solely on homocysteine (Hcy) levels, without assessing other biochemical markers that may be critical for CHF diagnosis, possibly missing additional relevant indicators.

In conclusion, this study demonstrated that chest CT exhibits high diagnostic performance in CHF, aiding clinicians in preoperative assessment and differentiation of the disease. Moreover, the combined diagnostic approach integrating serum Hcy levels further enhances diagnostic accuracy. Given that chest CT can accurately capture the clinical signs, our findings suggest that PVH, AD, CPE, and PE are significantly associated with CHF. These insights contribute to the expanding clinical application of chest CT in CHF diagnosis and management.

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## Disclosure of conflict of interest

None.

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## References

[1] Roger VL. Epidemiology of heart failure: a contemporary perspective. Circ Res 2021; 128: 1421-1434.

[2] Groenewegen A, Rutten FH, Mosterd A and Hoes AW. Epidemiology of heart failure. Eur J Heart Fail 2020; 22: 1342-1356.

[3] Di Palo KE and Barone NJ. Hypertension and heart failure: prevention, targets, and treatment. Cardiol Clin 2022; 40: 237-244.

[4] Heo S, Kang J, Shin MS, Lim YH, Kim SH, Kim S, An M and Kim J. Physical symptoms, depressive symptoms, and quality of life in patients with heart failure: cluster analysis. J Cardiovasc Nurs 2024; 39: 31-37.

[5] Schmeißer A, Rauwolf T, Groscheck T, Fischbach K, Kropf S, Luani B, Tanev I, Hansen M, Meißler S, Schäfer K, Steendijk P and Braun-Dullaeus RC. Predictors and prognosis of right ventricular function in pulmonary hypertension due to heart failure with reduced ejection fraction. ESC Heart Fail 2021; 8: 2968-2981.

[6] Soffer S, Morgenthau AS, Shimon O, Barash Y, Konen E, Glicksberg BS and Klang E. Artificial intelligence for interstitial lung disease analysis on chest computed tomography: a systematic review. Acad Radiol 2022; 29 Suppl 2: S226-S235.

[7] Di Cesare E, Carerj S, Palmisano A, Carerj ML, Catapano F, Vignale D, Di Cesare A, Milanese G, Sverzellati N, Francone M and Esposito A. Multimodality imaging in chronic heart failure. Radiol Med 2021; 126: 231-242.

[8] da Silva JP, Rahal SC, Castiglioni MCR, Baldissera Gonçalves RA, Doiche DP, Moresco A, Mamprim MJ and Vulcano LC. Radiography and computed tomography of the heart and lower respiratory tract in toco toucans (Ramphastos toco). Anat Histol Embryol 2020; 49: 541-549.

[9] Colin GC, Gerber BL, de Meester de Ravenstein C, Byl D, Dietz A, Kamga M, Pasquet A, Vancraeynest D, Vanoverschelde JL, D'Hondt AM, Ghaye B and Pouleur AC. Pulmonary hypertension due to left heart disease: diagnostic and prognostic value of CT in chronic systolic heart failure. Eur Radiol 2018; 28: 4643-4653.

[10] Siwik D, Apanasiewicz W, Żukowska M, Jaczewski G and Dąbrowska M. Diagnosing lung abnormalities related to heart failure in chest radiogram, lung ultrasound and thoracic computed tomography. Adv Respir Med 2023; 91: 103-122.
[11] Gospodarczyk A, Marczewski K, Gospodarczyk N, Widuch M, Tkocz M and Zalejska-Fiolka J. Homocysteine and cardiovascular disease - a current review. Wiad Lek 2022; 75: 2862-2866.
[12] Jin N, Huang L, Hong J, Zhao X, Chen Y, Hu J, Cong X, Xie Y and Pu J. Elevated homocysteine levels in patients with heart failure: a systematic review and meta-analysis. Medicine (Baltimore) 2021; 100: e26875.
[13] Age dependent associations of risk factors with heart failure: pooled population based cohort study. BMJ 2021; 373: n880.
[14] Savarese G, Becher PM, Lund LH, Seferovic P, Rosano GMC and Coats AJS. Global burden of heart failure: a comprehensive and updated review of epidemiology. Cardiovasc Res 2023; 118: 3272-3287.
[15] Park JJ and Choi DJ. Current status of heart failure: global and Korea. Korean J Intern Med 2020; 35: 487-497.
[16] Farwati M, Riaz H and Tang WHW. Digital health applications in heart failure: a critical appraisal of literature. Curr Treat Options Cardiovasc Med 2021; 23: 12.
[17] Decazes P, Hinault P, Veresezan O, Thureau S, Gouel P and Vera P. Trimodality PET/CT/MRI and radiotherapy: a mini-review. Front Oncol 2021; 10: 614008.
[18] Shaffie A, Soliman A, Fu XA, Nantz M, Giridharan G, van Berkel V, Khalifeh HA, Ghazal M, Elmaghraby A and El-Baz A. A novel technology to integrate imaging and clinical markers for non-invasive diagnosis of lung cancer. Sci Rep 2021; 11: 4597.
[19] Trimarchi G, Pizzino F, Paradossi U, Gueli IA, Palazzini M, Gentile P, Di Spigno F, Ammirati E, Garascia A, Tedeschi A and Aschieri D. Charting the unseen: how non-invasive imaging could redefine cardiovascular prevention. J Cardiovasc Dev Dis 2024; 11: 245.
[20] Chao H, Shan H, Homayounieh F, Singh R, Khera RD, Guo H, Su T, Wang G, Kalra MK and Yan P. Deep learning predicts cardiovascular disease risks from lung cancer screening low dose computed tomography. Nat Commun 2021; 12: 2963.
[21] Azour L, Kadoch MA, Ward TJ, Eber CD and Jacobi AH. Estimation of cardiovascular risk on routine chest CT: ordinal coronary artery calcium scoring as an accurate predictor of Agatston score ranges. J Cardiovasc Comput Tomogr 2017; 11: 8-15.
[22] Duran A and Mandras S. Pulmonary hypertension in heart failure. Curr Opin Cardiol 2021; 36: 205-210.
[23] Marra AM, Benjamin N, Cittadini A, Bossone E and Grünig E. When pulmonary hypertension complicates heart failure. Heart Fail Clin 2020; 16: 53-60.
[24] Huston JH and Shah SJ. Understanding the pathobiology of pulmonary hypertension due to left heart disease. Circ Res 2022; 130: 1382-1403.
[25] Husnain SMN and Shojaee S. Hepatic hydrothorax and congestive heart failure induced pleural effusion. Clin Chest Med 2021; 42: 625-635.
[26] Wang X, Wang F, Feng Z, Cai J and Liu J. The association between levels of serum homocysteine and chronic heart failure: a protocol for systematic review and meta-analysis. Medicine (Baltimore) 2021; 100: e24117.
[27] Yao Z, Li G and Li G. Correlation between serum urea nitrogen, cystatin C, homocysteine, and chronic heart failure. Am J Transl Res 2021; 13: 3254-3261.