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Original article

Simple echocardiographic scoring in screening aortic stenosis with focused cardiac ultrasonography in the emergency department

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ABSTRACT

Background: No established methodology exists for diagnosis of aortic stenosis (AS) using focused cardiac ultrasound (FOCUS). We evaluated the diagnostic accuracy of our developed visual AS score for screening AS in an emergency department.

Methods: Seventy-two emergency outpatients with suspected cardiovascular disease were studied. Emergency physicians assessed the visual AS score in addition to conducting the standard FOCUS, and then the aortic valve area index (AVAI) was measured by expert sonographers in the echocardiography laboratory. AVAI values >0.85 cm^2/m^2, 0.6–0.85 cm^2/m^2, and <0.6 cm^2/m^2 were defined as no or mild AS, moderate AS, and severe AS, respectively.

Results: Seventeen (24%) patients had moderate or severe AS. Visual AS scores assessed by emergency physicians and by expert sonographers showed excellent agreement ($\kappa = 0.93$), and a strong association was noted between the visual AS score assessed by emergency physicians and the AVAI assessed by expert sonographers ($R = -0.71$, $p < 0.0001$). A visual AS score ≥3 assessed by emergency physicians had a sensitivity of 82%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 95% for diagnosing moderate or severe AS. The prevalence of new-onset AS-related events during hospitalization was higher in patients with visual AS score ≥3 assessed by emergency physicians than in the remaining patients [7 (50%) vs. 2 (3%), $p < 0.0001$].

Conclusion: The visual AS score is a useful AS screening tool for emergency physicians who are not expert cardiologists.

Introduction

Aortic stenosis (AS) is a common valvular disease in clinical practice, with a growing global prevalence in the aging population [1,2]. Patients who visit emergency departments with various symptoms may often have AS-related pathophysiology and may sometimes require urgent diagnosis and treatment [3]. Transthoracic echocardiography is the standard procedure for screening AS and for diagnosing AS severity [4]; however, performing a comprehensive evaluation of AS in emergency situations can be difficult because the assessment takes time, experienced knowledge or techniques, and special equipment, such as spectral Doppler.

The rapid evaluation of acute or critical medical conditions has improved in recent years with the introduction of point-of-care (POC) ultrasonography [5,6]. One type of POC, focused cardiac ultrasound (FOCUS), is widely used in emergency settings to assess hemodynamic or cardiovascular pathophysiology, including hypovolemic shock, cardiogenic shock, congestive heart failure, pulmonary embolism, or cardiac tamponade [7,8]. However, no method has yet been established for the use of FOCUS in the diagnosis of AS.

We have previously developed a visual AS score to use as a simple index for AS screening with rapid echocardiography using a pocket-sized device [9]. In that study, we showed a close correlation between the visual AS score and the severity of AS, as

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evaluated with an aortic valve area index (AVAI). We also successfully diagnosed clinically significant AS with a high diagnostic accuracy using the visual AS score. In a subsequent study, we reported that the combination of our visual AS score and the conventional aortic valve calcification score [10,11] could predict further AS-related events [12]. We therefore hypothesized that our visual AS score might be useful in screening AS in emergency settings. The aim of the present study was to investigate the diagnostic accuracy of the visual AS score for AS screening in an emergency department by emergency physicians who were not expert cardiologists.

Methods

Study population

This prospective, observational study was conducted at the Kochi Health Sciences Center, a secondary and tertiary emergency public hospital. Between September 2018 and October 2019, emergency outpatients with suspected cardiovascular diseases, such as chest symptoms, consciousness disorder, abnormal vital signs, heart murmur, or abnormal electrocardiograms were enrolled. Patients with bicuspid aortic valve or a known detailed history of AS were excluded. Patients were also excluded if technical difficulty was encountered in observing the aortic valve cusps in a short-axis view or in evaluating the aortic valve area (AVA) calculated with the continuity equation in comprehensive echocardiography. The study protocol was approved by the institutional review board of the Kochi Health Sciences Center, and written informed consent was obtained from all patients.

Education of emergency physicians

Seven emergency physicians in their third to thirteenth postgraduate training year who were working in the emergency department participated in the study. They were not experts in cardiology or ultrasonography, but they had already acquired the basic techniques of FOCUS. They also underwent a brief 30-minute training program for the present study. The program consisted of lectures dealing with the theoretical basics and pitfalls in assessment of a visual AS score by the expert echocardiographer.

Point-of-care echocardiography by emergency physicians

Emergency physicians performed primary medical care for emergency outpatients in the emergency department. Patients with abnormal vital signs were evaluated with FOCUS and with the visual AS score immediately upon visiting the hospital. Other patients were also immediately evaluated with FOCUS and with the visual AS score if they presented with chest symptoms, abnormal vital signs, or other abnormal examination findings suspicious of cardiovascular diseases. The emergency physicians were permitted to confirm other test results, including auscultation, laboratory findings, electrocardiograms, X-rays, or other imaging modalities such as computed tomography scans, and they could start necessary treatment for the patients.

The emergency physicians performed conventional FOCUS and scoring of the visual AS score with portable CX-50 instruments (Philips Medical Systems, Andover, MA, USA), defined as POC-echo. The POC-echo procedure was performed at the bedside in the emergency department, with the patients in the supine position or, when possible, in the left-lateral decubitus position. The conventional FOCUS assessment involved visualizing a limited number of views, such as subcostal long axis, subcostal inferior vena cava, parasternal long-axis, parasternal short-axis, and apical four-chamber views, to assess the left and right ventricular size or systolic function, pericardial effusion or tamponade physiology, and volume status [7]. A visual AS score was evaluated by orientating the transducer and adjusting it to show the aortic valve in the parasternal short-axis view, so that the valve was centered in the display as clearly as possible. The lines between each of the three commissures were visualized in the physician's mind. Each aortic cusp opening was scored visually as follows: 0 = not restricted, 1 = restricted, or 2 = severely restricted. When a cusp did not open over the line between the commissures, the cusp opening was classified as restricted. When a cusp systolic motion was severely reduced or absent, the cusp opening was classified as severely restricted. The sum of the scores for the three cusps was defined as the visual AS score (range, 0–6) [9]. The time required for POC-echo was under 5 min. Examples of scoring the visual AS score are shown in Fig. 1.

Standard echocardiography

After admission to the hospital, the study subjects underwent comprehensive standard echocardiography (STD-echo) in the echocardiography laboratory managed and maintained according to the guidelines [13]. The STD-echo was performed within 2 weeks after the POC-echo during hospitalization, depending on each patient's need. The STD-echo was conducted by level 3 trained sonographers [14] blinded to the data obtained from POC-echo. Vivid E9 (GE Vingmed Ultrasound, Horten, Norway), EPIQ CVx, and EPIQ 7 G (Philips Medical Systems) instruments were used in the second-harmonic mode.

The left ventricular diastolic and systolic dimension, left ventricular mass index, and left ventricular ejection fraction were measured according to the usual guidelines [15]. Any left ventricular wall motion abnormality was also identified and recorded. Aortic, mitral, and tricuspid valvular regurgitations were qualified as none, mild, moderate, or severe using a multiparametric approach according to the guidelines [16]. Doppler flow data were obtained from the left ventricular outflow tract region in the pulsed-wave mode and from the aortic valve in the continuous-wave mode using multiple transducer positions to obtain the maximal velocity. The diameter of the left ventricular outflow tract was measured in the parasternal long-axis view at the position used to obtain the pulsed wave Doppler data. The AVA (AVA = area $_{\text{outflow}}$ × velocity-time integral $_{\text{outflow}}$/velocity-time integral $_{\text{valve}}$) was calculated using the continuity equation. The AVAI values were obtained by dividing the AVA by the body surface area [17]. AVAI >0.85 cm^2/m^2 represented no to mild AS, AVAI = 0.6–0.85 cm^2/m^2 indicated moderate AS, and AVAI <0.6 cm^2/m^2 signified severe AS.

The visual AS score was also assessed using STD-echo. The visual AS score and all quantitative parameters during systole, including the Doppler flow data for calculating AVA, were evaluated at a beat with equal subsequent cycles, both in POC-echo and STD-echo, for patients with atrial fibrillation, as previously reported for assessment of hemodynamics in atrial fibrillation [18].

Statistical analysis

Categorical variables were expressed as absolute values and percentages, and they were compared using the chi-square test. Continuous variables were expressed as the mean ± standard deviation and were compared between groups with Student's *t*-test. Linear regression analysis was applied to study the correlation between continuous variables. Agreement was evaluated using weighted Cohen's kappa coefficient with 95% confidence intervals (CIs). Kappa values of <0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80, and 0.81–1.0 were considered to indicate poor, fair, moderate, good, and excellent agreement, respectively. Standard methods

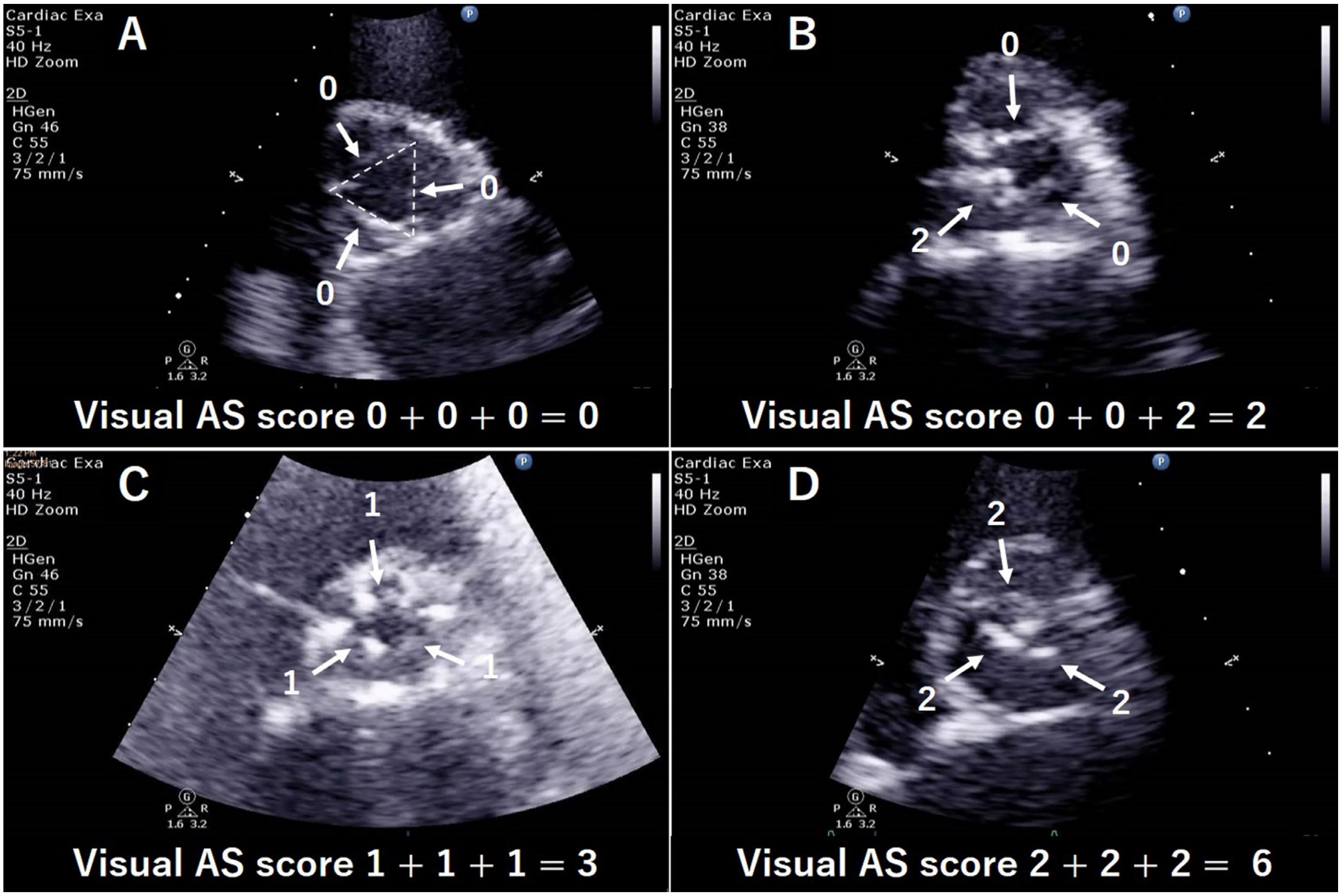

Fig. 1. Examples of the assessment of the visual aortic stenosis (AS) score. Each aortic cusp opening was visually scored as follows: 0 = not restricted, 1 = restricted, or 2 = severely restricted. The sum of the scores for the three cusps was defined as the visual AS score (range, 0–6). Examples are shown in (A) through (D).

were used to calculate the sensitivities, specificities, positive predictive values, negative predictive values, accuracies, positive likelihood ratios, and negative likelihood ratios of the visual AS score for diagnosing moderate or severe AS. The cut-off value was considered optimal when the sum of the sensitivity and the specificity was the highest. Logistic regression analysis was applied to study the association between the assessment regarding significant AS and the cardiovascular events during hospitalization. All statistical analyses were performed using commercially available MedCalc Statistical Software (version 19.1, MedCalc Software, Ostend, Belgium). A *p*-value <0.05 was considered statistically significant.

Results

We recruited 80 consecutive emergency outpatients admitted to the Kochi Health Sciences Center. Assessment of visual AS scores was feasible in 74 (93%) patients. Technical difficulties were encountered in six patients when attempting to visualize aortic valve cusps in POC-echo and these six patients were excluded. Five of these six patients also could not be assessed for visual AS score using STD-echo. We excluded 2 more patients because of technical difficulties in applying the continuity equation for poor image quality or for the observation of the coexistence of significant acceleration flow at the left ventricular outflow tract in STD-echo. No patients had bicuspid aortic valves. The remaining 72 patients constituted the final study group.

Table 1 shows the baseline clinical characteristics of all patients. The average age was 78 ± 14 years, and 41 (57%) patients were male. In the emergency department, 18 (25%) patients underwent echocardiographic assessment for respiratory disorder, 17 (24%) for hypotension or shock, 15 (21%) for consciousness disorder, 6 (8%) for abnormal electrocardiograms, 6 (8%) for fever, 5 (7%) for prior history of heart disease, 4 (6%) for chest pain, and 1 (1%) for peripheral embolism.

Cardiovascular disorders were raised as the main diagnosis on admission in 17 (24%) patients; these disorders included congestive heart failure in 9 (13%), arrhythmia in 3 (4%), ischemic heart disease in 2 (3%), syncope due to AS in 1 (1%), pulmonary embolism in 1 (1%), and aortic dissection in 1 (1%). By contrast, noncardiovascular disorders were raised as the main diagnosis on admission in 55 (76%) patients; these disorders included infectious diseases in 14 (19%), trauma in 9 (13%), cerebrovascular diseases in 8 (11%), respiratory diseases in 8 (11%), gastrointestinal diseases in 7 (10%), and other disorders in 9 (13%). Patients with moderate or severe AS evaluated by STD-echo were older than those with no or mild AS evaluated by STD-echo. No significant differences were noted in other baseline clinical characteristics between patients with no or mild AS and those with moderate or severe AS evaluated by STD-echo.

Table 2 shows the results of echocardiography for POC-echo and STD-echo. The heart rate was higher for POC-echo than for STD-echo (92 ± 23 bpm vs. 82 ± 19; $p = 0.002$). For STD-echo, the mean left ventricular ejection fraction was 61.0 ± 12.5%. Overall, 55 (76%) patients were diagnosed as having no or mild AS, 6 (8%) as having moderate AS, and 11 (15%) as having severe AS, as defined by the AVAI with STD-echo. Consequently, moderate or severe AS was seen in 17 (24%) patients. Atrial fibrillation was more frequent in patients with moderate or severe AS than in those with

Table 1
Baseline clinical characteristics.

	All (n = 72)	No or mild AS (n = 55)	Moderate or severe AS (n = 17)	p
Age (years)	78 ± 14	76 ± 15	86 ± 6	0.0059
Male (%)/female (%)	41 (57)/31 (43)	31 (56)/24 (44)	10 (59)/7 (41)	0.8589
Body mass index (kg/m²)	22.6 ± 3.9	22.6 ± 4.1	22.6 ± 3.6	0.9812
Body surface area (m²)	1.5 ± 0.2	1.5 ± 0.2	1.5 ± 0.1	0.2658
Heart rate (bpm)	92 ± 23	91 ± 24	94 ± 20	0.7101
Systolic blood pressure (mmHg)	134 ± 35	136 ± 34	124 ± 39	0.2249
Diastolic blood pressure (mmHg)	81 ± 22	83 ± 22	77 ± 23	0.3605
Reason for echocardiographic assessment				0.1781
Respiratory disorder (%)	18 (25)	13 (24)	5 (29)	
Hypotension or shock (%)	17 (24)	12 (22)	6 (35)	
Consciousness disorder (%)	15 (21)	10 (18)	4 (24)	
Abnormal electrocardiogram (%)	6 (8)	6 (11)	0 (0)	
Fever (%)	6 (8)	6 (11)	0 (0)	
Prior history of heart disease (%)	5 (7)	4 (7)	1 (6)	
Chest pain (%)	4 (6)	3 (5)	1(6)	
Peripheral embolism (%)	1 (1)	1 (2)	0 (0)	
Diagnoses on admission				0.4082
Cardiovascular disease (%)	17 (24)	12 (22)	5 (29)	
Congestive heart failure (%)	9 (13)	6 (11)	3 (18)	
Arrhythmia (%)	3 (4)	3 (5)	0 (0)	
Ischemic heart disease (%)	2 (3)	1 (2)	1 (6)	
Syncope due to AS (%)	1 (1)	0 (0)	1 (6)	
Pulmonary embolism (%)	1 (1)	1 (2)	0 (0)	
Aortic dissection (%)	1 (1)	1 (2)	0 (0)	
Infection or sepsis (%)	14 (19)	10 (18)	4 (24)	
Trauma (%)	9 (13)	8 (15)	1 (6)	
Cerebrovascular disease (%)	8 (11)	6 (11)	2 (12)	
Respiratory disease (%)	8 (11)	6 (11)	2 (12)	
Gastrointestinal disease (%)	7 (10)	5 (9)	2 (12)	
Other disorders (%)	9 (13)	8 (15)	1 (6)	

AS, aortic stenosis.

Table 2
Results of echocardiography.

	All (n = 72)	No or mild AS (n = 55)	Moderate or severe AS (n = 17)	p
POC-echo				
Heart rate (bpm)	92 ± 23	91 ± 24	94 ± 20	0.7101
Heart rhythm				0.0417
Sinus rhythm (%)	50 (69)	42 (76)	8 (47)	
Atrial fibrillation (%)	17 (24)	9 (16)	8 (47)	
Atrioventricular block (%)	3 (4)	3 (5)	0 (0)	
Pacing rhythm (%)	2 (3)	1 (2)	1 (6)	
Visual AS score				< 0.0001
0 (%)	52 (72)	50 (91)	2 (12)	
1 (%)	4 (6)	3 (5)	1 (6)	
2 (%)	2 (3)	2 (4)	0 (0)	
3 (%)	3 (4)	0 (0)	3 (18)	
4 (%)	5 (7)	0 (0)	5 (29)	
5 (%)	2 (3)	0 (0)	2 (12)	
6 (%)	4 (6)	0 (0)	4 (24)	
STD-echo				
Heart rate (bpm)	82 ± 19	80 ± 18	87 ± 22	0.1777
Heart rhythm				0.0009
Sinus rhythm (%)	56 (78)	48 (87)	8 (47)	
Atrial fibrillation (%)	13 (18)	5 (9)	8 (47)	
Atrioventricular block (%)	2 (3)	1 (2)	0 (0)	
Pacing rhythm (%)	1 (1)	1 (2)	1 (6)	
Left ventricular wall motion abnormality (%)	14 (19)	11 (20)	3 (18)	0.8315
Left ventricular mass index (g/m²)	94.7 ± 26.4	93.5 ± 24.9	98.2 ± 31.8	0.5309
Left ventricular end-diastolic volume (ml)	69.6 ± 27.0	70.3 ± 26.2	67.4 ± 30.8	0.7034
Left ventricular end-systolic volume (ml)	29.2 ± 19.3	29.3 ± 19.9	28.8 ± 18.5	0.9239
Left ventricular ejection fraction (%)	61.0 ± 12.5	60.9 ± 13.3	61.2 ± 10.1	0.9276
Left atrial volume index (ml/m²)	41.4 ± 28.6	35.4 ± 17.1	60.6 ± 46.6	0.0012
Moderate or severe aortic regurgitation (%)	2 (3)	1 (2)	1 (6)	0.3762
Moderate or severe mitral regurgitation (%)	18 (25)	9 (16)	8 (47)	0.0097
Moderate or severe tricuspid regurgitation (%)	14 (19)	7 (13)	6 (35)	0.0358
Peak aortic-jet velocity (m/s)	2.0 ± 1.0	1.6 ± 0.4	3.4 ± 1.3	< 0.0001
Mean aortic-valve gradient (mmHg)	12.4 ± 16.9	6.1 ± 3.5	32.8 ± 25.0	< 0.0001
Stroke volume index (ml/m²)	40.5 ± 12.3	42.2 ± 12.0	34.9 ± 12.4	0.0336
AVAI (cm²/m²)	1.16 ± 0.48	1.36 ± 0.35	0.52 ± 0.20	< 0.0001
AS severity				< 0.0001
None or mild (%)	55 (76)	55 (100)	0 (0)	
Moderate (%)	6 (8)	0 (0)	6 (35)	
Severe (%)	11 (15)	0(0)	11 (65)	

POC, point-of-care; AS, aortic stenosis; STD, standard; AVAI, aortic valve area index.

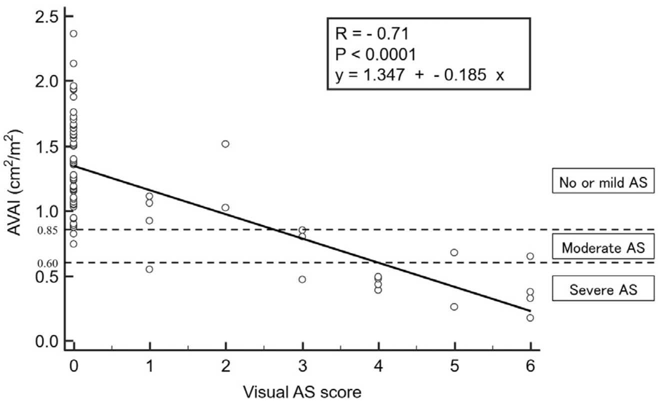

Fig. 2. Linear regression analysis between the visual aortic stenosis (AS) score assessed by emergency physicians and the aortic valve area index (AVAI) assessed by expert sonographers. A strong correlation was found between the visual AS score assessed by emergency physicians and the AVAI assessed by expert sonographers. All patients with visual AS score ≥3 had moderate or severe AS.

Table 3
Diagnostic accuracy of visual AS score ≥3 for moderate or severe AS, and severe AS.

	Moderate or severe AS	Severe AS
Sensitivity (%)	82	91
Specificity (%)	100	95
Positive predictive value (%)	100	71
Negative predictive value (%)	95	98
Accuracy (%)	96	93
Positive likelihood ratio	high	18
Negative likelihood ratio	0.18	0.09

AS, aortic stenosis.

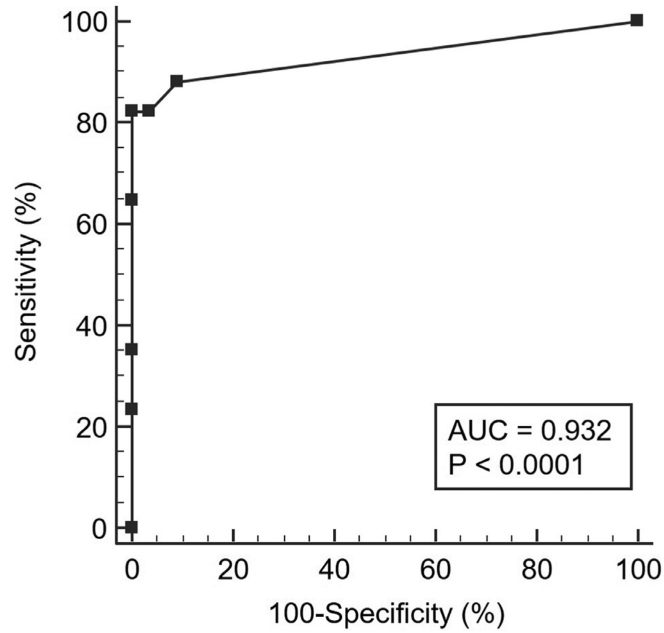

Fig. 3. Receiver operating characteristic curves for diagnosis of moderate or severe aortic stenosis (AS). A visual AS score ≥3 in point-of-care (POC)-echo was the optimal cut-off value for diagnosing moderate or severe AS with the highest sum of the sensitivity (82%) and the specificity (100%). The area under the curve (AUC) was 0.932.

no or mild AS. Moderate or severe mitral or tricuspid regurgitation was more frequent in patients with moderate or severe AS than in those with no or mild AS. The AVAI for STD-echo was smaller in patients with moderate or severe AS than in those with no or mild AS (0.52 ± 0.20 cm^2/m^2 vs. 1.36 ± 0.35 cm^2/m^2, $p < 0.0001$). The peak aortic-jet velocity and mean aortic-valve gradient for STD-echo were higher in patients with moderate or severe AS than those with no or mild AS (3.4 ± 1.3 m/s and 32.8 ± 25.0 mmHg vs. 1.6 ± 0.4 m/s and 6.1 ± 3.5 mmHg, $p < 0.0001$ and $p < 0.0001$, respectively). The distribution of the visual AS score for POC-echo was higher in patients with moderate or severe AS than those with no or mild AS ($p < 0.0001$).

The visual AS score assessed by POC-echo and the visual AS score assessed by STD-echo had an excellent agreement [$\kappa = 0.93$ (95% CI, 0.88–0.97)]. A strong correlation was found between the visual AS score for POC-echo and the AVAI for STD-echo ($R = -0.71$, $p < 0.0001$) (Fig. 2). The area under the curve (AUC) obtained using the visual AS score by POC-echo for diagnosing moderate or severe AS was 0.932 (Fig. 3). The optimal cut-off value of the visual AS score for diagnosing moderate or severe AS was 3, and the visual AS score ≥3 had a sensitivity of 82% (95% CI, 57–96%) and a specificity of 100% (95% CI, 94–100%). The agreement between POC-echo and STD-echo for a visual AS score ≥3 or <3 was obtained in 99% of the patients [$\kappa = 0.96$ (95% CI, 0.87–1.00)]. The diagnostic accuracies of the visual AS score for moderate or severe AS and for severe AS are shown in Table 3.

Among the 17 patients diagnosed as having moderate or severe AS, 1 patient with severe AS died of acute myocardial infarction and subsequent heart failure and 1 with severe AS died of sepsis and subsequent heart failure during hospitalization. One patient diagnosed as having moderate AS underwent a worsening of congestive heart failure during hospitalization and another 4 patients with severe AS underwent surgical or transcatheter aortic valve replacement during hospitalization. All seven of these patients who experienced new-onset cardiovascular events or aortic valve replacement during hospitalization had visual AS scores ≥3, as assessed by POC-echo. The prevalence of new-onset AS-related events including cardiac death, congestive heart failure, and aortic valve replacement during hospitalization was higher in patients with moderate or severe AS assessed by STD-echo than in patients with no or mild AS [7 (41%) vs. 2 (4%), $p < 0.0001$ by the chi-square test; odds ratio 18.6 (95%CI 3.4–103), $p = 0.0008$ by the logistic regression analysis). Similarly, the prevalence of new-onset AS-related events during hospitalization was higher in patients with visual AS score ≥3 assessed by POC-echo than in those with visual AS score <3 [7 (50%) vs. 2 (3%), $p < 0.0001$ by the chi-square test; odds ratio 28.0 (95%CI 4.8–162), $p = 0.0002$ by the logistic regression analysis].

Discussion

The present study examined the usefulness of our developed visual AS score in screening AS by emergency physicians who were not expert cardiologists. The main results of the present study were: 1) the observation of a strong correlation between the visual AS score for POC-echo performed by emergency physicians and the AVAI for STD-echo performed by expert sonographers; 2) a visual AS score ≥3 for POC-echo performed by emergency physicians had an excellent diagnostic accuracy for moderate or severe AS; and 3) the prevalence of new-onset AS-related events during hospitalization was higher in patients with visual AS score ≥3, as assessed by POC-echo in the emergency department, than in those with visual AS score <3.

AS is a progressive and life-threatening disease that carries the risk of severe congestive heart failure, cardiogenic shock, or sudden cardiac death in a symptomatic or even in an asymptomatic stage [10,19–21]. Degenerative AS is one of the most common valvular diseases, especially in elderly populations. Consequently, patients with degenerative AS can present to the emergency department with symptoms ranging from early disease to cardiogenic shock.

Moreover, a certain number of patients with non-cardiovascular disorders also present to the emergency department accompanied with undiagnosed AS or with known but asymptomatic AS [22,23]. An early and accurate diagnosis of clinically significant AS is therefore very important to ensure delivery of the correct treatments in emergency situations and could prevent subsequent fatal events during hospitalization or provide alternatives to surgical or transcatheter aortic valve replacement for symptom relief and/or increased life expectancy [24-27]. However, the current recommendations to determine AS require quantitative measurements using spectral Doppler from multiple views, and this must be performed by experts with experience, knowledge, and skills in echocardiography techniques [4].

POC ultrasonography is commonly used for determining the initial management of patients in the setting of the emergency department, critical care unit, and clinic, or even outside of the hospital by clinicians who have received at least focused training in ultrasound image acquisition and interpretation. It is noninvasive and immediately repeatable at bedside, along with the patient's condition changes. Therefore, diagnostic POC ultrasonography in emergency settings may lead to early diagnosis and early treatment, thereby shortening lengths of stay in the emergency department, preventing prolonged discomfort, circumventing adverse effects due to incorrect treatment choices, and decreasing morbidity and mortality.

FOCUS is generally utilized as a qualitative echocardiography technique, and it makes use of simple ultrasound equipment and basic ultrasound modes, such as primary B-mode (2D/greyscale) and occasionally color Doppler. Some articles have evaluated AS in FOCUS using calcification or a lack of morbidity of the aortic cusps or leaflets [28-30], whereas they used only subjective, vague, and unconvincing methods for diagnosing AS. We consider that our developed visual AS score could overcome this drawback of FOCUS.

In emergency settings, it is often difficult to place patients in the left-lateral decubitus position due to their condition, which may be less stable or less clear than in an echocardiography laboratory. Additionally, physicians sometimes encounter difficulties with showing the aortic valve in the short-axis view for geometrical reasons, such as sigmoid septum, and the visual AS scores tend to misestimate the severity of AS in such cases. However, it is not necessary to visualize the three cusps of the aortic valve at once to assess the visual AS score, and it should be acceptable to assess the mobility of each of the cusps separately, adjusting the angle or rotation of the probe. Therefore, the visual AS score for POC-echo demonstrates good accuracy for screening or diagnosing clinically significant AS in the present study. In the present study, emergency physicians could perform POC-echo within a short time using portable echocardiography. Overall, 55 (78%) of the patients were examined in a supine position, and a visual AS score could be assessed feasibly in 93% of all the enrolled patients. The visual AS score in POC-echo agreed well with the score obtained with STD-echo, and a visual AS score $\geq$3 had fair sensitivity and perfect specificity for moderate or severe AS.

We consider that our finding that a visual AS score of $\geq$3 indicates clinically significant AS is reasonable. Provided that the radius of the aortic annular ring is 1 cm, the area of the regular triangle is calculated as 1.3 cm^2, which corresponds closely to the cut-off value of 1.5 cm^2 for diagnosing more than moderate AS under current guidelines. Additionally, considering the mean body surface area of 1.5 m^2 of the population in the present study, the AVAI would be 0.86 cm^2/m^2, which corresponds almost exactly to the cut-off value of 0.85 cm^2/m^2 for diagnosing more than moderate AS under current guidelines. Our results suggest that if patients have a visual AS score $\geq$3, they need specialized evaluation of their AS severity and a detailed diagnosis. By contrast, if they have a visual AS score <3, they do not require further examination for AS. Notably, the prevalence of new-onset AS-related events during the hospitalization was significantly higher in patients with visual AS scores $\geq$3 assessed by POC-echo in the emergency department than in those with visual AS scores <3. This result was consistent with the principle that the emergency department should have the ability to provide rapid treatments for lifesaving and an accurate diagnosis for avoiding adverse events during hospitalization.

This study had several limitations. One is that our study included only a small population of patients and attending physicians from a single center. In addition, our patients were generally thin (body surface areas of about 1.5 m^2), as is usually seen in the Japanese population. Therefore, the acquisition of excellent echocardiographic images might have been easier than in other populations. Multicenter studies that include larger populations of patients with a wider range of ethnicities and emergency physicians will be needed to clarify the general utility of our developed visual AS score. A second limitation is that physical examination findings were not included in the present study. The transmission to the neck of a systolic ejection murmur, diminished second heart sound, delayed carotid artery upstroke, and carotid artery shudder are the physical findings representing significant AS, and these should be assessed as the first-line means of diagnosing AS. In the present study, performing a physical examination was left to the discretion of each emergency physician, and the diagnostic accuracy was not studied because the abilities to perform physical examinations obviously varied among emergency physicians. A concern remains that physical examination findings might have created some bias in the subsequent assessment of the visual AS score. In our opinion, however, this might be a strength of the present study, rather than a limitation. FOCUS is originally performed in combination with physical examinations and sometimes could be a reliable tool for enhancing the physical examination findings. Therefore, our data most likely reflect real-world clinical data. The last limitation is that the present study did not investigate low gradient AS [31-34]. The visual AS score is based on the simple concept of estimating the degree of aortic valve opening or valve area, which depends on flow dynamics, such that the cases of significant AS diagnosed with the visual AS score might include truly significant AS and pseudo-significant AS. However, we believe that the remarkable utility of the visual AS score is in screening for AS, and it is therefore appropriate to rule-in significant AS using the visual AS score and to then give a definitive diagnosis after a subsequent detailed examination, such as stress echocardiography.

Conclusions

A visual AS score obtained with our novel and simple method by emergency physicians who were not experts in cardiology gave a reasonable diagnostic accuracy as a screening tool for AS. A visual AS score <3 with FOCUS can successfully rule out clinically significant AS and a visual AS score $\geq$3 requires further examination for quantitative assessment to evaluate the AS severity by comprehensive echocardiography. Our results also suggest that the visual AS score can simply detect patients with high probabilities of AS-related events in the emergency department.

Disclosures

The authors declare that there is no conflict of interest.

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