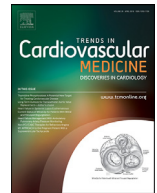




Contents lists available at ScienceDirect

Trends in Cardiovascular Medicine

journal homepage: www.elsevier.com/locate/tcm

Usefulness of handheld echocardiography for cardiovascular diseases in preventive cardiology

Andrea Stefanini^{a,*}, Maria Concetta Pastore^a, Cosimo Salvatici^a, Riccardo Liga^b, Antonio Capolongo^c, Francesca Amati^d, Egidio Imbalzano^e, Paolo Calabrò^c, Felice Gragnano^c, Giulia Elena Mandoli^a, Laura Spaccaterra^a, Elena Placuzzi^a, Andrea Rinaldi^f, Pietro Scicchitano^g, Annalisa Pasquini^h, Marta Focardi^a, Roberto Pedrinelliⁱ, Anna Vittoria Mattioli^j, Andrea Igoren Guaricci^d, Stefania Paolillo^k, Flavio D'Ascenzi^{a,1}, Matteo Cameli^{a,1}, On behalf of the Working Group on Hypertension, Prevention and Peripheral Circulation of the Italian Society of Cardiology

^a Department of Medical Biotechnologies, Division of Cardiology, University of Siena, Siena, Italy

^b Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy

^c Department of Translational Medical Sciences, University of Campania "Luigi Vanvitelli", Naples, Italy

^d University Cardiology Unit, Interdisciplinary Department of Medicine, Polyclinic University Hospital, 70124, Bari, Italy

^e Department of Clinical and Experimental Medicine, University of Messina, Messina, Italy

^f Unit of Cardiology, Department of Experimental, Diagnostic and Specialty Medicine-DIMES, University of Bologna, Sant'Orsola-Malpighi Hospital, IRCCS, Bologna, Italy

^g Cardiology Department, Hospital "F. Perinei" Altamura (BA), Italy

^h Department of Cardiovascular Sciences, Fondazione Policlinico Universitario A. Gemelli IRCCS, 00168, Rome, Italy

ⁱ Cardiac, Thoracic and Vascular Department, University of Pisa, Pisa, Italy

^j Department of Quality of Life, University of Bologna - Alma Mater Studiorum, Bologna, Italy

^k Department of Advanced Biomedical Sciences, University of Naples Federico II, Naples, Italy

ARTICLE INFO

Keywords:

Handheld echocardiography
Focused cardiac ultrasound
Echocardiography
Bedside assessment
Preventive cardiology

ABSTRACT

Cardiovascular diseases remain the leading cause of morbidity and mortality worldwide, and current risk scores based on personal history, physical examination and basic tests fail to identify a proportion of individuals who will experience cardiovascular events. In this context, handheld echocardiography (HHE) is an intermediate step between clinical assessment alone and comprehensive transthoracic echocardiography, with the potential to act as an imaging-based tool within cardiovascular prevention programmes. Through focused, bedside or outpatient examinations, HHE can detect early signs of hypertensive organ damage as well as left and right ventricular dysfunction and other structural cardiovascular abnormalities, beyond traditional clinical evaluation.

Through an examination of current evidence, technological developments, and clinical implementation pathways, this review provides a comprehensive overview of the evolving role of HHE as an adjunct to standard cardiovascular assessment, highlighting its potential to enhance early risk stratification in preventive cardiology. In this context, it proposes a pragmatic worklist for focused HHE examinations in at-risk individuals and illustrates representative HHE use cases, with involvement of non-cardiologists and the potential contribution of teleconsultation and digital integration. Finally, unresolved challenges are highlighted, defining the research priorities for the systematic integration of HHE into cardiovascular prevention strategies.

© 2026 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

List of abbreviations: AI, Artificial intelligence; FoCUS, Focused cardiac ultrasound; HHE, Handheld echocardiography; IVC, Inferior vena cava; LV EF, Left ventricular ejection fraction; LVH, Left ventricular hypertrophy; PH, Pulmonary hypertension; POCUS, Point-of-care ultrasound; RV, Right ventricle; TTE, Transthoracic echocardiography.

* Corresponding author at: Department of Medical Biotechnologies, Division of Cardiology, University of Siena, Viale Bracci 16, Siena, Italy.

E-mail address: astefanini94@gmail.com (A. Stefanini).

¹ Co-last authors.

<https://doi.org/10.1016/j.tcm.2026.07.002>

1050-1738/© 2026 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Please cite this article as: A. Stefanini, M.C. Pastore, C. Salvatici et al., Usefulness of handheld echocardiography for cardiovascular diseases in preventive cardiology, Trends in Cardiovascular Medicine, <https://doi.org/10.1016/j.tcm.2026.07.002>

Introduction

Cardiovascular diseases remain a major global health burden, highlighting the need for efficient tools for early detection and intervention. Ultrasound is a low-cost, accessible imaging modality, while standard echocardiography, although highly accurate, is limited by resource and accessibility constraints. Advances in miniaturisation have led to handheld ultrasound devices, enabling bedside assessment and extending physical examination beyond conventional approaches [1–3]. Handheld echocardiography (HHE) offers portability and broader applicability but remains limited by challenges in image acquisition, interpretation, and quantitative assessment compared with standard echocardiography [1].

In this narrative review, we summarize current evidence, technological developments, and clinical applications of HHE, with a particular focus on its potential integration into cardiovascular risk assessment pathways in preventive cardiology. In this context, the review provides an overview of clinical use cases and proposes a pragmatic worklist for focused HHE examinations as cardiovascular risk modifier and to guide referral for comprehensive echocardiography.

Methods

This narrative review was conducted through a comprehensive electronic literature search of PubMed to identify relevant studies. The search strategy was designed to maximize sensitivity and specificity by combining Medical Subject Headings, when available, with relevant free-text keywords using standard Boolean operators. Reference lists of the included articles were also manually screened to identify additional pertinent publications. Studies were considered eligible if they were published in English from earliest available records until December 2025 and addressed the role of handheld ultrasound technologies in cardiovascular assessment and prevention. The search strategy incorporated combinations of terms related to handheld echocardiography, focused cardiac ultrasound (FoCUS), echocardiography, bedside assessment, point-of-care cardiac imaging (POCUS), cardiovascular screening, and preventive cardiology. A total of 459 studies were identified. Duplicates, editorials, case reports and articles not directly related to the main review topic were excluded.

Technological landscape of handheld echocardiography

Echocardiographic equipment ranges from stationary high-end systems with full diagnostic capabilities to mobile/portable units with more limited functions, down to HHE, the smallest devices, which typically provide only 2D imaging with basic colour Doppler [4]. Ultrasound assessment exists along a continuum from comprehensive transthoracic echocardiography (TTE), allowing full quantitative evaluation, to focused bedside approaches such as emergency echocardiography, point-of-care ultrasound (POCUS), and focused cardiac ultrasound (FoCUS), which address specific clinical questions [5–7]. Within this framework, handheld ultrasound devices are mainly used for FoCUS and, despite their simplicity, their core imaging functions enable rapid bedside cardiovascular assessment, particularly in preventive cardiology.

History of handheld ultrasound

Handheld ultrasound has advanced through progressive miniaturisation and expanding point-of-care applications [8]. From bulky portable systems in the 1980s, advances in the 1990s–2000s led to increasingly compact devices. Further progress in phased-array and matrix transducers, together with wireless connectivity and smart-

phone/tablet integration, has significantly enhanced image quality and diagnostic performance [9].

Main handheld echocardiograms systems on the market

Portable ultrasound systems vary widely in form, connectivity, and imaging capabilities. These characteristics influence how they can be integrated into clinical pathways in preventive cardiology. Below, we describe a few of these systems (more detailed in Table 1) [10–19].

The GE Vscan

The GE Vscan family comprises pocket-sized ultrasound devices designed for rapid point-of-care imaging, including targeted cardiac examinations. Integrated artificial intelligence (AI) software provides real-time guidance on how to maneuver the probe to capture diagnostic-quality standard views [10].

Philips Lumify

The Philips Lumify is a portable ultrasound solution with different transducers connected via cable to a compatible smart device. Images and clips can be shared in real time for tele-ultrasound and remote consultation, which is particularly relevant in community or preventive cardiology settings where expert supervision may be useful [11].

Butterfly iQ

The Butterfly iQ and its successors are portable ultrasound devices built around a single semiconductor probe that can be used for multiple applications. The platform integrates cloud-based storage and remote review, facilitating follow-up and teaching and making it attractive for integrated preventive care pathways [12].

Siemens ACUSON P500

The ACUSON P500 is a compact, tablet-like ultrasound system that is portable, though not pocket-sized. It can accommodate multiple probes and offers a wide range of applications. In clinical practice, it is often used as an intermediate solution between high-end laboratory systems and handheld devices. It provides advanced echocardiographic imaging at the bedside in high-intensity or resource-limited environments [13].

Clarius Ultrasound

Clarius Ultrasound offers a range of portable, wireless probes that connect to smartphones or tablets. These probes also support M-mode, colour Doppler, and PW Doppler. The platform integrates AI to optimize image settings and simplify workflow, potentially helping inexperienced users in outpatient and preventive cardiology settings [14].

SonoSite Edge II

The SonoSite Edge II is a robust, clamshell-style portable ultrasound system. It is larger than pocket-sized devices, yet still easily transportable, particularly in emergency and intensive care settings. The focus is on durability, reliability, and image quality at the bedside. In many hospitals, it serves as a reliable PoCUS platform rather than a true pocket-sized HUD [15].

EchoNous Vein

Originally developed as a portable vascular access device, the EchoNous Vein provides high-resolution images of superficial veins and arteries. More recently, EchoNous platforms have been extended to include basic cardiac imaging capabilities and AI-driven workflows [16].

Table 1

Overview of selected handheld and portable ultrasound systems discussed in this review and key characteristics.

Overview of cardiac-capable systems mentioned in the manuscript. Device characteristics are summarised from manufacturer documentation and comparative evaluations of handheld ultrasound systems [10–19].

Device	Form factor	Main imaging scope	Key features
GE V-scan (and V-scan Air) [10]	True pocket-sized device, with either an integrated screen or a wireless probe connected to a smartphone	Multi-organ point-of-care imaging with a focus on rapid cardiac and vascular assessment at the bedside	Dual-probe options (sectorial + linear) enable both superficial and deep imaging; designed to complement physical examination with quick assessment of LV size and function, valves, pericardium and lungs. AI real-time guidance for standard views.
Philips Lumify [11]	Phased, convex or linear probe connected by cable to a compatible smartphone or tablet	Broad range of applications including cardiac, lung, abdominal, FAST and vascular imaging through different transducers	Probe-to-smartphone solution with dedicated cardiac and lung presets; emphasises ease of use, mobility and real-time connectivity/tele-ultrasound for remote collaboration.
Butterfly iQ [12]	Single semiconductor probe connected to a smartphone via app	“Whole-body” PoCUS with multiple presets for abdomen, heart, lung, vascular and other applications	Single-probe, whole-body concept with >20 software-defined presets; designed to cover multiple specialities with one handheld device and seamless cloud integration.
Siemens ACUSON P500 [13] Clarius Ultrasound [14]	Compact tablet-style ultrasound system with multiple probes; portable but not pocket-sized Wireless handheld probes paired with a smartphone or tablet	Wide spectrum of applications with PW/CW Doppler and advanced cardiovascular options Cardiac and lung ultrasound, trauma and abdominal/superficial imaging depending on the probe	Provides advanced echocardiographic imaging at the bedside; often used as a bridge between the echo laboratory and PoCUS in high-complexity settings. High-definition wireless scanner with B-mode, M-mode, colour/power Doppler and PW Doppler; designed for rapid assessment of heart, lungs and abdomen (up to ~40 cm depth) and integrates AI-assisted workflow optimisation.
SonoSite Edge II [15]	Rugged compact “clamshell” system, portable but not pocket-sized, with a large screen and multiple probes	Point-of-care multi-organ imaging, including cardiac and abdominal examinations in critical settings	Highly robust platform with emphasis on durability, reliability and image quality at the bedside; frequently used as a PoCUS system in emergency/critical care rather than as a true pocket-sized HUD.
EchoNous Vein [16]	Handheld device primarily dedicated to vascular access	High-resolution imaging of superficial veins and arteries for vascular access; in some settings used within broader PoCUS protocols	Designed for vascular access with 2D and Doppler imaging and AI-guided workflows, with potential integration into cardiovascular pathways.
Mindray TE Air [17]	Different transducer configurations, including phased-array, convex and linear probes.	Point-of-care cardiac, abdominal, vascular and lung ultrasound examinations in a highly portable format.	Wireless operation that makes it suitable for bedside assessment, emergency care and community-based screening programs.
Konted [18]	Pocket-sized wireless ultrasound device with dual-probe options.	Basic focused examinations in emergency or outpatient settings	Dual-probe or interchangeable transducer options for basic bedside imaging and educational use.

Abbreviations: AI, artificial intelligence; B-mode, brightness mode; CW, continuous-wave; ED, Emergency Department; HUD, handheld ultrasound device; ICU, intensive care unit; LV, left ventricle; M-mode, motion mode; PoCUS, point-of-care ultrasound; PW, pulsed-wave.

Mindray TE Air

The Mindray TE Air is a wireless HHE designed for point-of-care imaging with phased-array, convex, and linear transducer configurations, enabling comprehensive bedside assessment in a highly portable format. Its fully wireless design enhances mobility and workflow efficiency [17].

Konted ultrasound

The Konted HHE is a pocket-sized wireless ultrasound device designed for point-of-care imaging via connection to smartphones or tablets. It supports basic PoCUS modalities, and enables rapid bedside assessment of cardiac function, pericardial effusion, volume status, and basic lung ultrasound [18].

Rationale for handheld echocardiography in preventive cardiology

Cardiovascular risk assessment is based on clinical evaluation and SCORE2-based stratification, with secondary prevention patients classified as very high risk [20,21]. Guidelines also include imaging-based risk modifiers to refine risk estimation [20,21]. However, a substantial number of events still occur in low- or intermediate-risk individuals, highlighting limitations of current models.

From a preventive cardiology perspective, several echocardiographic findings may act as risk assessment tool because they reflect target-organ damage and are associated with adverse progn-

sis. These include left ventricular hypertrophy (LVH) and concentric remodelling, reduced LV systolic function or subclinical systolic dysfunction, left atrial enlargement as a marker of chronic pressure and volume overload, haemodynamically significant ($\geq$ moderate) valvular heart disease, right ventricular dilatation and pressure overload with possible pulmonary hypertension (PH), pericardial effusion and signs of pulmonary congestion on lung ultrasound [1,22–24]. Systematic screening with comprehensive TTE is not feasible because of limitations in cost, time and resources [1,9]. In clinical practice, echocardiography is therefore reserved for symptomatic patients, those with obvious abnormal clinical findings or with a high suspicion of disease, with the risk of leaving a proportion of individuals undiagnosed. In this context, HHE represents a possible intermediate solution between clinical assessment alone and imaging in the echocardiography laboratory. HHE devices are relatively inexpensive, highly portable and increasingly available, enabling rapid focused assessment of cardiac morphology and function directly at the point of care. They can be integrated into routine visits in hypertension and diabetes clinics, preventive cardiology clinics and, in secondary prevention, follow-up visits of patients with established cardiovascular disease to address specific questions (for example, re-evaluation of systolic function) [1,9,22]. HHE demonstrated to be a valuable alternative to TTE in the presence of focused clinical questions [25]. Moreover, HHE may appear particularly valuable for the refined assessment of patients scheduled for procedures posing an increased risk of adverse cardiac events, with non-cardiac surgery representing a paradigmatic

Table 2

Proposed handheld echocardiography worklist for preventive cardiology.

Proposed protocol for focused HHE examinations in at-risk individuals, awaiting validation. Each step is linked to predefined targets, mandatory items to record, binary screening questions, and downstream actions [1,5,23].

Step	HHE view	Main targets	Items to record	Screening questions (Yes/No)
0	Clinical Pre-scan	Baseline risk	Heart rate; blood pressure; rhythm (sinus / AF); main risk factors (hypertension, diabetes, dyslipidaemia, smoking, family history); indication for HHE	–
1	Parasternal long-axis (PLAX)	LV systolic function; aortic root; mitral and aortic valves	LV size (normal/dilated); wall thickness (normal/increased); global LV systolic function (preserved/reduced); obvious MV/AV lesion (none/suspected)	• LV hypertrophy or concentric remodelling? • LV systolic function reduced? • $\geq$ moderate MV or AV disease? • Aortic aneurism?
2	Parasternal short-axis (PSAX)	LV geometry; regional wall motion; indirect PH	LV shape; regional wall motion (normal/abnormal); RV size relative to LV (RV $\leq$ / $\geq$ LV); Coronary arteries origins; Pulsed-wave Doppler at the pulmonary valve	• Any regional wall motion abnormality? • RV diameter $\geq$ LV diameter? • Normal Coronary arteries origins? • Indirect estimation of PH
3	Apical 4-chamber (A4C)	LV and RV size/function; LA size; mitral and tricuspid valves	Visual LVEF category (preserved / mild/moderate/severe reduced); diastolic function; RV function (normal/reduced); LA size (normal/dilated); MR/TR severity (none-mild / $\geq$ moderate)	• LV systolic dysfunction confirmed? • Marked LA enlargement? Diastolic dysfunction?
4	RV-focused A4C (PH view)	RV pressure overload	RV free-wall motion; RV/LV ratio; systolic septal flattening;	• $\geq$ moderate MR or TR? • RV dilated with reduced function? • Septal flattening suggesting pressure overload?
5	Subcostal view + IVC	Pericardial effusion; volume status	Presence and size of pericardial effusion; IVC diameter and collapsibility;	• Pericardial effusion? • Tamponade signs (RA/RV diastolic collapse and plethoric IVC)?
6	Focused lung ultrasound	Pulmonary congestion and pleural effusion	Pattern of B-lines and presence of pleural effusion	• Marked volume overload? • Bilateral, multifocal B-lines compatible with pulmonary congestion? • Pleural effusion present?
7	Synthesis and image quality assessment	Global interpretation and ruling out major disease	Overall image quality; HHE classification (negative /positive); recommendation regarding TTE (not needed/advisable/mandatory)	• Any abnormal or non-diagnostic finding? • Image quality insufficient to rule out major pathology?

Abbreviations: A4C, apical 4-chamber; AF, atrial fibrillation; B-lines, ultrasound lung comet-tail artefacts; HHE, handheld echocardiography; IVC, inferior vena cava; LA, left atrium; LV, left ventricular; MR, mitral regurgitation; PH, pulmonary hypertension; PLAX, parasternal long-axis; PSAX, Parasternal short-axis; RA, right atrium; RV, right ventricle; TR, tricuspid regurgitation; TTE, transthoracic echocardiography.

example [26]. In this setting, preoperative FoCUS examination may improve patient management – also reducing the need for TTE assessment – and guide intra-procedural as well as post-operative patient management, possibly reducing all-cause mortality [26,27].

When used according to a structured worklist, HHE can reliably answer simple and clinically relevant questions, such as those summarised in the proposed worklist table (Table 2) [5,28]. Modern HHE platforms also allow image storage and remote reporting, so that examinations performed by non-expert operators (for example in primary care) can be reviewed by cardiologists. This combination of relatively low cost, reliability, availability and the possibility of remote expert review facilitates wider dissemination of HHE, including in the hands of non-specialists, in preventive care settings [8,22,29]. In patients in whom a focused HHE examination does not show relevant structural abnormalities (an “HHE-negative” study), the pre-test risk category is generally not modified, and risk factor management can be continued according to current guidelines, with routine follow-up [1,18]. Conversely, an “HHE-positive” study may justify reclassifying the patient into a “most scrutinized” category, intensifying pharmacological and lifestyle interventions, and referring the patient for comprehensive TTE, where detailed quantification and advanced Doppler techniques can be performed [1,9]. This approach has the potential to optimise the use of echocardiographic resources by prioritising comprehensive studies in those with the highest likelihood of pathological findings [1,9,22].

Methodologically heterogeneous studies, conducted in at-risk outpatient populations, including hypertensive and diabetic patients, suggest that HHE can reveal a high prevalence of previously unrecognised LVH, left atrial enlargement and subclinical systolic

dysfunction that are not apparent on traditional clinical and instrumental assessment [22,30,31]. In these studies, agreement between HHE and TTE was generally good for major structural abnormalities, with high specificity but more variable sensitivity: detection of systolic dysfunction showed a sensitivity of 74–97% and a specificity of 94–99%, whereas assessment of LV dilatation and hypertrophy demonstrates a sensitivity of 71–94% and a specificity of 97–100% [22,30,31]. False positives were typically mitigated by operator training, adherence to focused protocols and confirmation with comprehensive TTE, which remains the reference standard.

Similarly, the combination of focused cardiac echocardiography with lung ultrasound improves the ability to detect congestion compared with clinical assessment alone, in both acute and chronic heart failure (HF), reinforcing the idea that adding HHE to standard evaluation may modify risk classification and influence management decisions [23,24]. However large-scale data on hard outcomes and cost-effectiveness in preventive programmes are still limited.

Clinical applications in prevention

From a preventive cardiology perspective, the primary goal of HHE is the rapid identification of structural and congestion-related “red flags” that may modify cardiovascular risk classification (Fig. 1 and Fig. 2), prompt treatment intensification, and select patients who should be referred for comprehensive TTE. Major documents on handheld devices frame these tools as a complement to, rather than a replacement for, full echocardiographic studies [1,4–6,9,22]. The following subsections mirror the clinical questions and tar-

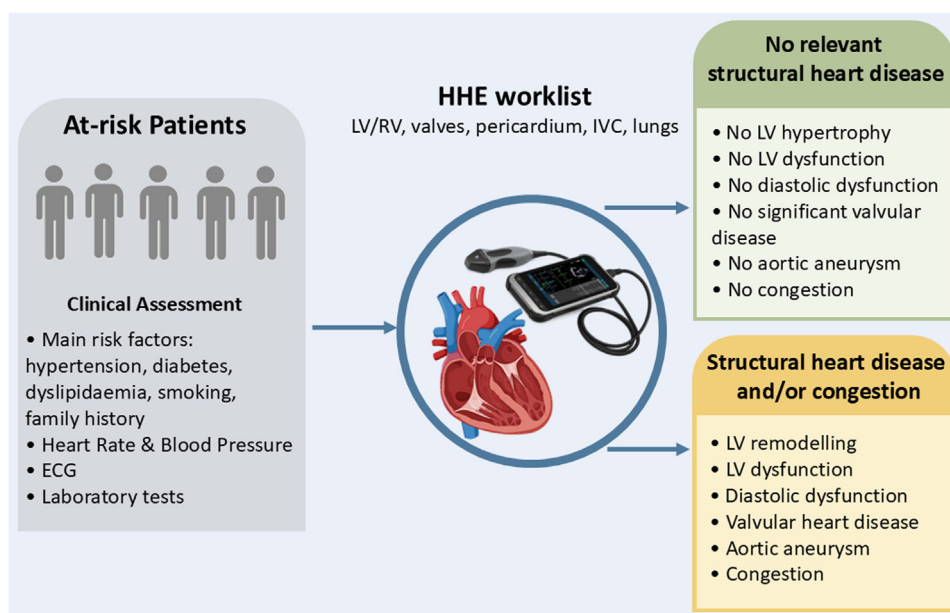


Fig. 1. Handheld echocardiography in preventive cardiology: from at-risk individuals to risk reclassification and targeted echocardiography.

At-risk individuals first undergo standard clinical assessment, including medical history, physical examination, blood pressure measurement, electrocardiogram and laboratory tests. HHE is then performed using a structured worklist to screen for major structural and functional abnormalities. HHE findings are used to reclassify risk and to triage patients into two groups: (i) those with no significant structural abnormalities, who continue lifestyle interventions and guideline-directed risk factor management with routine follow-up; and (ii) those with structural heart disease or evidence of congestion, who may benefit from intensified preventive therapy and closer follow-up and who require a comprehensive transthoracic echocardiogram.

Abbreviations: HHE, handheld echocardiography; IVC, inferior vena cava; LV, left ventricle; RV, right ventricle.

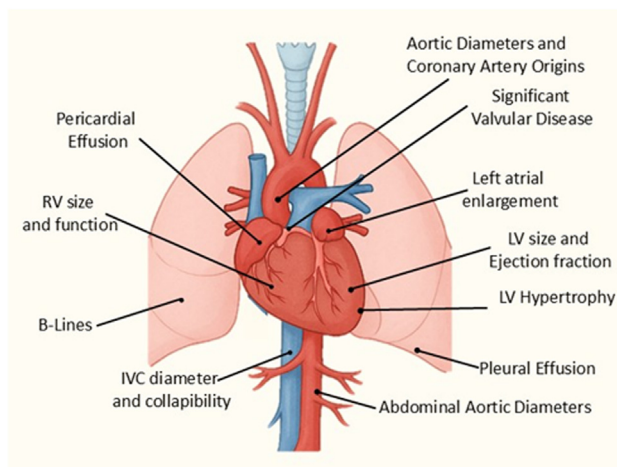


Fig. 2. Cardiac, Pulmonary, and Extracardiac targets assessed by handheld echocardiography [1,5,9,22]

IVC, Inferior Vena Cava. LV, Left Ventricular. RV, Right Ventricle.

gets included in the proposed HHE worklist awaiting validation (Table 2) and in the care pathway summarised in the Fig. 1.

LV hypertrophy and LV systolic function

In patients with hypertension, diabetes or chronic coronary artery disease, LVH and overt or subclinical reduction in global systolic function are classic markers of target-organ damage and are associated with adverse prognosis [1,9,22]. Early work using handheld devices in hypertensive cohorts showed that focused imaging can detect LVH in a substantial proportion of patients who would otherwise remain undiagnosed [32]. HHE allows a rapid qualitative assessment of LV size, wall thickness and global systolic function, with visual categorisation of LV ejection fraction (LVEF) into broad

classes and the ability to recognising obvious regional wall motion abnormalities when image quality is adequate [1,4,9,30].

Some devices incorporate automated or artificial intelligence-based applications for semi-automated LVEF estimation from apical views, which may be particularly helpful for less experienced operators, although performance is highly dependent on image quality and patient characteristics [33–35]. HHE is not suitable for advanced quantitative parameters such as myocardial strain or detailed diastolic function assessment, and cannot provide a full characterisation of HF with preserved ejection fraction [1,9]. In a preventive setting, a “positive” HHE examination showing marked LVH, LV dilatation, or clearly reduced LVEF warrants risk reclassification, a more aggressive therapeutic strategy, and referral for comprehensive standard echocardiography. Conversely, a “negative” study supports continuation of guideline-directed preventive care and routine follow-up [1,9,22,30].

Right ventricle and pulmonary pressure overload

Right ventricular (RV) dilatation and signs of pulmonary pressure overload carry important prognostic implications in HF, pulmonary disease and thromboembolism. HHE enables a qualitative assessment of RV size and global function, the RV/LV ratio and the presence of systolic interventricular septal flattening consistent with pressure overload, within the focused views recommended for FoCUS [1,5,6,22]. Measurement of the inferior vena cava (IVC) diameter and collapsibility provides an indication of right-sided filling pressures and overall volume status, particularly when integrated into limited cardiopulmonary FoCUS protocols [28,36].

In addition, studies in patients with suspected pulmonary embolism have shown that pocket-size devices can identify RV dilatation and dysfunction thereby refining risk stratification and improving diagnostic accuracy when added to clinical assessment [37,38]. However, HHE does not allow accurate estimation of pulmonary artery pressures or standardised quantification of RV functional indices, which require comprehensive echocardiography

[1,22]. In preventive and follow-up settings, a negative HHE examination for RV dilatation and overload helps to exclude major haemodynamic abnormalities, whereas a positive study identifies patients who should be referred for full TTE and, when appropriate, further workup for PH or chronic thromboembolic PH. Furthermore, the use of pulsed-wave Doppler at the level of the pulmonary valve can serve as an indirect estimator of PH. In the context of HHE, where continuous-wave Doppler is often unavailable, PW-derived parameters provide a valuable surrogate, allowing clinicians to obtain functional hemodynamic information.

Valvular abnormalities

At least moderate valvular heart disease, particularly clinically significant aortic stenosis and mitral or tricuspid regurgitation (including isolated tricuspid regurgitation independent of left-sided disease), has a major impact on follow-up strategies and prognosis. In this field, HHE has a pivotal role. Prospective comparisons have shown that handheld and pocket-size devices can reliably distinguish essentially normal valves from clearly abnormal ones and detect valvular lesions at least moderate in severity when the clinical question is framed in binary terms [1,9,22,25,30]. HHE enables recognition of markedly thickened or calcified valves, gross leaflet motion abnormalities and significant regurgitation based on the extent and direction of the colour Doppler jet in standard views [1,9].

Handheld systems equipped with continuous-wave Doppler have also demonstrated the feasibility of preliminary screening for haemodynamically significant aortic stenosis, although full quantification still requires standard TTE [39,40]. Overall, current evidence is largely limited to small feasibility and diagnostic accuracy studies and detailed assessment of transvalvular gradients, valve areas and regurgitation severity remains the domain of comprehensive echocardiography. Any HHE study suggesting valvular disease of at least moderate severity should be systematically followed by a complete echocardiographic examination [1,9,22].

Aortic root, pericardial effusion and pleural effusion

Assessment of the aortic root, pericardium and pleural spaces is another area in which HHE can provide relevant information in both primary and secondary prevention. In the parasternal long-axis view, handheld devices allow measurement of the aortic root with sufficient accuracy to identify overt dilatation, which should prompt more detailed imaging and, in selected patients, evaluation for aortic pathology [1,22]. Focused protocols incorporating handheld devices have also shown that pericardial effusions can be detected and their extent qualitatively assessed at the bedside, together with echocardiographic signs compatible with tamponade, such as right-sided chamber collapse and a plethoric IVC [28,41]. In the same examination, basal pleural effusions and dependent fluid collections can be visualised and integrated into the overall assessment of congestion [23,36]. Within the proposed worklist, a clearly dilated aortic root, pericardial effusion or clinically relevant pleural effusion are considered positive HHE findings that should trigger more detailed echocardiographic or tomographic imaging and closer clinical follow-up [1,22,41].

Extracardiac findings (lung congestion, carotid disease, femoral access complications, etc.)

Lung ultrasound performed with handheld systems allows rapid identification of bilateral B-lines and pleural effusions, which reflect increased extravascular lung water and correlate with the degree of congestion in patients with acute or chronic HF [23,24,42,43]. Adding lung ultrasound to the clinical examination

improves the ability to detect and grade congestion compared with physical examination alone, and structured reporting checklists have been proposed to standardise quantification in HF [21,42], recognizing that B-lines are non-specific findings and may reflect causes other than congestion, such as interstitial lung disease.

Pocket-size devices have also been used for bedside screening of significant carotid artery stenosis (also in patients undergoing cardiac surgery) and for the detection of femoral artery access-site complications after invasive procedures, with good agreement with standard vascular ultrasound [44–46]. In selected patients with favourable acoustic windows, a preliminary assessment of the abdominal aorta may be feasible and is conceptually aligned with POCUS protocols that include screening for abdominal aortic aneurysm. Nevertheless, most cardiac phased-array probes may not reliably visualize the abdominal aorta and dedicated evidence with handheld systems in structured abdominal aortic aneurysm screening programmes remains limited [7,35]. These extracardiac findings do not replace dedicated vascular imaging but can serve as additional imaging-based “risk modifiers” that refine global risk assessment and help identify patients who warrant intensified therapy or targeted follow-up in preventive cardiology clinics [21,44,47].

Taken together, these use cases can be translated into a pragmatic HHE worklist and care pathway for preventive cardiology, in line with FoCUS- and POCUS approaches endorsed by major societies [1,5,9]. In our proposal, each examination follows a limited set of standard views (parasternal long- and short-axis, apical four-chamber and RV-focused views, subcostal view with IVC assessment and focused lung ultrasound), with predefined targets, mandatory items to record and binary screening questions (Table 2) [5,6,28]. This structured approach (Fig. 1) is intended to standardise the use of HHE in prevention clinics and to optimise downstream use of echocardiography resources, albeit requiring validation [1,9,22].

Implementation and utilisation beyond cardiology

The impact of HHE on prevention largely depends on its dissemination beyond the echocardiography laboratory and the imaging cardiologist [1,9]. Bringing this triage tool into the settings where cardiovascular risk is actually managed – general practice and community clinics, hypertension, diabetes and dyslipidaemia clinics, and nurse-led services – makes a targeted HHE-based model realistically implementable [1,22]. However, widespread implementation will also require reorganisation of clinic workflows, protected time for scanning and appropriate reimbursement models. In these settings, HHE can be used by different professional profiles, provided that the scope of practice is clearly defined. In addition to cardiologists who are not advanced imagers, internists, general practitioners, emergency physicians and experienced nurses embedded in structured teams can perform limited examinations focused on a small number of binary questions [7,47]. The aim is structured triage, not full echocardiographic quantification.

Integration with image archiving systems and with concise, standardised reports is crucial to enable tele-consultation with expert cardiologists, especially for indeterminate studies and for non-specialist operators [8,29]. The use of HHE outside cardiology also has important organisational implications. On the one hand, it may reduce the number of unnecessary TTEs, anticipate the diagnosis of LV hypertrophy, significant valvular disease or congestion, and allow a more targeted follow-up, leading to more efficient use of echocardiographic resources [1,22,30]. On the other hand, if implemented without adequate governance, it may promote over-screening, increase false positives and false negatives, fragment data and encourage use of the tool outside its intended indications [22,31]. For this reason, the introduction of HHE in non-cardiology

settings should be accompanied by shared protocols that clearly define indications, admissible clinical questions, criteria for referral to standard TTE and quality indicators to be monitored over time [1,5]. Specifically, existing recommendations suggest minimum requirements for FoCUS training, including a combination of theoretical instruction, supervised image acquisition, and a predefined number of mentored examinations to achieve basic competence and quality assurance [1,5,6]. In particular, training requirements cannot be standardized in terms of a fixed number of hours or examinations, given the heterogeneity of trainees and clinical contexts; instead, competency should be the primary goal and assessed throughout practical training that should also ensure operators' awareness on their own limitations and the appropriate scope of FoCUS use [1,5,6].

In summary, when embedded within standardised care pathways, with appropriate training and specialist supervision, HHE can help bridge the gap between risk stratification based solely on clinical scores and the early identification of cardiovascular target-organ damage in at-risk populations [9,22].

Challenges and future directions

Despite rapid technological progress and the growing adoption of portable devices, the integration of HHE into structured cardiovascular prevention programmes is still limited by several barriers. These relate to diagnostic performance, training and quality assurance, protocol standardisation, digital integration and, above all, the paucity of data on clinical outcomes and cost-effectiveness [1,9,22].

Diagnostic and methodological limitations

Compared with comprehensive TTE, lower spatial and temporal resolution, reduced Doppler capabilities and the lack of advanced tools (such as strain imaging or a full diastolic evaluation) translate into a non-negligible risk of false negatives, particularly for mild or subclinical abnormalities [1,31]. At the other end of the spectrum, using HHE outside its predefined scope may favour false positives and overdiagnosis [48]. A key priority for the future is the definition and validation of simple, reproducible criteria specifically in preventive populations, rather than extrapolated from acute or hospital-based cohorts [5,22].

Protocols, digital integration and technology

Currently, there are no widely accepted prevention-specific protocols for HHE in cardiovascular risk clinics beyond general FoCUS and POCUS frameworks [5–7]. Key issues remain unresolved, including patient selection, examination frequency, required imaging views, and standardized reporting [5,22]. Integration with electronic health records is also limited, with risks of data fragmentation and poor longitudinal traceability [8]. Emerging tools such as AI-assisted acquisition and interpretation, and tele-echocardiography/tele-mentoring, offer promising solutions but require robust validation in preventive settings to ensure safety, reliability, and clinical impact [27,33,35].

Specifically, AI-based acquisition and measurement are increasingly integrated into commercially available echocardiography platforms; however, regulatory approval does not eliminate the need for local validation, quality assurance procedures and clinician oversight [49]. Current recommendations emphasize that AI tools should be regarded as clinical decision-support systems rather than autonomous diagnostic platforms [49].

Moreover, published studies have demonstrated good agreement with expert measurements, including studies involving

novice operators [50,51]. Nevertheless, performance remains dependent on image quality and clinical context, and results obtained in community settings should be interpreted with appropriate caution [49]. Automation bias is a potential limitation, as operators may over-rely on AI-generated outputs; therefore, consistent with current recommendations on trustworthy AI, human oversight remains essential, particularly in cases with suboptimal images or complex pathology [49]. Finally, regulatory clearance does not transfer medico-legal responsibility from clinicians to the software, highlighting the importance of quality assurance processes, appropriate governance and clear lines of responsibility [49].

Evidence gaps, health systems and cost-effectiveness

Perhaps the most relevant limitation is the lack of robust data on the impact of HHE-based strategies on hard clinical outcomes, service organisation and cost-effectiveness [1,9,22]. A few studies have evaluated pocket-sized echocardiography as a screening tool for structural heart disease, reporting good diagnostic accuracy and favourable short-term cost-effectiveness in outpatient or population-based cohorts, but they remain small and context-specific [52,53]. Most of the available evidence comes from diagnostic accuracy studies, feasibility series or small implementation projects, often conducted in hospital and acute care environments rather than in primary or secondary prevention clinics [1,31]. Key health-system questions therefore remain largely unanswered: who should perform HHE, how to embed it in the care pathways of hypertensive or diabetic patients, what is the optimal frequency of examinations, and what is the real cost-effectiveness and the net balance between avoided TTEs, earlier detection of structural disease, treatment intensification, events prevented and additional costs [1,8,22]. Issues of equity are also central: in low-resource settings and community screening programmes, HHE might expand access to basic imaging, but this requires well-regulated task shifting to nurses or community health workers, with clear boundaries of responsibility and appropriate supervision [7,22].

Future directions

For HHE to be integrated into structured prevention programmes, further hardware and software improvements are needed to overcome current diagnostic limitations in screening-oriented applications [1,22]. Simple, binary, prevention-oriented criteria for key cardiac abnormalities should be developed and validated [5,22]. Dedicated training and certification pathways, supported by simulation and audit, are required to ensure quality [2,6,48]. In addition, standardized protocols with integration into electronic records, AI support, and tele-echocardiography should be implemented to standardize workflows [5,8,29]. Finally, real-world implementation studies, including pragmatic and cluster-randomized designs, are needed to define the clinical and economic value of HHE in preventive settings [1,9,22].

Conclusions

HHE in preventive cardiology sits as an intermediate step between clinical assessment alone and comprehensive TTE. In at-risk individuals, focused HHE examinations can reveal early signs of cardiac target-organ damage that are not captured by physical examination or risk scores alone. To translate this into routine practice, clear definition of HHE use, operator training, standardised protocols, system integration, and evidence on outcomes and cost-effectiveness are required. If addressed in a coordinated way, these challenges may allow HHE to evolve from a promising technology into a structural component of preventive cardiology pathways.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Andrea Stefanini: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Data curation, Conceptualization. **Maria Concetta Pastore:** Writing – review & editing, Validation, Supervision, Data curation, Conceptualization. **Cosimo Salvatici:** Writing – original draft, Data curation. **Riccardo Liga:** Writing – review & editing, Validation, Supervision. **Antonio Capolongo:** Writing – original draft, Investigation, Data curation. **Francesca Amati:** Writing – review & editing, Validation, Supervision. **Egidio Imbalzano:** Visualization, Validation, Supervision. **Paolo Calabrò:** Visualization, Validation, Supervision. **Felice Gragnano:** Visualization, Validation. **Giulia Elena Mandoli:** Writing – review & editing, Visualization, Validation, Supervision. **Laura Spaccaterra:** Investigation, Data curation. **Elena Placuzzi:** Investigation, Data curation. **Andrea Rinaldi:** Visualization, Validation, Supervision. **Pietro Scicchitano:** Writing – review & editing, Visualization, Validation, Supervision. **Annalisa Pasquini:** Visualization, Validation, Supervision. **Marta Focardi:** Visualization, Validation, Supervision. **Roberto Pedrinelli:** Writing – review & editing, Visualization, Validation, Supervision. **Anna Vittoria Mattioli:** Writing – review & editing, Visualization, Validation, Supervision. **Andrea Igores Guaricci:** Visualization, Validation, Supervision. **Stefania Paolillo:** Writing – review & editing, Visualization, Validation, Supervision. **Flavio D'Ascenzi:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Matteo Cameli:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization.

References

- [1] Cardim N, Dalen H, Voigt JU, Ionescu A, Price S, Neskovic AN, et al. The use of handheld ultrasound devices: a position statement of the European association of cardiovascular imaging (2018 update). *Eur Heart J Cardiovasc Imaging* 2019;20(3):245–52. doi:10.1093/ehjci/jez145.
- [2] Solomon SD, Saldana F. Point-of-care ultrasound in medical education—stop listening and look. *N Engl J Med* 2014;370(12):1083–5. doi:10.1056/NEJMp1311944.
- [3] Kimura BJ. Point-of-care cardiac ultrasound techniques in the physical examination: better at the bedside. *Heart* 2017;103(13):987–94. doi:10.1136/HEARTJNL-2016-309915.
- [4] Sicari R, Galderisi M, Voigt JU, Habib G, Zamorano JL, Lancellotti P, et al. The use of pocket-size imaging devices: a position statement of the European association of echocardiography. *Eur J Echocardiogr* 2011;12(2):85–7. doi:10.1093/ehjci/ehj184.
- [5] Neskovic AN, Edvardsen T, Galderisi M, Garbi M, Gullace G, Jurcut R, et al. Focus cardiac ultrasound: the European association of cardiovascular imaging viewpoint. *Eur Heart J Cardiovasc Imaging* 2014;15(9):956–60. doi:10.1093/ehjci/jeu081.
- [6] Via G, Hussain A, Wells M, Reardon R, ElBarbary M, Noble VE, et al. International evidence-based recommendations for focused cardiac ultrasound. *J Am Soc Echocardiogr* 2014;27(7):683.e1–683.e33. doi:10.1016/j.echo.2014.05.001.
- [7] Moore CL, Copel JA. Point-of-care ultrasonography. *N Engl J Med* 2011;364(8):749–57. doi:10.1056/NEJMra0909487.
- [8] Bhavnani SP, Narula J, Sengupta PP. Mobile technology and the digitization of healthcare. *Eur Heart J* 2016;37(18):1428–38. doi:10.1093/EURHEARTJ/EHV770.
- [9] Chamsi-Pasha MA, Sengupta PP, Zoghbi WA. Handheld echocardiography: current state and future perspectives. *Circulation* 2017;136(22):2178–88. doi:10.1161/CIRCULATIONAHA.117.02662.
- [10] VscanTM handheld ultrasound systems | GE HealthCare (United States). Accessed November 24, 2025. <https://www.gehealthcare.com/products/ultrasound/handheld-ultrasound>.
- [11] Lumify handheld ultrasound | Philips. Accessed November 24, 2025. <https://www.usa.philips.com/healthcare/sites/lumify-handheld-ultrasound>.
- [12] iQ+ ultrasound | a single, whole-body imaging probe. Accessed November 24, 2025. <https://www.butterflynetwork.com/iq-plus>
- [13] ACUSON P500 ultrasound system - Siemens Healthineers. Accessed November 24, 2025. <https://www.siemens-healthineers.com/ultrasound/ultrasound-point-of-care/acuson-p500-ultrasound-machine>
- [14] Phased array scanner | Clarius. Accessed November 24, 2025. <https://clarius.com/scanners/pa/>
- [15] Sonosite Edge II | FUJIFILM Sonosite. Accessed November 24, 2025. <https://www.sonosite.com/in/products/sonosite-edge-ii>
- [16] Point of care ultrasound machines for medical offices | EchoNous. Accessed November 24, 2025. <https://echonous.com/product/>
- [17] Mindray T.E. Air i3P - Mindray. Accessed November 24, 2025. <https://www.mindray.com/it/products/ultrasound/point-of-care/te-air>
- [18] Konted ultrasound | Beijing Konted Medical Technology Co. Accessed November 24, 2025. <https://www.kontedmed.com>
- [19] Perez-Sanchez A, Johnson G, Pucks N, Soni RN, Lund TJS, Andrade AJ, et al. Comparison of 6 handheld ultrasound devices by point-of-care ultrasound experts: a cross-sectional study. *Ultrasound J* 2024;16(1):45. doi:10.1186/s13089-024-00392-3.
- [20] Visseren FLJ, Mach F, Smulders YM, Carballo D, Koskinas KC, Böck M, et al. 2021 ESC guidelines on cardiovascular disease prevention in clinical practice. *Eur Heart J* 2021;42(34):3227–337. doi:10.1093/eurheartj/ehab484. Erratum in: *Eur Heart J*. 2022 Nov 7;43(42):4468. doi:10.1093/eurheartj/ehac458.
- [21] SCORE2 working group and ESC cardiovascular risk collaboration. SCORE2 risk prediction algorithms: new models to estimate 10-year risk of cardiovascular disease in Europe. *Eur Heart J* 2021;42(25):2439–54. doi:10.1093/eurheartj/ehab309.
- [22] Filipiak-Strzecka D, Lipiec P, Kasprzak JD. Handheld ultrasound in cardiology: current perspective. *Adv Clin Exp Med* 2023;32(3):267–74. doi:10.17219/ACEM/158555.
- [23] Platz E, Jhund PS, Girerd N, Pivetta E, McMurray JJV, Peacock WF, et al. Expert consensus document: reporting checklist for quantification of pulmonary congestion by lung ultrasound in heart failure. *Eur J Heart Fail* 2019;21(7):844–51. doi:10.1002/ehf.1499.
- [24] Johannessen Ø, Myhre PL, Omland T. Assessing congestion in acute heart failure using cardiac and lung ultrasound - a review. *Expert Rev Cardiovasc Ther* 2021;19(2):165–76. doi:10.1080/14779072.2021.1865155.
- [25] Gianstefani S, Catibog N, Whittaker AR, Ioannidis AG, Vecchio F, Wathen PT, et al. Pocket-size imaging device: effectiveness for ward-based transthoracic studies. *Eur Heart J Cardiovasc Imaging* 2013;14(12):1132–9. doi:10.1093/ehjci/jeu091.
- [26] Halvorsen S, Mehili J, Cassese S, Hall TS, Abdelhamid M, Barbato E, et al. ESC scientific document group. 2022 ESC guidelines on cardiovascular assessment and management of patients undergoing non-cardiac surgery. *Eur Heart J* 2022;43(39):3826–924. Erratum in: *Eur Heart J*. 2023 Nov 7;44(42):4421. doi:10.1093/eurheartj/ehad577. doi:10.1093/eurheartj/ehac270.
- [27] Cauty DJ, Heiberg J, Yang Y, Royse AG, Margale S, Nanjappa N, et al. One-year results of the pilot multicentre randomised trial of preoperative focused cardiac ultrasound in hip fracture surgery. *Anaesth Intensive Care* 2019;47(2):207–8. Epub 2019 May 1. doi:10.1177/0310057X19838699.
- [28] Kennedy Hall M, Coffey EC, Herbst M, Liu R, Pare JR, Andrew Taylor R, et al. The "5Es" of emergency physician-performed focused cardiac ultrasound: a protocol for rapid identification of effusion, ejection, equality, exit, and entrance. *Acad Emerg Med* 2015;22(5):583–93. doi:10.1111/ace.12652.
- [29] Boman K, Olofsson M, Berggren P, Sengupta PP, Narula J. Robot-assisted remote echocardiographic examination and teleconsultation: a randomized comparison of time to diagnosis with standard of care referral approach. *JACC Cardiovasc Imaging* 2014;7(8):799–803. doi:10.1016/j.jcmg.2014.05.006.
- [30] Liebo MJ, Israel RL, Lillie EO, Smith MR, Rubenson DS, Topol EJ. Is pocket mobile echocardiography the next-generation stethoscope? A cross-sectional comparison of rapidly acquired images with standard transthoracic echocardiography. *Ann Intern Med* 2011;155(1):33–9. doi:10.7326/0003-4819-155-1-201107050-00005.
- [31] Mirabel M, Celermajor D, Beraud AS, Jouven X, Marijon E, Hagège AA. Pocket-sized focused cardiac ultrasound: strengths and limitations. *Arch Cardiovasc Dis* 2015;108(3):197–205. doi:10.1016/j.acvd.2015.01.002.
- [32] Vourvouri EC, Poldermans D, Schinkel AF, Koroleva LY, Sozzi FB, Parharidis GE, et al. Left ventricular hypertrophy screening using a hand-held ultrasound device. *Eur Heart J* 2002;23(19):1516–21. doi:10.1053/ehj.2002.3162.
- [33] Filipiak-Strzecka D, Kasprzak JD, Wejner-Mik P, Szymczyk E, Wdowiak-Okrojek K, Lipiec P. Artificial intelligence-powered measurement of left ventricular ejection fraction using a handheld ultrasound device. *Ultrasound Med Biol* 2021;47(4):1120–5. doi:10.1016/j.ultrasmedbio.2020.12.003.
- [34] Hjorth-Hansen AK, Magelssen MI, Andersen GN, Graven T, Kleinau JO, Landstad B, et al. Real-time automatic quantification of left ventricular function by hand-held ultrasound devices in patients with suspected heart failure: a feasibility study of a diagnostic test with data from general practitioners, nurses and cardiologists. *BMJ Open* 2022;12(10):e063793. doi:10.1136/bmjopen-2022-063793.
- [35] Narula S, Shameer K, Salem Omar AM, Dudley JT, Sengupta PP. Machine-learning algorithms to automate morphological and functional assessments in 2D echocardiography. *J Am Coll Cardiol* 2016;68(21):2287–95. doi:10.1016/j.jacc.2016.08.062.
- [36] Kimura BJ, Yogo N, O'Connell CW, Phan JN, Showalter BK, Wolfson T. Cardiopulmonary limited ultrasound examination for "quick-look" bedside application. *Am J Cardiol* 2011;108(4):586–90. doi:10.1016/j.amjcard.2011.03.091.
- [37] Dresden S, Mitchell P, Rahimi L, Leo M, Rubin-Smith J, Bibi S, et al. Right ventricular dilatation on bedside echocardiography performed by emergency

- physicians aids in the diagnosis of pulmonary embolism. *Ann Emerg Med* 2014;63(1):16–24. doi:[10.1016/j.annemergmed.2013.08.016](https://doi.org/10.1016/j.annemergmed.2013.08.016).
- [38] Filipiak-Strzecka D, Kasprzak JD, Lipiec P. Brief cardiovascular imaging with pocket-size ultrasound devices improves the accuracy of the initial assessment of suspected pulmonary embolism. *Int J Cardiovasc Imaging* 2018;34(10):1595–605. doi:[10.1007/S10554-018-1382-5](https://doi.org/10.1007/S10554-018-1382-5).
- [39] Abe Y, Ito M, Tanaka C, Ito K, Naruko T, Itoh A, et al. A novel and simple method using pocket-sized echocardiography to screen for aortic stenosis. *J Am Soc Echocardiogr* 2013;26(6):589–96. doi:[10.1016/j.echo.2013.03.008](https://doi.org/10.1016/j.echo.2013.03.008).
- [40] Sachpekidis V, Papadopoulou SL, Kantartzi V, Styliadis I, Nihoyannopoulos P. A novel handheld echocardiography device with continuous-wave doppler capability: implications for the evaluation of aortic stenosis severity. *J Am Soc Echocardiogr* 2022;35(12):1273–80 Epub 2022 Sep 2. doi:[10.1016/j.echo.2022.08.012](https://doi.org/10.1016/j.echo.2022.08.012).
- [41] Pare JR, Liu R, Moore CL, Sherban T, Kelleher MS Jr, Thomas S, et al. Emergency physician focused cardiac ultrasound improves diagnosis of ascending aortic dissection. *Am J Emerg Med* 2016;34(3):486–92. doi:[10.1016/j.ajem.2015.12.005](https://doi.org/10.1016/j.ajem.2015.12.005).
- [42] Dadon Z, Levi N, Alpert EA, Orlev A, Belman D, Glikson M, et al. The quality, safety, feasibility, and interpretive accuracy of echocardiographic and lung ultrasound assessment of COVID-19 patients using a hand-held ultrasound. *Echocardiography* 2022;39(7):886–94. doi:[10.1111/echo.15372](https://doi.org/10.1111/echo.15372).
- [43] Dini FL, Cameli M, Stefanini A, Aboumarie HS, Lisi M, Lindqvist P, et al. Echocardiography in the assessment of heart failure patients. *Diagn (Basel)* 2024;14(23):2730. doi:[10.3390/diagnostics14232730](https://doi.org/10.3390/diagnostics14232730).
- [44] Filipiak-Strzecka D, Kasprzak JD, Szymczyk E, Wejner-Mik P, Lipiec P. Bedside screening with the use of pocket-size imaging device can be useful for ruling out carotid artery stenosis in patients scheduled for cardiac surgery. *Echocardiography* 2017;34(5):716–22. doi:[10.1111/ECHO.13507](https://doi.org/10.1111/ECHO.13507).
- [45] Mantella LE, Colledanchise K, Bullen M, Héту MF, Day AG, McLellan CS, Johri AM. Handheld versus conventional vascular ultrasound for assessing carotid artery plaque. *Int J Cardiol* 2019;278:295–9 Epub 2018 Dec 5. doi:[10.1016/j.ijcard.2018.12.014](https://doi.org/10.1016/j.ijcard.2018.12.014).
- [46] Filipiak-Strzecka D, Michalski B, Kasprzak JD, Lipiec P. Pocket-size imaging devices allow for reliable bedside screening for femoral artery access site complications. *Ultrasound Med Biol* 2014;40(12):2753–8. doi:[10.1016/j.ultrasmedbio.2014.06.022](https://doi.org/10.1016/j.ultrasmedbio.2014.06.022).
- [47] Martin LD, Howell EE, Ziegelstein RC, Martire C, Shapiro EP, Hellmann DB. Hospitalist performance of cardiac hand-carried ultrasound after focused training. *Am J Med* 2007;120(11):1000–4. doi:[10.1016/j.amjmed.2007.07.029](https://doi.org/10.1016/j.amjmed.2007.07.029).
- [48] Jenkins S, Alabed S, Swift A, Marques G, Ryding A, Sawh C, et al. Diagnostic accuracy of handheld cardiac ultrasound device for assessment of left ventricular structure and function: systematic review and meta-analysis. *Heart* 2021;107(22):1826–34. doi:[10.1136/heartjnl-2021-319561](https://doi.org/10.1136/heartjnl-2021-319561).
- [49] Myhre PL, Grenne B, Asch FM, Delgado V, Khera R, Lafitte S, Lang RM, Pellicka PA, Sengupta PP, Vemulapalli S, Lam CSP. Artificial intelligence-enhanced echocardiography in cardiovascular disease management. *Nat Rev Cardiol* 2026;23(3):164–82 Epub 2025 Aug 5. doi:[10.1038/s41569-025-01197-0](https://doi.org/10.1038/s41569-025-01197-0).
- [50] Mor-Avi V, Khandheria B, Klempfner R, Cotella JI, Moreno M, Ignatowski D, et al. Real-time artificial intelligence-based guidance of echocardiographic imaging by novices: image quality and suitability for diagnostic interpretation and quantitative analysis. *Circ Cardiovasc Imaging* 2023;16(11):e015569 Epub 2023 Nov 13. doi:[10.1161/CIRCIMAGING.123.015569](https://doi.org/10.1161/CIRCIMAGING.123.015569).
- [51] Narang A, Bae R, Hong H, Thomas Y, Surette S, Cadieu C, et al. Utility of a deep-learning algorithm to guide novices to acquire echocardiograms for limited diagnostic use. *JAMA Cardiol* 2021;6(6):624–32. doi:[10.1001/jamacardio.2021.0185](https://doi.org/10.1001/jamacardio.2021.0185).
- [52] Tabib A, Samiei N, Peighambari MM, Rashidi Ghader F, Moradian M, Mohebbi A, et al. Pocket-sized echocardiography for screening structural heart disease: diagnostic accuracy and cost-effectiveness for population-based studies. *Cardiol Young* 2020;30(2):197–204. doi:[10.1017/S1047951119003111](https://doi.org/10.1017/S1047951119003111).
- [53] Kitada R, Fukuda S, Watanabe H, Oe H, Abe Y, Yoshiyama M, et al. Diagnostic accuracy and cost-effectiveness of a pocket-sized transthoracic echocardiographic imaging device. *Clin Cardiol* 2013;36(10):603–10. doi:[10.1002/clc.22171](https://doi.org/10.1002/clc.22171).