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EACVI DOCUMENT

Current clinical use of speckle-tracking strain imaging: insights from a worldwide survey from the European Association of Cardiovascular Imaging (EACVI)

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Aims Speckle-tracking echocardiography (STE) strain imaging has been a major advancement in myocardial function quantification. We aimed to explore current worldwide clinical application of STE.

Methods and results Access, feasibility, access, and clinical implementation of STE were investigated with a worldwide open-access online survey of the European Association of Cardiovascular Imaging. Participants (429 respondents and 77 countries) from tertiary centres (46%), private clinics, or public hospitals (54%) using different vendors for data acquisition and analysis were represented. Despite almost universal access (98%) to STE, only 39% of the participants performed and reported STE results frequently (>50%). Incomplete training and time constraints were the main reasons for not using STE more regularly. STE was mainly used to assess the LV (99%) and less frequently the right ventricular (57%) and the left atrial (46%) function. Cardiotoxicity (88%) and cardiac amyloidosis (87%) were the most frequent reasons for the clinical use of LV STE. Left atrial STE was used most frequently for the diagnosis of diastolic dysfunction and right ventricular STE for the assessment of right ventricle (RV) function in pulmonary hypertension (51%). Frequency of STE use, adherence to optimal techniques, and clinical appropriateness of STE differed according to training experience and across vendors. Key suggestions outlined by respondents to increase the clinical use of STE included improved reproducibility (48%) and standardization of strain values across vendors (42%).

Conclusion Although STE is now readily available, it is underutilized in the majority of centres. Structured training, improved reproducibility, and inter-vendor standardization may increase its uptake.

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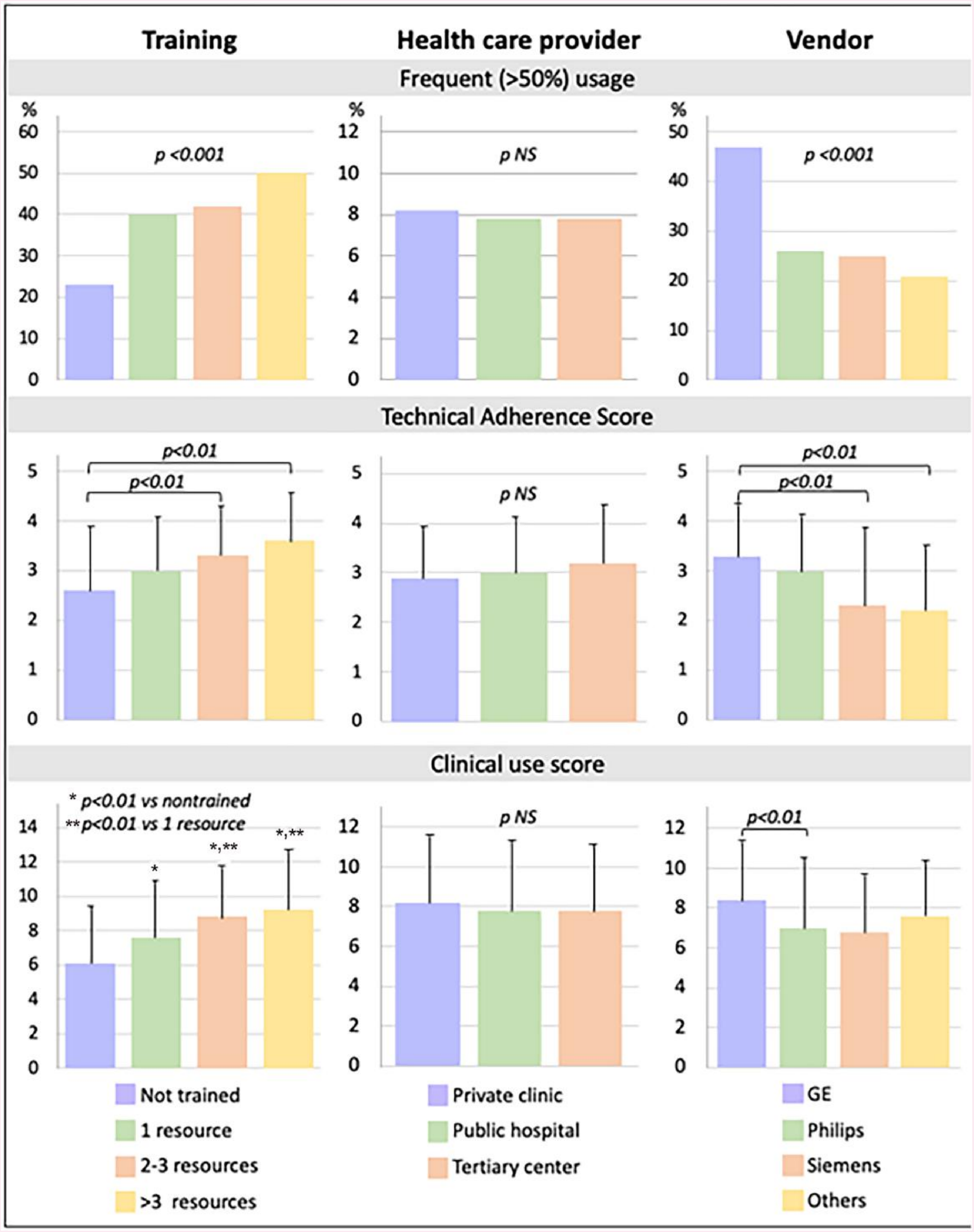
Graphical Abstract



Frequent reporting, technical adherence, and evidence-based clinical use of STE by training intensity, health care facility, and vendors.

Keywords speckle-tracking strain • echocardiography • clinical • inter-vendor

Introduction

Speckle-tracking echocardiography (STE) has been shown to be an invaluable tool in detecting subclinical left ventricular (LV) systolic dysfunction in different clinical scenarios, and to provide a favourable impact on the management of specific cardiac conditions by providing information that is not available with any of the currently used echocardiographic parameters. The exciting potential of this approach is reflected by the exponential increase in research and scientific publications over the last decade. Furthermore, STE is frequently highlighted by current recommendation documents from the European Association of Cardiovascular Imaging (EACVI) and American Society of Echocardiography (ASE) as a state of the art approach for patient evaluation.[1–7] Consequently, it is crucial to have a better understanding of how this imaging technique is used in current clinical practice, from both a technical and clinical perspective as well as the remaining barriers limiting its widespread clinical implementation.

Therefore, this survey aims (i) to understand the implementation of recommendations on ST strain imaging in clinical practice worldwide and (ii) to explore barriers and challenges in clinical applications. Ultimately, the survey seeks to inform future strategies to optimize integration of STE into routine patient assessment.

Methods

The present survey was conducted by the EACVI Scientific Initiatives Committee from 15 September to 15 October 2022 according to published criteria.[8] Participation in the survey was through an open-access weblink for physicians, sonographers, and technicians. The weblink of the survey was shared through the European Society of Cardiology (ESC) website, official bulletins of the ESC, and the social media for inviting the participants. Participants from 250 EACVI registered units around the world were invited to complete an online survey comprising 27 questions. The first 10 questions of the survey were prepared to obtain information about the access to STE and the feasibility of the tool in different categories of health care providers, nine questions aimed at obtaining information about the training and optimal technical use of STE software, and eight questions aimed to obtain information about the clinical implementation of STE in current clinical practice and the expected improvements to increase its integration into daily practice.

Statistics

Data were transferred into SPSS (Version 28.0) for statistical analyses. Categorical evaluations were transformed into semiquantitative scores. Training extent was grouped from 0 to 3 as follows: 0: no training ($n = 61$), 1: trained via one educational resource ($n = 261$), 2: trained via two or three educational resources ($n = 133$), and 3: trained through more than three ($n = 20$) educational resources. Technical adherence score (TAS) was obtained from five questions about the technical use of STE in the questionnaire: a point of 1 was assigned if the response complied with current EACVI recommendations, if not, a point of 0 was assigned (TAS $\leq$ 3 indicated poor adherence and $\leq$ 4 indicated good adherence). Clinical use score (CUS) was obtained by assigning a score of 1 to each evidence-based clinical condition where strain was used. For this purpose, we took into account EACVI consensus documents, recommendation papers, ESC guidelines, and meta-analyses.[2–7,9–20] According to the opted responses, the maximum TAS would be 5, and the maximum CUS would be 15 (*Table 1*). Comparison between the groups was performed by χ^2 for categorical variables. Scores were compared among groups by one-way ANOVA with Bonferroni *post hoc* comparisons if necessary.

Results

In total, 429 voluntary participants responded to the survey from 77 countries across the globe. The participants were from Algeria, Angola, Argentina, Armenia, Australia, Austria, Bahrain, Bangladesh, Belgium, Bosnia and Herzegovina, Brazil, Bulgaria, Canada, Chile, China, Columbia, Costa Rica, Croatia, Cyprus, Czechia, Denmark, Egypt, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, India, Iran, Iraq, Ireland, Italy, Japan, Jordan, Korea, Kuwait, Lebanon, Lithuania, Malaysia, Mexico, Mongolia, Morocco, Myanmar, the Netherlands, New Zealand, Nigeria, North Macedonia, Norway, Oman, Pakistan, Palestine, Paraguay, Peru, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Senegal, Serbia, Slovenia, South Africa, Spain, Sweden, Switzerland, Syrian Arab Republic, Taiwan, Tunisia, Turkiye, Ukraine, United Arab Emirates, UK, USA, Uruguay, and Uzbekistan.

Participants worked in tertiary centres (45%), public hospitals (37%), private clinics (17%), and intensive care or emergency departments (1%). More than half of the survey participants were senior echocardiographers (58%) and the others were early career echocardiographers (22%), multimodality imagers (16%), or sonographers (5%). Almost 95% of the participants worked in either cardiology or cardiothoracic departments with the remainder working in internal medicine, intensive care unit, or emergency department (*Figure 1*).

Table 1 Calculation of technical adherence and clinical use scores

Responses to questions showing technical adherence that were assigned a score of 1
(1) How do you assess LV global longitudinal strain? From three apical views.
(2) How do you assess left atrial longitudinal strain? From the average of apical four and two chambers.
(3) How do you quantify right ventricular strain? From both septum and free wall or by using the automated function imaging for the right ventricle.
(4) How do you assess LV longitudinal strain in atrial fibrillation? I obtain global longitudinal strain only if the cardiac cycles are similar and within physiological limits.
(5) Which algorithm do you use to define the region of interest? Automated algorithm with manual correction.
Evidence-based clinical use for specific diseases that were assigned a score of 1
(1) Heart failure with preserved ejection fraction
(2) Chemotherapy induced cardiomyopathy
(3) Amyloidosis
(4) Hypertrophic cardiomyopathy
(5) Ischaemic heart disease
(6) Fabry's disease
(7) Dilated cardiomyopathy (subclinical phase/early diagnosis)
(8) Aortic stenosis
(9) Adjunct to the diagnosis of arrhythmogenic cardiomyopathy
(10) Adjunct to patient selection for cardiac resynchronization therapy
(11) Adjunct for predicting the risk of developing atrial fibrillation
(12) Adjunct for predicting the risk of embolic stroke
(13) Adjunct for the diagnosis of diastolic dysfunction
(14) Pulmonary hypertension (right ventricle)
(15) Suspected right ventricular infarction

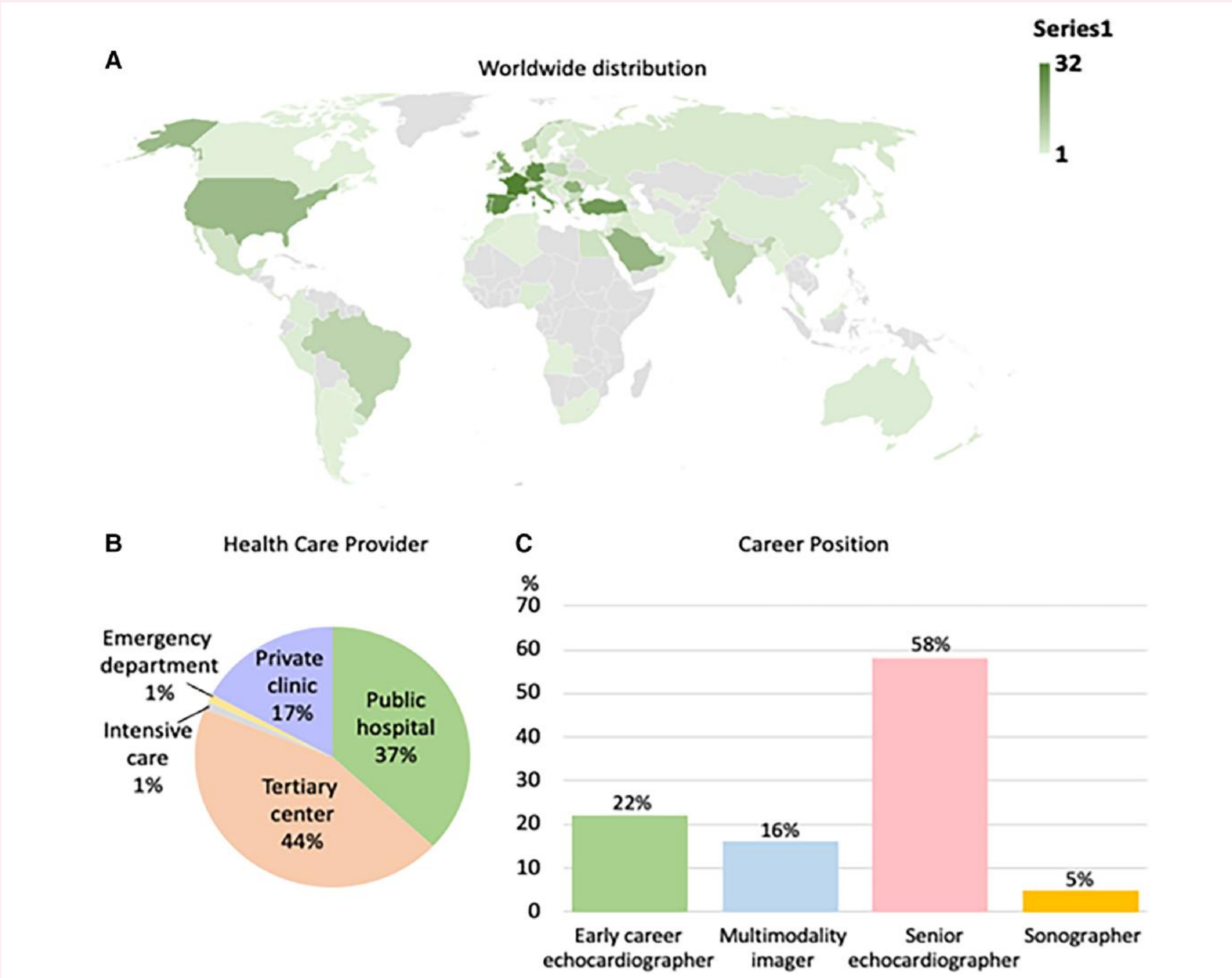


Figure 1 Distribution of the participants by country (*A*), by work environment (*B*), and by career position (*C*).

Access to STE

The majority of respondents had access to STE within their department (80%), 15% reported having access to STE within their hospital, and 5% either had access to it within their region (via referral) (3%) or did not have access to STE (2%) (*Figure 2A*).

Interestingly, nearly a quarter (23%) of the participants reported not using this technology despite having access to it. The most common reasons of not using STE were time constraints (49.7%) and the need for more training (37.6%). Other reasons included lack of motivation to spend time learning the technology (3.9%), not seeing the value in STE (3.9%), or a dislike for the post-processing algorithms available to them (4.9%).

Clinical usage and training resources

In terms of clinical usage, while 39% of the participants performed or reported speckle tracking frequently (>50% of their studies), 28% of the respondents included strain in their report infrequently (25–50% of their studies) and 22% very rarely (<25% of their studies), and 7% of the respondents used STE only for research purposes (*Figure 2B*).

The majority of respondents (84%) was trained in STE. Training at an expert centre (47%) or by performing research with the use of STE (43%) was the most common mean of training. Other training resources included national teaching courses (34%), EACVI e-learning platform (22%), and EACVI hands-on teaching courses (17%) (*Figure 3*). While 15% did not receive any training, 54% were trained on STE by means of more than one resource. Interestingly, 18 out of 38 (47%) who mentioned a need for more training had previous training (32 from one resource and 6 from more than one resource). Importantly, more extensive training in STE was associated with increasing CUS (CUS: 6.1 ± 3.2 in those who were not trained, CUS: $7.6 \pm 3.3^{*}$ in those who were trained via one resource, CUS: $8.8 \pm 3.0^{*,**}$ in those who were trained via two to three resources, and CUS: $9.2 \pm 3.4^{*,**}$ in those who were trained via more than three resources; $^{*}P < 0.01$ vs. not trained, $^{**}P < 0.01$ vs. one resource) (see *Graphical abstract*).

Offline vs. during acquisition preferences of STE analyses

The majority (63%) of respondents performed strain analyses during image acquisition while 37% performed offline analyses. EchoPAC

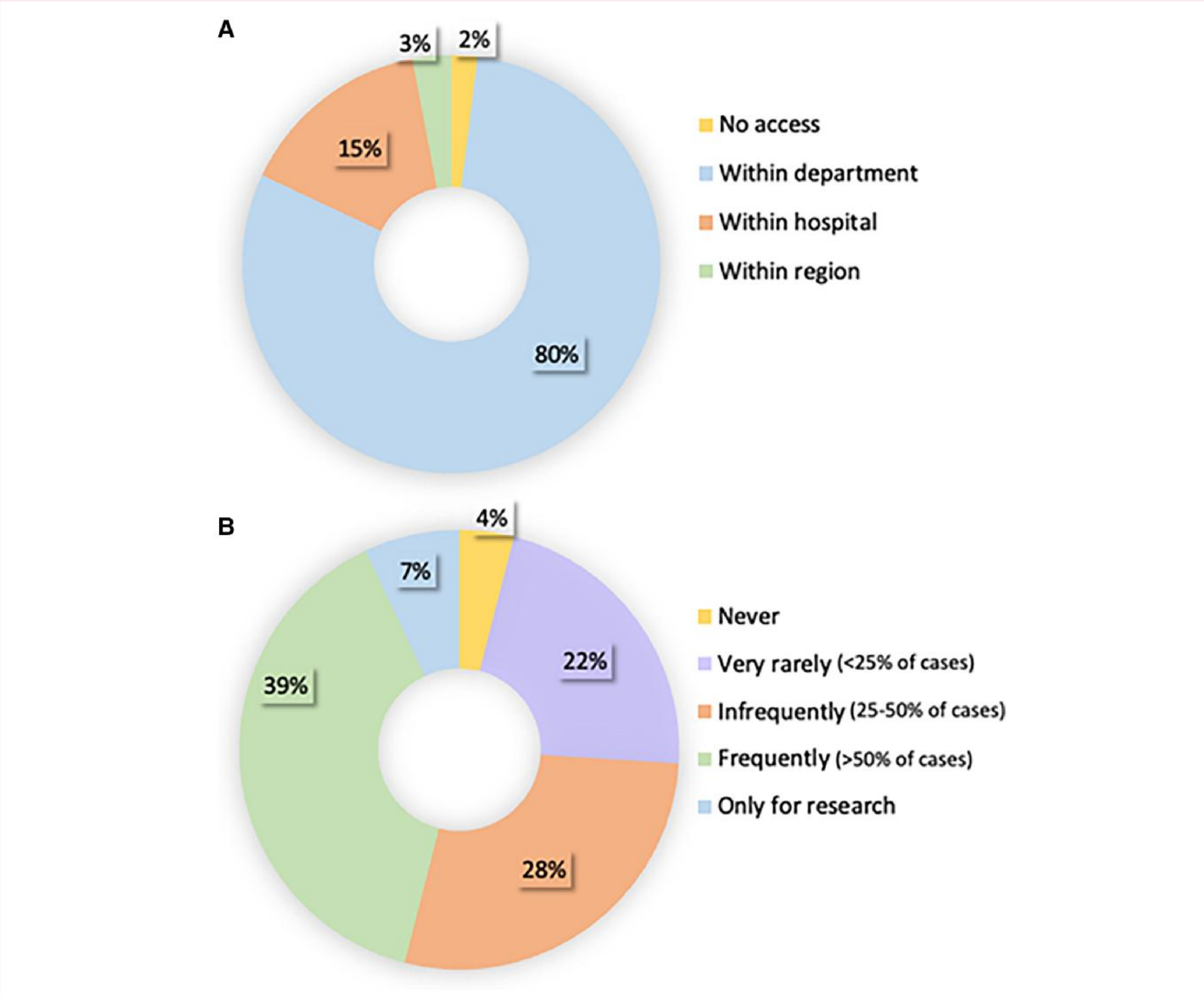


Figure 2 Access to speckle-tracking strain imaging (*A*) and usage frequency in clinical practice (*B*).

was the most widely (69%) used workstation for offline analysis among the respondents. TomTec was used by 10% and Xcelera by 7%. Other post-processing systems were used less frequently. Users from emergency departments and intensive care performed STE exclusively during image acquisition. Offline strain analyses were least frequent among private clinic practitioners (24%) whereas offline systems were used by 35% of public hospital practitioners and 44% of tertiary centre practitioners ($P < 0.001$). More extensive STE training was associated with more frequent use of offline analysis workstations, and offline strain analysis was performed by the majority of researchers (58%). Importantly, offline strain quantification was associated with higher CUS and TAS (*Table 2*).

In the majority of the countries, STE provided no revenue as an add-on to the regular transthoracic echocardiography [56 out of 79 countries (71%), and according to 85% of the respondents]. On the other hand, revenue for STE was declared by 88% of respondents from USA, else, in 22 countries, reimbursement or a fee was applied only occasionally.

Appropriate use of the technique

Among the users, almost all (99%) performed STE for th LV. For this purpose, 85% used global longitudinal strain (GLS) obtained from three apical views. However, 8% quantified LV longitudinal strain from the apical four- and two-chamber views while 6% quantified STE from only the apical four chamber. Automated algorithm analysis with manual correction of the region of interest was the most widely adopted approach (88%). Only 6% used fully automated algorithms and 5% manual-only tracings.

For clinical purposes, GLS was the most frequently used strain assessment tool (97%) followed by bull's eye plots (76%), the segmental strain curve pattern (33%), segmental peak systolic strain (28%), and time-to-peak strain (22%). In patients with atrial fibrillation, almost half the responders (49%) reported obtaining GLS using the automated algorithm only if the cardiac cycles were similar and within physiological limits. The others reported either taking an average of longitudinal strain measured manually from the three apical views regardless of cycle length variation (16%) or by assessing only the apical four-chamber average longitudinal strain (4%). Meanwhile, 30% did not quantify LV longitudinal strain in patients with atrial fibrillation.

Just under half (46%) of the survey participants quantified left atrial (LA) strain. The majority (59%) calculated LA longitudinal strain by taking an average of the apical four- and two-chamber views. Others used either the apical four-chamber or two-chamber views.

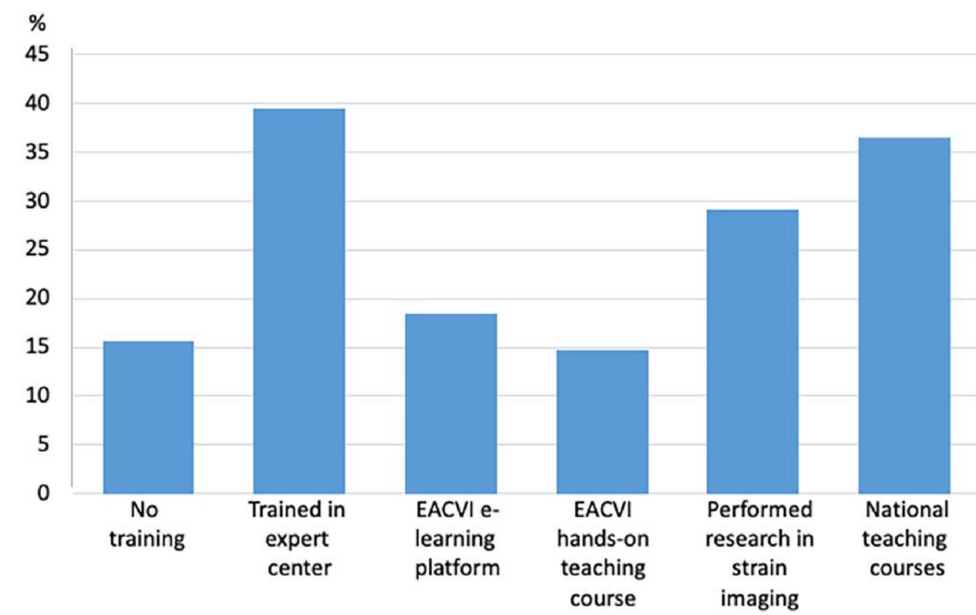


Figure 3 Resources used for training on STE.

For the RV, STE was used by 57% of the respondents: 35% measured STE in the RV free wall, and 27% took the average of STE measurements from the septum and free wall while 16% used the automated function imaging algorithm. Only 8% of respondents measured strain in the right atrium.

Training experience of the operator was associated with greater adherence to the technical recommendations provided by the EACVI/ASE standardization task force as shown in function of TAS in Central illustration (TAS: 2.6 ± 1.4 in those who were not trained, TAS: 3.0 ± 1.1 in those who were trained via one resource, TAS: 3.3 ± 1.2* in those who were trained via two to three resources, TAS: 3.6 ± 1.0* in those who were trained via more than three resources; *$P < 0.01$ vs. no training).

Characteristics of the usage of STE by vendors

Among respondents, General Electric (GE) was the most frequently used cardiac ultrasound vendor for STE (59%), followed by Philips (32%), Siemens (3%), and other brands (6%, including Canon, Toshiba, Esaote, and Mindray). Differences in the technical approach to LV strain assessment were observed among users of different vendors (*Table 3*). LV GLS assessment from three apical views was performed most frequently by GE and Philips users as well as RV and LA strain assessments. Strain pattern recognition with the bull's eye plot was most frequently adopted by GE users. Importantly, the clinical frequency of STE utilization also differed among users of different vendors. Strain analysis during the acquisition was performed more frequently than offline analysis across all vendors, but this trend was most prominent among Siemens users. Forty-seven per cent of GE users performed STE frequently (in >50% of the studies), in comparison to 26% of Philips, 25% of Siemens, and 21% of other brand users in their studies ($P = 0.001$). The majority (58%) of Siemens users performed STE in less than a quarter of their studies. Of note, the TAS was highest among GE followed by Philips users. The evidence-based clinical use score was also highest among GE users followed by other brand users and Philips users. Regarding STE vendor distribution across different institutions represented in the survey, GE and Philips were mostly used in tertiary centres, Siemens mostly in public hospitals, and other brands mostly in private clinics (see Graphical abstract). Training intensity did not differ between users of different vendors.

Applications of STE in clinical practice

The survey investigated the conditions where LV strain was considered most helpful in clinical decision-making. Diagnoses of cardiotoxicity (88%) and cardiac amyloidosis (87%) were highlighted as the most common conditions for the clinical use of STE. The other conditions stated by survey respondents are included in *Figure 4*.

While 62% of the participants envisaged using an impaired LV GLS as a trigger to optimizing medical treatment in patients with heart failure with preserved ejection fraction, 38% did not. Similarly, when asked regarding the use of LV GLS in heart failure with reduced ejection fraction (EF) (<50%), 35% reported always taking it into account as they considered GLS to be more reproducible than EF, 31% used it for monitoring response to medical therapy, 7% used it to monitor response to treatment in patients receiving cardiac resynchronization therapy, and 27% did not use GLS in this scenario. Interestingly, the majority (71%) reported never using LV strain with dobutamine stress, while 25% reported using strain for the assessment of viability and 4% for the study of LV dyssynchrony.

Clinical scenarios where RV strain was assessed by the participants included pulmonary hypertension (51%), arrhythmogenic cardiomyopathy (33%), routine echocardiographic exams to assess RV function (24%), suspicion of RV infarction (23%), and to aid selection of candidates for cardiac resynchronization therapy (7%).

The survey also investigated indications for performing LA strain, with the most common being the diagnosis of diastolic dysfunction (48%), followed by prediction of the risk of developing atrial fibrillation (30%), the routine assessment of LA function (19%), as well as the prediction of embolic stroke risk in both sinus rhythm (14%) and atrial fibrillation (10%).

Table 2 Relation of real time vs. offline strain analysis performance with training, health care provider, clinical usage, and technical adherence

		During image acquisition	Offline	*P* value
Training	Without training	43(78%)	12 (22%)	0.014
	Training from one resource	134 (63%)	79 (37%)	
	Training from >1 resource	84 (55%)	68 (45%)	
Health care provider	Private clinic	53 (75%)	18 (25%)	0.014
	Public hospitals	99 (64%)	56 (36%)	
	Tertiary centres	106 (56%)	84 (44%)	
Clinical usage frequency	Frequent use >50%	96 (58%)	69 (42%)	0.02
	Infrequent use 25–50%	71 (59%)	49 (41%)	
	Rare use <25%	75 (79%)	20 (21%)	
	For research	13 (42%)	18 (58%)	
Clinical use score		7.7 ± 3.6	8.9 ± 3.2	<0.001
Technical adherence score		3.03 ± 1.2	3.3 ± 1.1	0.02

Table 3 Vendor-related usage characteristics

	General Electric *n* = 261	Philips *n* = 141	Siemens *n* = 13	Other *n* = 14	*P*
LV strain assessment	98.1	98.6	100	93	
From three apical views	89	82	42	71	<0.001
Only from apical four-chamber view	4	7	42	7	
From apical four- and two-chamber views	6	10	17	21	
RV strain assessment	61	57	21	42	0.008
LA strain assessment	45	49	33	21	NS
Bull's eye pattern use	82	65	58	79	0.001
Analyse performance					
During acquisition	55	68	92	79	0.001
Offline	43	31	8	14	
Frequency of use					
>50% of studies	47	26	25	21	0.001
25–50% of studies	27	29	17	36	
<25% of studies	26	45	58	43	
Technical adherence score	3.3 ± 1.1	3.0 ± 1.2	2.3 ± 1.6*	2.2 ± 1.4**	0.001
Clinical use score	8.4 ± 3.2	7.0 ± 3.4**	6.8 ± 2.5*	7.6 ± 2.4	0.001
Health care provider					
Private clinic	13.4	19.1	33.3	57.1	0.001
Public hospital	38.2	36.2	50.0	21.4	
Tertiary centre	47.3	44.7	8.3	21.4	

LA, left atrial; LV, left ventricular; RV, right ventricular. Values are presented as percentages or mean ± standard deviation.
*$P < 0.05$ vs. General Electric.
**$P < 0.001$ vs. General Electric.

Suggestions for future developments

Finally, the survey gathered suggestions for solutions to increase the clinical use of STE. Improved measurement reproducibility was the most frequent answer provided (47%), followed by standardization of STE results to improve cross-interpretation across different vendors (42%). Faster algorithms (32%), increasing the revenue associated with performing STE (30%), the development of vendor neutral solutions (23%), and methods to apply STE to three-dimensional data sets

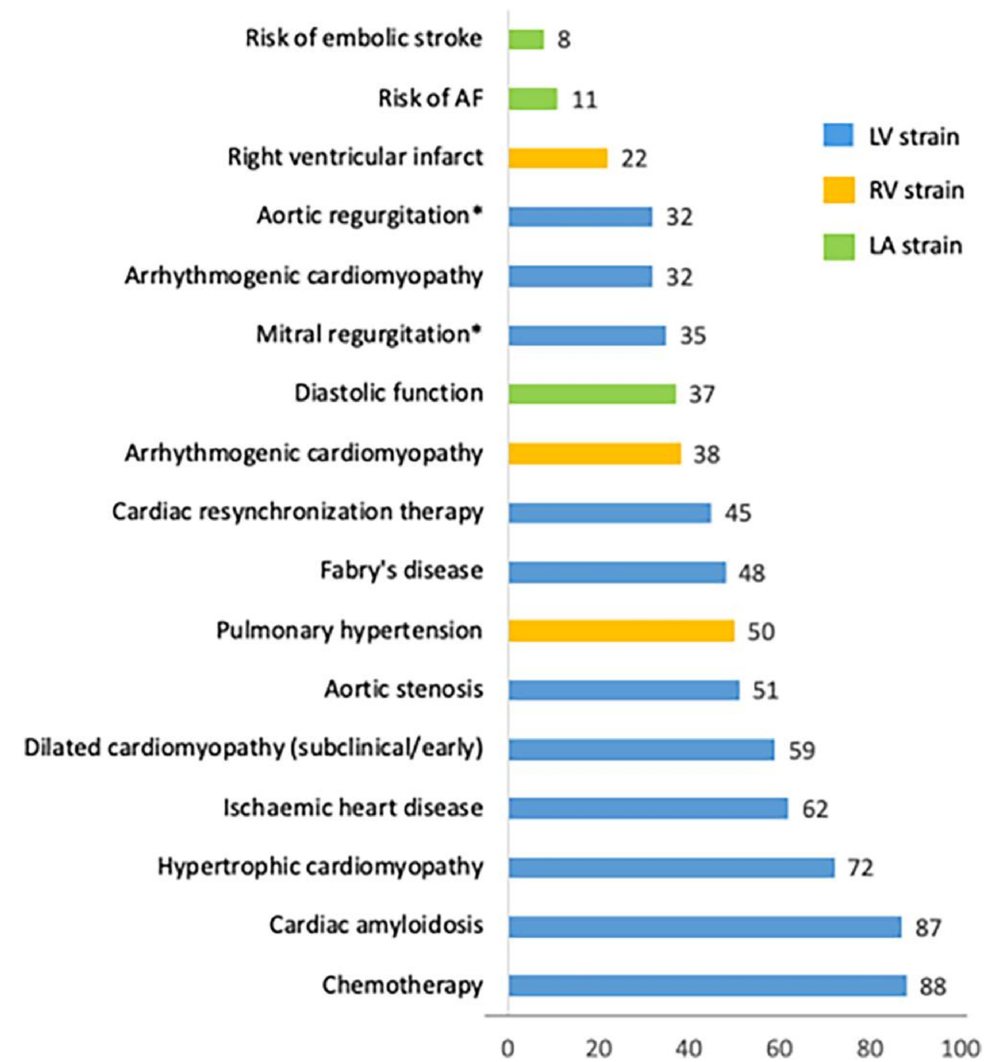


Figure 4 The use of STE for specific clinical purposes (presented as percentage of respondents) (* denotes the diseases that were not included in the calculation of CUS).

(18%) as well as higher frame rates (17%) were other important suggestions (*Figure 5*).

Discussion

The present survey is unique in providing real world data about the clinical use of STE from 77 countries, focusing on access, application, training, and vendors. The main findings are as follows: (i) despite near universal access, the performance of STE remains relatively low in clinical practice, (ii) the extent of operator training in STE is associated with the frequency of clinical usage, adherence to optimal technique defined by the strain standardization task force and evidence-based clinical use, (iii) a non-negligible percentage of echocardiographers did not have training on STE or did not feel self-confident enough despite having some training, and (iv) there is also important vendor-related variation in clinical use of STE.

Overall, the current clinical application of STE was lower in this survey than expected. Despite almost universal access, only 39% performed and reported STE frequently (>50%) in their reports. When used, the clinical conditions where STE was applied were compliant with the scientific evidence and recommendations of the EACVI, most commonly being utilized in the LV in patients with suspicion for cardiac amyloidosis and chemotherapy induced cardiotoxicity. Disease-oriented evidence-based consensus documents are also eagerly awaited as well as further scientific evidence demonstrating the clinical benefits of using STE in routine practice across different medical conditions. Time constraints and lack of training were the two most important reasons for not using STE in daily practice despite having access to it. Time constraints may explain partly the preference of performing STE analysis during acquisition rather than offline. Even though the performance of STE is rarely reimbursed, this was not described as an impeditive factor for its use, although it was described as a method of increasing the uptake and application of strain imaging in the future. The responses showed that most of the echocardiographers were trained at an expert centre or using educational resources provided by their national societies. Approximately, a third of the respondents had received training from the EACVI driven resources, underpinning the importance of the efforts to expand the exposure to EACVI training platforms. The survey showed that respondents

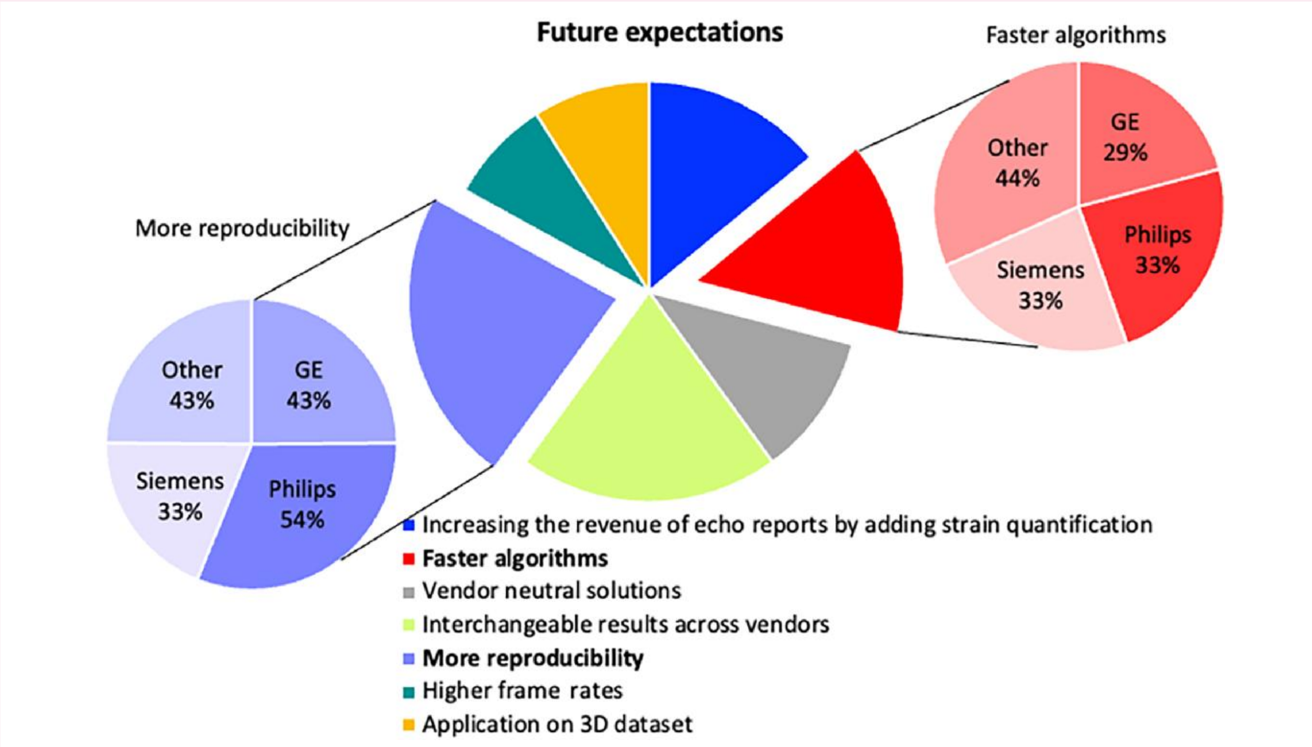


Figure 5 Answers to 'Which improvement would increase your clinical use of speckle-tracking imaging?'.

with more extensive training (training from more than one resource) in STE demonstrated more frequent usage of this approach, greater adherence to optimal imaging techniques, and more appropriate implementation of STE into clinical practice. The association between STE training experience and the frequency and quality of STE use in clinical practice suggests the need for a greater focus on structured training programmes including at least two steps in order to achieve the necessary level of expertise and confidence for the use of STE in patient management.

We observed prominent vendor-related differences in the frequency of STE use, as well as adherence to optimal techniques and appropriate clinical application.[21,22] Furthermore, there was a variation observed in vendor use according to place of work, with differences seen between tertiary centres, public hospitals, and private clinics. The explanation for these vendor-related differences requires further exploration but might include differences in processing algorithms and user-friendliness of the navigation platform among others. These differences might also present an opportunity for greater inter-vendor standardization efforts that might ultimately expand the clinical implementation of STE. Indeed, respondents felt that improved reproducibility and standardization of strain values across vendors were the key measures to improve uptake of STE in clinical practice.

Limitations

The survey reflects the answers of voluntary respondents and may suffer from sampling bias. Confirmatory data from a larger number of more diverse centres would be welcome. The responses may be biased based on the potential different perceptions or interpretations of the questions by the respondents. We used arbitrary scoring systems when attempting to quantify the responses regarding technical adherence and clinical appropriateness factors. The negative contribution of poor image quality as a reason of not using the STE was not evaluated.

Conclusions

In conclusion, STE is now a widely accessible clinical tool, yet, it is only routinely used in the minority of echocardiographic centres. Extensive training in STE appears important in determining a high frequency of STE use and is associated with improved adherence to optimal imaging techniques and clinical appropriateness. Improving exposure of the echocardiographers to training resources as well as increasing measurement reproducibility and inter-vendor standardization may all contribute to accelerate the routine clinical adoption of STE.

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Data availability

The data underlying this article are provided by the European Association of Cardiovascular Imaging (EACVI) by permission. Data will be shared on request to the corresponding author with permission of the EACVI.

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