Use of Artificial Intelligence to Assess Cardiac Function by Echocardiography: Systematic Review of the State of the Art

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Abstract

Background: **Echocardiography is part of the routine investigation of most heart diseases. However, its operator-dependent nature and the quality of the image obtained can cause significant variability in measurements and impair their interpretation. The method has advanced on its path of standardization and incorporation of new technologies in an attempt to reduce its deficiencies. Recently, part of this advancement was due to the incorporation of artificial intelligence (AI).**

Objectives: **The objective of this work was to investigate the use of AI in the assessment of cardiac function through echocardiography, discussing its potential to improve the method.**

Methods: **We conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), searching for articles within the period of 2000 to 2023.**

Results: **A total of 31 articles were included, classified into four categories of studies that used AI: 1) for image analysis and echocardiographic parameters (N = 14); 2) in the image acquisition process (N = 11); 3) for integration with clinical data (N = 3); and 4) for application to the exam flow (N = 3).**

Conclusion: **AI provides automation and standardization of images and respective measurements that result in more accurate diagnoses, overcoming the limitations encountered by the conventional method. However, the use of AI is still an evolving reality within echocardiography.**

Keywords: **Echocardiography; Artificial Intelligence; Machine Learning; Deep Learning; Global Longitudinal Strain.**

Introduction

Echocardiography is the most requested imaging method and is part of the routine investigation of most heart diseases. Due to its non-invasive, non-ionizing nature, high availability, and portability, the method is present in various clinical scenarios - outpatient, hospital, urgency and emergency units, intensive care units, and as a guide for interventional and surgical procedures - and normally is the first option to access cardiac anatomy and function. However, its operator-dependent nature and image quality can influence echocardiographic measurements. Since its development, the method has advanced in its path of standardization and incorporation of new technologies in an attempt to reduce its variability.

This advance is partly due to the incorporation of artificial intelligence (AI) into the method. "AI" is a broad term coined by Arthur Samuel in the 1960s. It applies to any computer program, such as algorithms and models, which imitate human logic and intelligence.[1] In echocardiography, the first use was in the 70s, when Fourier analysis was used to evaluate the mitral valve with the aid of M-mode.[2] Semi-automated measurements are already part of today's echocardiography laboratory practice. In their workflow, modern devices come equipped with software packages that assist in measurements and calculations, such as left ventricular ejection fraction (LVEF), myocardial deformation (strain), and the Doppler study for hemodynamic assessment.[1]

Machine learning is one of the subfields of AI. The computer receives the data, learns from it, predicts a result, and, using statistical methods, can even improve its performance the next time it is presented with similar data. This allows, for example, a trained machine to identify structures within a new image and label them accurately. Another subfield, known as deep learning, later emerged. This is applied when a large amount of data must be processed. In this case, the data is processed as large subsets. Just like in a biological neural network, the processing is organized in a hidden chain made up of thousands of consecutive artificial neural layers until a final result is reached.[1] An artificial neural network can use convolution operations, which allow a third to be generated from two input data called Convolutional Neural Networks.[3]

In this sense, AI in echocardiography can be extremely advantageous for identifying, quantifying, and interpreting images while minimizing the variance between assessments

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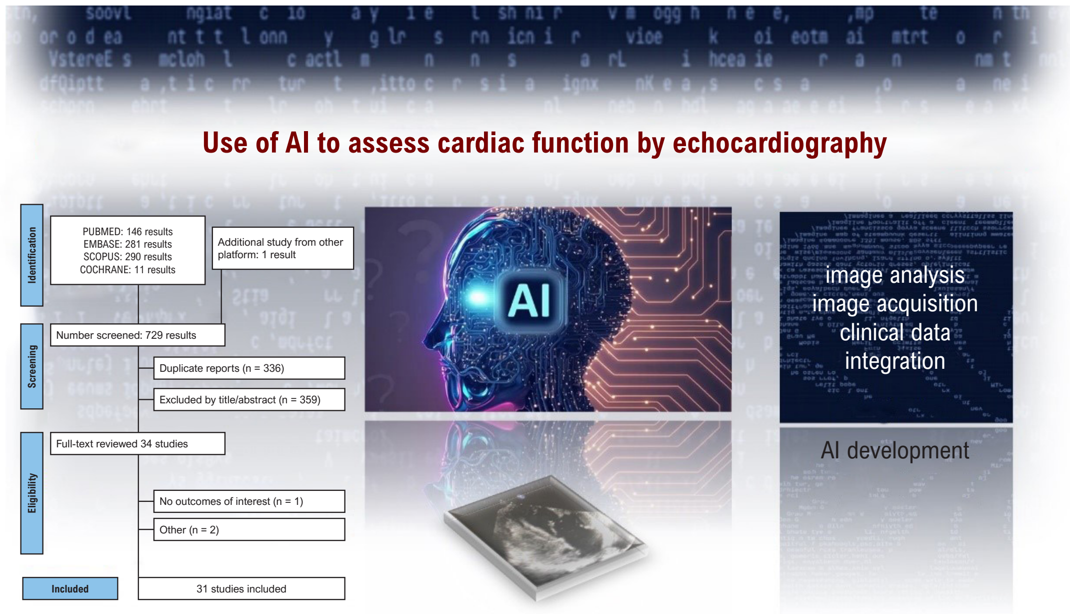
Central Illustration: **Use of Artificial Intelligence to Assess Cardiac Function by Echocardiography: Systematic Review of the State of the Art**



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Flowchart of search and selection of studies on the use of AI in echocardiography. AI: artificial intelligence.

and providing reproducible measurements and an accurate diagnosis. The examiner may find significant support in this technology, which would enable a reduction in time spent on data extraction and integration and, in turn, present the potential to make the healthcare system more sustainable.[4] Furthermore, AI-driven echocardiographic practice would not only streamline clinical decision-making but also provide learning methods with interactive feedback for training less-experienced examiners.[5]

Thus, the use of AI in echocardiography can be divided into four main scenarios: education, image acquisition, image analysis, and integration with clinical data.[6] Although there is evidence that positively affirms the role of AI technology in echocardiography diagnosis, there are still challenges to be overcome, such as insufficient standardization of echocardiography protocols and insufficient generalization of models in clinical applications.[6]

Given the limitations of the technique and the need to investigate future trends, this systematic review was conducted based on several studies to externally validate the performance of AI technology in echocardiography. Although similar works are found in the literature that investigated the application of AI in the automated analysis of echocardiographic images, this study sought to conduct a survey over the last five years on innovations in the area, with the aim of exploring the use of AI in echocardiography, analyzing current evidence for its effectiveness and discussing its potential to improve cardiac care.

Methods

This is a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[7] We searched for articles within the MEDLINE, EMBASE, SCOPUS, and Cochrane Central databases from January 2000 to March 2023, without language restrictions, with our target method being echocardiography, whose intervention is the use of AI during some stage of the exam, with full texts and descriptors present in the title or summary of the article. The following descriptors in English were used for the research: ("AI") AND ("Echocardiography") AND ("Function" OR "Strain"). We also checked these databases for the presence of previous or ongoing systematic reviews on the subject. We combined results from different databases and discarded repeated results using Zotero software. Two investigators (H.A.F.N and B.S.Y) performed the search independently and five investigators reached an agreement on study eligibility (H.A.F.N, B.S.Y, T.H.L.P.C, I.E.S, Y.M.R.B). Initially, a first screening was conducted to identify studies that evaluated the use of any type of AI during the echocardiography exam. In a second step, we selected the articles to be read in full through the Rayyan platform and assessed the relevance of the data, as well as whether there was more than one article evaluating the same cohort of patients. A third step consisted of reviewing the references of these selected articles to obtain other sources not revealed in the digital search. We classified the studies according to their design (case-control, randomized, retrospective cohort, prospective cohort, and case report), regarding the primary objective of using AI and the main result found with the study. For each study, we extracted the following information: first author; study institution; start and end date; year of publication; single center or multicenter; characteristics of the studied population (average age and distribution by sex); echocardiographic parameters evaluated; methods and windows used to assess cardiac function; AI model; study design; and study conclusions.

Results

We identified 729 references in searches of electronic databases, discarding 336 duplicates and another 359 excluded by title and/or abstract. We obtained 33 articles for full reading, of which three were discarded because they did not fit the scope of the review according to the authors. Only one additional article was included after manually searching the references (Figure 1). A total of 31 articles were included in the qualitative analysis of this review, being classified into four main categories: 1) studies that use AI for image analysis and echocardiographic parameters (N = 14, Table 1); 2) studies that use AI in the image acquisition process (N = 11, Table 2); 3) studies that use AI to integrate with clinical data (N = 3, Table 3); and 4) studies that trained AI software for application to the exam flow (N = 3, Table 4); All articles were published in English. Twenty-six articles are from a single center, with 7 (%) from the United States, 2 (%) from Israel, 2 (%) from Norway, 2 (%) from Italy, 2 (%) from England, 1 (%) from Germany, 1 (%) from Greece, 1 (%) from France, 1 (%) from Uganda, 1 (%) from Portugal, 1 (%) from Ireland, 1 (%) from Austria, 1 (%) from Netherlands, 1 (%) from China, 1 (%) from Canada, and 1 (%) from Japan. A single article was developed in several centers (13 different centers). Four articles did not inform of the country where the study took place.

Discussion

The implementation of AI tools in echocardiographic study has the potential to improve patient care and optimize diagnosis and treatment. The studies present in this systematic review are favorable to the application of automated technology in the examination routine, due to its similarity, feasibility, usefulness, precision, accuracy, and reproducibility comparable to manual assessment. Although the use of AI in the examination is still limited and, therefore, prone to modifications aimed

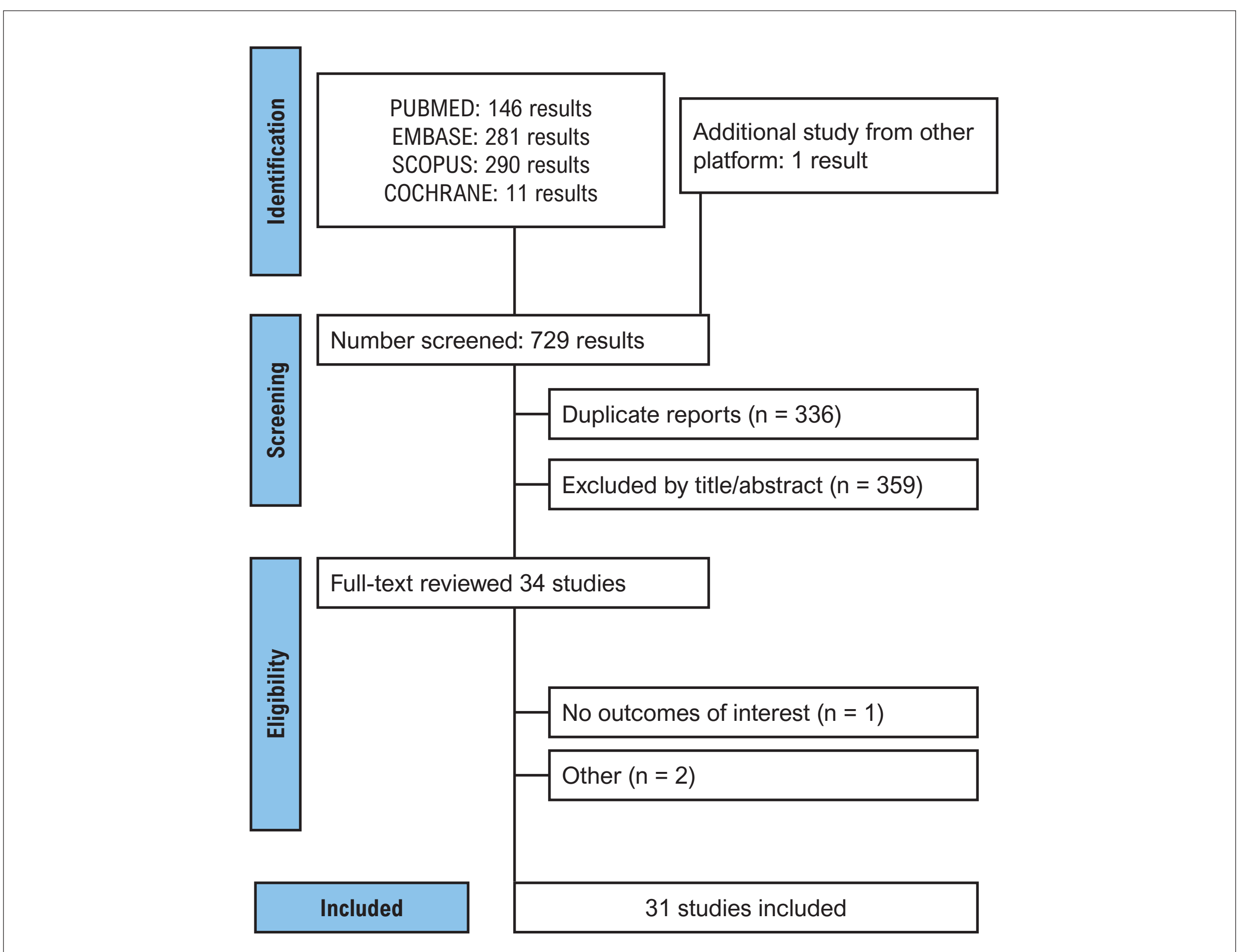

Figure 1 – *PRISMA flow diagram of study screening and selection*

Table 1 – Studies that use AI for image analysis

Author/year	Country	Design and objective	N	Evaluated parameters	AI model	Main results
Cottela *et al.*, 2023[8]		Retrospective cohort Evaluate AI calculation of LVEF and GLS in patients with amyloidosis	51	LVEF, GLS	EchoGo Core 2.0, Ultromics	Fully automated AI-calculated LVEF and GLS are comparable to manual measurements in patients with cardiac amyloidosis.
Sveric *et al.*, 2023[9]	Germany	Prospective cohort Investigate AI viability for the calculation of LVEF in the workflow	889	LVEF	LVivo Seamless™	The AI-based application automatically identified standard apical LV views and measured LVEF. It yielded equivalent results to the currently used MBS method and has the potential to improve LVEF quantification.
He *et al.*, 2023[10]	USA	Randomized clinical trial Compare AI with the sonographer's initial assessment of LVEF	3495	LVEF	EchoNet-Dynamic	Cardiologists were not able to distinguish between the initial assessments by AI versus the sonographer. The initial assessment of LVEF by AI was non-inferior to the assessment by sonographers.
Wang *et al.*, 2022[11]	USA	Retrospective cohort Evaluate AI software usability in patients with COVID-19	50	LVEF, GLS, EDV, ESF	EchoGo, Ultromics	EchoGo software output had high correlations with left ventricular volumes and moderate correlations with LVEF and GLS compared with standard TTE measurements.
Liel-Cohen *et al.*, 2022[12]	Israel	Retrospective cohort Evaluate AI's capability of identifying views and compare GLS results with conventional methods	100	GLS	LVivo Seamless™	The results provided by the AI-based LVivo Seamless solution showed excellent capability to automatically identify 4CH, 2CH, and 3CH views, along with excellent GLS results compared to automated functional imaging.
Sachpekidis *et al.*, 2022[13]	-	Retrospective cohort Evaluate the accuracy of a novel HUD with AI-assisted algorithm to automatically calculate LVEF	100	LVEF	Auto EF, Vivid™	The AI-assisted autoEF algorithm in a novel HUD can accurately calculate LVEF in real-time as compared to the recommended manual biplane Simpson's method on cart-based systems in an "all-comers" patient population.
Salte *et al.*, 2021[14]	Norway	Retrospective cohort Examine automated measurements of GLS using deep learning and AI compared with conventional methods	200	GLS	EchoPAC v.202, GE Ultrasound	Fully automated measurements of GLS using a novel deep learning AI-based technology for motion estimation are feasible and fast and they yield results comparable with the most widely used semiautomatic software.
Hanif *et al.*, 2021[15]	-	Transversal Test whether AI measurement of strain can be more reliable compared to human interpretation	52	GLS	EchoGo, Ultromics	AI-based longitudinal strain analysis was feasible on most echocardiograms without any operator intervention. The bias between EchoGo's longitudinal strain and conventional software appears small.
Penso *et al.*, 2022[16]	Italy	Transversal Feasibility, comparison, and assessment of AI strain measurement compared with conventional methods	203	RVEF, RVFWLS	3D Auto RV, Philips Medical Systems	The rapid analysis and excellent reproducibility of AI-based 3DE RV analysis supported the routine adoption of the system.
Di Candia *et al.*, 2022[17]	Italy	Transversal Compare results of a fully automated analysis and manual tracing analysis using a new AI software	28	LVEF	AI Simpson e AI Wall Motion Tracking	AI fully automated analysis was found to be technically simple, less time-consuming, and highly reproducible. This reduces the variability of manual measurements between different sonographers and at various times.
Papadopoulou *et al.*, 2022[18]	Greece	Transversal Evaluate the reliability and diagnostic accuracy of a HUD-assisted AI to automatically calculate ejection fraction	100	LVEF	Kosmos autoEF	The use of a novel HUD with AI-enabled capabilities provided similar LVEF results to those derived by manual biplane Simpson's method on cart-based systems and shows clinical potential.
Salte *et al.*, 2020[19]	Norway	Multicentric Prospective Examine the feasibility of automated measurements of GLS using AI compared to conventional speckle-tracking application	100	GLS	-	Fully automated measurements of GLS using a novel deep learning AI-based technology for motion estimation are feasible and fast and they yield results comparable with the most widely used semiautomatic software.

Popoff *et al.*, 2020[20]	France	Transversal Evaluate the accuracy and reproducibility of AI tool to compute LV volumes and EF, in comparison with cardiac magnetic resonance as reference	114	LVEF	A deep convolutional neural networks model	Compared to manual contouring, LV volumes, and EF by AI showed comparable or improved accuracy and higher reproducibility. These findings demonstrate the value of AI-based tools, with the potential for full automation, for objective assessment and follow-up of cardiac function.
Asch *et al.*, 2021[21]	USA	Prospective cohort Determine whether AI-automated estimates could be used to accurately classify LV function	233	LVEF	A machine learning algorithm, Caption Health	The new machine-learning algorithm allows accurate automated evaluation of LV function from echocardiographic views commonly used in the POC setting. This approach will enable more POC personnel to accurately assess LV function.

EDV: left ventricular end-diastolic volume; ESF: left ventricular end-systolic volume; GLS: global longitudinal strain; HUD: handheld ultrasound device; LVEF: left ventricle ejection fraction; POC: point-of-care; RVEF: right ventricle ejection fraction; RVFWLS: right ventricular free wall longitudinal strain; AI: artificial intelligence; AI: artificial intelligence; TTE: transthoracic echocardiogram; AutoEF: automatic ejection fraction; EF: ejection fraction; LV: left ventricle; 4CH: four chamber view; 2CH: two chamber view; 3CH: three chamber view.

Table 2 – Studies that use AI for image acquisition.

Author/year	Country	Study design and objective	N	Evaluated parameters	AI model	Main results
Peck *et al.*, 2023[22]	Uganda	Cross-sectional. Evaluate the ability of nonexperts to obtain diagnostic-quality images in patients with RHD using AI guidance with color Doppler	50	Presence/absence of RHD, abnormal mitral valve morphology, and mitral regurgitation	-	AI guidance with color Doppler is feasible to enable RHD screening by nonexperts, performing significantly better for assessment of the mitral than aortic valve.
Klempfner *et al.*, 2023[5]	USA	Prospective cohort. Determine the diagnostic acumen of echocardiographic studies obtained by inexperienced users guided by an AI algorithm	240	Left and right ventricular size and function, pericardial effusion, valve morphology, left atrial and inferior vena cava size	UltraSight algorithm	After minimal training with novel AI-guidance software, novice users can acquire images in ten standard cardiac echocardiographic views, with diagnostic quality approaching that of expert sonographers.
Dadon, Ziv *et al.*, 2022[23]	Israel	Randomized clinical trial Evaluate AI use as a didactic tool to improve noncardiologist clinicians' assessment of LVEF from the A4C view	-	LVEF	LVivo EF	The introduction of an AI-based tool to clinicians working in the emergency department improved the assessment accuracy of LVEF as compared to the control group.
Varudo *et al.*, 2022[24]	Portugal	Prospective cohort. To compare real-time measurements taken by novices and experts with LVEF reference measurements taken manually by echo experts	95	LVEF	Real-Time EF algorithm	Machine learning-enabled real-time measurements of LVEF were strongly correlated with manual measurements obtained by experts.
Burke *et al.*, 2022[25]	Ireland	Cross-sectional. Evaluate study quality by novice scanners with AI guidance	120	Image quality to determine LVEF, pericardial effusion	Caption AI System	The Caption AI technology safely allows novice users to provide efficient and accurate point-of-care echo in differing clinical settings to a standard comparable to expert scanners.
Narang *et al.*, 2021[26]	USA	Prospective cohort. Test whether novice users could obtain 10-view transthoracic echocardiographic studies of diagnostic quality using a DL-based software	240	Left ventricular size, function, pericardial effusion, and right ventricular size	Software Caption Guidance	The DL algorithm allows novices without experience in ultrasonography to obtain diagnostic transthoracic echocardiographic studies for evaluation of left ventricular size and function, right ventricular size, and the presence of a nontrivial pericardial effusion.

Surette *et al.*, 2020[27]	USA	Prospective multicentric clinical trial. Evaluate whether novice-acquired images guided by the software were of diagnostic quality in patients with and without implanted electrophysiological devices	240	Right ventricular size and function	-	New DL software can guide novices to obtain TTEs that enable qualitative assessment of RV size even in the presence of implanted EP devices.
Schneider *et al.*, 2020[28]	Austria	Cross-sectional. Evaluate if the new machine learning algorithm can help novice operators to acquire diagnostic image loops	14	LVEF	-	Machine-learning algorithms can guide ultrasound novices to acquire diagnostic echo loops and provide an automated LVEF calculation that agrees with a human expert.
Motazedian *et al.*, 2022[29]	Netherlands	Prospective cohort. Determine the accuracy of POCUS bedside AI-assisted LVEF compared to formal TTE	449	LVEF	EchoNous Kosmos	AI assisted POCUS performed by both novice and experienced scanners can accurately determine LVEF compared to a comprehensive TTE.
Zhai *et al.*, 2022[30]	China	Cross-sectional. Identify the degree of correlation between auto LVOT-VTI and the manual LVOT-VTI acquired by POCUS-trained doctors	46	LVOT-VTI	AI software tool	AI might provide real-time guidance among novice operators who lack the expertise to acquire the ideal standard view.
Fung *et al.*, 2019[31]	Canada	Prospective cohort. Evaluate the accuracy of the AI system for assessing image quality, as compared to subjective expert analysis	53	PLAX, PSAX, A2C, A4C and subcostal IVC	-	AI systems can assess image quality with modest accuracy.

A2C: apical two-chamber; A4C: apical four-chamber; DL: deep learning; IVC: inferior vena cava; LVEF: left ventricle ejection fraction; LVOT-VTI: left ventricular outflow tract velocity time integral; PLAX: parasternal long-axis; POCUS: point-of-care ultrasound; PSAX: parasternal short-axis; RHD: rheumatic heart disease; RV: right ventricle; TTE: transthoracic echocardiogram; AI: artificial intelligence; EP: electrophysiological.

at advancing and improving the method, the benefit that the technology represents for echocardiography seems to outweigh any fears or disadvantages.

Image analysis and echocardiographic parameters

AI-automated measurement of parameters such as LVEF and global longitudinal strain (GLS) can be comparable to manual measurement by experienced sonographers and incorporations of these tools have reliably maintained measurement accuracy.[8-13] This fact is relevant due to the additional benefits they offer: they increase the operational effectiveness of the exam and the consistency quality of the analysis;[6] allowing the reduction of variability between different examiners,[14-18] overcoming human limitations such as tiredness or distraction; and increasing the reproducibility of the exam.[1]

Image Acquisition

Much of the literature focuses on AI interpretation or analysis of already acquired images, but there is growing evidence regarding the use of AI technology for image acquisition by non-experts.[5,19-24] Automated technology can guide a non-expert examiner by recognizing incorrect images and the need for additional views or enhancements. It can also help standardize image acquisition and measurements.[1,6] In this way, it would be a tool used to optimize training and echocardiographic studies,[5,25,26] with the possibility of acquiring images of diagnostic quality comparable to those acquired manually by experts.[5,19,20,22-24] The technology is applicable in clinical practice, in emergencies, and in remote areas with scarce resources and few experienced professionals.[5,21,25,27]

Integration with clinical data

In the field of echocardiography, interpretation of exam findings is necessary to improve patient care and monitoring. Thus, training AI software to associate image data with patient clinical data allows the retention of relevant diagnostic information without the need for advanced analysis skills by an expert and without the expenditure of time and resources. Correlation with functional abnormalities, pathological states, prediction of outcomes, and risk stratification are examples of the usefulness of integrating algorithms with clinical data. The results presented by the study by Kusunose *et al.* support the possibility of using AI software for automated diagnosis of functional abnormalities, and the study by O'Driscoll *et al.* to calculate LVEF and GLS.[28,29] From a future perspective, the integration of AI software with clinical data could allow the creation of personalized therapies for each patient.

AI development

Databases of echocardiographic studies were used to train protocols and deep learning algorithms to detect cardiac dysfunction, identify anatomical abnormalities, and define workflows.[30-32] After training, the accuracy found was similar to the accuracies using conventional methodologies. This validation is essential since, in the development of AI software, both software and images come from external suppliers. The quality of the images used is a relevant point because, if the data entered is of low quality, biased, or restricted, the interpretation by the algorithm will be as well. A future challenge will be to develop deep learning algorithms that run on different equipment, have uniform naming standards, and store and retrieve data in a vendor-independent manner.[1]

Table 3 – Studies that use AI for integration with clinical data

Author/ year	Country	Study design and objective	N	Evaluated parameters	AI model	Main results
Kusunose *et al.*, 2019[32]	Japan	Prospective cohort. Investigate whether a DCNN could provide improved detection of RWMAs	300	Presence of wall motion abnormalities	ResNet, DenseNet, Inception-ResNet, Inception, and Xception	The results support the possibility of using DCNN for automated diagnosis of RWMAs in the field of echocardiography.
O'Driscoll *et al.*, 2022[33]	England	Retrospective cohort. Evaluate whether LVEF and GLS, automatically calculated by AI, increases the diagnostic performance of SE for CAD detection	512	LVEF and GLS at rest and stress	EchoGo Core 1.0, Ultromics	AI calculation of LVEF and GLS by contouring of contrast-enhanced and unenhanced SEs at rest and stress is feasible and independently improves the identification of obstructive CAD beyond conventional methods.
Asch, F.M. *et al.*, 2022[34]	Multicentric	Prospective cohort. Assess the hypothesis that AI-based analysis of echocardiographic images could predict mortality more accurately than conventional analysis by a human expert	870	LVEF, LVLS	EchoGo Core, Ultromics	AI-based analysis of LVEF and LVLS had similar feasibility as manual analysis and AI-based, but not manual, analyses were a significant predictor of in-hospital and follow-up mortality.

CAD: coronary artery disease; DCNN: deep convolutional neural network; GLS: global longitudinal strain; LVEF: left ventricle ejection fraction; LVLS: left ventricle longitudinal strain; RWMAs: regional wall motion abnormalities; SE: stress echocardiography.

Table 4 – Studies that developed an AI

Author and year	Country	Study design and objective	Number of patients	Evaluated parameters	AI Model	Main results
Asch *et al.*, 2019[38]	USA	Transversal Develop an algorithm and assess its feasibility and accuracy for automated quantification of LV EF by a well-trained expert computer against reference	99	LVEF	AutoEF (BayLabs)	A machine learning algorithm for the estimation of LV EF that avoids image segmentation and volume measurements is highly feasible and can yield results that are in close agreement with what experienced readers measure using conventional methodology.
Stowell *et al.*, 2021[35]	England	Transversal Develop a method based on machine learning, trained and validated with accredited experts from AI Echocardiography Collaborative	-	Left ventricle longitudinal tension	-	The open-source, vendor-independent AI-based strain measurement automatically produces values that agree with expert consensus as strongly as individual experts.
Tromp *et al.*, 2021[36]	Singapore	Transversal Develop a fully automated deep-learning workflow to classify, segment, and annotate two-dimensional videos and Doppler modalities in echocardiograms	-	-	-	Deep learning algorithms can automatically annotate 2D videos and Doppler modalities with similar accuracy to manual measurements by expert sonographers.

AutoEF: automatic ejection fraction; LVEF: left ventricle ejection fraction.

The incorporation of AI into clinical practice raises ethical concerns, primarily about responsibility, as care becomes more indirect, and transparency as the extent to which the patient needs to know and agree is called into question. It is worth remembering that the use of AI is already part of people's routine, and this type of technology is increasingly available to society. This interaction tends to be irreversible and, certainly, in medical practice - and in echocardiography - it will be no different. Even so, this is not a man versus machine competition. We cannot imagine a scenario in which one replaces the other. On the contrary, AI is in favor of the doctor and against the obscurity of human and systemic limitations, such as high demand, lack of specialists, ergonomics, and service exhaustion. Especially because, by increasing the operational effectiveness of the exam, there can be better use and direction of the specialist doctors' skills. It is expected that this incorporation will contribute to the democratization of access to the exam, representing an advance in health care.

However, this systematic review has its limitations. First, the vast majority of studies have a cross-sectional design. However, as our objective was diagnostic validation, studies with this design are sufficient to show the non-inferiority of their methods. Designs that study long-term association measures may better clarify the benefits of AI for the quality of longitudinal patient follow-up. Second, AI software usually requires a minimum image quality. Sometimes, patients with poor windows were excluded.[10,14,15] In several of the studies, the images analyzed were collected in ideal scenarios, by experienced specialists, or were packages from supplier centers. Therefore, larger studies with low-quality images, especially in patients with poor windows, hemodynamically unstable, or in non-ideal settings (ICU, emergency) should be encouraged. Third, most softwares are capable of measuring a limited number of parameters. Thus, further studies can validate the benefits of using AI beyond the parameters studied in this review.

Conclusion

The application of AI in the area of echocardiography has proven to be a highly effective and accurate method in four main domains (Central Illustration). AI provides the automation and standardization of images and respective measurements, which results in more accurate diagnoses, overcoming the limitations found in manipulation by a human sonographer. Furthermore, AI has also proven to be a facilitating tool in obtaining satisfactory results even when used by non-experts. The advantages offered by AI make the exam much faster and more accessible, as the duration of training for a specialist professional is one of the challenges of exam availability in public health. Therefore, as a result of the facts presented, AI is a beneficial resource that can be widely implemented in echocardiography services, as the advantages presented by the method cover a wide range of dimensions, from the accuracy of results and data integration for clinical correlation to the prevention of ergonomic diseases related to the sonographer's work.

Author Contributions

Conception and design of the research, acquisition of data and analysis and interpretation of the data: Neves HAF, Yuasa BS, Costa THLP, Santos IE, Benavides YMR, Lofrano-Alves MS; writing of the manuscript: Neves HAF, Yuasa BS, Costa THLP, Santos IE, Benavides YMR; critical revision of the manuscript for intellectual content: Lofrano-Alves MS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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