



The Year in Hungarian Cardiology 2024: Cardiac Imaging – From cauliflower to radiomics

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Author's video summary and
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Hungarian researchers published the results of 25 investigations in peer-reviewed international journals in 2024, with an overwhelming majority of these papers published in Q1-ranking journals. New achievements in echocardiography were published, including 3D echocardiography, myocardial work, and strain analysis. Radiomics has been implemented in cardiac magnetic resonance studies. Still, the performance analysis of a novel magnetic resonance sequence and the result of an MR-derived strain analysis have also been published. 2024 was the year of photon counting CT in Hungarian imaging, but other interesting cardiac CT-related results have also been revealed related to coronary artery disease, aortic stenosis, and thromboembolic risk estimation.

Keywords: echocardiography, cardiac CT, cardiac MR, strain analysis, photon-counting detector, deep learning

A magyar kardiológia eredményei 2024-ben: kardiológiai képalkotás – a karfioltól a radiomikáig

2024-ben magyar kutatók 25 eredeti tudományos közleménnyel járultak hozzá a kardiológiai képalkotás fejlődéséhez, amelyek túlnyomó többsége Q1-es folyóiratokban jelent meg. A szívultrahangos kutatások terén a publikációk érintik a 3D-képalkotást, a myocardialis munkát és a strainanalízist is. A szív mágneses rezonanciás vizsgálatának radiomikai módszerekkel történő kiegészítése, az új szekvenciák képminőségének elemzése, illetve az MR-alapú strainanalízis is figyelemre méltó eredményekhez vezetett. Bár a szív komputertomográfiás (CT) vizsgálatához kötődő kutatások jelentős része a fotonszámoló detektoros CT-hez kötődött, a koszorúérbetegség, az aortastenosis és a tromboembóliás rizikó meghatározás terén is izgalmas eredmények születtek.

Kulcsszavak: echokardiográfia, szív-CT, szív-MR, strainanalízis, fotonszámoló detektor, deep learning

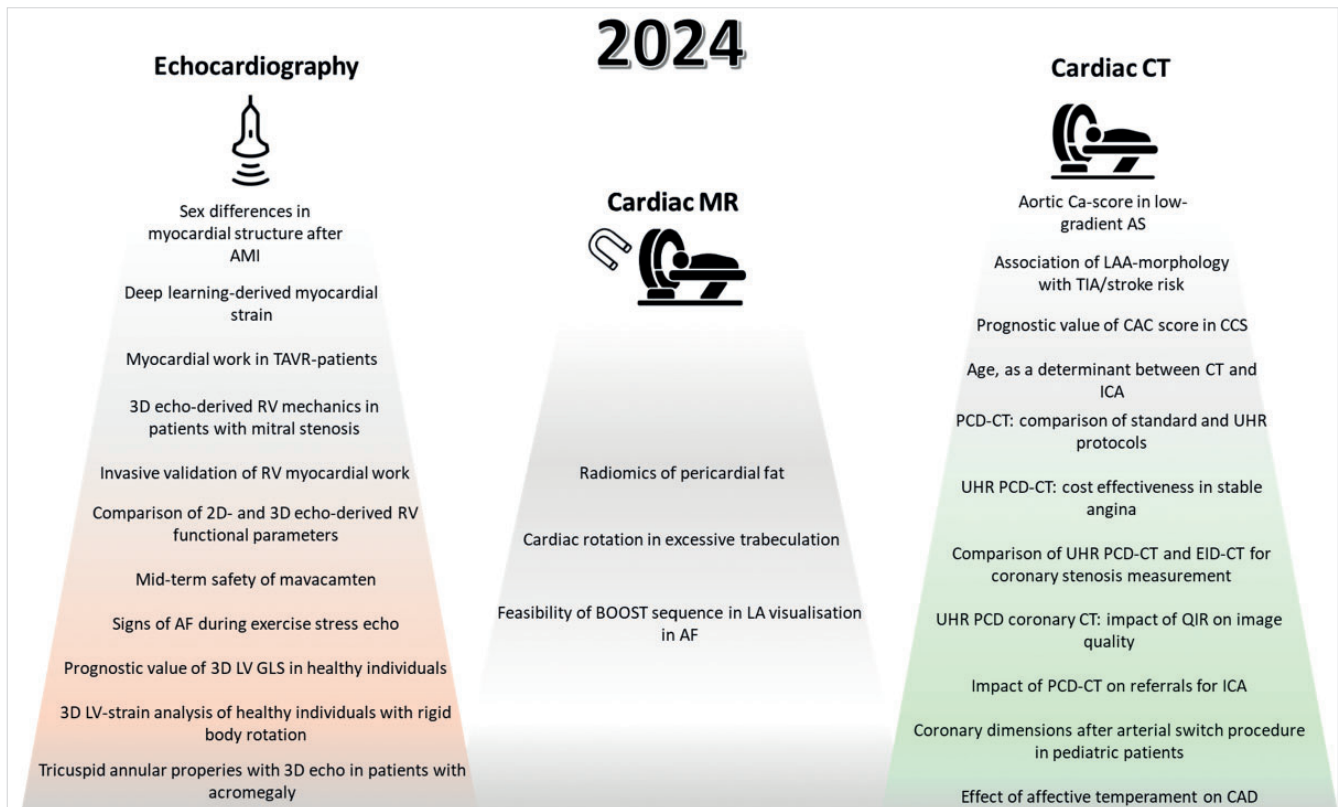
Introduction

In 2024, Hungarian researchers published the results of 25 investigations on cardiac imaging in internationally recognized peer-reviewed journals. The quality and importance of these publications are well represented in *Figure 1*, with 92% of research with Hungarian contributions published in Q1-ranking journals. In this review, the authors intend to summarize these remarkable achievements.

Echocardiography

The echocardiography working group of Semmelweis University closed 2024 with a remarkable list of publications, many of which resulted from successful international cooperation.

An echocardiographic substudy of the PARADISE-MI randomized controlled trial was published on sex differences after high-risk myocardial infarction. 544 patients were enrolled in this substudy within 7 days after



GRAPHICAL ABSTRACT. The topics of investigations involving cardiac imaging led or contributed by Hungarian researchers were published in international peer-reviewed journals in 2024.

Abbreviations: MR: magnetic resonance imaging; CT: computerised tomography; AMI: acute myocardial infarction; TAVR: transaortic valve replacement; 3D: three-dimensional; RV: right ventricular; 2D: two-dimensional; AF: atrial fibrillation; LV: left ventricular; GLS: global longitudinal strain; LA: left atrial; Ca: calcium; AS: aortic stenosis; LAA: left atrial appendage; TIA: transient ischemic stroke; CAC: coronary artery calcium; CCS: chronic coronary syndrome; ICA: invasive coronary arteriography; PCT: photon-counting detector; UHR: ultra-high resolution; EID: energy-integrating detector; QIR: quantum iterative reconstruction; CAD: coronary artery disease

myocardial infarction. All underwent echocardiography at the time of randomization and 8 months later. Women had higher left ventricular (LV) ejection fraction (EF), lower LV end-diastolic and end-systolic volume indexes, and LV mass index at baseline. However, the

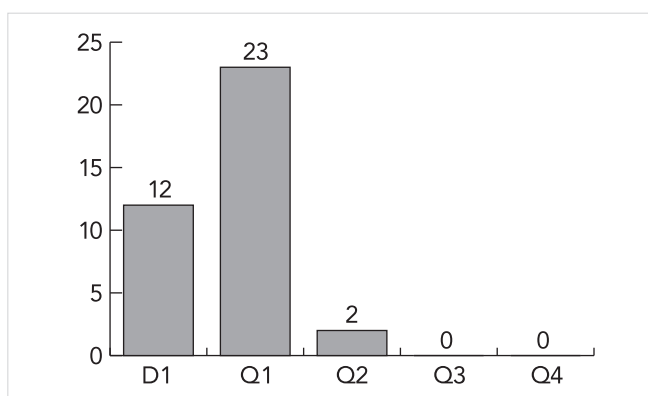


Figure 1. Number of publications with the contribution of Hungarian researchers according to journal ranking (based on SJR 2023)

differences between men and women were not significant anymore, after adjusting for baseline clinical differences at control visit. The relationship between echocardiographic parameters and clinical outcome was not modified by sex (1).

In another interesting collaboration, the same working group developed an automated deep learning strain (DLS) analysis pipeline to validate its performance across multiple applications and populations (including athletes and patients with cardiac hypertrophy and amyloidosis). According to their findings, DLS showed lower variation than conventionally measured global longitudinal strain (GLS), which promises a new opportunity to override intervender and observer variability in strain measurement (2).

As patients undergoing transaortic valve replacement (TAVR) may represent a more frail patient population, the paper of *Ladányi Zs et al.* on myocardial work by echocardiography may be of outstanding importance in the prognosis estimation of these patients. The EF, GLS, global myocardial work index, and global const-

ructive work (GCW) have been examined in 90 TAVR candidates before and 12 months after the procedure, as well as N-terminal pro-B-type natriuretic peptide (NT-proBNP) levels in all patients. Pre-procedure GCW and a history of atrial fibrillation (AF) were independent predictors of post-procedure NT-proBNP-levels (3).

In another paper by *Ladányi Zs et al.*, right ventricular function was investigated in patients with mitral stenosis (MS). Therefore, 39 patients and controls of the same age and sex underwent conventional, speckle-tracking, and three-dimensional (3D) echocardiographic examinations to assess right ventricular mechanics. A reduced 3D right ventricular (RV) EF, global circumferential, and longitudinal strains were revealed in the MS group compared to controls. In both MS subgroups (AF versus sinus rhythm), the radial and longitudinal ejection fractions were decreased compared to controls, but no notable differences were found between the two MS subgroups regarding these parameters. The antero-posterior EF was significantly lower only in the AF MS subgroup compared to controls (4).

Lakatos BK et al. invasively validated the accuracy of myocardial work derived from the RV pressure-strain relationship to estimate the RV contractility in patients with suspected or confirmed pulmonary hypertension. After examining 60 patients by RV pressure-conductance catheterization and detailed 3D echocardiography, a relationship between global myocardial work index (GMWI) and end-systolic elastance was described. On the contrary, RV EF and RV GLS revealed a significant correlation with ventriculo-atrial coupling. Significant differences in all measured parameters, including RV GMWI, within all Reveal Lite 2 Risk Categories were also discovered. This finding may ease the risk stratification and follow-up in patients with RV dysfunction (5).

Tolvaj M et al. from the same study group investigated the comparability of conventional two-dimensional (2D) echocardiographic parameters of RV function with 3D echocardiography-derived RV EF and their impact on survival ($n=750$). The guideline-recommended echocardiographic cut-off values ($TAPSE < 17$ mm, $FAC < 35\%$, $FWLS > -20\%$) were only modestly associated with RV EF $< 45\%$. All RV functional echocardiographic parameters proved to be significant mortality predictors, with the highest hazard ratios calculated if at least 2 conventional echocardiographic parameters showed RV systolic dysfunction (6).

An interesting article about the long-term effects of mavacamten on electromechanical dispersion and deformation in obstructive hypertrophic cardiomyopathy (HCM) was published by *Del Franco A et al.*, with the participation of *Pálincás ED*. For that reason, six participants from the open-label extension of the EXPLORER-HCM study were examined by echocardiography at baseline and after 3 years of mavacamten therapy to assess LV GLS and regional electromechanical dispersion using

speckle tracking imaging and QT dispersion analysis. After 3 years of treatment, a consistent improvement was found in peak systolic dispersion and a marked improvement in QT dispersion, but no change in GLS. These results suggest a long-term effect of mavacamten on energetic sustainability and electrical stability, and the preserved GLS is also reassuring concerning the mid-term safety of sustained cardiac myosin inhibition (7).

Ágoston G and *Varga A* participated in the Stress Echo 2030 international working group. As part of this collaboration, a publication about changes in left atrial (LA) function during exercise stress echocardiography was revealed at the end of the last year. In 1055 patients in sinus rhythm, resting and stress LA volume index, LA reservoir strain, systemic hypertension, exercise $E/e' > 7$, $\Delta TAPSE < 5$ mm, lower LV contractile reserve, and lower heart rate reserve were distinguishing parameters between paroxysmal/persistent AF (PAF) patients and participants without PAF. A composite score (sum of these nine parameters) > 4 indicated PAF with 79% sensitivity and 65% specificity (8).

The 3D Echocardiography Working Group of the University of Szeged also ended the year with a long list of publications. In a publication by *Nemes A* and colleagues, echocardiographic data from 124 healthy individuals were drawn from the MAGYAR-Healthy Study to examine the long-term prognostic value of 3D speckle tracking-derived LV GLS. Patients with events had thicker interventricular septa, larger LV mass and lower LV GLS. LV GLS proved to be the only independent echocardiographic predictor of event-free survival (9).

In another paper based on the data of the MAGYAR-Healthy Study, LV strains of 171 healthy subjects with normally directed rotational mechanics were compared to the parameters of 10 healthy individuals with LV rigid body rotation (RBR). Global deformation proved to be normal even in cases of LV-RBR, but reduction in apical and lateral LV circumferential- and area strains was also present in cases with clockwise-RBR (10).

New results from the MAGYAR-Path Study were also received last year, in which 3D speckle-tracking echocardiography-derived tricuspid annular (TA) properties of 29 patients with acromegaly and 57 healthy controls were compared. Among patients with acromegaly, significantly dilated TA was detected with preserved TA function (11).

Cardiac computed tomography (CT)

Researchers from Semmelweis University participated in the DISCHARGE clinical trial, which enrolled intermediate-risk adult patients with stable chest pain who were referred for invasive coronary angiography (ICA) and were randomly assigned for ICA or coronary CT. The results of two substudies were published last year. In the first publication, the authors evaluated the prog-

nostic importance of CT-derived coronary artery calcium score (CAC) in 1,749 participants. Patients with 0 CAC score had a lower risk of major adverse cardiovascular events (MACE), as did the 1-399 CAC score group, compared to the 400 or higher CAC score group. No significant differences in MACE were observed between the sexes (12).

The possible effect of age on MACE and major procedure-related complications was investigated in the second article. 3561 patients were enrolled in this trial. According to their findings, the age and randomization group (CT or ICA) were not associated with MACE, while the major procedure-related complications were lower in younger patients receiving CT (13).

Juhász D et al. investigated the prognostic value of the aortic valve calcium score (AVCS) in patients with symptomatic low gradient aortic stenosis (LGAS) patients waiting for transcatheter aortic valve intervention (transcatheter AVI, N=84). AVCS was not a significant predictor of all-cause mortality. Compared to conservative treatment, AVI was a significant and independent predictor of survival among LGAS patients with low AVCS, even after adjustment for clinical variables (14).

Simon J et al. analyzed the clinical data and left atrial appendage (LAA) morphology and function obtained by cardiac CT and transoesophageal echocardiography in the context of stroke/TIA risk. All of the involved 649 patients had been diagnosed with AF before and were scheduled for catheter ablation. LAA morphologies depicted by CT were divided into 4 groups: cauliflower, chicken wing, swan, and windsock shapes. After adjustment for the main risk factors, the LAA flow velocity ≤ 35.3 cm/s and the swan LAA shape appeared as an independent risk factor for stroke/TIA. The windsock morphology proved to be protective (15).

Vattay B et al. used standard and ultra-high resolution (UHR) protocols to investigate coronary angiography's qualitative and quantitative image quality using photon-counting detector computed tomography (PCD-CT). PCD-CT provided high qualitative and quantitative image quality during the assessment of coronaries and stents. Based on the qualitative evaluation, the highest image quality was found with Bv44 kernel, QIR 3/4 and both 0.4 and 0.6 mm on standard images, while Bv56, QIR 4 and 0.2 mm on UHR images (16).

Vecsey-Nagy M et al. published three scientific papers on PCD coronary CT angiography. In the first publication, the authors estimated the costs associated with PCD-CT and energy-integrating detector (EID)-CT and the referral for subsequent testing using a decision and simulation model. PCD-CT was associated with an 18.9% reduction in the number of functional follow-up tests, a 6.0% reduction in performed ICAs, and a 9.4% decrease in major procedure-related complications. The use of PCD-CT also revealed the potential to reduce the financial burden on healthcare systems (17). The second publication compared the performance of

UHR PCD-CT and EID-CT in coronary stenosis measurement. 49 patients with coronary calcification on EID-CT were prospectively enrolled for UHR PCD-CT angiography within 30 days. The percentage diameter stenosis (PDS) values based on PCD-CT were lower than EID-CT measurements for calcified and partially calcified plaques, but no significant differences could be demonstrated for non-calcified lesions. This difference in stenosis degrees led to a 49% reclassification rate to a lower category of the Coronary Artery Disease Reporting and Data System with PCD-CT. In a subset of 12 patients, UHR-based PDS values showed higher agreement with quantitative coronary angiography than EID-CT measurements (18).

The third investigation aimed to assess the impact of different quantum iterative reconstruction (QIR) levels on the image quality of UHR coronary CT angiography (CCTA). Therefore, a dynamic vessel phantom containing two calcified lesions (25% and 50% stenosis) was scanned at prespecified heart rates with PCD-CT, and the *in vivo* examinations were performed on 102 patients. The subjective and objective image assessment concluded that the QIR algorithm may improve image quality without compromising image sharpness or accurate stenosis measurements (19).

Simon J et al. published another interesting study focusing on PCD-CT last year. To compare the performance of PCD-CT and EID-CT in the evaluation of coronary stenosis, 401 patients were scanned with EID-CT and 411 patients with PCD-CT. The authors concluded that after PCD-CT examination, obstructive coronary artery disease was reported less frequently (despite the higher CAC score in that group); therefore, PCD-CT evaluation patients with PCD-CT reduced the rate of referrals to ICA (20).

Arterial switch operation for complete transposition of the great arteries may contain the long-term risk of coronary events. *Fontos M et al.* involved 78 asymptomatic pediatric patients who had undergone neonatal arterial switch procedure at the patients' mean age of 10.7 years. All participants underwent coronary CTA. Although most of the coronary diameters fell within the accepted range, acute branching angle and more anterior origin were associated with smaller ostial coronary artery diameter Z-scores (21).

A recently published multidisciplinary study by *Sipos B et al.* assessed affective temperament in 351 patients referred for coronary CT angiography for suspected coronary artery disease. The dimensions of affective temperament was assessed by Temperament Evaluation of Memphis, Pisa, Paris and San Diego Autoquestionnaire (TEMPS-A). A significant inverse association was found between the hyperthymic temperament score and the Segment Stenosis Score (SSS) among men. Also, in men, hyperthymic temperament was an independent predictor of both SSS and Segment Involvement Score (SIS). Regarding women,

a significant positive association between irritable temperament and SSS and SIS could be shown (22).

Cardiac magnetic resonance

The association of a greater amount of pericardial adipose tissue (PAT) with worse cardiovascular outcomes is widely studied and has already been well-established in the literature. Szabó L and colleagues applied radiomics analysis method for cardiac MR for the first time to aid the development of models for discrimination of prevalence and prediction of incident heart failure (HF). Using UK Biobank data of patients with prevalent or incident HF and also data of non-HF comparators, sex, age, and 28 radiomic features describing the size and texture of PAT served as predictors in binary classification models trained to detect prevalent or incident HF. The radiomics models showed marginally better performance than the PAT area alone. This pioneering study may pave the way for radiomic model-supported HF detection (23).

Grebur K et al. investigated the cardiac rotational parameters in symptomatic patients with excessive LV trabeculation with preserved EF and in healthy subjects by cardiac MR feature-tracking and speckle-tracking echocardiography. Subclinical mechanical differences were identified using both imaging modalities between the patient – especially in cases with genetic involvement- and the control group (24).

Dohy Zs et al. conducted a study on patients with AF scheduled for ablation or electrocardioversion to investigate the feasibility of the 3D whole-heart bright-blood and black-blood phase-sensitive inversion recovery (BOOST) sequence to assess pulmonary veins (PV). Although a significant proportion of T2 preparation prepulse BOOST images were unsuitable for assessing PVs, all magnetization transfer preparation BOOST acquisitions achieved diagnostic quality. This novel cardiac MR sequence may facilitate pre-procedure PV examination in AF patients who are not able to hold their breath or for whom contrast administration or ionizing radiation is contraindicated (25).

Conclusion

2024 ended with numerous scientific advancements in cardiac imaging, driven by significant contributions from Hungarian researchers. These studies encompassed a wide range of topics, utilizing diverse echocardiographic modalities, innovative cardiac MR imaging techniques, and various cardiac CT applications.

Declaration of interest

The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

References

1. Wang X, et al. Sex differences in cardiac structure and function following acute myocardial infarction: Insights from the PARADISE-MI echocardiographic sub-study. *Eur J Heart Fail* 2024; <https://doi.org/10.1002/ehf.3472>
2. Kwan AC, et al. Deep Learning-Derived Myocardial Strain. *JACC Cardiovasc Imaging* 2024; 17: 715–725. <https://doi.org/10.1016/j.jcmg.2024.01.011>
3. Ladányi Z, et al. Non-invasive myocardial work as an independent predictor of postprocedural NT-proBNP in elderly patients undergoing transcatheter aortic valve replacement. *GeroScience* 2024. <https://doi.org/10.1007/s11357-024-01302-0>
4. Ladányi Z, et al. The effects of mitral stenosis on right ventricular mechanics assessed by three-dimensional echocardiography. *Sci Rep* 2024; 14: 17112. <https://doi.org/10.1038/s41598-024-68126-y>
5. Lakatos BK, et al. Right ventricular pressure-strain relationship-derived myocardial work reflects contractility: Validation with invasive pressure-volume analysis. *J Heart Lung Transplant Off Publ Int Soc Heart Transplant* 2024; 43: 1183–1187. <https://doi.org/10.1016/j.healun.2024.03.007>
6. Tolvaj M, et al. Significant Disagreement Between Conventional Parameters and 3D Echocardiography-Derived Ejection Fraction in the Detection of Right Ventricular Systolic Dysfunction and Its Association With Outcomes. *J Am Soc Echocardiogr Off Publ Am Soc Echocardiogr* 2024; 37: 677–686. <https://doi.org/10.1016/j.echo.2024.04.005>
7. Del Franco A, et al. Long-Term Effects of Mavacamten on Electromechanical Dispersion and Deformation in Obstructive Hypertrophic Cardiomyopathy. *Circ Heart Fail* 2024; 17: e011188. <https://doi.org/10.1161/CIRCHEARTFAILURE.123.011188>
8. Zagatina A, et al. Left atrial function during exercise stress echocardiography as a sign of paroxysmal/persistent atrial fibrillation. *Cardiovasc Ultrasound* 2024; 22: 13. <https://doi.org/10.1186/s12947-024-00332-0>
9. Nemes A, et al. Long-Term Prognostic Impact of Three-Dimensional Speckle-Tracking Echocardiography-Derived Left Ventricular Global Longitudinal Strain in Healthy Adults-Insights from the MAGYAR-Healthy Study. *J Cardiovasc Dev Dis* 2024; 11: 237. <https://doi.org/10.3390/jcdd11080237>
10. Nemes A, Kormányos Á, Ambrus N, Lengyel C. Left ventricular deformation in the presence of left ventricular 'rigid body rotation' in healthy adults-three-dimensional speckle-tracking echocardiographic insights from the MAGYAR-Healthy Study. *Quant Imaging Med Surg* 2024; 14: 4605–4616. <https://doi.org/10.3390/jcm12124153>
11. Nemes A, et al. Three-Dimensional Speckle-Tracking Echocardiography-Derived Tricuspid Annular Properties in Acromegaly – Results from the MAGYAR-Path Study. *Biomedicines* 2024; 12: 1464. <https://doi.org/10.3390/biomedicines12071464>
12. Biavati F, et al. Coronary Artery Calcium Score Predicts Major Adverse Cardiovascular Events in Stable Chest Pain. *Radiology* 2024; 310: e231557. <https://doi.org/10.1148/radiol.231557>
13. The DISCHARGE Trial Group. Age and Computed Tomography and Invasive Coronary Angiography in Stable Chest Pain: A Prespecified Secondary Analysis of the DISCHARGE Randomized Clinical Trial. *JAMA Cardiol* 2024; 9: 346–356. <https://doi.org/10.1001/jamacardio.2024.0001>
14. Juhász D, et al. Prognostic and therapeutic implications of a low aortic valve calcium score in patients with low-gradient aortic stenosis. *Eur Heart J – Cardiovasc Imaging* 2024; [jeae276](https://doi.org/10.1093/ehjci/jeae276). <https://doi.org/10.1093/ehjci/jeae276>
15. Simon J, et al. Association of Left Atrial Appendage Morphology and Function With Stroke and Transient Ischemic Attack in Atrial Fibrillation Patients. *Am J Cardiol* 2024; 221: 37–43. <https://doi.org/10.1016/j.amjcard.2024.03.025>
16. Vattay B, et al. Qualitative and quantitative image quality of coronary CT angiography using photon-counting computed tomography: Standard and Ultra-high resolution protocols. *Eur J Radiol* 2024; 175: 111426. <https://doi.org/10.1016/j.ejrad.2024.111426>
17. Vecsey-Nagy M, et al. Cost-effectiveness of ultrahigh-resolution photon-counting detector coronary CT angiography for the evaluation of stable chest pain. *J Cardiovasc Comput Tomogr January-February, 2025*; 19(1): 106–112. <https://doi.org/10.1016/j.jcct.2024.10.011>
18. Vecsey-Nagy M, et al. Intraindividual Comparison of Ultrahigh-Spatial-Resolution Photon-Counting Detector CT and Energy-Integrating Detector CT for Coronary Stenosis Measurement. *Circ Cardiovasc Imaging* 2024; 17: e017112. <https://doi.org/10.1161/circimaging.124.017112>
19. Vecsey-Nagy M, et al. Ultra-high resolution coronary CT angiography on photon-counting detector CT: bi-centre study on the impact of quantum iterative reconstruction on image quality and accuracy of stenosis measurements. *Eur J Radiol* 2024; 176: 111517. <https://doi.org/10.1016/j.ejrad.2024.111517>
20. Simon J, et al. Photon-counting detector CT reduces the rate of referrals to invasive coronary angiography as compared to CT with whole heart coverage energy-integrating detector. *J Cardiovasc Comput Tomogr* 2024; 18: 69–74. <https://doi.org/10.1016/j.jcct.2023.11.079>
21. Fontos M, et al. Coronary Artery Dimensions on Computed Tomography Following the Neonatal Arterial Switch Operation for the Complete Transposition of the Great Arteries. *Pediatr Cardiol* 2024. <https://doi.org/10.1007/s00246-024-03662-y>
22. Sipos B, et al. Association between affective temperaments and the severity and the extent of coronary artery disease as obtained by coronary CT angiography. *J Affect Disord* 2024; 363: 47–54. <https://doi.org/10.1016/j.jad.2024.07.092>
23. Szabó L, et al. Radiomics of pericardial fat: a new frontier in heart failure discrimination and prediction. *Eur Radiol* 2024; 34: 4113–4126. <https://doi.org/10.1007/s00330-023-10311-0>
24. Grebur K, et al. The effect of excessive trabeculation on cardiac rotation-A multimodal imaging study. *PLoS One* 2024; 19: e0308035. <https://doi.org/10.1371/journal.pone.0308035>
25. Dohy Z, et al. Feasibility and image quality of bright-blood and black-blood phase-sensitive inversion recovery (BOOST) sequence in clinical practice using for left atrial visualization in patients with atrial fibrillation. *Eur Radiol* 2024; 34: 2689–2698. <https://doi.org/10.1007/s00330-023-10257-3>