White Paper

The role of Artificial Intelligence in the Echocardiography workflow

Courtesy of Prof Luigi P. Badano
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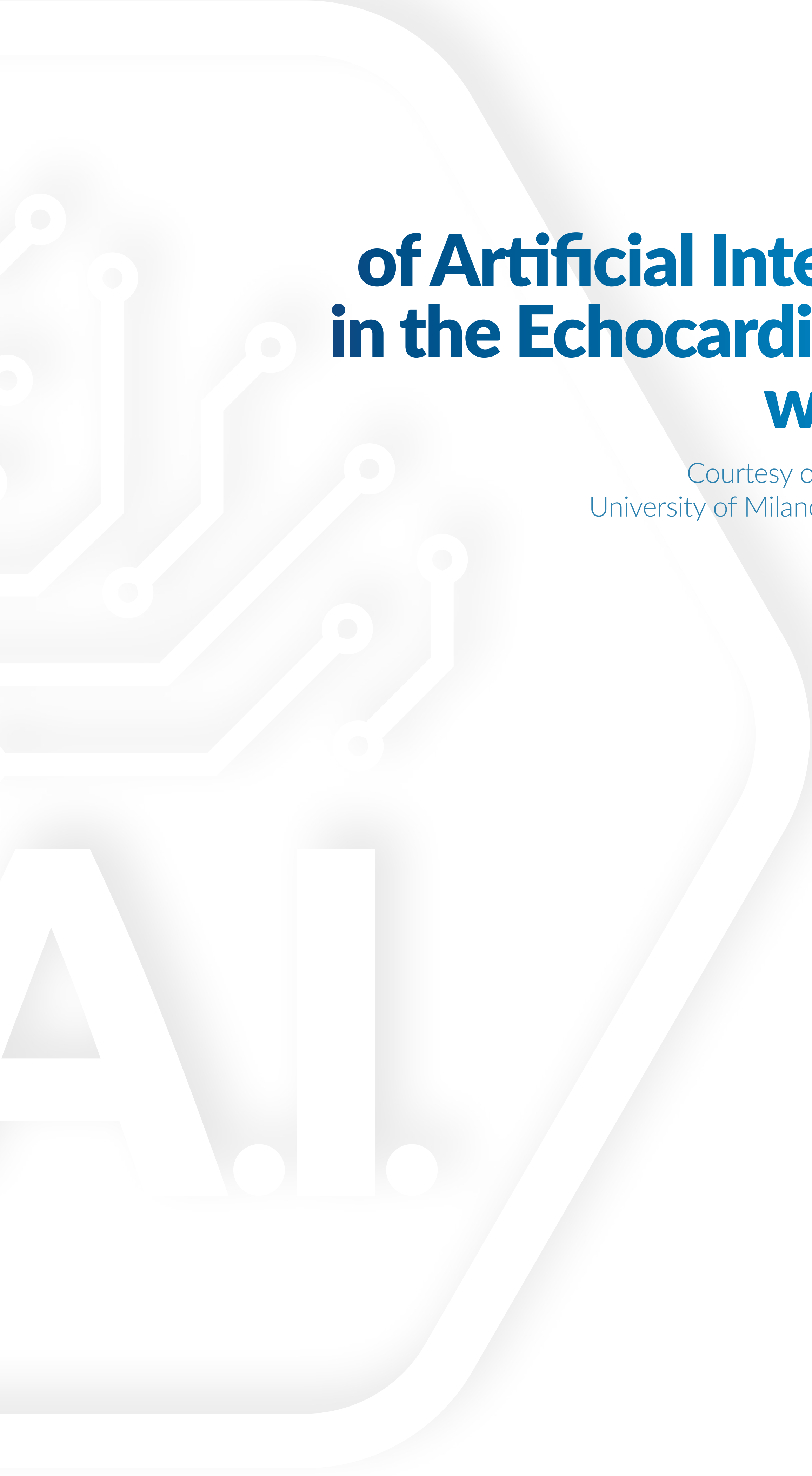

esaote

“Intelligence is an up-and-coming tool to help us in our cardio examinations, automating specific measurements.”

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Background

Cardiovascular diseases are a group of disorders of the heart and blood vessels and include coronary heart disease, cerebrovascular disease, valvular heart diseases, and other conditions. According to the World Health Organization, an estimated **17.9 million people die of cardiovascular diseases each year**. The prevalence of cardiovascular diseases has been increasing in recent years because of the progressive aging of the general population and the rise in cardiovascular risk factors such as obesity, diabetes, high blood pressure, and high cholesterol[1].

In addition, the number of patients with chronic cardiovascular diseases is also steadily increasing due to progress in treatment that have both improved survival rates in acute heart diseases and prolonged the life expectancy of patients with chronic conditions. As a result, the number of patients who need management of their cardiac condition is increasing worldwide.

Among the tests to diagnose and follow up patients with suspected or confirmed heart disease, echocardiography is by far the most frequently prescribed examination after electrocardiography. In 2022, 276,253,181 echocardiograms were performed worldwide and this number is expected to increase by 6% between 2023 and 2030[2].

This expected increase in clinical utilization of echocardiography is also driven by the versatility, safety, and clinical impact of the technique, which have expanded its use outside the cardiology department (e.g. in internal medicine, emergency departments, etc.). Advances in technology have made the test more accurate and accessible, resulting in earlier detection and treatment of conditions such as heart failure, cardiomyopathies, heart valve diseases, and pericardial diseases.

The increasing number of echocardiographic studies, and the use of this technique by non-cardiologists (internists, anaesthesiologists, nurses, emergency doctors, etc.) are raising new issues over the costs for the health system and the accuracy of the test. Precise and reliable echocardiographic assessment is required for clinical decision-making and patient management[3-6]. **All these issues will be crucial factors in the future of the technique and for patient care**.

The introduction of artificial intelligence (AI) can help to standardise the acquisition of the images and to speed up and increase the reproducibility of the measurements.

By standardising and automating the processes, a faster workflow is achieved while maintaining the quality of the exam and reducing operator stress.

For example, measurement of left ventricular volumes to obtain ejection fraction (LVEF) is heavily dependent on image quality and operator experience. AI may help to overcome these issues. The AI algorithms may provide assistance to standardise the acquisitions (e.g. avoiding foreshortening of apical views) and provide automatic endocardial border tracing to reduce both inter-operator and test/re-test variability[7].

AutoCM (Auto Cardio Measurements)

A critical step in producing the echocardiographic report is the quantitative assessment of the geometry and function of cardiac structures. Traditionally, users were required to access the measurement menu manually and choose the appropriate measurement according to the image/trace displayed. In recent years, Esaote ultrasound systems have implemented software packages to improve the workflow of the echocardiographic examination.

The accurate measurement of left ventricular dimensions in the parasternal long axis view is useful to assess left ventricular geometry and functions. AI offers a valuable tool for automating this process, resulting in rapid and semi-automated measurement of these wall thickness and left ventricular linear dimensions.

Esaote AutoCM can identify the anatomical structures, measure wall thicknesses and left ventricular diameters, and calculate the mass and fractional shortening of the left ventricle with just one click. The process is straightforward: identification by the clinicians of the correct diastolic frame in the parasternal long axis view (**Figure 1**), selection of the left ventricular dimension folder in the measurement menu, then the AI-based software package automatically identifies the endocardial points to measure intra-ventricular septal thickness (IVS), left-ventricular internal diameter (LVID) and left-ventricular posterior wall thickness (LVPW).

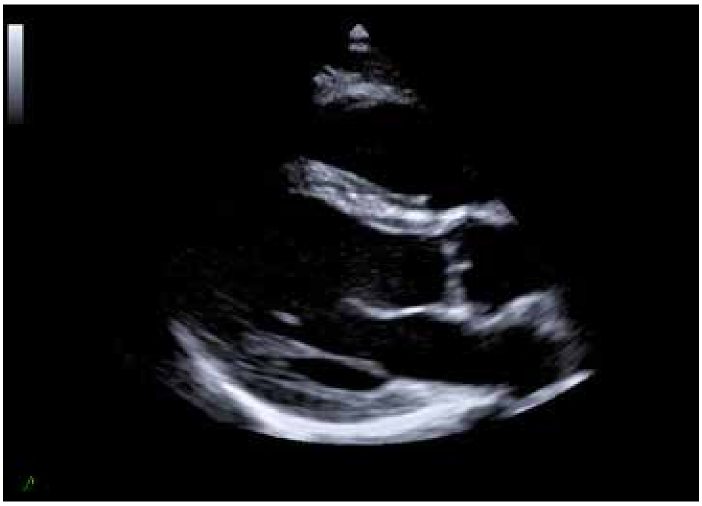
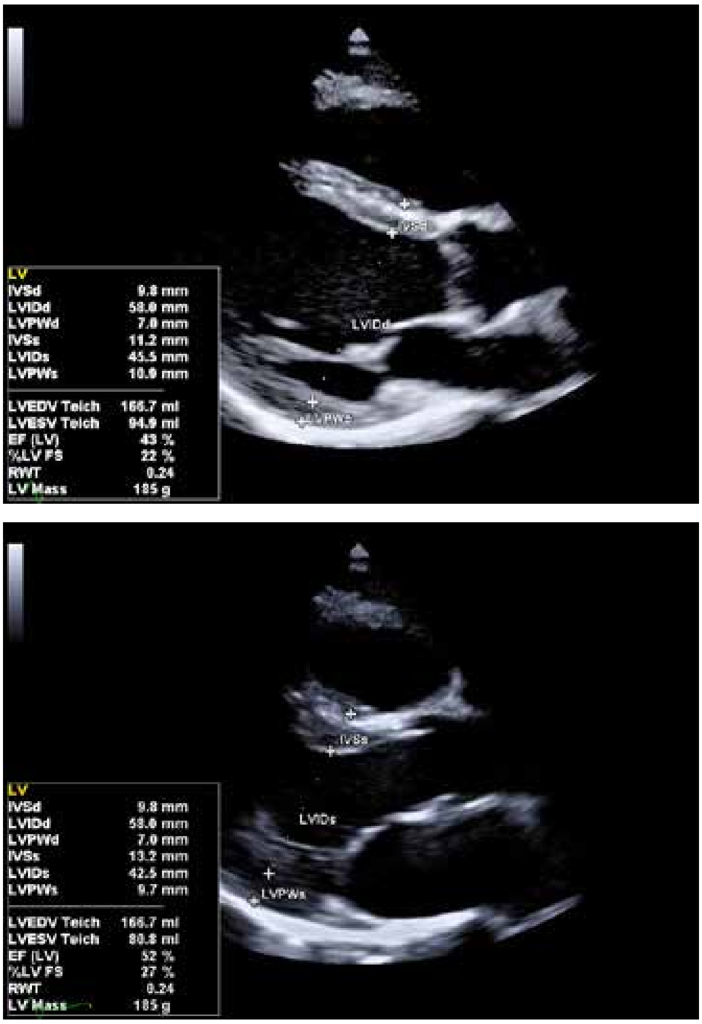


Fig. 1: Parasternal long axis (PLAX)

In just a few clicks, AutoCM offers:

- Measurement in one second of intraventricular septal thickness (IVS), leftventricular internal diameter (LVID) and leftventricle posterior wall thickness (LVPW), and calculations of mass and fractional shortening (**Figure 2**, **Clip 1**)
- Reduced intra-operator variability and increased reproducibility of measurements.



LV	
IVSd	9.8 mm
LVIDd	58.0 mm
LVPWd	7.0 mm
IVSs	11.2 mm
LVIDs	45.5 mm
LVPWs	10.9 mm
LVEDV Teich	166.7 ml
LVESV Teich	94.9 ml
EF (LV)	43 %
%LV FS	22 %
RWT	0.24
LV Mass	185 g

LV	
IVSd	9.8 mm
LVIDd	58.0 mm
LVPWd	7.0 mm
IVSs	13.2 mm
LVIDs	42.5 mm
LVPWs	9.7 mm
LVEDV Teich	166.7 ml
LVESV Teich	80.8 ml
EF (LV)	52 %
%LV FS	27 %
RWT	0.24
LV Mass	185 g

Fig. 2: AutoCM measures in PLAX

Clip 1: AutoCM

AutoEF

Left ventricular ejection fraction (LVEF) is one of the pivotal measurements to address the management of patients with heart failure, myocardial infarction, revascularisation, valvular diseases, chemotherapy, cardiomyopathies, etc.

The accurate assessment of LVEF by two-dimensional echocardiography requires operator experience and skill to identify the correct end-systolic and end-diastolic frames, in the apical four- and two-chamber views, and the precise tracing of the endocardial borders.

AutoEF, powered by artificial intelligence, can identify the end-diastolic and end-systolic frames of the selected four- or two-chamber view using scan plane recognition, and can automatically trace their endocardial border (**Figure 3**).

Fig. 3: AutoEF

AutoEF is a fully automated software package based on deep learning methodology. It has been developed to:

- Minimise the time required to obtain LV volumes (to **3 seconds**) (**Clip 2**)
- Reduce intra- and inter-operator variability in LV volume calculations

Clip 2: AutoEF

Validation approach

These volumetric results are compared with ED, ES volumes and EF results from manually annotated ED and ES contours by a trained annotator. The volumes are determined using the monoplane Simpson rule. The resulting ED and ES volumes (within one cardiac cycle) are used to determine EF.

Additionally, the Dice score is calculated for every automatic LV segmentation contour and for the manually annotated LV contour.

The validation of the automatic LV segmentation has been performed on the data sets as set out above, which were not part of the training or testing sets used during the learning process of the algorithm. Comparison of the automatic and manual LV contours resulted in an average Dice score of 0.96 ±0.02 for the ED phase and 0.94 ±0.03 for the ES phase.

XStrain™

The European Association of cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE) associations recommend reporting LV myocardial strain analysis alongside LVEF in the report of the echocardiographic exams. Compared to LVEF, LV global longitudinal strain (GLS) is considered a more sensitive marker of myocardial function, to detect subclinical myocardial dysfunction in patients with LVEF within the normal range.

Two-dimensional speckle tracking echocardiography (2DSTE) is a greyscale-based, angle-independent technique used to assess myocardial deformation throughout the cardiac cycle. Myocardial deformation is quantified as strain (the percentage of the shortening of a myocardial segment during systole compared to its diastolic length) or strain rate (the velocity at which the strain occurs).

The XStrain™ software package identifies the bright endocardial speckles generated by the scattering of the ultrasound beam after its interaction with the blood myocardium interface and follows them frame by frame throughout the cardiac cycle. Then, using an algorithm, it calculates the magnitude of myocardial deformation in longitudinal and circumferential directions and generates strain and strain-rate curves.

Taking advantage of the latest Esaote technology powered by AI, XStrain™ can automatically detect the endocardial border of the three LV apical views (e.g. four-chamber, two-chamber, and apical long-axis).

Artificial Intelligence offers:

- User-friendly methodology
- Time savings in everyday routine workflow
- Reproducibility, reducing intra-operator variability (**the average Dice coefficient across all cases was 0.92 with a standard deviation of 0.023**).

The system works semi-automatically, requiring user interactivity in the recognition of the correct echo view. In the meantime, AI can automatically detect the diastolic frame and traces the endocardial border (**Figures 4-5**).

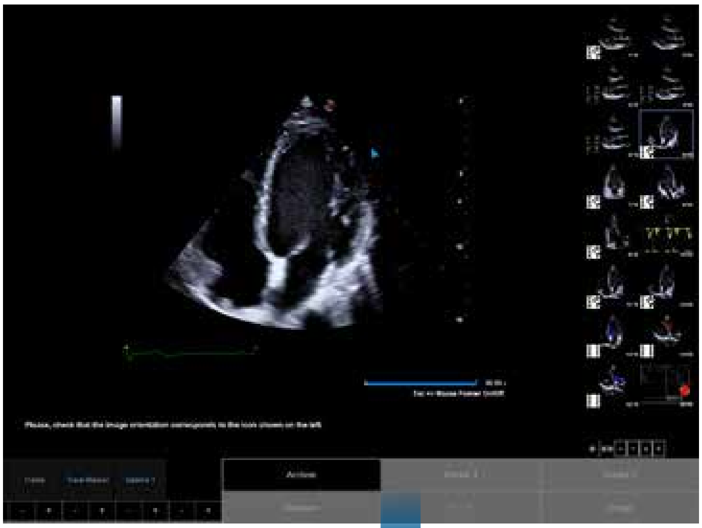


Fig. 4: XStrain™ in four-chamber view

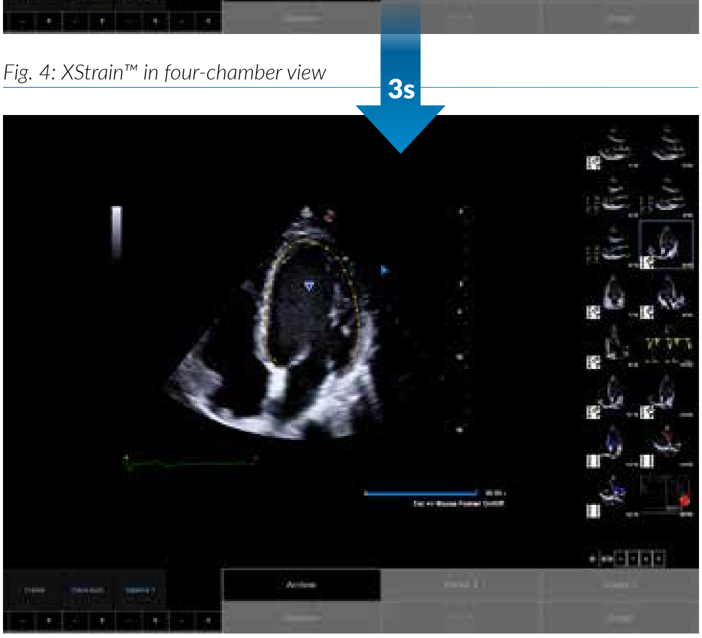
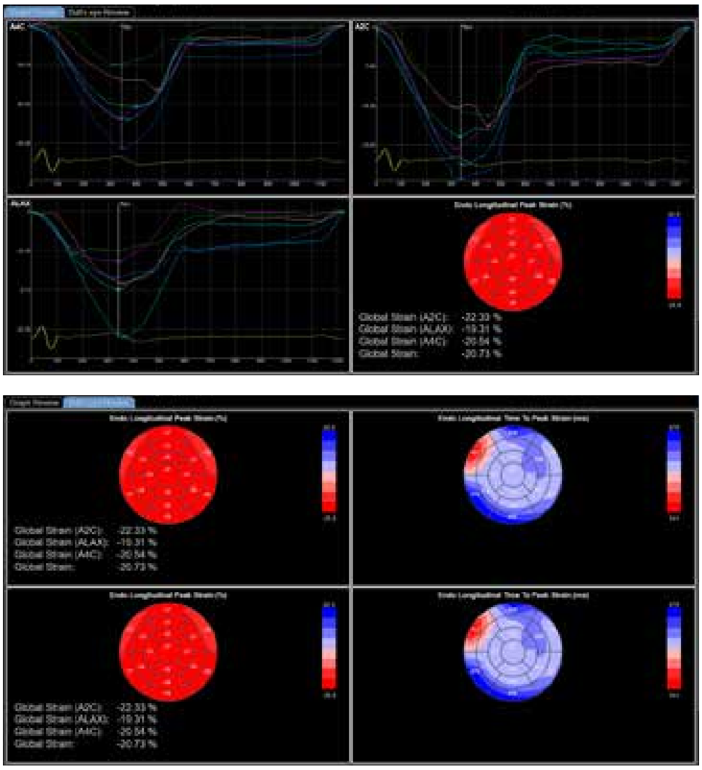


Fig. 5: XStrain™ auto-contouring

Segmental myocardial strain, strain curves, LV GLS and strain rate values, and bull's-eye graphs can all be obtained in a few seconds (**Figure 6-7**).



Global Strain (A2C): -22.33 %
Global Strain (ALAX): -19.31 %
Global Strain (A4C): -20.54 %
Global Strain: -20.73 %

Global Strain (A2C): -22.33 %
Global Strain (ALAX): -19.31 %
Global Strain (A4C): -20.54 %
Global Strain: -20.73 %

Global Strain (A2C): -22.33 %
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Global Strain (A4C): -20.54 %
Global Strain: -20.73 %

Fig. 6-7: XStrain™ bull's-eye view

XStrain™ AI in no way prevents the user from performing self-segmentation and editing the related values. In each step of the process, the data processing can be repeated or adjusted, including in semiautomatic or manual segmentation using the threepoint method.

The validation test was performed as follows:

Automatic segmentation uses two machine learning algorithms, one for the apical 4- and 2 chamber views, and one for the apical long-axis view. Both algorithms were trained using a fixed (locked) static dataset. The apical 4- and 2 chamber views algorithm was trained on 373 image runs, of which 294 were used for training and 79 for testing. The apical long axis view algorithm was trained on 218 image runs; 176 for training and 42 for testing.

The subjects enrolled were aged ≥18 and had a variety of LV functional states, but all had a regular heart rate.

The input for the learning was as follows:

- Pixel data
- The binary mask of the LV blood pool
- The left hinge point of the mitral valve
- The right hinge point of the mitral valve (apical 4- and 2 chamber views) or the LV outflow tract border point (apical long axis view)
- The apex point

All reference annotations were made by a trained annotator.

In order to validate the accuracy of the LV segmentation, the segmented contours were compared to annotations on the same frames by a trained annotator, conducted on a data set that contained a mix of apical 4- and 2 chamber, and apical long-axis views. The average Dice coefficient over all cases was 0.92 with a standard deviation of 0.023.

Clip 3: XStrain™

Conclusions

Echocardiography is the most frequently used cardiac imaging test, but it also entails a high level of knowledge of the method and sampling of measurements. This is due in particular to the number of quantitative parameters to be obtained, which, moreover, are increasing as a result of the new systems' calculation capacity. Meanwhile, the prevalence and the complexity of cardiovascular diseases continue to increase grow, and the need for accurate image acquisition and accurate quantification are expected to rise likewise[8].

AI is becoming a necessary tool to reduce the time needed to perform echocardiographic examinations and to improve the accuracy and reproducibility of the measurements. Despite the promising potential of AI in echocardiography, certain challenges and limitations also need to be addressed. One of the major challenges is the lack of large, high-quality datasets to train AI algorithms, the black boxes of many AI algorithms, medical responsibility for mistakes linked to the use of AI, etc. In conclusion, AI has the potential to revolutionize echocardiography by enhancing the accuracy and efficiency of this technique, given its ability to aid in image acquisition and processing. However, the challenges and limitations of AI in echocardiography need to be addressed to ensure its safe and effective integration into clinical practice.

Finally, application of AI to echocardiography is not intended to replace physicians but to improve their productivity, workflow, and diagnostic performance[8]. Cardiologists and clinicians will determine the capability of AI in diagnosis, and they will remain responsible for final decisions.

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