



Current Awareness and Status of Transthoracic Echocardiography in Kumamoto Prefecture

— A Report of the Kumamoto Cardiovascular Echocardiography Standardization Project —

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Background: There are few reports on current awareness and status of transthoracic echocardiography (TTE), including the actual performance rate according to echocardiographic guidelines, in a specific area or region.

Methods and Results: This cross-sectional survey study was conducted in Kumamoto Prefecture from October 2018 to March 2019. There are 366 medical institutions advocating cardiology in Kumamoto Prefecture. Of these, 259 (101 hospitals and 158 clinics) returned questionnaires regarding TTE. In all, 150,570 TTEs were performed in 2017. Of these, 132,771 (88%) were performed in hospitals and 17,799 (12%) were performed in clinics. Physicians performed only 5% of TTEs, whereas sonographers performed 86%. Although the modified Simpson method was performed in 90% of hospitals, 3-dimensional echocardiography was performed in only 2% of hospitals. In addition, the left atrial volume index was not examined in approximately 60% of hospitals, and the mean E/E' ratio was not examined in 80% of hospitals. Multivariable logistic regression analysis revealed that having a Fellow of the Japan Society of Ultrasonic in Medicine was significantly and independently associated with guideline-oriented TTE (odds ratio 9.43; 95% confidence interval 1.22–72.71, $P < 0.05$).

Conclusions: The rate of echocardiographic measurements performed according to echocardiographic guidelines is exceptionally low in Kumamoto Prefecture. Sufficient dissemination of echocardiographic guidelines may be important in improving this rate.

Key Words: Echocardiographic guideline; Kumamoto Prefecture; Transthoracic echocardiography

The presence of left ventricular (LV) systolic dysfunction is a poor prognostic marker in many cardiovascular diseases. Therefore, assessment of LV systolic function using transthoracic echocardiography (TTE) can provide useful information in the clinical setting.^{1,2} Although the LV ejection fraction (LVEF) is the most commonly used echocardiographic marker to evaluate LV

systolic function, LVEF obtained by conventional methods has some limitations.^{3,4} Echocardiographic technology has continued to evolve, with major developments in real-time 3-dimensional echocardiography. The American Society of Echocardiography (ASE) and European Association of Cardiovascular Imaging (EASCI) 2015 guidelines recommend real-time 3-dimensional echocardiography for

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Table 1. Medical Institutions, Number of TTEs Performed, and the Profession of Those Performing TTEs	
No. medical institutions performing TTE in Kumamoto Prefecture	
Total no.	187
Hospitals	87 (47)
Clinics	100 (53)
No. TTEs performed in 2017	
Total no.	150,570
Performed in hospitals	132,771 (88)
Performed in clinics	17,799 (12)
Occupation of those performing TTEs in each medical institution	
Physician	82 (44)
Sonographer	80 (43)
Physician and sonographer	20 (11)
Others (nurse or radiologist)	5 (3)
No. TTEs performed by each occupation	
Physician	7,443 (5)
Sonographer	129,778 (86)
Physician and sonographer	11,915 (8)
Others (nurse or radiologist)	1,434 (1)

Unless indicate otherwise, data are given as n (%). TTEs, transthoracic echocardiograms.

evaluating LV global systolic function.⁵ Echocardiographic assessment of LV diastolic function is an integral part of the routine evaluation of patients presenting with symptoms of dyspnea or heart failure. To evaluate LV diastolic dysfunction, the 2016 ASE and EASCI guidelines recommended that left atrial maximum volume index (LAVI) and the ratio between E-wave velocity and the mean of septal and lateral E' (mean E/E' ratio) are assessed.⁶ However, few studies have reported on the actual rate of TTE performance according to these guidelines in a specific area or region. This is because obtaining echocardiographic information from all medical institutions, from small clinics to large general hospitals, is difficult. To this end, we established the Kumamoto Cardiovascular Echocardiography Standardization Project (K-CHAP) in 2018 with the aim of standardizing the echocardiographic techniques and expertise of echocardiologists in Kumamoto Prefecture. Through this project, we have connected with various echocardiologists and medical institutions, which has enabled us to undertake the present cross-sectional survey study in Kumamoto Prefecture.

The aim of this study was to clarify current awareness and status of TTE, including the rate at which it is performed according to echocardiographic guidelines in one specific area in Japan.

Methods

Study Design

The present cross-sectional survey study was conducted in

Kumamoto Prefecture, located in southwestern Japan, from October 2018 to March 2019. In 2017, the population of Kumamoto Prefecture was 1,765,079 (Kumamoto Prefectural Government Homepage; <https://www.pref.kumamoto.jp/default.aspx>) and the area of Kumamoto Prefecture was 7,409 km² (Geospatial Information Authority of Japan; <https://www.gsi.go.jp/index.html>).

For this study, questionnaires were sent to medical institutions (hospitals and clinics) advocating cardiology on the Kumamoto Prefectural Government homepage (https://www.pref.kumamoto.jp/kiji_27800.html) and information regarding echocardiographic procedures was obtained from these medical institutions. In this study, a hospital was defined as a medical institution that has ≥ 20 beds, whereas a clinic was defined as a medical institution that is focused on outpatient care and has < 20 beds, as per the Ministry of Health, Labour and Welfare (<https://www.mhlw.go.jp/toukei/saikin/hw/iryosd/08/dl/02.pdf>). Hospitals in this study were divided into 2 groups according to the number of TTEs performed (the top 20 and then the other hospitals), and the 2 groups were compared. In addition, guideline-oriented TTE was defined as evaluation of both LAVI and mean E/E' ratio, and hospitals were divided into 2 groups (guideline-oriented or non-guideline-oriented TTE) and the 2 groups were compared.

The study protocol conformed to the principles of the Declaration of Helsinki, and was approved by the Institutional Review Board of Kumamoto University (Kumamoto University Reference no. 1540). The present study was a cross-sectional study that was conducted using the opt-out method. The study protocol was extensively publicized at Kumamoto University and on our website (<http://www2.kuh.kumamoto-u.ac.jp/tyuokensabu/custom12.html>), and provided patients and medical institutions the opportunity to withdraw from the study.

Questionnaires

Two types of questionnaires were constructed: one was for hospitals and the other was for clinics. For hospitals, a detailed questionnaire was created comprising 4 sections, as follows: the number of TTEs performed from 2013 to 2017; the main profession of those performing echocardiography; the number of echocardiologists; and variables evaluated by TTE, such as using the modified Simpson method or 3-dimensional echocardiography to evaluate LV systolic function, and LAVI and mean E/E' ratio to evaluate LV diastolic function. A simple questionnaire was designed for clinics, comprising 2 sections: the number of TTEs performed in 2017 and the main profession of those performing echocardiography.

Kumamoto Community Medicine Design

"Kumamoto Community Medicine Design" was devised in Kumamoto Prefecture to create a system that can effectively provide a high standard of medical care by local people, even if health resources (e.g., human resources or facilities) are limited. According to this design, Kumamoto Prefecture was divided into 10 subareas: Kumamoto and Kamimashiki, Uki, Ariake, Kamoto, Kikuchi, Aso, Yatsushiro, Ashikita,

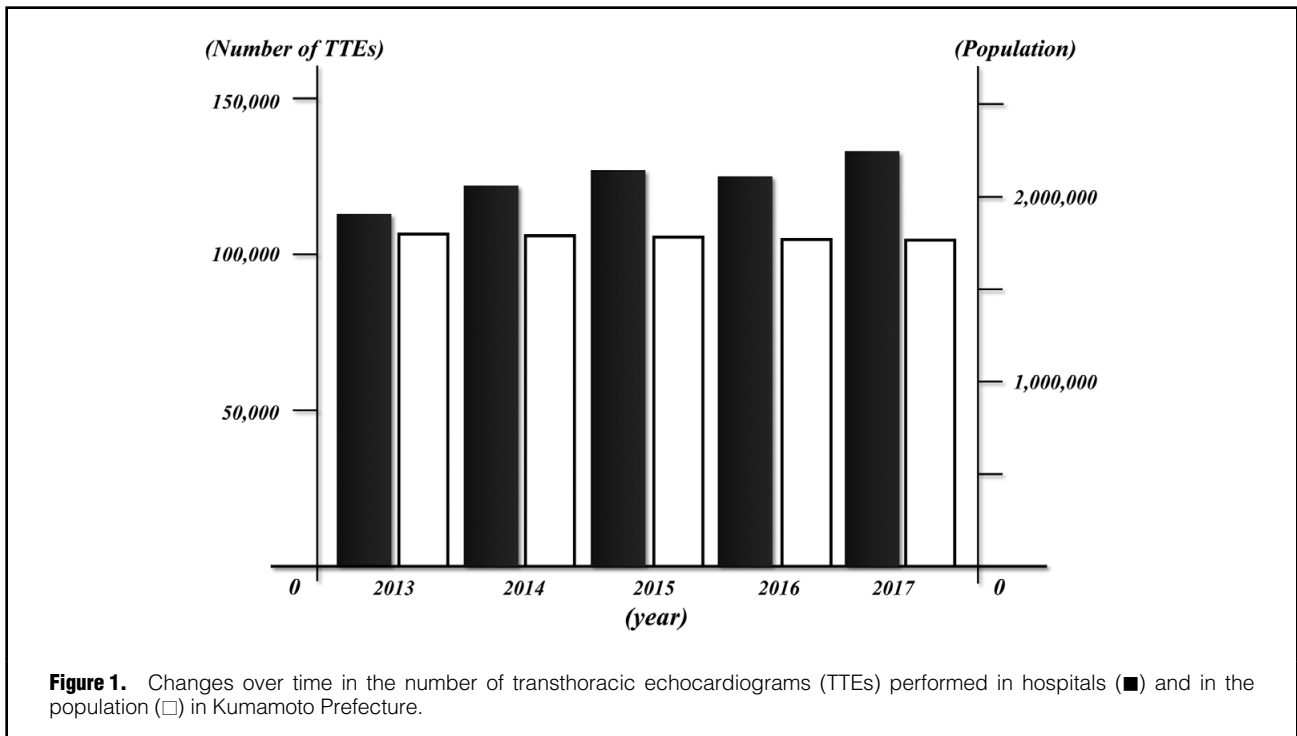
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Kuma, and Amakusa (**Supplementary Figure**). In this study, we reintegrated these areas into 3 areas, namely Central (Kumamoto and Kamimashiki, Uki), North (Ariake, Kamoto, Kikuchi, Aso), and South (Yatsushiro, Ashikita, Kuma, Amakusa). Several factors related to TTE were compared among these subareas or reintegrated areas.

Kumamoto Cardiovascular Echocardiography Standardization Project

The present questionnaire survey was an activity of K-CHAP. Various types of echocardiologists are involved in K-CHAP, including those from Kumamoto University Hospital, Kumamoto Association of Medical Technologist, and Japan Primary Care Association, Kumamoto branch, as well as those from other cardiologic hospitals (Saiseikai Kumamoto Hospital, Japanese Red Cross Kumamoto Hospital, Kumamoto Chuo Hospital, Kumamoto City Hospital, National Hospital Organization Kumamoto Medical Center, Kumamoto Rosai Hospital, Kumamoto General Hospital, Hitoyoshi Medical Center, Arao Municipal Hospital, Tamana Central Hospital, Minamata City General Hospital and Medical Center, Yamaga Medical Center, Aso Medical Center, Miyuki Hospital, Sakura Juuji Hospital, and Saiseikai Misumi Hospital).

Statistical Analysis

Several factors were compared between the top 20 and other hospitals according to the number of TTEs performed or between the guideline-oriented and non-guideline-oriented TTE groups; comparisons were made using the Mann-Whitney U test or χ^2 test. When independent variables associated with hospitals performing guideline-oriented TTE were evaluated, the following variables were initially incorporated into univariate logistic regression analysis models: number of beds, TTEs, sonographers and ultrasound diagnostic systems, mean time to perform TTE for

1 patient, having a Fellow of the Japan Society of Ultrasonic in Medicine (FJSUM), and being in the central area. Variables with $P < 0.05$ were incorporated into a multivariable logistic regression analysis model. This analysis was conducted using SPSS for Windows, version 24.0 (IBM, Armonk, NY, USA). Statistical significance was set at 2-sided $P < 0.05$.

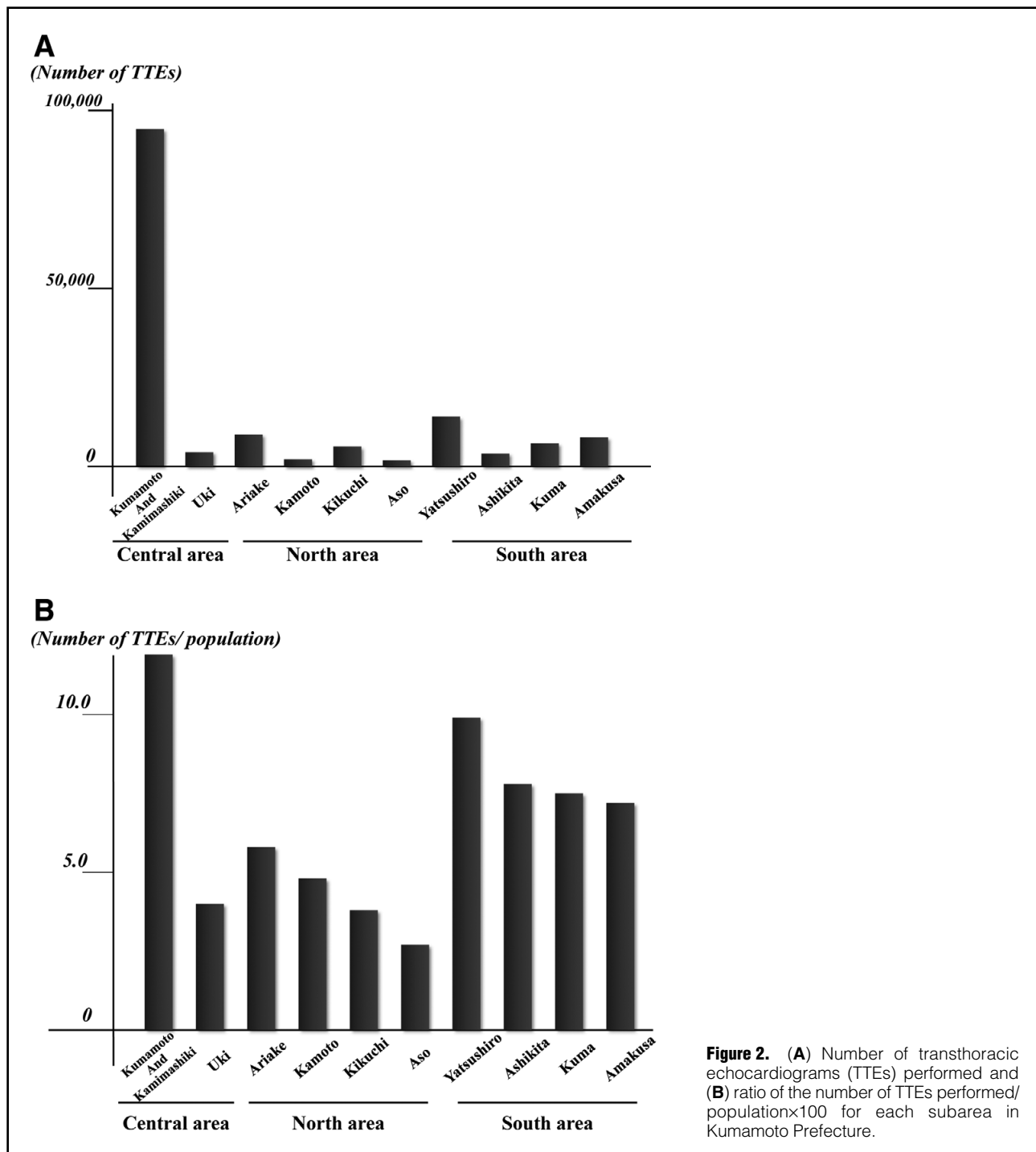
Results

Medical Institutions, Number of TTEs, and Profession of Those Performing TTEs

In Kumamoto Prefecture, there were 366 medical institutions (113 hospitals, 253 clinics) advocating cardiology on the Kumamoto Prefectural Government homepage (https://www.pref.kumamoto.jp/kiji_27800.html). Questionnaires about TTE were sent to all 366 medical institutions. Responses were received from 259 (71%) medical institutions (101 hospitals, 158 clinics), but 72 (14 hospitals, 58 clinics) did not perform TTE. Therefore, the final sample in the present study was 187 medical institutions (87 hospitals, 100 clinics). **Table 1** shows the number of medical institutions, the number of TTEs performed, and the profession of those performing TTE. In all, 150,570 TTEs were performed in Kumamoto Prefecture in 2017. Of these, 132,771 (88%) were performed in hospitals and 17,799 (12%) were performed in clinics. In 44% of medical institutions, TTE was performed by physicians, whereas in 43% of medical institutions TTE was performed by sonographers. Physicians performed only 5% of TTEs in Kumamoto Prefecture, whereas sonographers performed 86%.

Changes in the Number of TTEs Performed Over Time

Figure 1 shows changes in the number of TTEs performed in hospitals and in the population of Kumamoto Prefecture from 2013 to 2017. Although the population in Kumamoto



Prefecture decreased gradually, the number of TTEs increased gradually, except in 2016.

Response Rate and Number of TTEs Performed According to Subarea

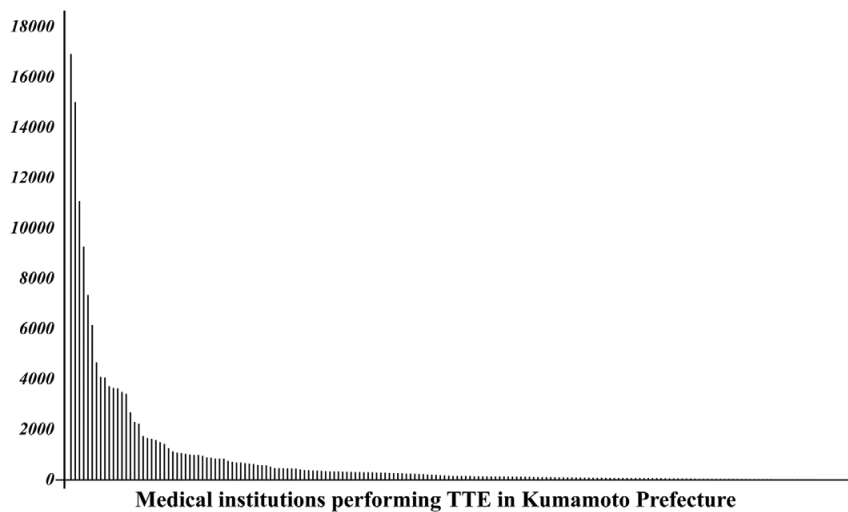
In many subareas, the response rate to the questionnaire was higher for hospitals than clinics (Supplementary Table). The number of TTEs performed was higher in the Kumamoto and Kamimashiki subarea than in the other subareas (Supplementary Table; Figure 2A). Because there was a large difference in the number of people among subareas, we

compared the ratio of the number of TTEs performed to that of the population multiplied by 100 (number of TTEs/population) among each subarea (Figure 2B). The number of TTEs/population was highest in the Kumamoto and Kamimashiki subarea and lowest in the Aso subarea. When we reintegrated Kumamoto Prefecture into 3 areas (Central, North, and South), the number of TTEs/population was highest in the Central area (Table 2). There was large difference in the number of TTEs/population between the North and South areas (4.56 vs. 8.34), and the elderly population was higher in the South than North area (30%

Table 2. Comparisons Among the North, Central and South Areas			
	North area	Central area	South area
No. TTEs	18,999	98,997	32,010
Total population	416,448	898,378	383,702
% Elderly population (>65 years)/total population	30	25	35
No. TTEs/population×100	4.56	11.02	8.34
No. medical institutions	83	202	81
No. large medical institutions (>200 beds)	8	16	6
No. sonographers	66	214	52

The subareas in Kumamoto Prefecture were reintegrated into 3 areas, namely Central (Kumamoto and Kamimashiki, Uki), North (Ariake, Kamoto, Kikuchi, Aso), and South (Yatsushiro, Ashikita, Kuma, Amakusa). TTE, transthoracic echocardiography.

A
(Number of TTEs)



B
(Number of TTEs)

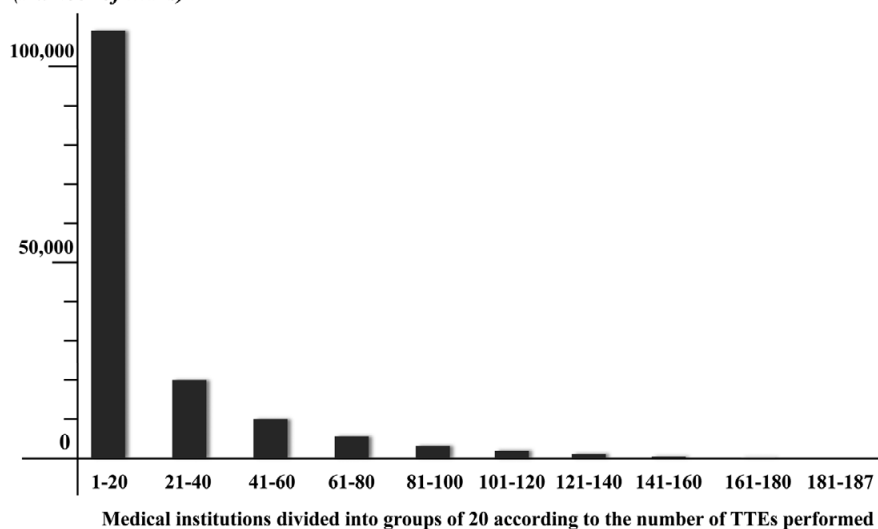


Figure 3. (A) Number of transthoracic echocardiograms (TTEs) performed by individual medical institutions in Kumamoto Prefecture, arranged in descending order. (B) Medical institutions were divided into groups of 20 according to the number of TTEs they performed; the top 20 medical institutions performed the most TTEs in Kumamoto Prefecture.

	Top 20 hospitals (n=20)	Other hospitals (n=67)	P-value
No. beds	369±168	152±100	<0.01
No. sonographers	6.7±5.8	2.1±1.8	<0.01
No. ultrasound diagnostic systems	3.4±2.0	1.2±0.4	<0.01
Time to perform TTE for 1 patient (min)	26.8±7.9	25.9±7.9	0.75
Having an FJSUM	5 (25)	1 (2)	<0.01
Being in the Central area	11 (55)	44 (66)	0.30

Unless indicated otherwise, data are given as the mean±SD or n (%). P-values were obtained by the Mann-Whitney U test and χ^2 test. FJSUM, Fellow of the Japan Society of Ultrasonic in Medicine; TTE, transthoracic echocardiography.

vs. 25%). However, there were not many differences in the number of medical institutions, large medical institutions, and sonographers between North and South areas.

Number of TTE Procedures Performed in Each Medical Institution

Figure 3A shows the number of TTEs performed by each medical institution in Kumamoto Prefecture. There were large differences in the number of TTEs performed among medical institutions, so we divided medical institutions into groups of 20 according to the number of TTEs performed in descending order (e.g., the top 20 institutions were in the first group, those performing 21–40 TTEs were in the second group etc.). The top 20 medical institutions were found to perform 72% of TTEs in Kumamoto Prefecture (**Figure 3B**). When hospitals were divided into 2 groups according to the number of TTEs performed (i.e., the top 20 hospitals and then all other hospitals), the number of beds (mean [±SD] 369±168 vs. 152±100; $P<0.01$), sonographers (6.7±5.8 vs. 2.1±1.8; $P<0.01$), ultrasound diagnostic systems (3.4±2.0 vs. 1.2±0.4), and having an FJSUM (25% vs. 2%; $P<0.01$) were all significantly higher for the top 20 hospitals than the other hospitals (**Table 3**).

Rate of Echocardiographic Measurements Performed According to American Heart Association Guidelines in Hospitals

Figure 4A shows the rate of performance of the modified Simpson method or 3-dimensional echocardiography for evaluation of LV systolic function in hospitals. The modified Simpson method was performed in 90% of hospitals. However, 3-dimensional echocardiography was performed in only 2% of hospitals, even for selected patients. **Figure 4B** shows the rate of determining LAVI using the modified Simpson method or the area length method and the rate of determining the E/E' ratio using tissue Doppler imaging, both of which are recommended as useful markers of diastolic function. Surprisingly, LAVI was not examined in approximately 60% of hospitals in Kumamoto Prefecture. In contrast, the mean E/E' ratio was examined in 20% of hospitals and 48% of hospitals determined only the septal E/E' ratio; 31% of hospitals in Kumamoto Prefecture did not examine the E/E' ratio. When hospitals were divided into 2 groups, namely guideline-oriented and non-guideline-oriented TTE group, the number of TTEs (mean [±SD] 3,951±4,990 vs. 1,129±2,298; $P<0.01$), ultrasound diagnostic systems (3.0±2.6 vs. 1.6±1.0; $P<0.05$), and having an FJSUM (31% vs. 3%) were all significantly higher in the guideline-oriented than non-guideline-oriented TTE group

(**Table 4A**). Multivariable logistic regression analysis revealed that having an FJSUM was significantly and independently associated with guideline-oriented TTE (odds ratio 9.43; 95% confidence interval 1.22–72.71; $P<0.05$; **Table 4B**).

Discussion

This study reports several findings regarding TTE in Kumamoto Prefecture: (1) most TTEs were performed by sonographers; (2) the number of TTEs performed increased over time; (3) the number of TTEs was fewer in the North than South area; and (4) the rate of performing echocardiographic measurements according to echocardiographic guidelines was exceptionally low.

The field of valvular heart disease is rapidly progressing, with new knowledge regarding the natural history of patients with valvular heart disease, advances in diagnostic imaging, and improvements in catheter-based and surgical interventions. Transcatheter aortic valve replacement has proven useful and its use has spread worldwide,^{7,8} with indications for transcatheter aortic valve replacement changing from high-risk patients to intermediate- or low-risk patients.^{9–11} In addition, transcatheter mitral repair is popular in various medical institutions.^{12,13} Therefore, diagnosing valvular heart disease is more important than previously. To diagnose valvular heart disease, comprehensive TTE with 2-dimensional imaging and Doppler imaging is recommended to correlate echocardiographic findings with initial impressions in the initial clinical evaluation.¹⁴ Although the population in Kumamoto Prefecture decreased gradually over time, this study showed a time-dependent increase in the use of TTE, except in 2016. This finding may reflect the increasing importance of TTE for evaluating valvular heart disease. In 2016, an earthquake occurred in Kumamoto Prefecture and many medical institutions could not perform TTE, which may explain why a low number of TTEs was performed in 2016.

This study showed that most TTEs were performed by sonographers. Thus, the main profession of those performing echocardiography in Kumamoto Prefecture is sonographer. Kajihara et al reported previously that TTE was performed by sonographers in approximately 80% of institutions in Japan and by physicians in only approximately 10% of institutions.¹⁵ However, in the present study the proportion of medical institutions in which physicians performed TTE was similar to that of medical institutions in which sonographers performed TTE. Therefore, there is a considerable difference in results between the previous and present studies.

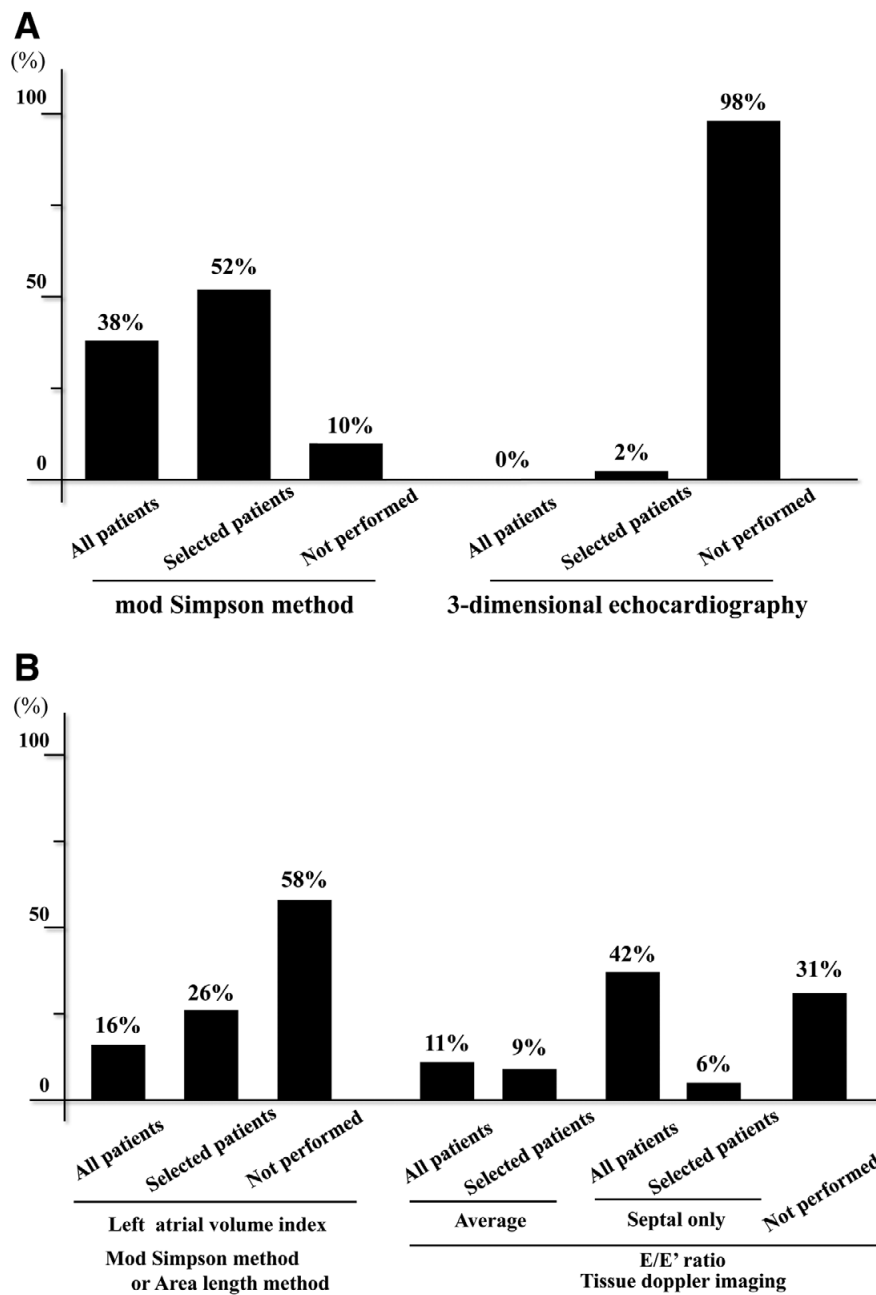


Figure 4. (A) Rate at which the modified Simpson method or 3-dimensional echocardiography are performed for evaluation of left ventricular systolic fraction in hospitals. (B) Rate at which the left atrial volume index is determined using the modified Simpson method or the area length method and the rate at which the mean or septal-only E/E' ratio is determined using tissue Doppler imaging.

The previous study was used responses to questionnaires from registered medical sonographers in Japan.¹⁵ Therefore, that study may reflect the status of selected medical institutions. In contrast, we obtained responses to questionnaires from >70% of various types of medical institutions, from small clinics to large general hospitals, advocating cardiology in Kumamoto Prefecture. Therefore, the results of the present study may represent the true current status of TTE in Kumamoto Prefecture and be close to the current status

in Japan. Although the number of TTEs performed in clinics is small compared with the number performed in hospitals, sufficient diagnostic techniques are important for echocardiologists, even in clinics, to ensure that cardiovascular disease is not overlooked. Therefore, K-CHAP, in collaboration with the Japan Primary Care Association, Kumamoto Branch, provides a hands-on echocardiographic seminar for physicians in clinics each year to improve their echocardiographic techniques.

Table 4. (A) Comparisons Between Guideline-Oriented and Non-Guideline-Oriented TTE Groups, (B) Factors Associated With Guideline-Oriented TTE					
(A)	Guideline-oriented TTE (n=13)		Non-guideline oriented TTE (n=71)		P-value
	No. beds	282±217		189±133	
No. TTEs	3,951±4,990		1,129±2,298		<0.01
No. sonographers	5.3±6.9		2.8±2.7		0.23
No. ultrasound diagnostic systems	3.0±2.6		1.6±1.0		<0.05
Time to perform TTE for 1 patient (min)	27.7±6.3		25.6±8.7		0.41
Having an FJSUM	4 (31)		2 (3)		<0.01
Being in the Central area	8 (62)		44 (65)		0.8
(B)	Univariate analysis		Multivariable analysis		P-value
	OR (95% CI)	P-value	OR (95% CI)	P-value	
No. beds, /1	1.00 (1.00–1.01)	0.05			
No. TTEs, /1	1.00 (1.00–1.00)	<0.05	1.00 (1.00–1.00)		0.82
No. sonographers, /1	1.15 (0.99–1.33)	0.06			
No. ultrasound diagnostic systems, /1	1.71 (1.15–2.53)	<0.01	1.38 (0.54–3.50)		0.5
Having an FJSUM (yes)	15.11 (2.41–94.60)	<0.01	9.43 (1.22–72.71)		<0.05
Time to perform TTE for 1 patient, /1 min	1.03 (0.96–1.11)	0.41			
Being in Central area, /1	0.85 (0.25–2.88)	0.8			

CI, confidence interval; FJSUM, Fellow of the Japan Society of Ultrasonic in Medicine; OR, odds ratio; TTE, transthoracic echocardiography. (A) Unless indicated otherwise, data are given as the mean±SD or n (%). P-values were obtained by the Mann-Whitney U test and χ^2 test. (B) P-values were obtained by logistic regression analysis.

In Kumamoto Prefecture, the number of TTEs was highest in the Central area. This may be due to the large number of medical institutions, large medical institutions, and sonographers in the Central area. However, fewer TTEs were performed in the North than South area, even though there are not so many differences in the number of medical institutions, large medical institutions, and sonographers between these 2 areas. The reason for the difference in the number of TTEs performed between these 2 areas is unclear. However, the South area has a greater elderly population than the North area, which may be one reason for the difference in the number of TTEs performed between these 2 areas.

TTE is useful for evaluating cardiac function and is being continuously improved. With each discovery of new technology, the echocardiographic examination has progressively become more comprehensive and integrated with more diverse technology. The ASE established standards for 2-dimensional TTE examinations in 1980,¹⁶ and updated recommended components of this examination in 2011.¹⁷ In addition, the 2015 ASE and EASCI guidelines recommended real-time 3-dimensional echocardiography to evaluate LV global systolic function,⁵ and the 2016 ASE and EASCI guidelines recommended using the mean E/E' ratio and LAVI to assess LV diastolic function.⁶ However, regardless of whether these new technologies are useful for evaluating cardiac function, it is meaningless if these technologies are not performed by medical institutions. This study showed that only 2% of hospitals in Kumamoto Prefecture performed real-time 3-dimensional echocardiography. This finding indicates that 3-dimensional echocardiography is not popular in Kumamoto Prefecture. Three-dimensional echocardiography may not be performed in many hospitals in Kumamoto Prefecture because it takes too long to evaluate the results of 3-dimensional echocardiography, there is a lack of 3-dimensional echocardiographic capacity in ultrasonic diagnostic systems, or

there is insufficient dissemination of the ASE guidelines. The rates of LAVI and mean E/E' examinations were also extremely low, despite these parameters being useful in evaluating LV diastolic function. Evaluation of these diastolic parameters does not take much time, and most ultrasonic diagnostic systems have the capacity to evaluate these parameters. Therefore, we believe that insufficient dissemination of the ASE guidelines may be the reason why these parameters are not evaluated in hospitals in Kumamoto Prefecture. In addition, this study showed that having an FJSUM was significantly associated with guideline-oriented TTE. This indicates that dissemination of the ASE guidelines by FJSUM may be useful in ensuring guideline-oriented TTE is performed. To perform TTE according to these guidelines, sufficient dissemination of echocardiographic guidelines may be important in Kumamoto Prefecture. Therefore, in the hands-on seminar provided by K-CHAP, these echocardiographic guidelines are disseminated to echocardiologists in Kumamoto Prefecture, especially to those in hospitals without an FJSUM.

Study Limitations

This study has several limitations. First, this study was a cross-sectional survey study and data were self-reported. Therefore, there may have been respondent bias. Second, this study was conducted in Kumamoto Prefecture, which is only a small area of Japan. Therefore, this study may have been affected by regional specificity. However, the present study is the first report to include 70% of various types of medical institutions advocating cardiology, from small clinics to large general hospitals. Thus, we believe the results of this study are a true reflection of the current awareness of TTE in Kumamoto Prefecture and may be close to current awareness of TTE in Japan. Validation using a similar cross-sectional survey study would be useful to evaluate the universality of the findings of the present

study. However, there are no similar studies because it is not easy to obtain echocardiographic information from all medical institutions in a specific area. Future similar studies in other specific areas of Japan are needed to evaluate the universality of the present findings. Third, we sent questionnaires to medical institutions advocating cardiology. We excluded medical institutions that did not advocate cardiology, even if the institutions performed TTE. Therefore, there may have been selection bias. Although the response rate is important for accurate evaluation of the status of TTE, the response rate in this study was not 100%; this is another important study limitation. However, despite several limitations, we believe that the results are meaningful because they are believed to reflect the true current status of TTE in Japan.

Conclusions

The rate at which echocardiographic measurements are performed according to echocardiographic guidelines in Kumamoto Prefecture is exceptionally low. Sufficient dissemination of echocardiographic guidelines is thought to be important for improving this issue.

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Disclosures

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Supplementary Files

Please find supplementary file(s);
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