Artificial Intelligence for the Automated Quantification of Left Ventricular Ejection Fraction, Volumes and Strain

Ultromics has developed EchoGo, an AI driven automated system to assist in the assessment of cardiovascular function in adult transthoracic echocardiograms.

EchoGo Core combines advanced computational vision, artificial intelligence (AI), longitudinal datasets and clinical insights to provide automated analysis of the left ventricle.

The image-based analysis tool processes echocardiograms to report left ventricular global longitudinal strain (GLS), left ventricular ejection fraction (LVEF) and left ventricular volumes (LV Volumes) to support clinicians in the assessment of left ventricular function.

EchoGo Core combines several convolutional neural networks (CNN) to detect the optimal tomographic view selection, identifies the correct end-diastolic and end-systolic frames and auto-contours the endocardium in the apical four and two chamber views.

Following acquisition, echocardiographic images are automatically sent to the Ultromics platform for analysis, where the system provides a report back to the clinician within minutes for consideration while interpreting studies. This is a zero click and zero variability system. The returned report includes numerical results for LVEF, LV Volumes and GLS.

Automated Myocardial Strain Imaging is here to stay in Echocardiography

EchoGo Core automates the calculation of LVEF and LV Volumes, which conventionally require manual traces of the left ventricular cavity. While LVEF and LV volumes have conventionally been the standard for evaluating left ventricular systolic function, myocardial strain imaging has emerged as a valuable tool in assessing left ventricular function.

EchoGo Core also automates the calculation of GLS which is conventionally a manual process requiring expensive additional packages on the ultrasound machine or off-line analysis products.

The cardiovascular community has been evaluating the utility of measuring Strain as a means of assessing myocardial function for well over a decade.

Over this time many advancements have been made in echocardiography technology, from the improvement of hardware resolution to the utilization of artificial intelligence. These advancements have greatly improved our ability to leverage strain as a key indicator for monitoring subclinical changes of left ventricular function.

While the measurement of Strain has been the cause of much debate in the cardiology community, its sensitivity for measuring early changes in myocardial function is now widely accepted.

An increasingly popular measure of left ventricular function is global longitudinal strain (GLS) as it is more sensitive to subtle functional changes than ejection fraction[4].

In particular, GLS has emerged as one of the most valuable markers for global LV function compared to circumferential and radial strain as it is more reproducible and more useful clinically, and is shown to be superior to LVEF.

GLS provides important information with regard to prediction of outcomes and early subclinical disease in areas of cardiotoxicity, heart failure and heart transplant[1].

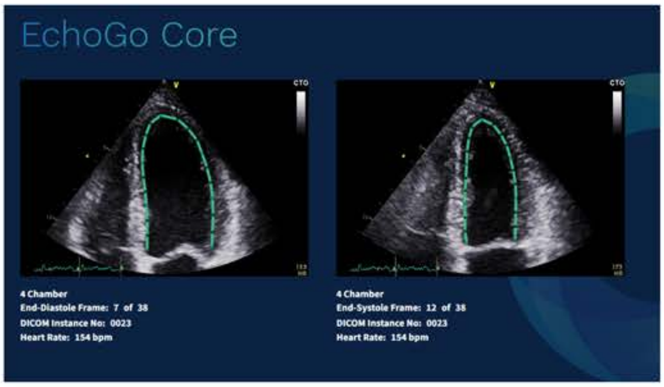
Focus on Artificial Intelligence and Machine Learning Technology

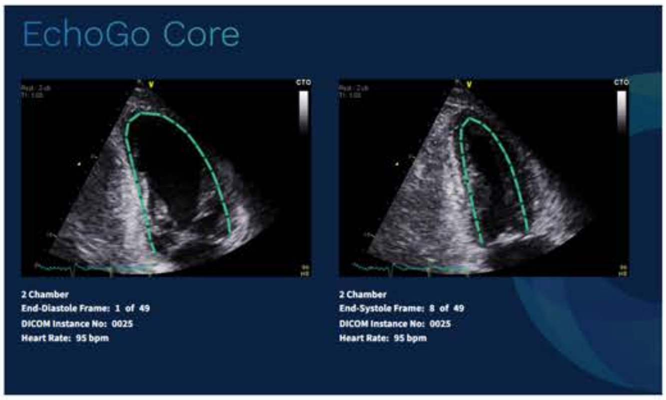
EchoGo Core strives to reduce subjectivity at every step in the clinical post-processing pipeline.

In traditional analysis, results provided from post-acquisition analysis of echocardiograms largely depend on the practitioner and the analysis package used[1-4], leading to concerns over the reliability and clinical utility of results. Variability is introduced in many of the analysis steps, for example: selecting the cardiac views, identifying key points in the cardiac cycle, and outlining the endocardial border. Moreover, the analysis can be time-consuming[5], decreasing the possible throughput in the clinical workflow, and leading to burnout of healthcare staff[6-8].

EchoGo Core eliminates subjectivity and decreases processing time at every step in the clinical post-processing pipeline, thereby providing robust, reliable, and rapid analysis of echocardiograms.

This automated and scalable analysis pipeline consists of multiple sophisticated algorithms, including deep learning techniques, developed by an interdisciplinary team working on datasets from large multi-center trials across multiple continents. The datasets encompass many clinical scenarios including poor image quality, thereby enabling application of this tool in many realistic clinical settings.





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The AI Pipeline

The below image displays a schematic of an example analysis pipeline in which the following steps take place:

1) Input Video - file loading, in which a DICOM file is loaded and assessed for any technical flaws;

2) View Classification - the view is detected using a deep learning model;

3) Automated Contouring - knowledge of the view enables automatic choice of the best neural network for segmentation of the left ventricle;

4) Cycle Selection - from the left ventricular endocardial borders, a suitable cardiac cycle is identified, including specifying the end-diastolic and end-systolic frames;

5) Feature Calculations - clinical measures, including LVEF, LV Volumes and GLS can be automatically derived from the cardiac cycle. Variations on this pipeline can be developed depending on specific clinical requirements.

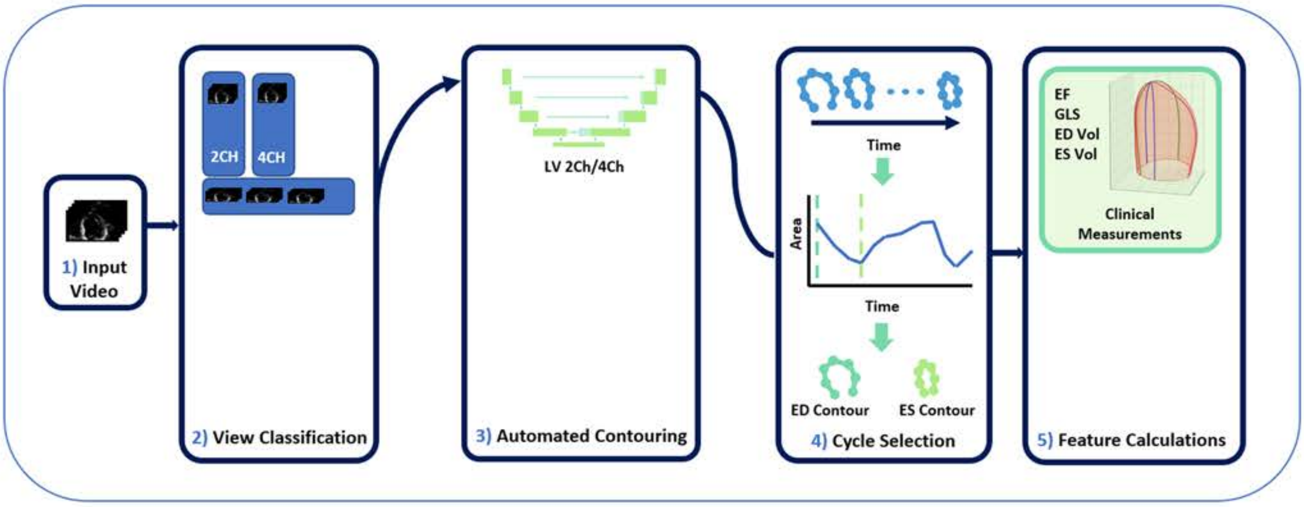


Figure 1: The fully automated analysis pipeline is shown progressing from left to right. An input video from a DICOM file is read and the view classified into one of eight classes. This determines which of the auto-contouring models is to be used. From the contours an appropriate cardiac cycle is algorithmically selected, from which an end-diastolic and end-systolic contour are passed to the next module. Here, various geometric features and sophisticated automated diagnostic calculations can be computed, e.g. LVEF, LV Volumes and GLS.

In order to perform frame selection, relevant DICOM tag information is extracted, including the number of frames, the time between frames and heart rate. An approximate for the cardiac cycle start frame, end frame, and number of frames in the cardiac cycle is determined using a proprietary formula. To calculate the end-diastole and end-systole frames, the area at every frame is calculated using Gauss's area formula and a rule-based algorithm is applied to detect if the selected cycle is reversed. For frames in one end-diastole to to end-systole sequence that are within a given proportion of cardiac cycle number of frames, the end-diastole and end-systole contours are extracted from a set of contours by considering many possible end-diastole and end-systole candidates, before removing those with area differences less than a given threshold, or area ratios less than determined thresholds. After this filtering, the final filtered candidate with the largest area difference is chosen. This approach allows for the robust extraction of cardiac cycles from the echo image.

EchoGo Core Perfomance Evaluation

Accuracy and precision was assessed against commercially available software. Over 300 studies were processed by five professionally accredited operators. EchoGo Core was shown to provide accurate and robust measurements of LVEF, LV Volumes and GLS. Inter-operator variability demonstrated improved precision when using automated EchoGo Core.

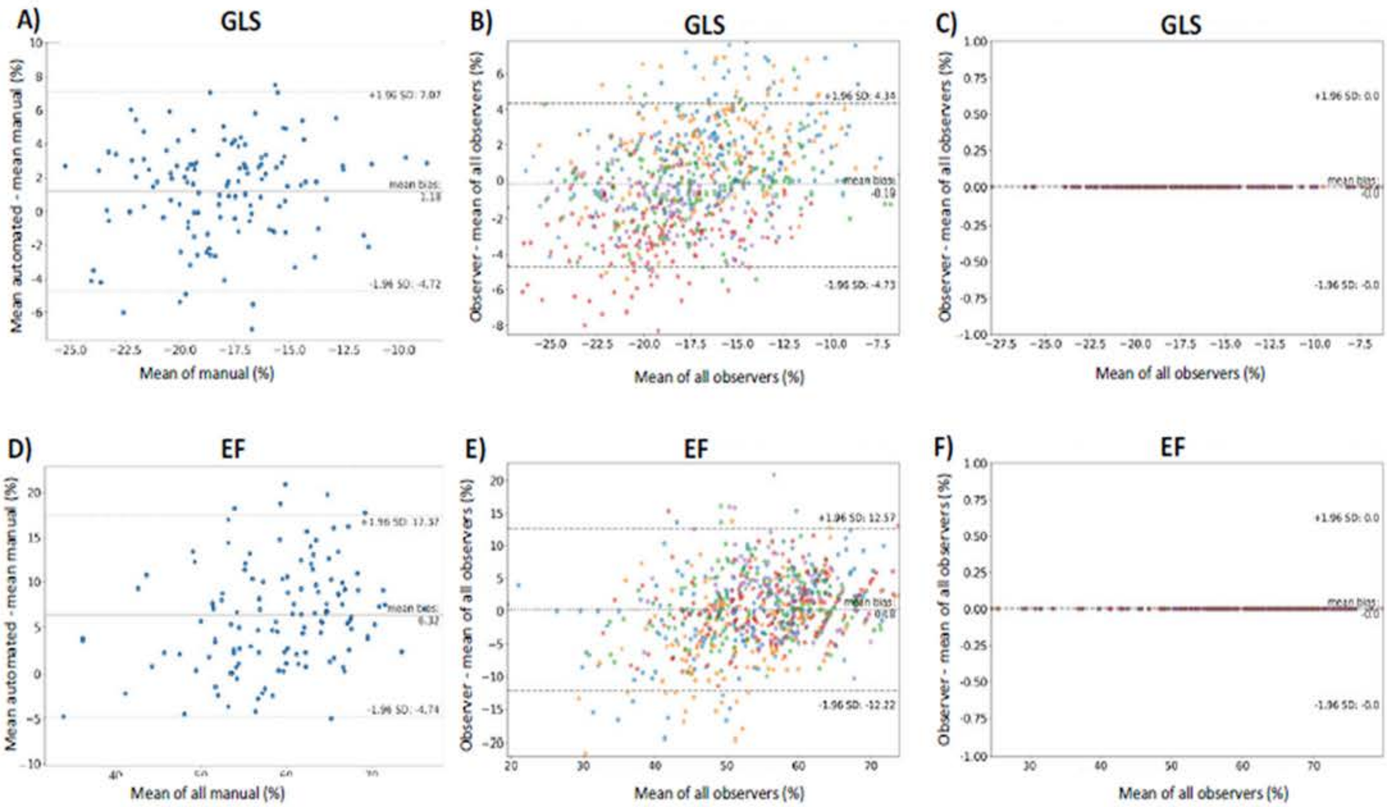


Figure 2. The CNN based LV segmentations were quantitatively assessed using ejection fraction (EF) and global longitudinal strain (GLS) values against commercially available software that required manual contouring by means of Bland-Altman plots. EF and GLS values produced by five operators using current practices were compared to those produced by the automated CNNs (A and D, respectively). Inter-observer reproducibility between 5 operators calculating EF and GLS using routine clinical practice were compared by means of Bland-Altman plots (B and E, respectively). Inter-observer reproducibility between 5 repeated calculations of EF and GLS using the automation CNNs were compared by means of Bland-Altman plots (C and F, respectively).

Validation and Comparisons

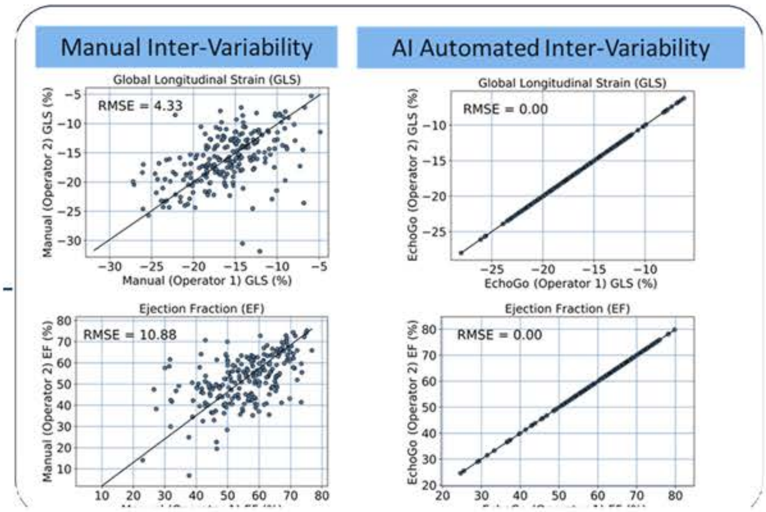
The efficacy of the network's segmentation performance was assessed using the Sørensen-Dice Coefficient (DC) compared to 550 frames contoured by 3 trained echocardiographers, included images acquired across 7 ultrasound manufacturers and models from 12 clinical sites. The DC for the LV segmentation models were greater than 90%.

To assess the accuracy and precision of EchoGo Core and ED/ES frame selection, 378 unseen patients' resting echocardiograms were processed, respectively, by six qualified echocardiographers and cardiologists. As a quantitative comparator representing routine clinical practice, the same images were processed using typical clinical echocardiogram quantification software by five qualified echocardiographers and cardiologists.

All operators were blinded to the patient information and output from both applications. Each application was used to compute ejection fraction (EF), global longitudinal strain (GLS) and volumes at ED and ES. Inter- and intra-observer variability was assessed. EF and GLS values were compared to the mean value derived from 5 independent quantifications as per routine clinical practice.

Additional comparison to CMR was also conducted for 34 healthy subjects. For quantitative assessments, RMSE, Deming regression plots and Bland-Altman analysis showed good agreement to cardiac magnetic resonance imaging (CMR) data (0.7% and -4.2 bias for EF and GLS, respectively).

When comparing values derived from routine clinical practices against those produced by EchoGo Core, RMSE values of 5.02% and 2.89% for EF and GLS, respectively, were demonstrated. An inter- and intra-observer RMSE of up to 4.7% for GLS and 12.0% for EF was observed when the same images were processed by five operators using routine clinical software. In comparison, no variation was observed (0% RMSE for EF, GLS, respectively) when using EchoGo Core.



Accuracy of EchoGo Core

Measure	n	Bias (CI)	Comparitor
Global Longitudinal Strain (%)	124	1.17 (0.64 - 1.70)	Cardiac Ultrasound - Manual Tracing
Ejection Fraction (%)	124	6.36 (5.36 - 7.35)	Cardiac Ultrasound - Manual Tracing
Global Longitudinal Strain (%)	34	-0.85 (-2.24 - 0.54)	Cardiac MR - Short axis stack
Ejection Fraction (%)	34	-3.34 (-6.07 - -0.60)	Cardiac MR - Short axis stack

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Artificial Intelligence-based product for clinical use in Echocardiography

• EchoGo Core provides automated view selection and contouring that generates accurate and precise numerical measurements of LVEF, LV Volumes by utilizing artificial intelligence and machine learning technologies.

• EchoGo Core also applies these technologies to automate global longitudinal strain.

• GLS has emerged as a valuable tool for the assessment of left ventricular function complementing conventional measures of LVEF and LV Volumes.

• EchoGo Core has been extensively tested and validated to ensure a reliable and credible alternative to conventional solutions.

• Additionally, the automated nature of the AI and ML utilized by EchoGo Core provides an attractive replacement to the conventional manual workflows that require costly and time-consuming manual steps to obtain these measurements.

• Artificial Intelligence and machine learning technologies, when applied to echocardiography, prove to be a valuable step in the more efficient ubiquitous adoption of automated LVEF, LV Volumes, and GLS to the broader echocardiographic patient spectrum.

Full Automation Service
EF, GLS, LV Volumes with Zero Variability

EchoGo CORE

Rapid 'Zero Click' Workflow

Zero-click operations and AI service delivers simplicity through automation, potentially saving up to 15 mins per study

High Precision

Accurately analyzes cardiac function, enabling physicians to make confident diagnostic decisions regardless of skill level

Zero Variability

Automatically selects best clip, defines contours and quantifies cardiac analysis, delivering high reproducibility and accuracy

Drives Value

Increases revenue through myocardial Strain imaging with new CPT code +93356, from January 2020

Full Stack Service

Delivers analysis to any vendor at any scale, through a cloud-based service with 24-hour support and class-leading security

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EchoGo Core is FDA-cleared for use in the United States, not CE Marked for use in the UK and European Union

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