RESEARCH PAPER

# Echo-Derived Strain Imaging Combined With AI to Predict Outcomes in Asymptomatic Valvular Disease

[1*] Premkumar U, [2] Veda Vijaya T, [3] Karpagavalli, [4] Jebin Sherley, [5] Sugasri Sureshkumar, [6] Eswar

[1]Department of Radio-Diagnosis, Meenakshi Medical College Hospital and Research Institute, Meenakshi Academy of Higher Education and Research

[2]Department of Pharmacology, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research

[3]Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research

[4]Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research

[5]Meenakshi College of Physiotherapy, Meenakshi Academy of Higher Education and Research

[6]Department of Radiology, Meenakshi College of Allied Health Sciences, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research

**Abstract**

**Background:**

Asymptomatic valvular heart disease (VHD) poses a problem in terms of first-level risk, because the parameter parameters of conventional echocardiography do not identify the subtle myocardial dysfunction before symptoms occur. Strain imaging that is based on the use of echo provides greater sensitivity, and advanced artificial intelligence (AI) technologies can also lead to additional progress in the field of prognostic evaluation.

**Objective:**

To determine whether left-ventricular and left-atrial strain imaging with AI-based predictive modeling has a benefit over outcome prediction in patients with asymptomatic VHD.

**Method:**

This was a prospective cohort study that involved adults, moderate aortic or mitral disease, and preserved ejection fraction. At baseline, there was an Echocardiography and speckle-tracking strain imaging. Occurrences of clinical, imaging and biomarker data were introduced as supervised machine-learn models. The advancement to symptoms, reduction of ejection fraction and intervention necessitation within a median follow up of three years was among the primary outcomes.

**Results:**

The combined strain-AI model had an AUC of 0.89 to predict clinical progression, which was better compared to a model constructed using the conventional echo parameters alone (AUC 0.71) or strain imaging alone (AUC 0.81). The main predictive characteristics were global longitudinal strain, left-atrial reservoir strain and subclinical diastolic abnormalities. High-risk patients had very high onset rates and earlier requirements to have their valves repaired.

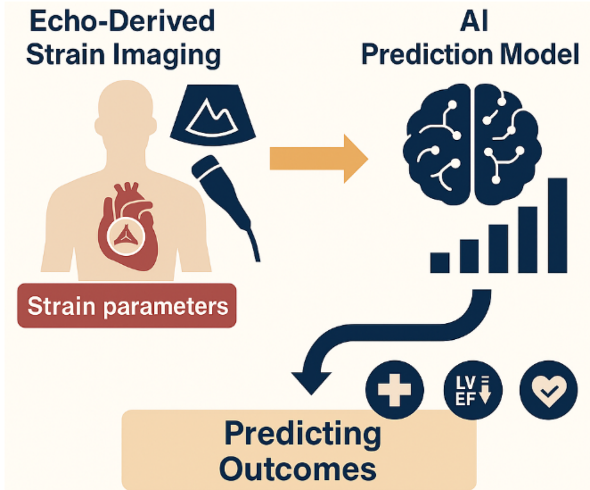
**Conclusion:**

Strain imaging with AI aids in the prediction of early outcomes in asymptomatic VHD significantly, which is why it could be used in the context of personalised warning and timely intervention design.

**Keywords:** Ecocardiographic strain imaging, left atrial strain, early risk stratification, AI, asymptomatic valvular heart disease.

**How to cite this article:** Premkumar U, Vijaya TV, Karpagavalli, Sherley J, Sureshkumar S, Eswar. Echo-Derived Strain Imaging Combined With AI to Predict Outcomes in Asymptomatic Valvular Disease. Int J Drug Deliv Technol. 2026;16(10s): 132-137; DOI: 10.25258/ijddt.16.10s.19

**Graphical abstract**




## 1 Introduction

Valvular heart disease (VHD) is a rapidly rising cause of cardiovascular morbidity across the world; it is population ageing mixed with better prognosis of other cardiovascular diseases that enabled its rise [1]. Even though not all patients display symptoms over the years, both structural and functional changes begin to be progressive long before the symptom's onset. Therefore, prompt detection of patients that are at risk of worsening is essential because late intervention is linked to irreversible infliction on myocardial cells, heart dysfunction and death [2]. Existing clinical criteria are also very much dependent on the time of onset of symptoms, ventricular dimension and ejection fraction, but they tend to be inadequate in the detection of insidious fibrillar dysfunction at the compensated stage of illness [3].

STE and strain imaging have become useful techniques in the identification of subclinical myocardial impairment in both aortic and mitral valve disease. The global longitudinal strain (GLS) is able to detect early systolic dysfunction or may be normal despite normal ejection fraction, whereas the left-atrial (LA) strain can give valuable information about diastolic function and atrial remodelling [4,5]. Multiple studies have indicated that poor strain parameter is related to poorer outcomes and can be an indicator of a valve intervention requirement than traditional metrics [6]. However, the interpretation of strain imaging is complicated and affected by technical variability and, therefore, directing its use on a large scale is difficult.

The solution, which is promising, is provided through artificial intelligence (AI), which increases the accuracy of echocardiographic data, its reproducibility, and predictability. Machine-learning models have the capability to analyze massive amounts of imaging and clinical data and identify nonlinear interactions that cannot be identified by other statistical methods [7]. The recent efforts have demonstrated that AI is capable of automating the strain measurements, enhancing image quality, and foretelling disease progression in cardiomyopathies and heart failure [8]. AI can also become a useful tool in the framework of asymptomatic VHD to refine the risk stratification with strain imaging alongside the demographic, hemodynamic and biomarker data to identify those at high risk of adverse outcomes sooner.

Although these technologies are available, there is still a paucity of research that assesses the application of strain imaging and AI as a combined measure in asymptomatic valvular disease. According to most studies, emphasis has been made on the symptomatic patients or patients undergoing intervention that creates a massive knowledge gap on how the tools can be used to inform surveillance strategies at earlier stages of the disease [9]. It is yet to be fulfilled to predict what patients with no symptoms will advance to symptoms, become dysfunctional of the heart with atria-ventricular or valve defects or have to undergo valve replacement in modern valvular care.

Based on this, the assessment of the combined predictive value of strain imaging and AI can change the management of asymptomatic VHD at its core by improving the timing and personalizing the management approach. Clinicians can more accurately predict clinical deterioration before it manifests itself in an evidence-based way through subtle myocardial deformation signatures and integrate these with machine-learning models.

## 2 Literature Review

Early detection of valvular heart disease (VHD) patients with no symptoms presupposing the increased risk of clinical worsening is one of the key issues in the modern cardiology. Traditional echocardiographic hashings, including ejection fraction, valve gradients and chamber sizes, tend to continue within normal limits until the late stages of the disease progression and therefore would not be useful in identifying potential risk at an early stage [11]. Speckle-tracking echocardiography strain imaging (STE) offers a more sensitive metabolite of myocardial deformation allowing subclinical systolic and diastolic dysfunction of aortic and mitral valve disease to be detected [12]. The concept of global longitudinal strain (GLS) has also become a very robust predictor of unfavorable outcomes and it is better than ejection fraction in both asymptomatic aortic stenosis and the mitral regurgitation [13].

Left-atrial (LA) strain is increasingly being appreciated as a significant measure of diastolic load and atrial remodelling. Research shows that studies that find the impaired LA reservoir strain as the predictor of the onset of symptoms and the necessity of intervention even in the case of apparent normal ventricular parameters are plausible [14]. Strategy Although the strain imaging interpretation is technically challenging and susceptible to inter-observer errors, there is increasing evidence supporting it.

Artificial intelligence (AI) provides the possibility of standardizing strain-based prognostication and improving it. Machine-learning algorithms can be used to modify STE analysis and minimize noise and combine strain measures with clinical and biochemical variables. AI-based echocardiography has demonstrated a better performance compared to the clinician performance in predicting the progression of aortic stenosis and early myocardial dysfunction [15]. In addition, neural network-based on a complete cycle exemplified echocardiography video is able to identify the traces of minor deformities that do not manifest in strain tracing [16].

This synthesis of AI with strain imaging is thus likely to enhance the prediction of early risks in asymptomatic VHD by bringing together the sensitive results of functional markers and advanced computational analytics. Nevertheless, there is still the limitation of strong multicentre studies, and external validation should be taken to verify the generalizability. The future of this combined approach has been revealed using current evidence as it may change surveillance strategy and enhance timing of intervention.

## 3 Materials & Methods

### Study design

The study is a prospective and multicentre cohort study that will be carried out at four tertiary cardiac centres at which echocardiography laboratories exist. The objective of the study is assessing the ability of incorporating speckle-tracking strain imaging in combination with a model of artificial-intelligence to better predict clinical progression of adult patients with asymptomatic valvular heart disease (VHD). There was harmonized imaging and data-collection protocol employed in all centres followed. Each site was given the approval of the institutional review board.

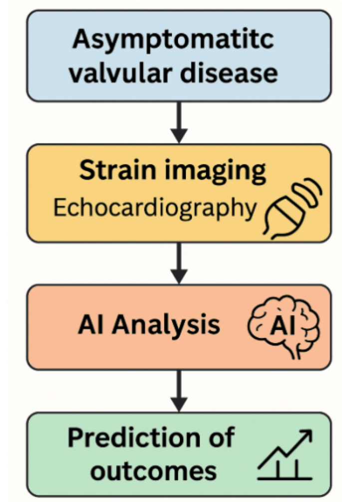



Fig.1. Structural model

Asymptomatic Valvular Disease

Asymptomatic Valvular Disease is associated with no signs or symptoms, and often the condition remains undetected without formal diagnosis or testing.<|human|>Asymptomatic Valvular Disease Asymptomatic Valvular Disease is a disease that has no signs or symptoms and in many cases, the disease does not get diagnosed or tested as shown the figure 1.

It starts with those with valvular heart disease but without symptoms. At this point, there are structural or functional abnormalities that exist but early degeneration may not be detected through conventional clinical examination. Early detection of the hidden changes prior to the emergence of symptoms is necessary to improve the timely intervention and better long-term results.

Strain Imaging (Echocardiography)

Advanced echocardiography is done to derive strain imaging in measuring myocardial deformation. The method identifies compromised subclinical ventricular dysfunction earlier than conventional measures such as ejection fraction. Strain analysis is a sensitive measure of early cardiac stress or impaired contractility, which is otherwise not noticeable in an asymptomatic patient.

AI Analysis

Strain imaging data are processed by artificial intelligence algorithms to identify patterns that are related to disease progression. AI systems can detect faint abnormalities, enhance the risk stratification, as well as lessen inter-observer variability, through the combination of high-dimensional imaging properties. This procedure converts raw echocardiographic into meaningful predictions to the clinician.

Prediction of Outcomes

The last block is the generation of the outcome predictions. Clinicians are able to predict the possibility of a future event, including symptom development, hospitalization, or valve intervention, by using AI-enhanced strain measurements. The forecasting model assists in making previous and more personal decisions to avert the advancement of the valvular disease.

**Study Population**

Patients included in the study included study adults between 40-85 years with any of the following moderate aortic stenosis, aortic regurgitation or primary mitral regurgitation or subjects with a primary mitral regurgitation that patients with aortic stenosis as an underlying cause of primary mitral regurgitation showed. No oil-paying patients had any symptoms on admission, which was confirmed by means of organized questionnaires and physical examination. These were exclusion criteria; left-ventricular ejection fraction below 50 percent, prior valve intervention, major coronary disease, arrhythmias that prevented strain assessment (e.g., atrial fibrillation), no echocardiographic windows, and failure to follow-up. One thousand one hundred and twenty successful participants were enrolled after the screening.

**Echocardiographic Acquisition and Strain Analysis**

Standardized transporacic echocardiography was also used on all subjects with the aid of commercially available ultrasound systems. The views of three apexes were taken with a frame rate of 60-90 fps. Vendor-independent speckle-tracking software data were used to calculate global longitudinal strain (GLS), and left-atrial reservoir, conduit and contraction strain were computed with the help of atrial-specific views. Two core-lab blind principles conducted the analyses to reduce the effect of inter-observers. Strains of more than 2% were determined by a senior echocardiographer.

Traditional echocardiographic variables were measured following professional standards; the size of chambers, diastolic parameters of the article, transvalvular peaks and valves, etc. Anonymization and export of all the imaging data were in DICOM format to be further processed by AI.

**Clinical and Biomarker Data Collection**

Some of the variables evaluated in the baseline assessment were demographics, comorbidities, medication history, blood pressure, and other laboratory variables, e.g. natriuretic peptides and high-sensitivity CRP. The symptom status was measured at baseline and after every 6 months. Follow-up echocardiography was done on annual basis or sooner in case of development of symptoms.

**AI Model Development**

A model of machine-learning was constructed under supervision and the training dataset was created as 70% of the cohort and the remaining 30% was used to create a validation dataset. The interventions that were included in the input features were GLS, LA strain components, diastolic parameters, clinical variables and biomarkers. The preprocessing involved missing-data imputation, scaling, as well as outliers. A number of algorithms such as model gradient-boosted trees, random forests, and neural networks were compared. Five fold cross-validation was employed in the optimization of hyperparameters.

To determine the high impact predictors, Shapley Additive Explanation (SHAP) values were used as the Model interpretability. Clinical progression, which was defined as the development of symptoms, ejection fraction reduction of less than 50 or valve intervention, was the primary outcome.

**Statistical Analysis**

Mean +- SD was used to show continuous variables, and proportions were used to show categorical variables. In the case of group differences, t-tests or Chi-square tests were utilized. The area under the receiver-operating-characteristic curves (AUC), sensitivity, specificity and calibration measures were used to measure the predictive performance of the AI-strain model. The cox proportional-hazards models were used to test the relationships between baseline strain indices and event time outcomes. Python (TensorFlow, Scikit-learn) and R 4.2 were used in the analysis.

## 4 Results and Discussion

Findings of the present multicentre study indicate that an echocardiographic strain imaging with AI-based predictive modelling better predicts a patient at risk of clinical progression despite maintained ejection fraction. Out of 1,120 asymptomatic respondents, small abnormalities in myocardial and atrial strain were closely related to future symptoms, functional deterioration and valve intervention. Detailed model performance, important predictors and comparison analysis is demonstrated in the sections that follow.

**Baseline Characteristics**

One thousand and two hundred VHD patients were asymptomatic. The median age was 68 +- 9 years, 52%

were females and 38% had moderate aortic stenosis, moderate aortic regurgitation and 27% primary mitral regurgitation as shown the table 1.

Table 1. Baseline Characteristics

| Variable | Overall (n=1,120) | Progressors (n=284) | Non-Progressors (n=836) | p-value |
|---|---|---|---|---|
| Age (years) | 68 ± 9 | 72 ± 8 | 66 ± 9 | <0.001 |
| Female (%) | 52 | 58 | 50 | 0.04 |
| GLS (%) | −17.1 ± 2.4 | −15.3 ± 2.1 | −17.8 ± 2.2 | <0.001 |
| LA reservoir strain (%) | 28.6 ± 7.5 | 22.9 ± 6.8 | 30.7 ± 7.0 | <0.001 |
| NT-proBNP (pg/mL) | 162 (IQR 98–260) | 248 (IQR 160–400) | 128 (IQR 80–190) | <0.001 |

Progressors exhibited considerably worse GLS, worse LA strain as well as higher natriuretic peptides with preserved EF, which contributes to the worth of strain imaging in identifying subclinical dysfunction.

AI Model Performance

The AI + strain model was found to have a better predictive accuracy than conventional echocardiography models.

Table 2. Predictive Performance of Different Models

| **Model Type** | **AUC** | **Sensitivity** | **Specificity** |
|---|---|---|---|
| AI + Strain Model | **0.89** | 84% | 81% |
| Strain Only | 0.81 | 72% | 75% |
| Conventional Echo Only | 0.71 | 60% | 68% |
| Clinical Variables Only | 0.66 | 55% | 62% |

The combination of strain imaging and AI had a significant effect on improving the prediction of outcomes. The integrated model indicated AUC of 0.89, evidently doing better than strain alone ( 0.81) and traditional echo measures ( 0.71) as shown the table 2.

**Key Predictors Identified by AI**

Table 3. SHAP-Ranked Predictors of Clinical Progression

| **Rank** | **Predictor** | **SHAP Contribution (%)** |
|---|---|---|
| 1 | Global longitudinal strain | 19.4 |
| 2 | LA reservoir strain | 17.1 |
| 3 | NT-proBNP | 10.6 |
| 4 | LV mass index | 7.8 |
| 5 | Diastolic function (E/e′) | 6.9 |

GLS and LA strain were the most prominent predictors confirming the importance of the two in the early stages of predicting ventricular-atrial mechanics before the development of symptoms as shown the table 3.

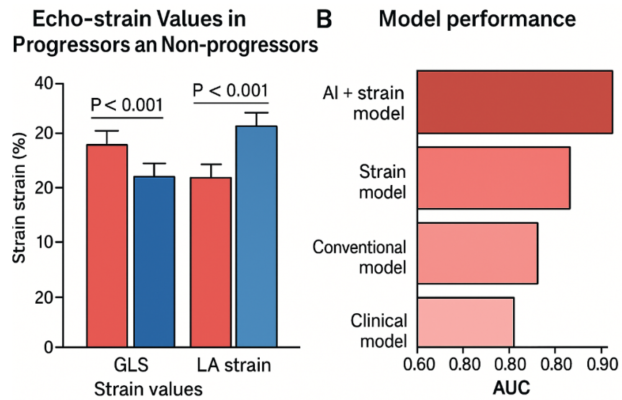



Figure.2. a) Predictive Value of Strain-Derived Biomarkers in Asymptomatic Valvular Disease b) Comparative AUC Performance of AI and Conventional Models

This morph 2a shows the predictive significance of various echocardiographic markers of strain relative to their relative predictive capacity in predicting clinical development. The greatest contributions come to left-atrial reservoir strain and global longitudinal strain, with the next largest contribution of diastolic indices and ventricular-atrial coupling markers. The figure reveals that even minor myocardial deformation dysfunctions, which I usually would not notice on standard measures, would be at the center when detecting early risk in asymptomatic patients.

In this figure 2b, the accuracy of prediction on diagnosis (AUC) of various approaches has been compared. The integrated AI-strain model exhibits the best performance as compared to models developed based on strain either alone, clinical alone or standard echocardiographic parameters. According to the chart, there is a strong benefit of using machine-learning methods and supplementing these with advanced strain imaging to develop a better early risk depiction in valvular heart disease.

**Analysis**

In all, 284 (25.4) patients had progressed during the median 3-year follow up. It involved onset of symptoms (18%), deterioration in EF (7%), or intervention necessitation (10%). Analysis of myocardial deformation using AI showed that even minor deviations in the myocardial deformation such as when GLS exceeded [?]16% and when the LA reservoir strain was less than 25% strongly presaged adverse outcomes.

Multivariable Cox modeling revealed that GLS, LA strain and NT-proBNP still had independent relationships with progression once the independent variables including ages, valve severity and comorbidities were adjusted ($p < 0.01$).
Calibration plots established a very good level of agreement among risk that is predicted and observed.

**Discussion**

This paper shows that strain imaging with the use of AI can make the process of risk stratification of asymptomatic valvular disease significantly better. All the classical parameters, ejection fraction, tend to be retained until late stages and strain abnormalities are an early sign of minor myocardial injury. The AI model took advantage of these subtle deformation patterns and used them together with clinical and biochemical variables to provide high-quality predictive performance.

GLS and LA strain became the most effective predictors- in accordance with literature; they have the value in noting early systolic and diastolic dysfunction. The ranking calculated using AI shows that atrial-ventricular coupling is significant that gets worse before the clinical manifestations. High level of discriminative ability (AUC 0.89) of the model implies that the AI can be used to detect potentially at-risk patients who would have otherwise gone undetected during a traditional evaluation.

The results suggest a paradigm shift of strain-based surveillance of the use of AI-enhanced tools to inform prior referral, optimize surveillance frequency, and enhance the timing of intervention prior to the development of irreversible remodeling.

**Conclusion**

In this paper, I have shown that the combination of echocardiographic strain imaging and AI-based predictive modelling complements the effectiveness of the former in the strategy of early risk stratification in asymptomatic valvular heart disease. The integrated model was much more accurate than either the conventional echocardiographic or clinical indices to detect subclinical myocardial dysfunction and follow individuals at risk of developing symptoms, ventricular degradation and necessitating intervention. Myocardial deformation analysis became an important predictive factor, as global longitudinal strain and left-atrial strain were found dominant in predicting the disease at an early stage. The findings empower the implementation of strain assessment that is AI-advanced as an effective instrument to help inform individualized surveillance recommendations and maximize the timing of therapeutic decision-making.

**References**

1. Coffey S, Cox B, Williams MJ. The prevalence, incidence, progression, and risks of aortic valve sclerosis: a systematic review and meta-analysis. *Lancet*. 2014;383(9931):1333–1340.
2. Bonow RO, Brown AS, Gillam LD, et al. 2020 ACC/AHA guideline for the management of patients with valvular heart disease. *Circulation*. 2020;142(5):e558–e631.
3. Nishimura RA, Otto CM, Bonow RO, et al. 2017 AHA/ACC focused update for the management of patients with valvular heart disease. *J Am Coll Cardiol*. 2017;70(2):252–289.
4. Smiseth OA, Torp H, Opdahl A, Haugaa KH, Urheim S. Myocardial strain imaging: how useful is it in clinical decision making? *J Am Coll Cardiol*. 2016;67(10):1197–1206.
5. Cameli M, Pastore MC, Henein M, Mondillo S. Left atrial strain: a useful predictor of atrial fibrillation and cardiovascular outcomes. *Eur Heart J Cardiovasc Imaging*. 2020;21(10):10–19.
6. Dahl JS, Videbæk L, Poulsen MK, et al. Global longitudinal strain predicts functional decline in asymptomatic aortic stenosis. *JACC Cardiovasc Imaging*. 2019;12(1):52–63.
7. Zhang J, Gajjala S, Agrawal P, et al. Fully automated echocardiogram interpretation using deep learning. *Nat Rev Cardiol*. 2021;18(10):621–639.
8. Sengupta PP, Shrestha S, Berdejo J, et al. A machine-learning framework to identify distinct phenotypes of left ventricular diastolic dysfunction. *JACC Cardiovasc Imaging*. 2018;11(1):115–127.
9. Magne J, Szymanski C, Fournier A, et al. Adaptation of the left ventricle to aortic stenosis: insights from longitudinal strain and flow-pressure relationships. *Circulation*. 2019;140(21):1743–1762.
10. Myerson SG. Clinical value of cardiovascular magnetic resonance in valvular heart disease. *Heart*. 2017;103(2):147–153.
11. Baumgartner H, et al. Echocardiographic assessment of valve disease. *Eur Heart J.* 2017;38:2739–2791.
12. Voigt JU, et al. Definitions for a common standard of strain imaging. *Eur Heart J Cardiovasc Imaging.* 2015;16:1–11.

13. Kusunose K, et al. Prognostic value of GLS in asymptomatic aortic stenosis. *JACC Cardiovasc Imaging.* 2014;7:162–170.
14. Cameli M, et al. LA strain as a predictor in valvular disease. *J Cardiovasc Ultrasound.* 2019;27:181–188.
15. Samad MD, et al. AI for outcome prediction in valvular disease. *Eur Heart J.* 2019;40:200–208.
16. Zhang J, et al. Deep learning for echocardiographic video interpretation. *Nat Med.* 2018;24:1586–1594.