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1 **Current Clinical Use of Speckle Tracking Strain Imaging: Insights from a Worldwide Survey**
2 **from the European Association of Cardiovascular Imaging-EACVI**

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4 Leyla Elif Sade¹, Shruti S. Joshi², Matteo Cameli³, Bernard Cosyns⁴, Victoria Delgado⁵, Erwan
5 Donal⁶, Thor Edvardsen⁷, Ricardo Fontes Carvalho^{8,9}, Robert Manka¹⁰, Tomaz Podlesnikar^{11,12},
6 Bogdan A. Popescu¹³, Jadranka Separovic Hanzevacki¹⁴, Marta Sitges¹⁵, Marc R. Dweck²

7
8 1University of Pittsburgh Medical Center, Heart and Vascular Institute, Department of Cardiology,
9 Pittsburgh, PA, USA.

10 2 BHF Centre for Cardiovascular Science, Chancellor's building, University of Edinburgh, Little
11 France Crescent, Edinburgh, EH16 4SB, United Kingdom

12 3 Department of Cardiovascular Disease, University of Siena, Siena, Italy.

13 4 Cardiology Department, Centrum voor Hart en Vaatziekten (CHVZ), Universitair ziekenhuis
14 Brussel, Brussels, Belgium.

15 5 Hospital Universitari Germans Trias i Pujol, Badalona, Barcelona, Spain

16 6 Cardiologie, CHU de RENNES, LTSI UMR1099, INSERM, Universite' de Rennes-1, Rennes,
17 France.

18 7 Department of Cardiology, Oslo University Hospital, Rikshospitalet and University of Oslo

19 8 Serviço de Cardiologia, Centro Hospitalar de Vila Nova de Gaia/Espinho, Gaia - Portugal.

20 9 Centro de Investigação Cardiovascular (UniC@RISE), Faculdade de Medicina, Universidade do
21 Porto, Porto - Portugal.

22 10 Department of Cardiology, University Heart Center, University Hospital Zurich, Zurich,
23 Switzerland.

1 11 Department of Cardiac Surgery, University Medical Centre Maribor, Ljubljanska ulica 5, 2000
2 Maribor, Slovenia;

3 12 Department of Cardiology, University Medical Centre Ljubljana, Zaloška cesta 2, 1000 Ljubljana,
4 Slovenia

5 13 Department of Cardiology, University of Medicine and Pharmacy 'Carol Davila' -Euroecolab,
6 Emergency Institute for Cardiovascular Diseases 'Prof. Dr. C. C. Iliescu', Bucharest, Romania Sos.
7 Fundeni 258, sector 2, 022328 Bucharest, Romania.

8 14 Department of Cardiovascular Diseases, University Hospital Centre Zagreb, School of Medicine,
9 Zagreb, Croatia.

10 15 Cardiovascular Institute, Hospital Clínic, Universitat de Barcelona, Institut d'Investigacions
11 Biomèdiques August Pi i Sunyer (IDIBAPS), CIBER, Centro de Investigación Biomédica en Red ,
12 Spain.

13

14

15 Address for Correspondence

16 Leyla Elif Sade, MD

17 200 Lothrop street

18 UPMC, Heart and Vascular Institute

19 Presbyterian Hospital, Ste E354.2

20 Pittsburgh, PA, 15232, USA

21 Sadele2@upmc.edu

22

23

24

25

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2 L E Sade : None

3 S S Joshi: None

4 M Camelli: Participated data safety monitoring or advisory board for Novo nordisk and Astra Zeneca,
5 received equipment, or other services from Novartis

6 B Cosyns: participated on a Data safety Monitoring Board or advisory board for AMGEN, BMS

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19

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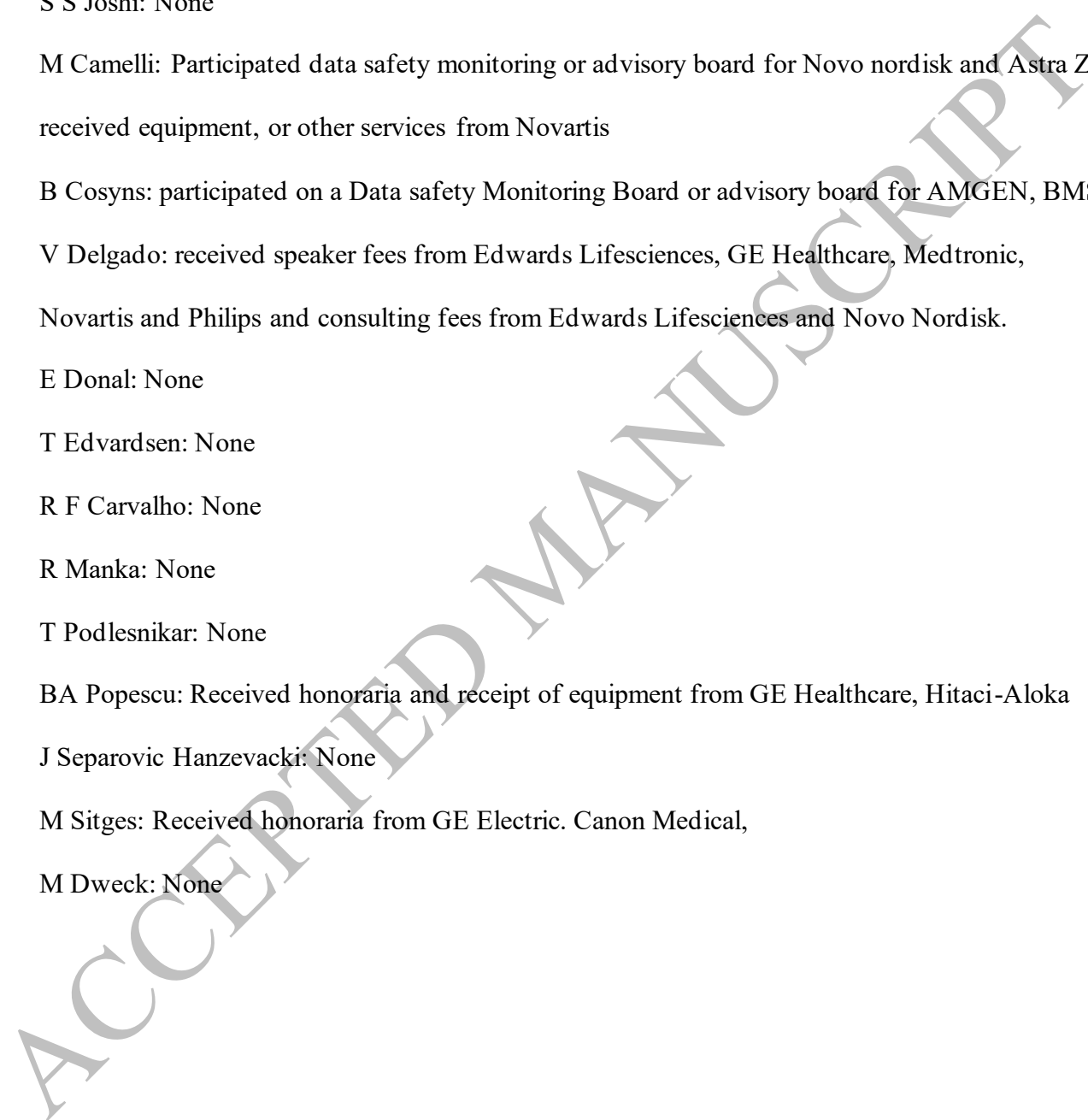
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1 2 **ABSTRACT**

3
4 **Background:** Echocardiographic speckle-tracking strain imaging (STE) has been a major advance in
5 myocardial function quantification. We aimed to explore current world-wide clinical application of
6 STE.

7 **Methods:** Access, feasibility, access, and clinical implementation of STE were investigated with a
8 worldwide open-access online survey of the European Association of Cardiovascular Imaging
9 (EACVI).

10 **Results:** Participants (429 respondents, 77 countries) from tertiary centers (46%), private clinics or
11 public hospitals (54%) using different vendors for data acquisition and analysis were represented.
12 Despite almost universal access (98%) to STE, only 39% of the participants performed and reported
13 STE results frequently (>50%). Incomplete training and time constraints were the main reasons for not
14 using STE more regularly. STE was mainly used to assess the left ventricular (99%) and less
15 frequently the right ventricular (57%) and the left atrial (46%) function. Cardiotoxicity (88%) and
16 cardiac amyloidosis (87%) were the most frequent reasons for the clinical use of left ventricular STE.
17 Left atrial STE was used most frequently for the diagnosis of diastolic dysfunction and right
18 ventricular STE for the assessment of RV function in pulmonary hypertension (51%). Frequency of
19 STE use, adherence to optimal techniques and clinical appropriateness of STE differed according to
20 training experience and across vendors. Key suggestions outlined by respondents to increase the
21 clinical use of STE included improved reproducibility (48%) and standardization of strain values
22 across vendors (42%).

23 **Conclusions:** Although STE is now readily available, it is underutilized in the majority of centers.
24 Structured training, improved reproducibility and inter-vendor standardization may increase its uptake.

25

1 **Keywords:** Speckle tracking strain, echocardiography, clinical, inter-vendor.

2 **Introduction**

3 Speckle tracking echocardiography (STE) has been shown to be an invaluable tool in detecting
4 subclinical LV systolic dysfunction in different clinical scenarios, and to provide a favorable impact
5 on the management of specific cardiac conditions by providing information which is not available
6 with any of the currently used echocardiographic parameters. The exciting potential of this approach is
7 reflected by the exponential increase in research and scientific publications over the last decade.
8 Furthermore, STE is frequently highlighted by current recommendation documents from the European
9 Association of Cardiovascular Imaging (EACVI) and American Society of Echocardiography (ASE)
10 as a state of the art approach for patient evaluation.¹⁻⁷ Consequently, it is crucial to have a better
11 understanding of how this imaging technique is used in current clinical practice, from both a technical
12 and clinical perspective as well as the remaining barriers limiting its widespread clinical
13 implementation.
14 Therefore, this survey aims 1) to understand the implementation of recommendations on ST strain
15 imaging in clinical practice worldwide and 2) to explore barriers and challenges in clinical
16 applications. Ultimately the survey seeks to inform future strategies to optimize integration of STE
17 into routine patient assessment.

18 19 **Methods**

20 The present survey was conducted by the EACVI Scientific Initiatives Committee from 15 September
21 to 15 October 2022 according to published criteria (8). Participation in the survey was through an
22 open access weblink for physicians, sonographers and technicians. The weblink of the survey was
23 shared through the European Society of Cardiology (ESC) website, official bulletins of the ESC, and

1 the social media for inviting the participants. Participants from 250 EACVI registered units around the
2 world were invited to complete an online survey comprising 27 questions. The first 10 questions of the
3 survey were prepared to obtain information about the access to STE and the feasibility of the tool in
4 different categories of health care providers, 9 questions aimed at obtaining information about the
5 training and optimal technical use of STE software, and 8 questions aimed to obtain information about
6 the clinical implementation of STE in current clinical practice and the expected improvements to
7 increase its integration into daily practice.

8

9 **Statistics**

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

23

1 **Results**

2
3 In total, 429 voluntary participants responded to the survey from 77 countries across the globe. The
4 participants were from, Algeria, Angola, Argentina, Armenia, Australia, Austria, Bahrain,
5 Bangladesh, Belgium, Bosnia and Herzegovina, Brazil, Bulgaria, Canada, Chile, China, Columbia,
6 Costa Rica, Croatia, Cyprus, Czechia, Denmark, Egypt, Estonia, Finland, France, Georgia, Germany,
7 Greece, Hungary, India, Iran, Iran, Iraq, Ireland, Italy, Japan, Jordan, Korea, Kuwait, Lebanon,
8 Lithuania, Malaysia, Mexico, Mongolia, Morocco, Myanmar, the Netherlands, New Zealand, Nigeria,
9 North Macedonia, Norway, Oman, Pakistan, Palestine, Paraguay, Peru, Poland, Portugal, Romania,
10 Russian Federation, Saudi Arabia, Senegal, Serbia, Slovenia, South Africa, Spain, Sweden,
11 Switzerland, Syrian Arab Republic, Taiwan, Tunisia, Turkiye, Ukraine, United Arab Emirates, United
12 Kingdom of Great Britain and Northern Ireland, United States of America, Uruguay, Uzbekistan.

13
14 Participants worked in tertiary centers (45%), public hospitals (37%), private clinics (17%) and
15 intensive care or emergency departments (1%). More than half of the survey participants were senior
16 echocardiographers (58%) and the others were early career echocardiographers (22%), multimodality
17 imagers (16%) or sonographers (5%). Almost 95% of the participants worked in either cardiology or
18 cardiothoracic departments with the remainder working in internal medicine, intensive care unit or
19 emergency department (Figure 1).

21 **Access to Speckle Tracking Echocardiography**

22 The majority of respondents had access to STE within their department (80%), 15% reported having
23 access to STE within their hospital and 5% either had access to it within their region (via referral)
24 (3%) or did not have access to STE (2%) (Figure 2A).

1
2 Interestingly, nearly a quarter (23%) of the participants reported not using this technology despite
3 having access to it. The commonest reasons of not using STE were time constraints (49.7%) and the
4 need for more training (37.6%). Other reasons included lack of motivation to spend time learning the
5 technology (3.9%), not seeing the value in STE (3.9%) or a dislike for the post processing algorithms
6 available to them (4.9%).

8 **Clinical Usage and Training Resources**

9 In terms of clinical usage, whilst 39% of the participants performed or reported speckle tracking
10 frequently (>50% of their studies), 28% of the respondents included strain in their report infrequently
11 (25-50% of their studies), 22% very rarely (<25% of their studies) and 7% of the respondents used
12 STE only for research purposes (Figure 2B).

13
14 The majority of respondents (84%) were trained in STE. Training at an expert center (47%) or by
15 performing research with the use of STE (43%) were the most common means of training. Other
16 training resources included national teaching courses (34%), the EACVI e-learning platform (22%),
17 and EACVI hands-on teaching courses (17%) (Figure 3). While 15% did not receive any training,
18 54% were trained on STE by means of more than one resource. Interestingly, 18 out of 38 (47%) who
19 mentioned a need for more training had previous training (32 from 1 resource, 6 from more than 1
20 resources). Importantly, more extensive training in STE was associated with increasing CUS (CUS:
21 6.1 ± 3.2 in those who were not trained, CUS: $7.6 \pm 3.3^*$ in those who were trained via 1 resource,
22 CUS: $8.8 \pm 3.0^{*\dagger}$ in those who were trained via 2-3 resources, CUS: $9.2 \pm 3.4^{*\dagger}$ in those who were

1 trained via more than 3 resources; * $p < 0.01$ vs not trained, † $p < 0.01$ vs 1 resource) (Central
2 illustration).

4 **Offline versus during acquisition preferences of STE analyses**

5 The majority (63%) of respondents performed strain analyses during image acquisition while 37%
6 performed offline analyses. EchoPAC was the most widely (69%) used workstation for offline
7 analysis among the respondents. TomTec was used by 10%, Xcelera by 7%. Other postprocessing
8 systems were used less frequently. Users from emergency departments and intensive care performed
9 STE exclusively during image acquisition. Offline strain analyses were least frequent among private
10 clinic practitioners (24%) whereas offline systems were used by 35% of public hospital practitioners
11 and 44% of tertiary center practitioners ($p < 0.001$). More extensive STE training was associated with
12 more frequent use of offline analysis workstations and offline strain analysis was performed by the
13 majority of researchers (58%). Importantly, offline strain quantification was associated with higher
14 CUS and TAS (Table 2).

15
16 In the majority of the countries, STE provided no revenue as an add-on to the regular transthoracic
17 echocardiography (56 out of 79 countries (71%), and according to 85% of the respondents). On the
18 other hand, revenue for STE was declared by 88% of respondents from the United States of America,
19 else, in 22 countries reimbursement or a fee was applied only occasionally.

21 **Appropriate use of the technique**

22 Among the users almost all (99%) performed STE for the left ventricle (LV). For this purpose, 85%
23 used global longitudinal strain (GLS) obtained from 3 apical views. However, 8% quantified LV

1 longitudinal strain from the apical 4- and 2- chamber views whilst 6% quantified STE from only the
2 apical 4-chamber. Automated algorithm analysis with manual correction of the region of interest was
3 the most widely adopted approach (88%). Only 6% used fully automated algorithms and 5% manual-
4 only tracings.

5
6 For clinical purposes, GLS was the most frequently used strain assessment tool (97%) followed by
7 bull's eye plots (76%), the segmental strain curve pattern (33%), segmental peak systolic strain (28%)
8 and time to peak strain (22%). In patients with atrial fibrillation, almost half the responders (49%)
9 reported obtaining GLS using the automated algorithm only if the cardiac cycles were similar and
10 within physiological limits. The others reported either taking an average of longitudinal strain
11 measured manually from the 3 apical views regardless of cycle length variation (16%) or by assessing
12 only the apical 4 chamber average longitudinal strain (4%). Meanwhile, 30% did not quantify LV
13 longitudinal strain in patients with atrial fibrillation.

14
15 Just under half (46%) of the survey participants quantified left atrial (LA) strain. The majority (59%)
16 calculated LA longitudinal strain by taking an average of the apical 4- and 2-chamber views. Others
17 used either the apical 4-chamber or 2-chamber views.

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

22

1 Training experience of the operator was associated with greater adherence to the technical
2 recommendations provided by the EACVI / ASE standardization taskforce as shown in function of
3 TAS in Central illustration (TAS: 2.6 ± 1.4 in those who were not trained, TAS: 3.0 ± 1.1 in those
4 who were trained via 1 resource, TAS: $3.3 \pm 1.2^*$ in those who were trained via 2-3 resources, TAS:
5 $3.6 \pm 1.0^*$ in those who were trained via more than 3 resources; $*p < 0.01$ versus no training) .
6

7 **Characteristics of the Usage of STE by Vendors**

8 Among respondents, General Electric (GE) was the most frequently used cardiac ultrasound vendor
9 for STE (59%), followed by Philips (32%), Siemens (3%), other brands (6%, including Canon,
10 Toshiba, Esaote, Mindray). Differences in the technical approach to LV strain assessment were
11 observed among users of different vendors (Table 3). LV GLS assessment from 3 apical views was
12 performed most frequently by GE and Philips users as well as RV and LA strain assessments. Strain
13 pattern recognition with the bull's eye plot was most frequently adopted by GE users. Importantly, the
14 clinical frequency of STE utilization also differed among users of different vendors. Strain analysis
15 during the acquisition was performed more frequently than offline analysis across all vendors, but this
16 trend was most prominent among Siemens users. Forty-seven percent of GE users performed STE
17 frequently (in $>50\%$ of the studies), in comparison to 26% of Philips, 25% of Siemens and 21% of
18 other brand users in their studies ($p=0.001$). The majority (58%) of Siemens users performed STE in
19 less than a quarter of their studies. Of note, the technical adherence score was highest among GE
20 followed by Philips users. The evidence based clinical use score was also highest among GE users
21 followed by other brand users and Philips users. Regarding STE vendor distribution across different
22 institutions represented in the survey, GE and Philips were mostly used in tertiary centers, Siemens,

1 mostly in public hospitals and other brands mostly in private clinics (Central illustration). Training
2 intensity did not differ between users of different vendors.

4 **Applications of STE in Clinical Practice**

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

9
10 Whilst 62% of the participants envisaged using an impaired LV GLS as a trigger to optimizing
11 medical treatment in patients with heart failure with preserved ejection fraction, 38% did not.
12 Similarly, when asked regarding the use of LV GLS in heart failure with reduced ejection fraction
13 (EF) (<50%), 35% reported always taking it into account as they considered GLS to be more
14 reproducible than EF, 31% used it for monitoring response to medical therapy, 7% used it to monitor
15 response to treatment in patients receiving cardiac resynchronization therapy and 27% did not use
16 GLS in this scenario. Interestingly, the majority (71%) reported never using LV strain with
17 dobutamine stress, while 25% reported using strain for the assessment of viability and 4% for the
18 study of LV dyssynchrony.

19
20 Clinical scenarios where RV strain was assessed by the participants included pulmonary hypertension
21 (51%), arrhythmogenic cardiomyopathy (33%), routine echocardiographic exams to assess RV
22 function (24%), suspicion of RV infarction (23%) and to aid selection of candidates for cardiac
23 resynchronization therapy (7%).

1
2 The survey also investigated indications for performing LA strain, with the most common being the
3 diagnosis of diastolic dysfunction (48%), followed by prediction of the risk of developing atrial
4 fibrillation (30%), the routine assessment of LA function (19%), as well as the prediction of embolic
5 stroke risk in both sinus rhythm (14%) and atrial fibrillation (10%).

7 **Suggestions for Future Developments**

8 Finally, the survey gathered suggestions for solutions to increase the clinical use of STE. Improved
9 measurement reproducibility was the most frequent answer provided (47%), followed by
10 standardization of STE results to improve cross-interpretation across different vendors (42%). Faster
11 algorithms (32%), increasing the revenue associated with performing STE (30%), the development of
12 vendor neutral solutions (23%) and methods to apply STE to 3-dimensional data sets (18%) as well as
13 higher frame rates (17%) were other important suggestions (Figure 5).

15 **Discussion**

16 The present survey is unique in providing real world data about the clinical use of STE from 77
17 countries, focusing on access, application, training, and vendors. The main findings are as follows: 1)
18 Despite near universal access, the performance of STE remains relatively low in clinical practice. 2)
19 The extent of operator training in STE is associated with the frequency of clinical usage, adherence to
20 optimal technique defined by the strain standardization task force and evidence based clinical use. 3)
21 A non-negligible percentage of echocardiographers did not have training on STE or did not feel self-
22 confident enough despite having some training. 4) There is also important vendor related variation in
23 clinical use of STE.

1
2 Overall, the current clinical application of STE was lower in this survey than expected. Despite almost
3 universal access, only 39% performed and reported STE frequently (>50%) in their reports. When
4 used, the clinical conditions where STE was applied were compliant with the scientific evidence and
5 recommendations of the EACVI, most commonly being utilized in the left ventricle in patients with
6 suspicion for cardiac amyloidosis and chemotherapy induced cardiotoxicity. Disease oriented
7 evidence-based consensus documents are also eagerly awaited as well as further scientific evidence
8 demonstrating the clinical benefits of using STE in routine practice across different medical
9 conditions. Time constraints and lack of training were the 2 most important reasons for not using STE
10 in daily practice despite having access to it. Time constraints may explain partly the preference of
11 performing STE analysis during acquisition rather than offline. Even though the performance of STE
12 is rarely reimbursed this was not described as a impeditive factor for its use, although it was described
13 as a method of increasing the uptake and application of strain imaging in the future. The responses
14 showed that most of the echocardiographers were trained at an expert center or using educational
15 resources provided by their national societies. Approximately, a third of the respondents had received
16 training from the EACVI driven resources, underpinning the importance of the efforts to expand the
17 exposure to EACVI training platforms. The survey showed that respondents with more extensive
18 training (training from more than 1 resource) in STE, demonstrated more frequent usage of this
19 approach, greater adherence to optimal imaging techniques and more appropriate implementation of
20 STE into clinical practice. The association between STE training experience and the frequency and
21 quality of STE use in clinical practice suggests the need for a greater focus on structured training
22 programs including at least 2 steps in order to achieve the necessary level of expertise and confidence
23 for the use of STE in patient management.

1
2 We observed prominent vendor related differences in the frequency of STE use, as well as adherence
3 to optimal techniques and appropriate clinical application.^{21,22} Furthermore, there was variation
4 observed in vendor use according to place of work, with differences seen between tertiary centers,
5 public hospitals and private clinics. The explanation for these vendor related differences requires
6 further exploration but might include differences in processing algorithms and user-friendliness of the
7 navigation platform among others. These differences might also present an opportunity for greater
8 inter-vendor standardization efforts that might ultimately expand the clinical implementation of STE.
9 Indeed, respondents felt that improved reproducibility and standardization of strain values across
10 vendors were the key measures to improve uptake of STE in clinical practice.

11
12

13 **Limitations**

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

20

21 **Conclusions**

22 In conclusion, STE is now a widely accessible clinical tool, yet it is only routinely used in the minority
23 of echocardiographic centers. Extensive training in STE appears important in determining a high

1 frequency of STE use and is associated with improved adherence to optimal imaging techniques and
2 clinical appropriateness. Improving exposure of the echocardiographers to training resources as well
3 as increasing measurement reproducibility and inter-vendor standardization may all contribute to
4 accelerate the routine clinical adoption of STE.

6 **Data Availability**

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

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20 **Figure legends**

21 **Central illustration:** Frequent reporting, technical adherence and evidence based clinical use of STE
 22 by training intensity, health care facility and vendors

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

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

26 **Figure 3:** Resources used for training on STE.

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

29 **Figure 5:** Answers to “Which improvement would increase your clinical use of speckle tracking
 30 imaging?”.

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Tables:

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 left ventricular global longitudinal strain? From 3 apical views.
2. How do you assess left atrial longitudinal strain? From the average of apical 4- and 2-chamber.
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 left ventricular 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. Ischemic 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)
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 15. Suspected right ventricular infarction

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4 **Table 2:** Relation of real time versus offline strain analysis performance with training, health care
5 provider, clinical usage and technical adherence.

		During image acquisition	Offline	P value
	Without training	43(78%)	12 (22%)	0.014
Training	Training from 1 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 centers	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

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2 **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 3 apical views	89	82	42	71	<0.001
Only from apical 4-chamber view	4	7	42	7	
From apical-4, and -2 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
Analyze 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 center

47.3

44.7

8.3

21.4

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- 1 LA; left atrial, LV; left ventricular, RV; right ventricular. Values are presented as percentages or mean
2 \pm standard deviation. *p<0.05 vs General Electric, †p<0.001 vs General Electric

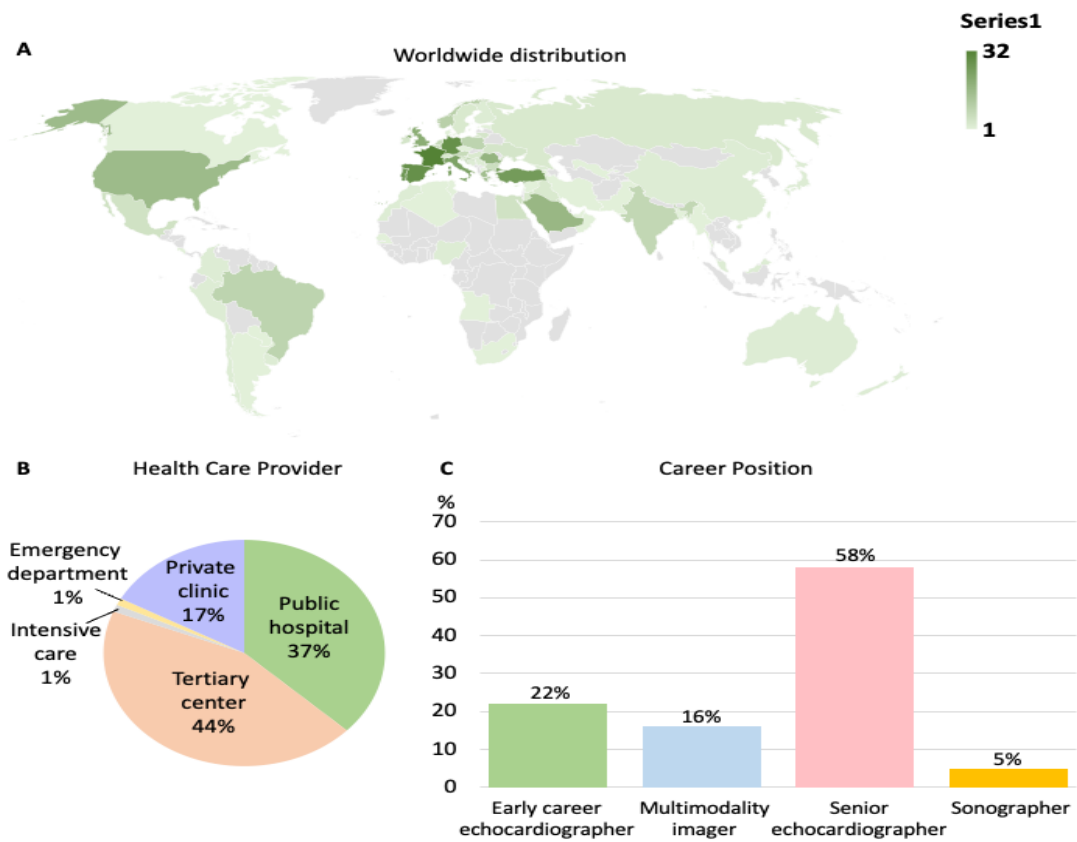


Figure 1

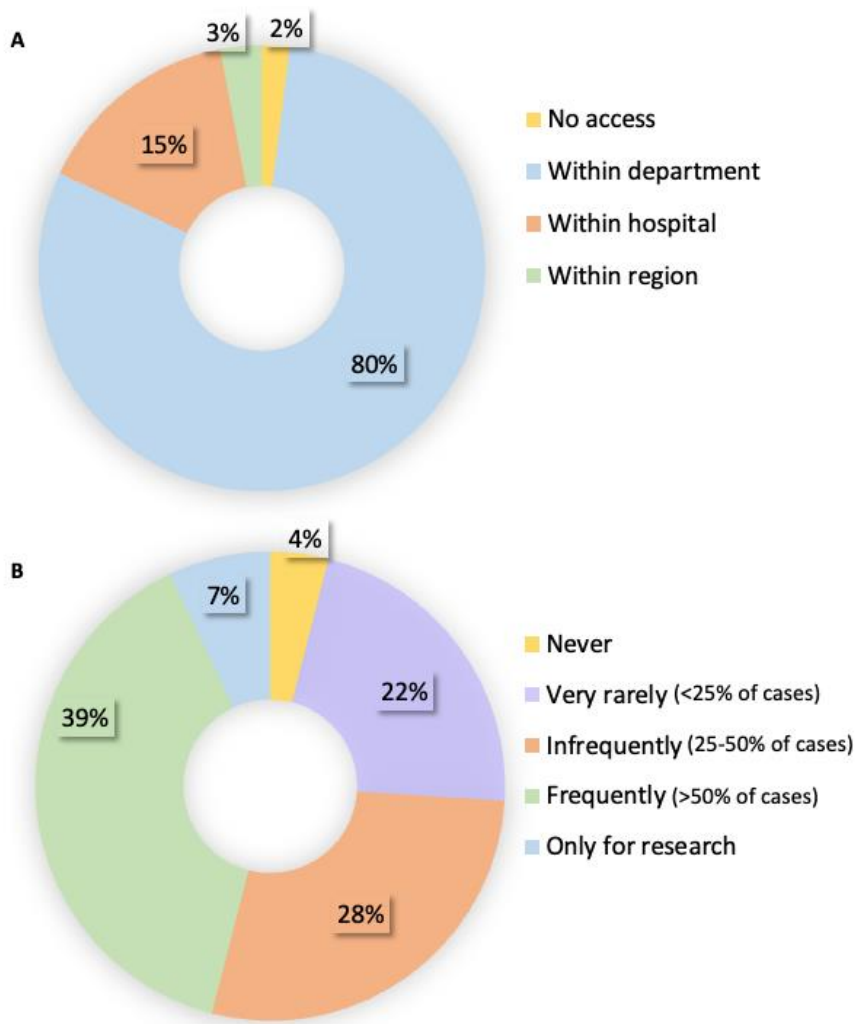


Figure 2

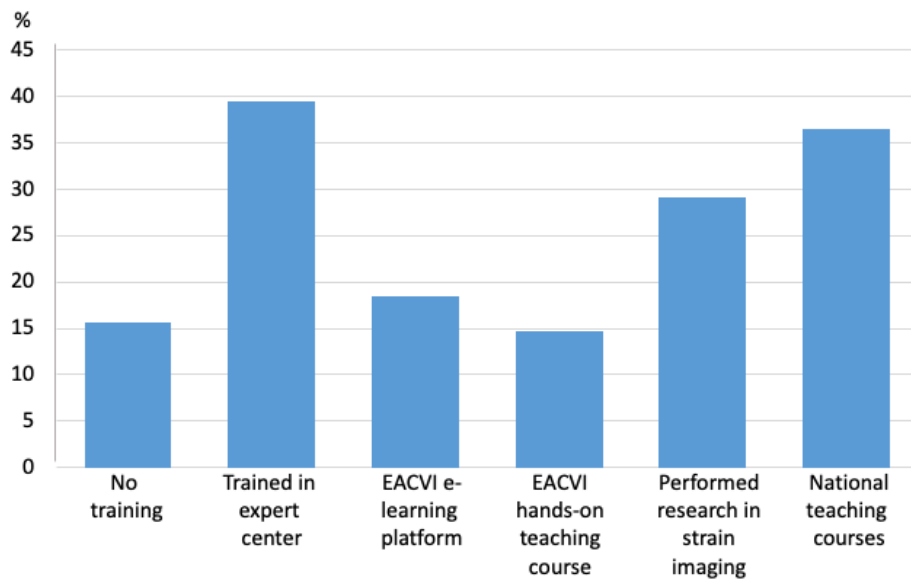


Figure 3

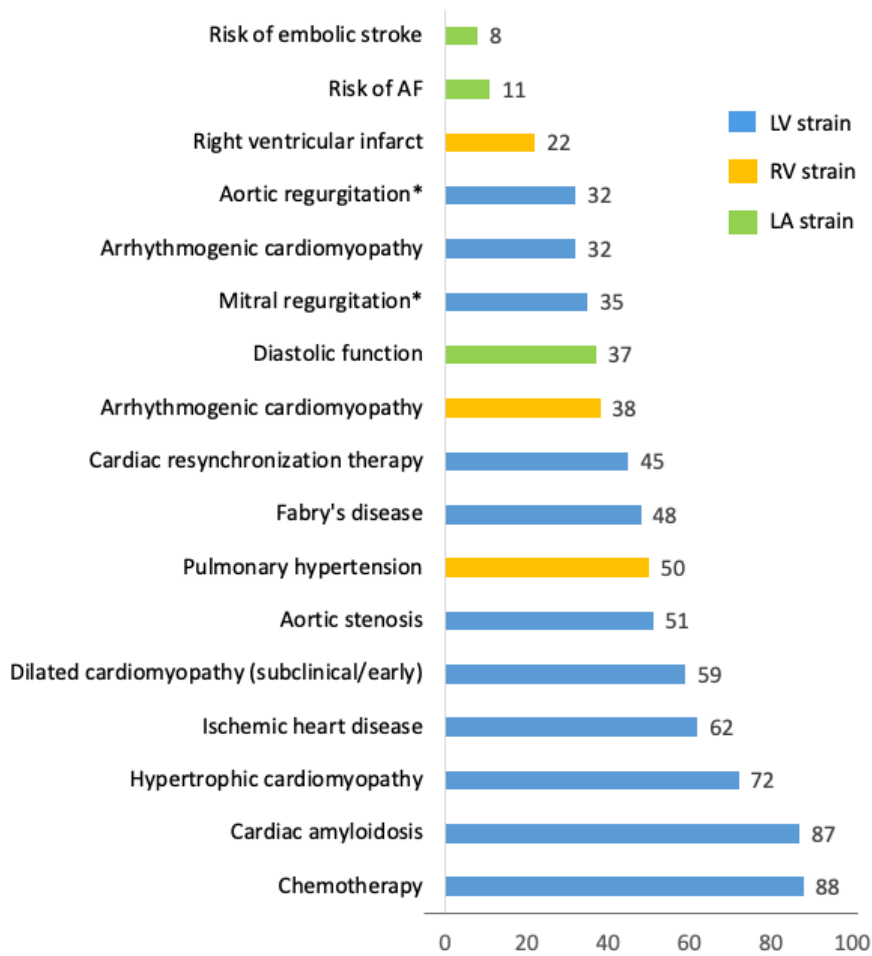


Figure 4

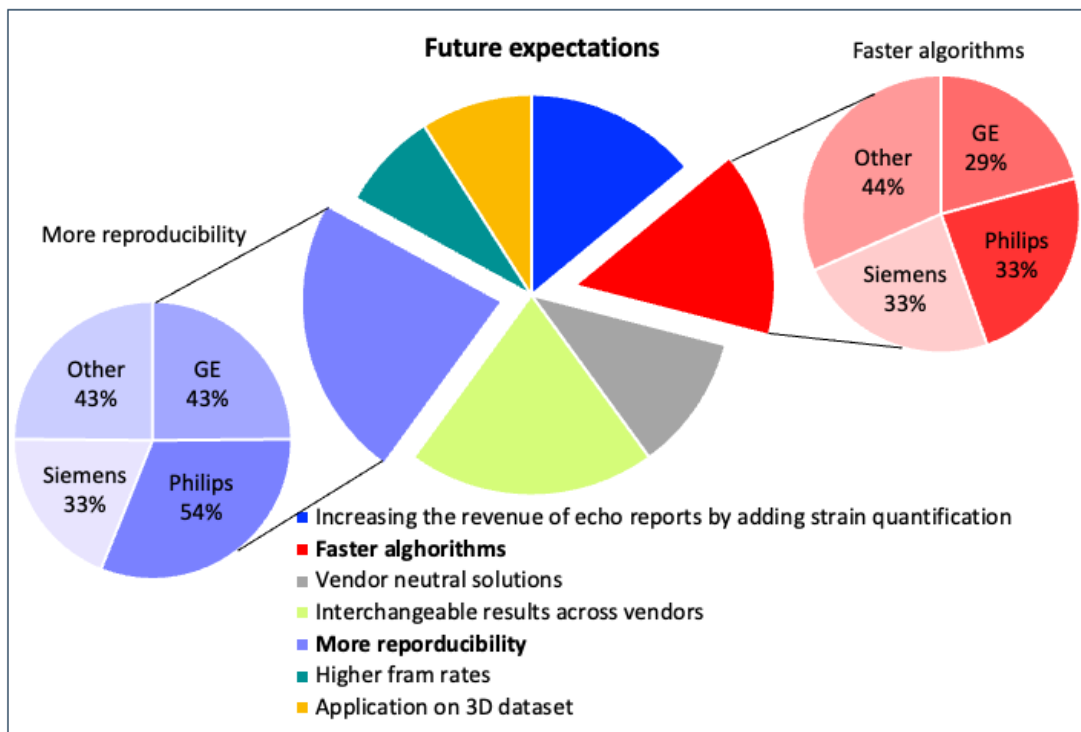


Figure 5