DANISH MEDICAL JOURNAL

Original Article

Heart size on chest CT and its association with acute heart failure in the emergency department

Emilie Melgaard[1], Lucas Malta Westergaard[1], Anne Sophie Olesen[2], Kristina Miger[2], Sandra Tonning[1], Silas Nyboe Ørting[3], Jens Petersen[3], Olav Wendelboe Nielsen[4] & Johannes Grand[1]

1) Department of Cardiology, Copenhagen University Hospital – Amager and Hvidovre Hospital, 2) Department of Cardiology, Copenhagen University Hospital – Bispebjerg and Frederiksberg Hospital, 3) Department of Computer Science, University of Copenhagen, 4) Department of Clinical Medicine, University of Copenhagen, Denmark

Dan Med J 2026;73(5):A09250765. doi: 10.61409/A09250765

ABSTRACT

INTRODUCTION. Acute heart failure (AHF) is a diagnosis requiring rapid treatment. Cardiomegaly on chest radiograph is a common marker of cardiac pathology used to identify AHF, but it has limited sensitivity. Low-dose chest CT (LDCT) may improve assessment, though no standardised CT method exists. We examined the association between LDCT heart-to-lung ratio and clinical AHF.

METHODS. We included 230 consecutive emergency department patients with acute dyspnoea. Maximal heart and lung diameters were measured on axial LDCT slices using automated segmentation (TotalSegmentator v1). A heart-to-lung ratio (%) was calculated. AHF diagnosis was adjudicated by cardiologists. Logistic regression assessed the association between heart-to-lung ratio, analysed as a continuous variable, and AHF (OR per one-percentage-point increase with 95% CI).

RESULTS. Among 230 patients, 100 were diagnosed with AHF. Using heart-to-lung ratio categorically, 106 had < 50% and 124 ≥ 50%. Using heart-to-lung ratio continuously, a one-percentage-point increase in heart-to-lung ratio was associated with AHF (OR: 1.19, 95% CI: 1.12-1.27, p < 0.001), with an optimal cut-off of 52% (area under the curve = 0.85).

CONCLUSIONS. The heart-to-lung ratio on LDCT was significantly associated with AHF, with an optimal threshold just above the radiographic cut-off. Standardising CT-specific cut-offs may enhance diagnostic accuracy in emergency care.

FUNDING. None.

TRIAL REGISTRATION. The National Ethics Committee on Health Research Ethics, Denmark, approved the original study (Project-id: H-17000869).

Acute heart failure (AHF) is characterised by a rapid onset of cardinal symptoms such as dyspnoea and is associated with high morbidity, mortality and a significant risk of rehospitalisation, which makes prompt assessment and treatment initiation essential [1, 2]. While dyspnoea is one of the primary symptoms of AHF, it is also observed in other acute conditions, including exacerbation of chronic obstructive pulmonary disease, pneumonia and pulmonary embolism [3]. Consequently, imaging plays a key role in distinguishing between these diagnoses in patients presenting with dyspnoea in the emergency department (ED) [4]. Chest radiographs and lung ultrasounds are commonly used in acute settings, not only when AHF is suspected, but also for differential diagnosis [5]. However, due to low sensitivity, additional imaging modalities, including chest CT, are often required in acute or frail patients [6]. In recent years, the availability and use of CT in the ED have increased, providing valuable insights into conditions affecting patients with dyspnoea [7, 8].

On an anteroposterior chest radiograph, cardiomegaly is traditionally defined as a cardiothoracic ratio > 50%. This original threshold is typically used as a trigger to recommend further cardiological evaluation [9, 10]. Although CT offers more detailed imaging and could improve assessment in suspected AHF, no standardised method for evaluating cardiomegaly on CT exists, leading to substantial variation in interpretation [8, 11]. Furthermore, the literature on this topic is very limited, and the 50% cardiothoracic ratio for cardiomegaly has not been validated for CT imaging [12]. However, an enlarged heart on low-dose chest CT (LDCT) has previously been identified as one of the five most important CT signs for assessing the risk of AHF [8]. Therefore, the aim of this study was to investigate the relationship between heart size from chest CT and the clinical diagnosis of AHF.

Methods

Design

This study was based on a consecutive sampling of patients admitted to the ED with acute dyspnoea between November 2017 and October 2019 at Bispebjerg University Hospital, Copenhagen, Denmark. The National Ethics Committee approved the original study on Health Research Ethics, Denmark (project id: H-17000869) [8]. All patients provided informed written consent before participating in the study.

The study included patients presenting with dyspnoea accompanied by at least one objective sign of the condition, such as peripheral oedema, jugular venous distention, orthopnoea or bilateral rales on auscultation [4, 8]. Patients were excluded if they could not give informed consent due to cognitive impairments, declined to provide written consent or were not Danish citizens. Additional exclusion criteria included patients scheduled for a chest CT for other clinical indications, such as suspected pulmonary embolism, aortic dissection or aneurysm. Furthermore, individuals with acute coronary syndrome, those experiencing circulatory instability requiring inotropic support, respiratory instability requiring ventilation (either mechanical or non-mechanical) or who had a life expectancy of less than three months were excluded from the study.

All patients underwent a thorough clinical examination, blood sampling, chest radiography, detailed echocardiographic assessment and LDCT. All study examinations had to be completed within 12 hours of admission.

Calculation of heart-to-lung ratio on low-dose CT

The LDCTs were acquired using a multislice CT scanner (Somatom Definition Flash, Siemens Medical Solutions, Forchheim, Germany) with a low-dose protocol (< 2 mSv) and without contrast enhancement [8].

TotalSegmentator version 1 [13] was used to obtain time-saving, repeatable and fully automated segmentations. Because version 1 does not provide a complete heart segmentation but only segmentations of individual cardiac structures, the total heart segmentation was defined as the union of the left and right atria, the left and right ventricles and the myocardium. The total lung volume was defined as the segmented lung tissue and, if pleural effusion was present, as the union of the lung and pleural effusion. The heart-to-lung ratio was defined as the ratio of the maximal heart diameter to the maximal lung tissue diameter, each measured in millimetres on the axial slice where each structure reached its largest diameter. Because the maximal diameters do not necessarily occur on the same slice, the heart and lung measurements were performed independently. The heart-to-lung ratio was calculated as: heart diameter divided by lung diameter × 100%. An increase in heart-to-lung ratio, therefore, reflects a proportionally larger cardiac size relative to thoracic width.

Echocardiography

The examinations were conducted using the EPIQ 5 Ultrasound system (Philips) with an X5-1 transducer and subsequently analysed using IntelliSpace Cardiovascular 4.1.0.0 (Philips). Recordings and interpretations were reviewed and approved by expert cardiologists accredited in echocardiography [8].

The examinations were performed by experienced cardiologists in accordance with the 2016 European Society of Cardiology guidelines [14]. The protocol emphasised key parameters, including left ventricular ejection fraction, E/A ratio, E/e' ratio, left atrial volume index and the quantification of severe valvular disease.

Definition of clinical acute heart failure diagnosis

Two cardiologists assessed clinical AHF by reviewing echocardiography, clinical information, blood tests and medical records. Any discrepancies were resolved through discussion with a third cardiologist. The evaluation covered all essential components for diagnosing AHF [2, 15], with particular emphasis on echocardiographic markers of congestion, including elevated left ventricular filling pressure, in conjunction with cardiac dysfunction or an acute precipitating factor. Notably, the cardiologists did not review chest radiographs or CT radiology images to avoid circular reasoning [1]. An AHF likelihood scale was made based on previously identified criteria, categorising patients according to a five-point Likert scale: 1. Not at all, 2. Somewhat improbable, 3. Neutral, 4. Somewhat probable, 5. Definite. From these, a binary classification was created, grouping 1-3 as not having AHF and 4-5 as having clinical AHF.

Statistical analysis

All statistics were performed using R (version 4.4.1). Continuous variables were presented as medians with IQR and compared using the Kruskal-Wallis test. Categorical variables were presented as counts with percentages and compared using the χ^2 test. A p-value < 0.05 was considered statistically significant.

In this study, the heart-to-lung ratio was the primary predictor variable. Patients were grouped according to heart-to-lung ratio < 50% and ≥ 50% when the variable was used categorically, as presented in **Table 1** and **Table 2**. A logistic regression model was used to assess the association between a one-percentage-point increase in heart-to-lung ratio measured on LDCT and the OR of AHF with 95% CI. When assessing the association between heart-to-lung ratio and odds of AHF, the heart-to-lung ratio was treated as a continuous variable. The model was adjusted for clinically relevant confounders associated with increased heart size: age, sex, BMI, hypertension and prior history of heart failure. The diagnostic performance of the adjusted logistic regression model was evaluated using receiver operating characteristic (ROC) curve analysis, and the area under the curve (AUC) was calculated. Optimal cut-off values for the heart-to-lung ratio were determined using the Youden index.

TABLE 1 Baseline characteristics according to heart-to-lung ratio among dyspnoeic patients admitted to the emergency department.

	Heart-to-lung ratio < 50% ($N_{<50}$ = 106)	Heart-to-lung ratio ≥ 50% ($N_{\geq 50}$ = 124)	p value
Patient characteristics			
Male sex, n (%)	63 (59.4)	68 (54.8)	0.570
Age, median (IQR), yrs	74 (65-79)	77 (70-82)	0.073
BMI, median (IQR), kg/m²	25.2 (21.7-28.7)	26.4 (23.5-30.4)	0.041
Smoking:			
Prior smoker, n (%)	66 (62.3)	70 (56.5)	0.448
Active smoker, n (%)	28 (26.4)	24 (19.4)	0.264
Pack years, median (IQR)	40 (21.5-50.0)	35 (16-50)	0.368
Maximal heart diameter, median (IQR), mm	120.3 (101.7-132.9)	123.2 (110.9-140.7)	0.006
Maximal lung diameter, median (IQR), mm	268.4 (220.4-294.6)	218.9 (192.8-259.2)	< 0.001
Heart-to-lung ratio median (IQR), %	46.6 (42.6-48.5)	55.9 (53.4-59.5)	< 0.001
Medical history, n (%)			
Heart failure:			
Heart failure, total	17 (16.0)	42 (33.9)	0.003
Heart failure with reduced ejection fraction	10 (9.4)	21 (16.9)	0.142
Heart failure with mildly reduced ejection fraction	5 (4.7)	12 (9.7)	0.238
Heart failure with preserved ejection fraction	1 (0.9)	6 (4.8)	0.184
Ischaemic heart disease	21 (19.8)	38 (30.6)	0.085
Valvular heart disease	8 (7.5)	27 (21.8)	0.005
Aortic valve stenosis	4 (3.8)	18 (14.5)	0.011
Atrial fibrillation	18 (17.0)	59 (47.6)	< 0.001
Hypertension	61 (57.5)	80 (64.5)	0.344
Diabetes	21 (19.8)	37 (29.8)	0.111
Prior stroke	17 (16.0)	21 (16.9)	0.996
COPD	65 (61.3)	52 (41.9)	0.005
Asthma	25 (23.6)	17 (13.7)	0.078
Pulmonary hypertension	4 (3.8)	10 (8.1)	0.280
Other chronic lung disease	6 (5.7)	8 (6.5)	1.000
Kidney disease	6 (5.7)	15 (12.1)	0.144
Malignant disease	26 (24.5)	20 (16.1)	0.155
Medication, n (%)			
Beta blockers	26 (24.5)	57 (46.0)	0.001
Digoxin	3 (2.8)	8 (6.5)	0.331
Amiodarone	4 (3.8)	3 (2.4)	0.833
Calcium channel antagonists:			
Class 1: dihydropyridines, and class 3: benzothiazepines	4 (3.8)	6 (4.8)	0.944
Class 2: phenylalkylamines	19 (17.9)	25 (20.2)	0.794
ACE inhibitors	25 (23.6)	28 (22.6)	0.981
Angiotensin-receptor blockers	20 (18.9)	29 (23.4)	0.501
Thiazides	17 (16.0)	14 (11.3)	0.391
Spironolactone	5 (4.7)	15 (12.1)	0.081
Loop diuretics	22 (20.8)	57 (46.0)	< 0.001
Acetylsalicylic acid	22 (20.8)	21 (16.9)	0.568
ADP receptor inhibitors	15 (14.2)	6 (4.8)	0.027
Vitamin K antagonists	0	13 (10.5)	0.002
Direct oral anticoagulants	16 (15.1)	42 (33.9)	0.002
Inhalers:			
Beta2 agonist	69 (65.1)	57 (46.0)	0.006
Anticholinergic	51 (48.1)	40 (32.3)	0.021
Steroid	37 (34.9)	38 (30.6)	0.585

ACE = angiotensin-converting enzyme.

TABLE 2 Echocardiography parameters according to heart-to-lung ratio among dyspnoeic patients admitted to the emergency department.

	Heart-to-lung ratio < 50% ($N_{<50}$ = 106)	Heart-to-lung ratio ≥ 50% ($N_{\geq 50}$ = 124)	p value
Left ventricle ejection fraction, median (IQR), %	60 (50-60)	50 (34.8-60.0)	< 0.001
Left ventricle diameter, median (IQR), cm	4.5 (4.1-5.0)	5 (4.4-5.6)	< 0.001
Interventricular septum diameter, median (IQR), cm	1 (0.9-1.2)	1.1 (0.9-1.3)	0.029
Left ventricle posterior wall diameter, median (IQR), cm	0.9 (0.8-1.1)	1 (0.9-1.1)	0.004
Left ventricle volume index, median (IQR), ml/m²	83.3 (64.9-99.8)	100.3 (81.7-128.0)	< 0.001
TAPSE, median (IQR), mm	21 (18-25)	20 (15-22)	0.029
Left atrium volume, median (IQR), ml	51.1 (39.2-66.0)	75.2 (53.5-95.0)	< 0.001
Left atrium volume index, median (IQR), ml/m²	27.8 (20.8-34.5)	39.6 (27.8-49.5)	< 0.001

TAPSE = tricuspid annular plane systolic excursion.

Trial registration: The National Ethics Committee on Health Research Ethics, Denmark, approved the original study (project id: H-17000869).

Results

Baseline characteristics

A total of 230 participants were included in the present study (median age: 75 years (IQR: 67-81 years); 57% were male, the median left ventricular ejection fraction was 55% (IQR: 45-60%) and the median heart size on LDCT was 122 mm (IQR: 106-137 mm, SD: 22.5 mm)). Among the included patients, a total of 100 were diagnosed with AHF.

In total, 124 patients (54%) had a heart-to-lung ratio < 50%, and 106 patients (46%) had a heart-to-lung ratio ≥ 50%. The ≥ 50% group had a larger maximal heart diameter (123.2 mm vs. 120.3 mm, p = 0.006) and a smaller maximal lung diameter (218.9 mm vs. 268.4 mm, p < 0.001) than the < 50% group (Table 1).

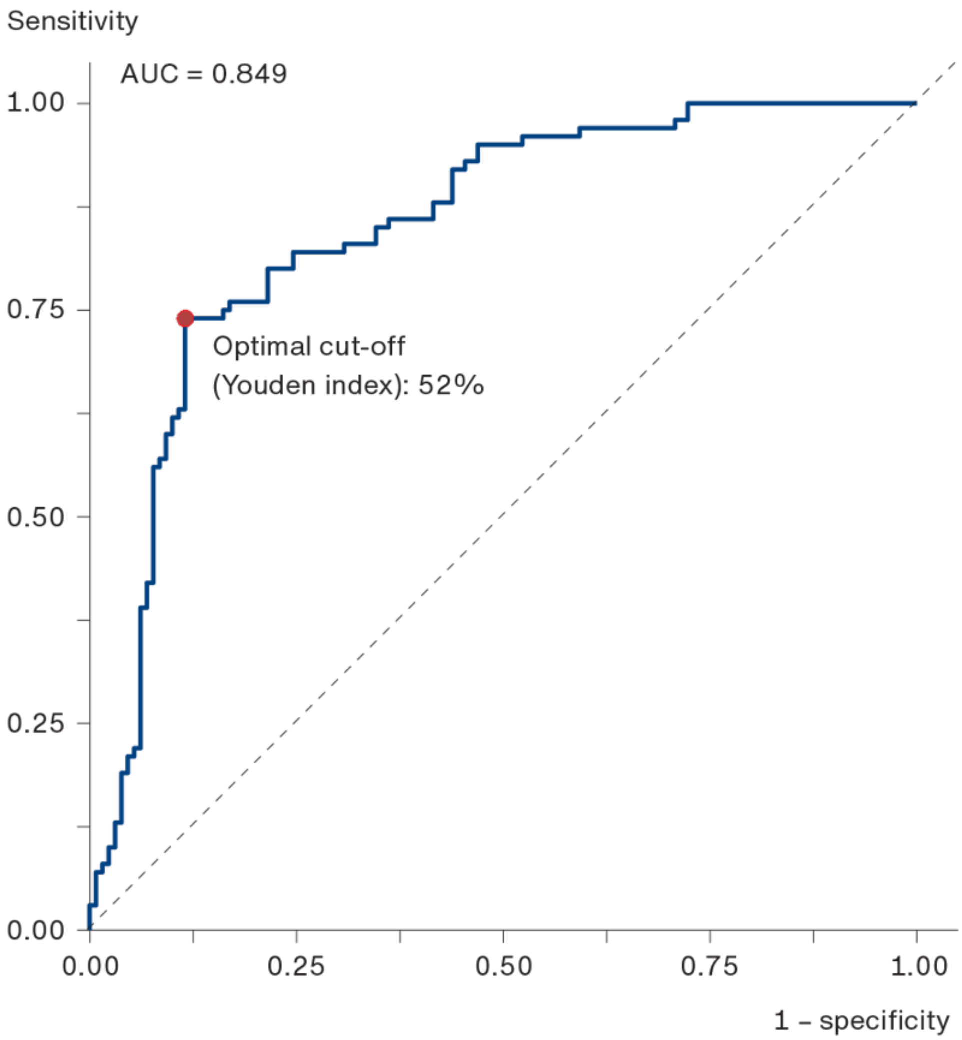
Patients with a heart-to-lung ratio of≥ 50% had a higher proportion of comorbidities, including heart failure (p = 0.003), valvular heart disease (p = 0.004) and atrial fibrillation (p < 0.001) (Table 1).

Association between CT-verified heart-to-lung ratio and adjudicated acute heart failure

Both the unadjusted logistic regression model (OR = 1.20, 95% CI: 1.14-1.27, p < 0.001) and the adjusted logistic regression model (OR = 1.19, 95% CI: 1.12-1.27, p < 0.001) demonstrated a significant association between a CT-assessed one-percentage-point increase in heart-to-lung ratio and AHF. In the adjusted model, male sex (OR = 2.01, 95% CI: 1.01-4.00, p = 0.047), higher age (OR = 1.05, 95% CI: 1.01-1.09, p = 0.008) and a history of heart failure (OR = 2.42, 95% CI: 1.13-5.19, p = 0.02) were significantly associated with AHF.

A ROC curve was generated from the adjusted logistic regression model using the calculated predicted probability of AHF, yielding an AUC of 0.85. The Youden index identified an optimal cut-off value for the heart-to-lung ratio at 52%, representing the threshold that maximised sensitivity and specificity for predicting AHF (**Figure 1**).

FIGURE 1 Receiver-operating characteristic curve illustrating the association between acute heart failure diagnosis and the heart-to-lung ratio on low-dose chest CT. The area under the curve (AUC) was 0.849 (95% CI: 0.798-0.899). The Youden index identified the optimal heart-to-lung ratio cut-off value as 52%, indicated by the red marker. The diagonal line represents a non-discriminative model (AUC = 0.5).



Echocardiography measurements in relation to low-dose CT heart-to-lung ratio

The association between high and low heart-to-lung ratios and echocardiographic measures is presented in Table 2. Among patients with a heart-to-lung ratio ≥ 50%, higher values for several parameters were reported, including left ventricular diameter ($p < 0.001$), interventricular septum diameter ($p = 0.02$), left atrium volume index ($p < 0.001$), left ventricular volume index ($p < 0.001$) and left ventricular ejection fraction ($p < 0.001$).

Discussion

This study found a significant association between a one-percentage-point increase in heart-to-lung ratio and risk of AHF (OR: 1.19, 95% CI: 1.12-1.27, $p < 0.001$). Furthermore, we identified 52% as the optimal heart-to-lung cut-off on LDCT for detecting AHF, suggesting its potential to serve as a simple, readily available biomarker for future clinical use and research.

Cardiomegaly is a key radiological finding in suspected AHF and is strongly linked to structural and functional cardiac abnormalities [16], highlighting its clinical relevance as an indicator of heart disease and a prognostic factor [10]. In this context, assessing heart size using both chest radiograph and CT plays a crucial role in diagnosing and risk-stratifying patients with suspected AHF, often serving as an important step before further investigations, such as echocardiography [17].

When comparing groups based on heart-to-lung ratio, the absolute difference in heart size was minimal, whereas lung size emerged as the primary distinguishing factor. This finding aligns with the higher prevalence of chronic obstructive pulmonary disease in the < 50% heart-to-lung ratio group [18] and is consistent with reports showing hyperinflation in patients with COPD [19]. This may indicate that a low heart-to-lung ratio largely reflects lung hyperinflation rather than the absence of cardiac pathology, suggesting a potential rule-out value in patients with COPD. Nevertheless, echocardiographic assessment revealed significant structural differences with larger cardiac chambers and thicker myocardial walls in patients with a heart-to-lung ratio ≥ 50%. These results reinforce the clinical relevance of CT-based heart size evaluation, as previously suggested by Chae et al. [20].

Although chest radiographs remain widely used in the ED, recent studies suggest that LDCT may offer superior diagnostic accuracy in detecting signs of AHF and significantly better performance than chest radiographs in detecting pulmonary congestion [4, 8].

Given the increasing use of CT in emergency settings [7], establishing a clear diagnostic cut-off for the heart-to-lung ratio on LDCT to indicate AHF in dyspnoeic patients is essential for improving clinical decision-making and guiding further treatment.

Study strengths and limitations

This study has several strengths, including a short time from hospital admission to clinical evaluation and radiological examinations, with all investigations being conducted according to the predefined protocol [8]. Additionally, the segmentation of the maximal heart and lung diameters was performed without knowledge of the clinical diagnoses of AHF, reducing bias. The use of segmentation as the main method can be seen as a methodological strength and may be valuable in the absence of a universal CT standard for cardiac and lung size. The method provides reproducible and consistent results. However, it is not yet available in clinical practice.

Limitations include the need for informed consent, which excluded severely dyspnoeic patients, and the exclusion of those with acute coronary syndrome requiring continuous telemetry. Restricting the cohort to individuals over 50 years improves the relevance for higher-risk groups but limits generalisability to younger populations.

Conclusions

In this study investigating heart-to-lung ratio in a consecutive cohort of acute chest CTs, we found a strong correlation between increased heart-to-lung ratio and clinical AHF. An optimal cut-off value for distinguishing patients at low or high risk of AHF on LDCT was identified at 52%. Given the increasing use of CT in emergency settings, establishing standardised radiological criteria for heart size on CT could enhance clinical decision-making and improve patient management, with a low heart-to-lung ratio potentially serving as a rule-out marker of AHF. Future studies should further explore the role of cardiac findings on LDCT.

Correspondence *Emilie Melgaard*. E-mail: emilie.louisa.renner.melgaard@regionh.dk

Accepted 23 February 2026

Published 17 April 2026

Conflicts of interest KM reports financial support from or interest in the Danish Cardiovascular Academy, the Novo Nordisk Foundation and the Danish Heart Foundation. ST reports financial support from or interest in Hjerteforeningen, Eli Lilly, Novo Nordisk, Bayer and AG. JP and ASO report financial support from or interest in the Novo Nordisk Foundation. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. These are available together with the article at ugeskriftet.dk/dmj

References can be found with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2026;73(5):A09250765

doi 10.61409/A09250765

REFERENCES

1. McDonagh TA, Metra M, Adamo M, et al. 2023 Focused Update of the 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) with the special contribution of the Heart Failure Association (HFA) of the ESC. Eur J Heart Fail. 2024;26(1):5-17. https://doi.org/10.1002/ejhf.3024
2. McDonagh TA, Metra M, Adamo M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J. 2021;42(36):3599-3726. https://doi.org/10.1093/eurheartj/ehab368
3. Parshall MB, Schwartzstein RM, Adams L, et al. An official American Thoracic Society statement: update on the mechanisms, assessment, and management of dyspnea. Am J Respir Crit Care Med. 2012;185(4):435-452. https://doi.org/10.1164/rccm.201111-2042ST
4. Miger K, Olesen ASO, Grand J, et al. Computed tomography or chest X-ray to assess pulmonary congestion in dyspnoeic patients with acute heart failure. ESC Heart Fail. 2024;11(2):1163-1173. https://doi.org/10.1002/ehf2.14688
5. Yamashina A. Cardiac imaging in heart failure; chest X-ray. J Card Fail. 2013;19(10):S119. https://doi.org/10.1016/j.cardfail.2013.08.087
6. Alghamdi SS, Abdelaziz I, Albadri M, et al. Study of cardiomegaly using chest X-ray. J Radiat Res Appl Sci. 2020;13:(1):460-467. https://doi.org/10.1080/16878507.2020.1756187
7. Bellolio MF, Heien HC, Sangaralingham LR, et al. Increased computed tomography utilization in the emergency department and its association with hospital admission. West J Emerg Med. 2017;18(5):835-845. https://doi.org/10.5811/westjem.2017.5.34152
8. Miger K, Fabricius-Bjerre A, Olesen ASO, et al. Chest computed tomography features of heart failure: a prospective observational study in patients with acute dyspnea. Cardiol J. 2022;29(2):235-244. https://doi.org/10.5603/CJ.a2022.0004
9. Pan D, Pellicori P, Dobbs K, et al. Prognostic value of the chest X-ray in patients hospitalised for heart failure. Clin Res Cardiol. 2021;110(11):1743-1756. https://doi.org/10.1007/s00392-021-01836-9
10. Truszkiewicz K, Por&;ba R, Ga&; P. Radiological cardiothoracic ratio in evidence-based medicine. J Clin Med. 2021;10(9):2016. https://doi.org/10.3390/jcm10092016
11. Winklhofer S, Berger N, Ruder T, et al. Cardiothoracic ratio in postmortem computed tomography: reliability and threshold for the diagnosis of cardiomegaly. Forensic Sci Med Pathol. 2014;10(1):44-49. https://doi.org/10.1007/s12024-013-9504-9
12. Danzer C. The cardiothoracic ratio: an index of cardiac enlargement. Am J Med Sci. 1919;157(4):513-554. https://doi.org/10.1097/00000441-191904000-00007
13. Wasserthal J, Breit HC, Meyer MT, et al. TotalSegmentator: robust segmentation of 104 anatomic structures in CT images. Radiol Artif Intell. 2023;5(5):e230024. https://doi.org/10.1148/ryai.230024
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(8):891-975. https://doi.org/10.1002/ejhf.592

15. Bozkurt B, Coats AJ, Tsutsui H, et al. Universal definition and classification of heart failure: a report of the Heart Failure Society of America, Heart Failure Association of the European Society of Cardiology, Japanese Heart Failure Society and Writing Committee of the Universal Definition of Heart Failure. J Card Fail. 2021;27(4):387-413. https://doi.org/10.1016/j.cardfail.2021.01.022
16. Agostoni P, Cattadori G, Guazzi M, et al. Cardiomegaly as a possible cause of lung dysfunction in patients with heart failure. Am Heart J. 2000;140(5):e24. https://doi.org/10.1067/mhj.2000.110282
17. Remy-Jardin M, Faivre JB, Santangelo T, et al. Imaging the heart-lung relationships during a chest computed tomography examination: is electrocardiographic gating the only option? J Thorac Imaging. 2010;25(3):239-246. https://doi.org/10.1097/RTI.0b013e3181e0f8c9
18. Biselli P, Grossman PR, Kirkness JP, et al. The effect of increased lung volume in chronic obstructive pulmonary disease on upper airway obstruction during sleep. J Appl Physiol (1985). 2015;119(3):266-271. https://doi.org/10.1152/japplphysiol.00455.2014
19. Xu Y, Yamashiro T, Moriya H, et al. Hyperinflated lungs compress the heart during expiration in COPD patients: a new finding on dynamic-ventilation computed tomography. Int J Chron Obstruct Pulmon Dis. 2017;12:3123-3131. https://doi.org/10.2147/COPD.S145599
20. Chae M, Na JU, Lee JH, et al. A study on computed tomography cardiothoracic ratio in predicting left ventricular systolic dysfunction. Clin Exp Emerg Med. 2023;10(1):52-59. https://doi.org/10.15441/ceem.22.382

