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Original Article

Analysis of Transesophageal Echocardiography Appropriateness for Diagnosing Infective Endocarditis: Insights From Two Tertiary-Care Hospitals

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ABSTRACT

Background: Echocardiography plays a key role in the diagnosis of infective endocarditis (IE), and recommendations have been published regarding the appropriate use of transesophageal echocardiography (TEE). The objective of this study is to evaluate the utilization of TEE in Regina, Saskatchewan, in the diagnosis of IE.

Methods: A retrospective chart review was performed on patients aged ≥ 18 years who received a TEE test for the diagnosis of IE from January 1 to December 31, 2019. The primary outcome included the proportion of TEE uses that complied with the American College of

RÉSUMÉ

Contexte : L'échocardiographie joue un rôle clé dans le diagnostic de l'endocardite infectieuse (EI), et des recommandations ont été publiées concernant l'utilisation appropriée de l'échocardiographie transœsophagienne (ETO). L'objectif de cette étude est d'évaluer l'utilisation de l'ETO à Regina, en Saskatchewan, pour diagnostiquer l'EI.

Méthodologie : Un examen de dossiers rétrospectif a été réalisé chez des patients âgés d'au moins 18 ans qui se sont prêtés à une ETO pour diagnostiquer une EI entre le 1er janvier et le 31 décembre 2019. Le critère d'évaluation principal était le pourcentage d'ETO réalisées

Infective endocarditis (IE) is an infection of the heart valves or the inner lining of the heart. IE is a serious medical diagnosis associated with high rates of mortality and morbidity[1,2]; therefore, timely and accurate diagnosis is of the utmost importance. Echocardiography plays a key role in the diagnosis of IE.

Transthoracic echocardiography (TTE) is recommended as the first-line imaging modality in cases of suspected IE.[3] Although transesophageal echocardiography (TEE) has a higher sensitivity for identifying the presence of vegetations,[3] it is a more invasive investigation, with higher risks to the patient and higher costs to the healthcare system.[4] The American College of Cardiology Foundation (ACCF) and the American Society of Echocardiography (ASE) have developed a set of appropriate-use criteria for the use of TTE and TEE in the diagnosis of IE.[5] The 2015 European Society of Cardiology (ESC) guidelines for the management of IE also have an algorithm showing the role of echocardiography in the diagnosis and assessment of IE.[3] Despite the publication of these recommendations, the use of TEE in the diagnosis of IE varies among patient populations and clinician practices.

Owing to a high prevalence of injection drug use (IDU), Saskatchewan, Canada has many suspected and confirmed cases of IE.[6] The primary objectives of this study are to evaluate the local utilization of TEE in the diagnosis of IE and assess the level of adherence to current recommendations.

Methods

We conducted a retrospective chart-review study on patients aged ≥ 18 years who had undergone TEE for the diagnosis of IE at Regina General Hospital or Pasqua Hospital, between January 1, 2019 and December 31, 2019. Regina General Hospital and Pasqua Hospital are two university-associated tertiary-care centres in Regina, Saskatchewan, Canada, serving a population of approximately 226,000.[7] Exclusion criteria included having

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Cardiology Foundation and American Society of Echocardiography (ACCF and ASE) recommendations and the European Society of Cardiology (ESC) recommendations.

Results: A total of 204 admissions involving 188 patients who had TEE performed for the diagnosis of IE occurred within the study period. The mean age was 53.1 ± 17.1 years. Of the 204 TEE uses, 152 (74.5%) were considered appropriate by the ACCF and ASE recommendations. Having at least one predisposing condition (adjusted odds ratio [aOR] 4.30 [95% confidence interval [CI] 2.11-9.04), $P < 0.001$]) was more likely to be associated with appropriate TEE use, per the ACCF and ASE criteria. Of the 204 TEE uses, only 80 (39.2%) were considered appropriate by the ESC recommendations. Having a history of intravenous drug use (aOR 3.08 [95% CI 1.08-9.27], $P = 0.04$) and having blood cultures positive for IE-related organisms (aOR 2.31 [95% CI 1.16-4.80], $P = 0.02$)) were more likely to be associated with appropriate TEE use, per ESC recommendations.

Conclusions: The current study suggests that the use of TEE in the diagnosis of IE demonstrated variable levels of adherence to recommendations published by the ACCF and ASE and by the ESC, with significant discrepancy between the two.

conformément aux recommandations de l'American College of Cardiology Foundation et de l'American Society of Echocardiography (ACCF et ASE), et à celles de la European Society of Cardiology (ESC).

Résultats : Au total, 204 admissions ont eu lieu chez 188 patients pour se prêter à une ETO visant à diagnostiquer une EI durant la période de l'étude. L'âge moyen des patients était de 53,1 ± 17,1 ans. Parmi les 204 ETO réalisées, 152 (74,5 %) ont été jugées adéquates selon les recommandations de l'ACCF et de l'ASE. La présence d'au moins une affection prédisposante (risque relatif approché ajusté [RRAa] : 4,30; intervalle de confiance [IC] à 95 % : 2,11 à 9,04; $p <$ 0,001) était plus susceptible d'être associée à l'utilisation appropriée de l'ETO d'après les critères de l'ACCF et de l'ASE. Parmi les 204 ETO réalisées, seules 80 (39,2 %) ont été jugées adéquates conformément aux recommandations de l'ESC. Des antécédents d'utilisation de drogues intraveineuses (RRAa : 3,08; IC à 95 % : 1,08 à 9,27; $p = 0,04$) ou une hémoculture positive pour les microorganismes liés à l'EI (RRAa : 2,31; IC à 95 % : 1,16 à 4,80; $p = 0,02$) étaient plus susceptibles d'être associés à l'utilisation appropriée de l'ETO d'après les recommandations de l'ESC.

Conclusions : La présente étude donne à penser que l'utilisation de l'ETO pour diagnostiquer l'EI présente des niveaux variables d'adhésion aux recommandations publiées par l'ACCF et l'ASE d'une part, et par l'ESC d'autre part, avec un écart significatif entre les deux.

undergone TEE for a purpose other than diagnosing IE, as well as having undergone intraoperative TEE. Paper and electronic medical charts were reviewed to obtain clinical information. This study was approved by the research ethics committee of the Saskatchewan Health Authority (REB 20-91).

Clinical information, including age, sex, predisposing heart condition (per the modified Duke criteria[8]), IDU, physical examination findings, and blood culture results were collected. Findings on TTE and TEE were recorded. Clinical outcomes, including length of hospital stay, readmission, and mortality, available until December 31, 2020, were included in the analysis. As individual patients may have multiple hospitalizations with multiple instances of TEE use, each hospitalization was considered a separate encounter, and only the first use of TEE in a hospitalization was evaluated. Clinical suspicion of IE was determined based on the modified Duke criteria.[8] Cases that fall into the category of "possible IE" were considered to have a moderate level of clinical suspicion, whereas cases of "rejected IE" were considered to have a low level of clinical suspicion. The primary outcome is the proportion of TEEs that are deemed appropriate, based on the recommendations set out by the ACCF and ASE, and the ESC, respectively.

According to the ACCF and ASE appropriate-use criteria, TEE is deemed an appropriate initial or supplemental test in patients who have a moderate or high pretest probability of IE (eg, those with *Staphylococcus aureus* bacteremia, fungemia, a prosthetic heart valve, or an intracardiac device).[5] Based on the ESC Recommendations for the Practice of Echocardiography in Infective Endocarditis, TEE should be performed after initial TTE when one of the following is present: (i) a prosthetic heart valve or an intracardiac device; (ii) a high level of clinical suspicion of IE after a negative or nondiagnostic TTE test; or (iii) a suspicion of a new complication after a positive TTE test.[2]

Descriptive statistics were generated for all variables. Each use of TEE was categorized as either appropriate or inappropriate, based on the recommendations published by the ESC, and by the ACCF and ASE, respectively. Qualitative variables were expressed as counts and percentages, and quantitative variables were expressed as mean ± standard deviation or median (interquartile range), depending on the variable distribution. Comparison of continuous variables was performed using either the two-sided Student t test or the Mann-Whitney U test (as appropriate), and categorical variables were compared using either the χ^2 test or Fisher's exact test (as appropriate). The variables associated with the outcome variable from bivariate analysis with a P-value of < 0.10 were included in the multivariable logistic regression model. Statistical analyses were performed using R 4.2.1 (R Foundation, Vienna, Austria), with the significance level set at $P < 0.05$.

Results

Patient characteristics and outcomes

Data were collected on 204 admissions of 188 patients who had TEE performed for the diagnosis of IE within the study period. The mean age was 53.1 ± 17.1 years. Of the 188 patients, female patients comprised 41.0% (n = 77) of the study population. The most prevalent comorbidities included hypertension (n = 74; 39.3%), hepatitis C (n = 54; 28.7%), and diabetes mellitus (n = 48; 25.5%). A total of 64.4% of patients (n = 121) had at least one predisposing condition for having IE, with 11.7% (n = 22) having a prosthetic valve, 9.6% (n = 18) having an intracardiac device, 42.6% (n = 80) having a history of IDU, and 11.2% (n = 21) having a history of IE. TTE was used prior to TEE in 115 cases (56.4%). A total of 3.9% of admissions (n = 8) included subsequent TEE, after the initial TEE, during the same

hospitalization. Patient characteristics and case presentations are summarized in Table 1.

The median length of stay was 17.5 days (interquartile range [IQR]: 10.0, 32.3), and 24 (11.8%) of the admissions resulted in the patient leaving against medical advice. Of the 204 admissions, 14 (6.9%) involved surgical intervention for the management of IE. The rate of 30-day readmission, 1-year readmission, in-hospital mortality, and 1-year mortality were 22.7% (n = 46), 49.0% (n = 99), 12.7% (n = 26), and 33.3% (n = 68), respectively. Details regarding clinical outcomes are summarized in Table 1.

Appropriateness based on the ACCF and ASE recommendations

Of the 204 uses of TEE, 152 (74.5%) were considered appropriate according to the ACCF and ASE recommendations (Fig. 1). Neither the age ($P = 0.45$) nor sex ($P = 0.21$) of patients differed based on the appropriateness of TEE use. All TEE use in patients with prosthetic valves ($P = 0.004$) or intracardiac devices ($P = 0.01$) was considered appropriate. Patients who had at least one predisposing condition were more likely to have an appropriate use of TEE ($P < 0.001$). The appropriateness of TEE use was not associated with IDU ($P = 0.43$) or a history of IE ($P = 0.45$).

Based on bivariate analyses, the presence of a fever ($P = 0.53$), murmur ($P = 0.71$), vascular phenomenon ($P = 0.56$), or signs of congestive heart failure ($P = 0.74$) were not associated with the appropriate use of TEE. Blood cultures positive for an organism consistent with IE ($P < 0.001$) and *S aureus* bacteremia ($P < 0.001$) were associated with appropriate TEE use. Alternatively, bacteremia with an organism not consistent with IE was associated with inappropriate use of TEE ($P < 0.001$). The factors associated with appropriate vs inappropriate use of TEE are summarized in Table 2.

Based on a multivariable logistic regression model, the presence of at least one predisposing heart condition was associated with appropriate TEE use (adjusted odds ratio [aOR] 4.30 [95% confidence interval {CI} 2.11-9.04), $P < 0.001$), whereas blood cultures that were positive for an organism not related to IE were associated with inappropriate TEE use (aOR 0.18 [95% CI 0.07-0.45], $P < 0.001$) based on the ACCF and ASE recommendations. The factors associated with the appropriate and inappropriate use of TEE based on multivariate analyses are summarized in Table 3.

Vegetations were more likely to be seen in appropriately ordered TEE, based on bivariate analysis (n = 43; 28.3%; $P = 0.02$). However, 11.5% (n = 6) of inappropriate TEE uses also showed a vegetation. No difference in the clinical outcomes occurred between hospitalizations involving appropriate vs inappropriate TEE use, including length of hospital stay ($P = 0.07$), proportion of patients leaving against medical advice ($P = 0.50$), 30-day readmission ($P = 0.21$), 1-year readmission ($P = 0.52$), and mortality ($P = 0.69$). The outcomes associated with the appropriate vs inappropriate use of TEE are summarized in Table 2.

Appropriateness based on ESC recommendations

Of the 204 uses of TEE, only 80 (39.2%) were appropriate according to the ESC recommendations (Fig. 2).

Table 1. Patient characteristics, clinical presentations, and hospitalization outcomes

Patient characteristics (n = 188)	n (%)*
Age, y, mean ± SD	53.1 ± 17.1
Sex, female	77 (41.0)
Medical comorbidities	
Hypertension	74 (39.4)
Diabetes mellitus	48 (25.5)
Hepatitis C	54 (28.7)
Human Immunodeficiency Virus (HIV)	14 (7.4)
Myocardial infarction	30 (16.0)
Congestive heart failure	27 (14.4)
Atrial fibrillation	30 (16.0)
Chronic obstructive pulmonary disease	24 (12.8)
Chronic kidney disease (eGFR < 30 ml/min per 1.73 m^2)	20 (10.6)
Cirrhosis	7 (3.7)
Any predisposing risk factor	121 (64.4)
Prosthetic valves	22 (11.7)
Intracardiac device	18 (9.6)
Injection drug use	80 (42.6)
Clinical presentations (n = 204)	
Fever	31 (15.2)
Murmur	65 (31.9)
Vascular phenomenon	39 (19.1)
Congestive heart failure	38 (18.6)
Blood cultures positive for IE-related organisms	139 (68.1)
Staphylococcus aureus bacteremia	110 (53.9)
Blood cultures positive for an organism not related to IE	26 (12.7)
TTE performed prior to TEE	115 (56.4)
Clinical outcomes (n = 204)	
Vegetation seen on TEE	49 (24.0)
Aortic valve	16 (32.7)
Mitral valve	16 (32.7)
Pulmonic valve	1 (2.0)
Tricuspid valve	19 (38.8)
Multi-valve	4 (8.2)
Intracardiac device lead	1 (2.0)
Moderate or severe valvular regurgitation	24 (49.0)
Undergoing cardiovascular surgery	14 (6.9)
Length of stay [IQR], days	17.5 [10.0, 32.3]
Leaving against medical advice	24 (11.8)
30-day readmission	46 (22.7)
1-year readmission	99 (49.0)
1-year mortality	68 (33.3)

eGFR, estimated glomerular filtration rate; IE, infective endocarditis; IQR, interquartile range; SD, standard deviation; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.

*Unless otherwise indicated.

Based on bivariate analyses, no difference was present in the age ($P = 0.10$) or sex ($P = 0.41$) of patients based on the appropriateness of TEE use. TEE use appropriateness was not associated with the presence of prosthetic valves ($P = 0.11$) or intracardiac devices ($P = 1.00$). IDU was not associated with appropriately ordered TEE ($P = 0.09$). Having at least one predisposing heart condition was more likely to be associated with appropriate TEE use ($P = 0.001$). No association occurred between TEE use appropriateness and the presence of a fever ($P = 1.00$), murmur ($P = 0.06$), vascular phenomenon ($P = 0.51$), or signs of congestive heart failure ($P = 0.34$). Blood cultures positive for an organism consistent with IE ($P = 0.07$) and *S aureus* bacteremia ($P = 0.21$) were

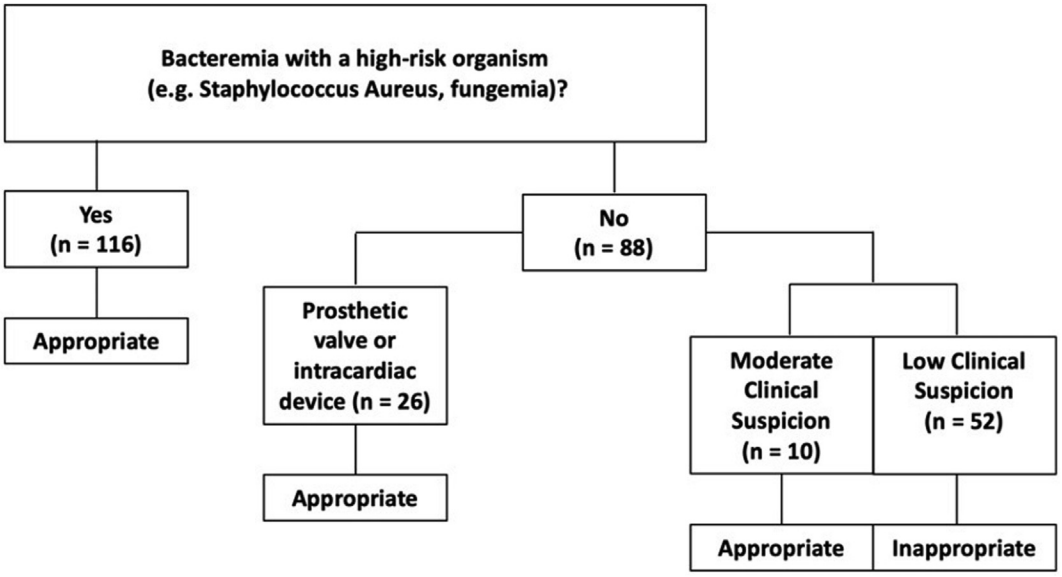

Figure 1. Algorithm for determining the appropriateness of transesophageal echocardiography use, based on American College of Cardiology Foundation and American Society of Echocardiography recommendations.

not associated with appropriate TEE use. The factors associated with appropriate vs inappropriate use of TEE, based on bivariate analyses, are summarized in Table 2.

When variables from the bivariate analyses with a *P*-value of < 0.10 were included in a multivariable logistic regression model, older patient age (aOR 1.05 [95% CI 1.02-1.07], $P = 0.001$), a history of IDU (aOR 3.08 [95% CI 1.08-9.27], $P = 0.04$), and blood cultures positive for an IE-related organism (aOR 1.05 [95% CI 1.02-1.07], $P = 0.001$) emerged as variables significantly associated with appropriate TEE use, based on the ESC recommendations. The factors associated with the appropriate vs inappropriate use of TEE, based on multivariate analyses, are summarized in Table 3.

Table 2. Factors associated with the appropriateness of transesophageal echocardiography (TEE) use, based on bivariate analyses

	ACCF and ASE criteria			ESC criteria		
Factors	Appropriate (n = 152)	Not appropriate (n = 52)	*P*	Appropriate (n = 80)	Not appropriate (n = 124)	*P*
Age, y, mean ± SD	53.3 ± 16.7	51.2 ± 17.0	0.451	55.1 ± 17.1	51.2 ± 16.5	0.10
Female sex	59 (38.8)	26 (50.0)	0.212	30 (37.5)	55 (44.4)	0.41
Any predisposing factor	112 (73.7)	22 (42.3)	**< 0.001**	64 (80.0)	70 (56.5)	**0.001**
Prosthetic valves	25 (16.4)	0	**0.004**	14 (17.5)	11 (8.9)	0.11
Intracardiac device	20 (13.2)	0	**0.01**	8 (10.0)	12 (9.7)	1.00
IDU	67 (44.1)	19 (36.5)	0.43	40 (50.0)	46 (37.1)	0.09
History of IE	23 (15.1)	5 (9.6)	0.445	12 (15.0)	16 (12.9)	0.83
Fever	25 (16.4)	6 (11.5)	0.53	12 (15.0)	19 (15.3)	1.00
Murmur	50 (32.9)	15 (28.8)	0.71	32 (40.0)	33 (26.6)	0.06
Vascular phenomenon	31 (20.4)	8 (15.4)	0.56	13 (16.3)	26 (21.0)	0.51
Congestive heart failure	27 (17.8)	11 (21.2)	0.74	18 (22.5)	20 (16.1)	0.34
Blood cultures positive for IE-related organisms	131 (86.2)	8 (15.4)	**< 0.001**	61 (76.3)	78 (62.9)	0.58
Staphylococcus aureus bacteremia	110 (72.4)	0	**< 0.001**	48 (60.0)	62 (50.0)	0.21
Blood cultures positive for an organism not related to IE	12 (7.9)	14 (26.9)	**< 0.001**	12 (15.0)	14 (11.3)	0.58
Outcome variables						
Vegetation seen on TEE	43 (28.3)	6 (11.5)	**0.02**	25 (31.2)	24 (19.4)	0.08
Undergoing cardiovascular surgery	12 (7.9)	2 (3.8)	0.497	9 (11.2)	5 (4.0)	0.09
Length of stay [IQR]	20.0[11.0, 33.0]	15.0 [9.0, 28.0]	0.066	20.0 [11.8, 32.3]	16.5 [11.8, 32.8]	0.20
Leaving against medical advice	20 (13.2)	4 (7.7)	0.420	11 (13.8)	13 (10.5)	0.63
30-d readmission	38 (25.2)	8 (15.4)	0.207	19 (23.8)	27 (21.8)	0.84
1-y readmission	71 (47.3)	28 (53.8)	0.517	42 (52.5)	56 (45.2)	0.28
1-y mortality	49 (32.2)	19 (36.5)	0.691	24 (35.5)	44 (35.5)	0.51

Values are n (%), unless otherwise indicated. Boldface indicates significance.

ACCF, American College of Cardiology Foundation; ASE, American Society of Echocardiography; ESC, European Society of Cardiology; IE, infective endocarditis; IQR, interquartile range; IVDU, intravenous drug use; SD, standard deviation.

Table 3. Variables associated with appropriate transesophageal echocardiography (TEE) use based on American College of Cardiology Foundation (ACCF) and American Society of Echocardiography (ASE) recommendations and European Society of Cardiology (ESC) recommendations, respectively, based on multivariable logistic regression

ACCF and ASE recommendations		
Factor	aOR (95% CI)	*P*
Any predisposing factors	4.30 (2.11−9.04)	**< 0.001**
Blood cultures positive for an organism not related to IE	0.18 (0.07−0.45)	**< 0.001**
ESC recommendations		
Age	1.05 (1.02−1.07)	**0.001**
IDU	3.08 (1.08−9.27)	**0.04**
Blood cultures positive for IE-related organisms	2.31 (1.16−4.80)	**0.02**

Boldface indicates significance.

aOR, adjusted odds ratio; CI, confidence interval; IE, infective endocarditis; IVDU, intravenous drug use.

Vegetations were not more likely to be seen in appropriately ordered TEE (n = 25; 31.2%; $P = 0.08$), as 19.4% (n = 24) of inappropriate uses of TEE also showed a vegetation. No difference in outcomes occurred between hospitalizations involving appropriate vs inappropriate uses of TEE, including length of hospital stay ($P = 0.20$), proportion of patients leaving against medical advice ($P = 0.63$), 30-day readmission ($P = 0.84$), 1-year readmission ($P = 0.28$), and mortality ($P = 0.51$). The outcomes associated with the appropriate vs inappropriate use of TEE are summarized in Table 2.

Based on the ESC recommendations, TTE must be performed prior to TEE,[2] whereas the ACCF and ASE recommendations state that TEE can be performed as an initial test.[5] If TEE performed on a patient with an intracardiac device and/or a prosthetic valve were deemed appropriate by the ESC criteria, regardless of whether TTE was performed first, the following factors were associated with TEE use appropriateness, based on bivariate analysis: the presence of at least one predisposing risk factor ($P < 0.001$); a prosthetic valve ($P < 0.001$); an intracardiac device ($P < 0.001$); a murmur ($P = 0.01$); signs of congestive heart failure ($P = 0.02$); and blood cultures positive for an IE-related organism ($P = 0.01$). Appropriate TEE use also was associated with the presence of a vegetation ($P = 0.001$) and the proportion of patients undergoing cardiovascular surgery ($P = 0.01$). The factors associated with appropriate TEE use, when initial TEE was deemed appropriate for patients with an intracardiac device and/or a prosthetic valve, in the ESC vs the ACCF and ASE recommendations, were better aligned.

Discussion

In this retrospective study, the appropriateness of the use of TEE for the diagnosis of IE was examined at 2 tertiary-care hospitals, based on two sets of published recommendations by major cardiovascular societies. A point that should be highlighted is that this is a population at high risk of IE. Almost two-thirds of the patients (64.4%) had at least one predisposing condition for IE, and a significant proportion (42.2%) had a history of IDU. The prevalence of patients with IDU was significantly higher, compared to that quoted in the current literature.[9-11] The significant rate of mortality and morbidity associated with a high prevalence of patients with IDU was reflected by the high proportion of positive TEE tests (24.0%) and the poor clinical outcomes— 49.0% were rehospitalized within a year, and 33.3% died within the same timeframe. A previous study also found that the diagnosis of IE was associated with in-hospital mortality in a similar population,[6]

Of the TEE uses examined in this study, 74.5% were considered appropriate, based on the ACCF and ASE recommendations. The proportion of appropriately used TEE was significantly lower than those quoted in other studies that examined TEE indications in a broader context, which were in the range of 91.3%-97%.[12-15] In contrast, one study that assessed TEE use specifically for the diagnosis of IE found that 75.8% of the studies were appropriate, based on the ACCF and ASE recommendations, a percentage similar to that in the findings of the current study.[16] Studies had shown that among the inappropriate indications for the use of TEE, the most common was the diagnosis of IE in a low-risk population.[14,17] This finding suggests that decision-making surrounding the use of TEE in the diagnosis of IE is often challenging. When faced with a possible diagnosis with serious consequences, clinicians may order tests that are outside of the accepted indications. In this study, a significant proportion of TEE uses deemed to be inappropriate showed a vegetation, justifying their use. However, indiscriminate and inappropriate use of TEE can have significant impact at the patient and population levels. Not only are patients subjected to the risk of the procedure, but also, at centres where the availability of echocardiographic resources is limited, inappropriate TEE use for the diagnosis of IE can delay echocardiography services needed for other indications.

A surprising finding is the striking difference between the proportions of appropriate TEE uses, as based on different cardiovascular societies' recommendations. A total of 74.5% of TEE uses were considered appropriate based on the ACCF and ASE recommendations. However, only 39.2% were considered appropriate based on the ESC recommendations. Although the 2 sets of recommendations share many similarities, one main difference was that, based on ESC recommendations, TTE must be performed prior to TEE.[2] The ACCF and ASE recommendations, however, state that TEE can be performed as an initial test.[5] This difference prompts an interesting clinical dilemma as to whether an initial TEE test should be performed for certain patient populations, such as those with prosthetic heart valves or intracardiac devices. Performing TEE as the initial test may shorten the time to a definitive diagnosis and management plan.[18] In a case-based simulation, the initial use of TEE was found to be the most cost-effective approach in a patient with a moderate probability of IE.[4] On the other hand, initial TTE still provides valuable information, such as that regarding left ventricular systolic function and wall-motion abnormality. Furthermore, for patients at low risk of IE who had a negative TTE test, or for those with uncomplicated right-sided IE seen on TTE, a subsequent TEE test may not be necessary.[2] In these cases, performing an initial TEE test may subject the patient to undue risk, and the healthcare system to undue cost. Ultimately, TTE and TEE are not mutually exclusive investigations in the diagnosis of IE, but rather are

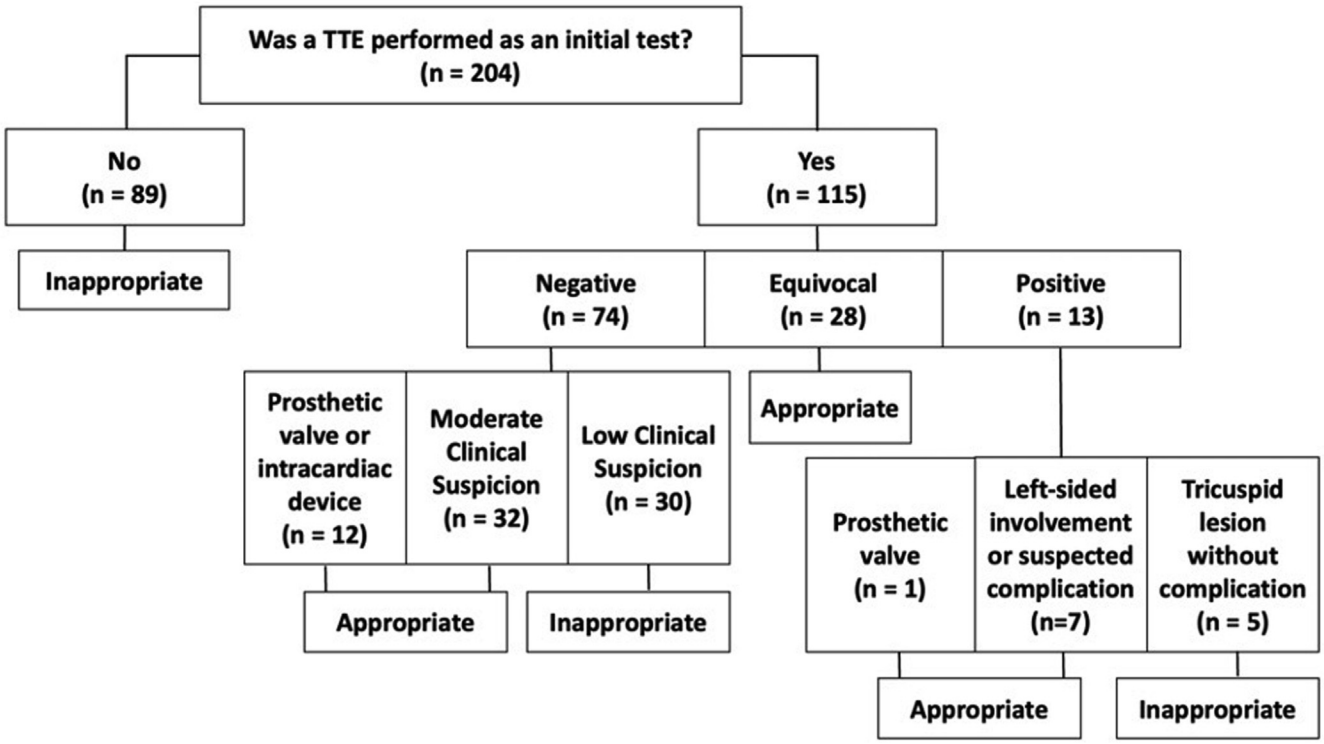

Figure 2. Algorithm for determining the appropriateness of transesophageal echocardiography (TEE) use, based on European Society of Cardiology recommendations.

complimentary tools. Further research is needed to understand the patient cohort who would benefit from initial TEE for the diagnosis of IE.

Both sets of recommendations relied on the risk stratification of patients to gauge the appropriateness of TEE use in the diagnosis of IE. Given that risk of IE was based on the modified Duke criteria, the finding that predisposing conditions and positive blood cultures were more likely to be associated with the appropriate use of TEE is unsurprising. However, not all criteria outlined in the modified Duke criteria demonstrated this association. The presence of a fever and vascular phenomena were not associated with the appropriate use of TEE. Although both are common presentations in IE,[18] gauging the appropriateness of using TEE to investigate a fever or a cardiac source of an embolism is difficult. On one hand, they are nonspecific signs that also have noninfectious etiologies. In the absence of other risk factors or bacteremia, TEE may not be warranted. On the other hand, although the modified Duke criteria have a high sensitivity level,[19] clinical suspicion may persist in cases deemed to be at low risk for IE,[16,20] justifying the use of TEE. Based on multivariate analyses, bacteremia with an IE-related organism, such as *S aureus*, was associated with appropriate TEE use, according to the ACCF and ASE recommendations, but not the ESC recommendations. An older study found that among patients with *S aureus* bacteremia, 25% had IE.[21] As a result, TEE was deemed to be essential in patients with *S aureus* bacteremia, to establish the diagnosis. However, more recent studies support a more selective approach to the use of TEE. In a study of 705 episodes of *S aureus* bacteremia, TEE use did not change the duration of antimicrobial therapy.[22] Kaasch et al.[23] proposed that only patients with prolonged bacteremia, the presence of a permanent cardiac device, hemodialysis dependency, spinal infection, or nonvertebral osteomyelitis should undergo TEE to exclude IE. Several risk stratification scores (**P**rediction **o**f **S**taphylococcus Aureus **I**nfective Endocarditise **T**ime to Positivity, **I**V Drug Use, **V**ascular Phenomena, Pre**e**xisting Heart Condition [POSITIVE]; **P**redicting **R**isk Of **En**d**o**carditis Us**i**ng a **C**linical **T**ool [PREDICT]; and VIRSTA) have been developed to classify the likelihood of endocarditis in patients with *S aureus* bacteremia.[24,25] The differences between the ACCF and ASE vs the ESC recommendations highlight many uncertainties regarding the specific patient population who would benefit from TEE for the diagnosis of IE.

Although the modified Duke criteria were used widely to assess the pretest probability of a patient having IE, 11.5% and 19.4% of the "inappropriate" uses of TEE (based on the ACCF and ASE, and the ESC recommendations, respectively) also showed a vegetation. This finding shows a pitfall in basing test orders on the ACCF and ASE, and the ESC recommendations alone. In a study examining cases of suspected IE, a multidisciplinary endocarditis team identified that 16.3% of cases excluded by the modified Duke criteria had possible or definite IE.[20] Previous studies have explored prescreening TEE requisitions to minimize use of inappropriate tests.[21] However, such interventions would need to take into account the prevalence of IE in a specific setting. In Regina, Saskatchewan, where the prevalence of IDU and IE is high, the risk of missing a diagnosis of IE is significant.

This study evaluated the appropriateness of TEE use specifically for the diagnosis of IE. In this area of study, many

questions remain, despite the published recommendations. This study had a respectable sample size, given the timeframe and the small number of centres involved. Furthermore, although many previous studies assessed appropriateness based only on the ACCF and ASE recommendations, the current study compared two sets of recommendations developed by major cardiovascular societies, which allowed for key differences to be identified. Nonetheless, the current study had several limitations. First, this study was conducted at only two hospitals within a small geographic area. Therefore, the results might not be generalizable to other centres. Second, the retrospective nature of this study means that only associations between different factors could be demonstrated, precluding definitive conclusions regarding causation. Third, the clinical scenarios surrounding the use of TEE could be derived from only what was documented in patient charts. Clinicians' failure to recognize or document physical examination findings (such as the presence of a murmur and vascular phenomenon) may introduce bias. However, based on a contemporary prospective report, the prevalences of certain physical examination findings, including Janeway lesions, Osler nodes, and splinter hemorrhages, were low, between 2%-8%.[2] Most IE cases were diagnosed using objective microbiological and radiographical evidence. As this study examined data from 2019, the 2015 ESC guideline[3] was used for reference. However, a comparison of this guideline with the recommendations from the updated 2023 ESC guideline[26] on the use of TEE in the diagnosis of IE revealed no significant difference. Another point that should be acknowledged is that advanced imaging modalities (eg, cardiac computed tomography and positron emission tomography) have an emerging role in the diagnosis of IE; therefore, the indications for TEE use in the diagnosis of IE may change in the near future.

Conclusion

IE is a serious medical condition with poor clinical outcomes. Echocardiography plays a crucial role in the diagnosis and management of IE. The presence of predisposing risk factors was associated with appropriate TEE use in the diagnosis of IE, whereas presence of the other components of the modified Duke criteria was not. The current study suggested that the use of TEE in the diagnosis of IE demonstrated a variable level of adherence to published recommendations developed by the ACCF and ASE, and by the ESC, with significant discrepancy between the two. Furthermore, a significant proportion of TEE tests deemed to be inappropriate by current recommendations also revealed vegetations. This finding suggests a lack of clarity in current recommendations regarding the appropriate use of TEE for the diagnosis of IE, and these may need clarification to better guide clinical decision-making. The findings of this study will help address clinicians' knowledge gaps in the use of TEE and inform more-appropriate use of TEE for this indication.

Ethics Statement

This research reported has adhered to the relevant ethical guidelines.

Patient Consent

The authors confirm that patient consent is not applicable to this article. This was a retrospective study using de-identified data. Due to the number of participants involved, and the retrospective nature, the Internal Review Board did not require consent from the patient.

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