Appropriate Use Criteria in Echocardiography: An Observational Institutional Study with the Perspective of a Quality Improvement Project

Vanessa Rameh and Antoine Kossaify

Echocardiography Unit, Cardiology division, University Hospital Notre Dame des Secours, Byblos, Lebanon.

ABSTRACT

BACKGROUND: Appropriate use criteria (AUC) in echocardiography are essential tools for aligning the indications of echocardiography with the best clinical standards, improving clinical outcome, restraining abuse, and preserving health-care resources.

OBJECTIVES: The aim of this study was to ascertain the AUC for transthoracic echocardiography in a university hospital and create a quality improvement project (QIP).

METHODS: The assessment of 501 inpatients who received transthoracic cardiac echo was conducted according to the 2011 AUC report. Indications were classified as appropriate, uncertain, or inappropriate, and patients not matching any of the abovementioned divisions were grouped in the *nonfitting* category.

RESULTS: Of the 501 eligible patients, 374 patients (74.66%) were in the appropriate group, 85 patients (16.96%) in the inappropriate group, 20 patients (3.99%) in the uncertain group, and 22 patients (4.39%) in the nonfitting category.

DISCUSSION: Interpretation and analysis of the obtained results are presented, along with the results of many comparable studies; moreover, a QIP was set up accordingly.

CONCLUSION: AUC are useful to assess local practice, preserve health-care resources, and improve clinical outcome.

KEYWORDS: appropriate use criteria, echocardiography, transthoracic

CITATION: Rameh and Kossaify. Appropriate Use Criteria in Echocardiography: An Observational Institutional Study with the Perspective of a Quality Improvement Project. *Clinical Medicine Insights: Cardiology* 2016:10 23–28 doi: 10.4137/CMC.S36504.

TYPE: Original Research

PEER REVIEW: Five peer reviewers contributed to the peer review report. Reviewers' reports totaled 1237 words, excluding any confidential comments to the academic editor.

ACADEMIC EDITOR: Thomas E. Vanhecke, Editor in Chief

RECEIVED: October 14, 2015. **RESUBMITTED:** December 16, 2015. **ACCEPTED FOR PUBLICATION:** January 04, 2016.

FUNDING: Authors disclose no external funding sources.

COMPETING INTERESTS: Authors disclose no potential conflicts of interest.

CORRESPONDENCE: antoinekossaify@yahoo.com

Introduction

Echocardiography is one of the most commonly used paraclinical tests in cardiology. It is a widely available, cost-effective, and noninvasive test that provides valuable data regarding initial diagnosis, management, and follow-up of many cardiac conditions. The echocardiographic procedure comprises the initial request and indication, test performance, test interpretation, and reporting and archiving of results.

There are many modes of echocardiography currently available and implemented in humans: M-mode, two-dimensional mode, three-dimensional mode, Doppler tissue imaging, and speckle tracking imaging. Moreover, echocardiography may be implemented with variable modalities: transthoracic echocardiography (TTE), contrast echocardiography, stress echocardiography, and transesophageal echocardiography. Moreover, echocardiogram may be performed on a regular basis or in an emergency setting.

In view of this diversity of methods and uses, appropriate use criteria (AUC) in echocardiography are essential to improve clinical outcomes while preserving resources. From a clinical perspective, AUC enable a better adjustment of echocardiography indication to the clinical condition, avoiding potential over- or underindications; from a socioeconomic perspective, AUC allow the avoidance of unnecessary health expenses in a relatively restricted health-care budget.

The latest AUC of echocardiography were published in 2011 by the American College of Cardiology Foundation, the Appropriate Use Criteria Task Force, and the American Society of Echocardiography (AUC 2011).[1] This report combines and updates the original transthoracic and transesophageal echocardiography appropriateness criteria published in 2007[2] and the original stress echocardiography appropriateness criteria published in 2008.[3] The AUC 2011 considered 202 indications developed by diverse writing groups and scored each indication by a separate independent technical panel on a scale of 1–9, to designate appropriate use (median 7–9), uncertain use (median 4–6), and inappropriate use (median 1–3).

Although AUC regarding echocardiography were published many years ago (2007, 2008, and 2011), we estimate that very little is known about adherence to AUC in Lebanon and, to the best of our knowledge, AUC regarding echocardiography were not previously evaluated or reported in any medical

facility in Lebanon. In this study, we sought to evaluate the prevalence rate of appropriateness of TTE in a university hospital in Lebanon, with the objective of creating a quality improvement project (QIP) regarding TTE indications.

Patients and Methods

This was a cross-sectional, observational, single-center study conducted at the University Hospital Notre Dame de Secours, Byblos, Lebanon, in the period between May and July 2015. An initial enrollment of 520 consecutive patients comprised inpatients who were >18 years old at the time of enrollment, and for whom a TTE was requested during the hospital stay. Echo request was assessed via the order form and through extensive examination of patient record. Medical records were considered incomplete when the echo request could not be clearly reported after extensive record examination; 19 patients with incomplete medical record were excluded. Accordingly, 501 of the 520 patients were found eligible for this study. The main reasons for incomplete medical record were inadequate clinical information on the patient, failure to report on a change in clinical status, and/or date of last echo not reported.

In the named facility, contrast echocardiography, stress echocardiography, and transesophageal echocardiography were not available at the time of this study, and accordingly, AUC were studied regarding only TTE at rest. Among the 202 criteria cited in the AUC 2011, only 98 related to TTE; therefore, studied patients were analyzed regarding these 98 criteria. Of note, patients for whom the echo indication was not found matching any of the 98 criteria were categorized in the *nonfitting* group. Among the 98 AUC 2011 criteria evaluated in this study, 57 were defined as appropriate, 12 as uncertain, and 29 as inappropriate. All standard echocardiographic techniques for image acquisition, interpretation, and reporting were performed by qualified sonographers in the named facility using the commercially available echocardiograph with a 3.5-MHz transducer (Philips iE33 ultrasound system; Philips Medical Systems).

Data collection was performed using the patients' archived records, echocardiography unit registry, and picture archiving and communication system (PACS). Specifically, the PACS was used to assess the time delay between the previous and the current echo examinations. Echo indications were documented mainly using the patient record; the order form was also considered as an additional but accessory means to confirm the requisition,[4] and in case there was a discordance between the order form and the patient record, the medical record was considered the most reliable source and the order form was neglected. If two or more echo indications were found in the medical record, the one that was most relevant to the current clinical condition was taken into consideration. Moreover, when requests exhibited more than one indication that fit into the AUC 2011, the most appropriate one was retained.

Patient characteristics included major cardiovascular risk factors and potential cardiac comorbidities (coronary artery disease, heart failure, hypertension, valvular heart disease, arrhythmia, etc.). The present study protocol was approved by the institutional research board and was carried out in accordance with the Declaration of Helsinki. After presentation of the study to the IRB (institutional Research Board), no ethical concern was retained and advised that Ethics Approval was not required.

Analysis was performed using the software Statistical Package for the Social Sciences (IBM). Data were expressed as mean ± standard deviation, or number and percentage, as appropriate. Searching for independent correlates with AUC appropriateness was not performed, as it was beyond the scope of this study.

Results

The patient population comprised 501 patients, with 297 males (59.28%) and with a mean age of 65 ± 14.1 years. Table 1 lists the demographic and clinical characteristics of the patients. Of the 501 eligible patients, 331 patients (66.07%) were referred by cardiologists, and the remaining 170 patients (33.93%) by noncardiologists. We did not assess the rate of appropriate echo examinations requested by cardiologists, given that many of these requests were done by cardiology fellows who are usually but not always supervised by cardiologists, and therefore, it was impossible to verify the real demanding person with certainty in such cases. We counted 290 (58%) discordant requests (discordance between order form requisition and data from medical record); of note, a discordance does not necessarily imply an inappropriate request, it only reflects a discordance between the order form and the record data. As previously mentioned, in these cases, we used the record data to evaluate the appropriateness of the request.[4] Of the 501 patients, 374 patients (74.66%) were found fitting into the appropriate category, with the variable scores of 7, 8, or 9; 85 patients (16.96%) into the inappropriate category; 20 patients (3.99%) into the uncertain category; and 22 patients (4.39%) into the nonfitting group. Table 2 summarizes these divisions along with the variable scores from 1 to 9.

Among the 98 criteria established by the AUC 2011, only 34 criteria were figured in this study population.

Table 1. Demographic and clinical characteristics of the study population.

VARIABLE	VALUE
Age (mean ± SD) Male gender, n (%)	65 ± 14.1 297 (59.28%)
Hypertension, n (%)	309 (61.67%)
Dyslipidemia, n (%)	227 (45.31%)
Diabetes, n (%)	158 (31.53%)
Tobacco, n (%)	206 (41.11%)
Coronary artery disease, n (%)	158 (31.53%)
Heart failure, n (%)	60 (11.97%)
Valvular heart disease, n (%)	37 (7.38%)
Arrhythmia, n (%)	62 (12.37%)

Table 2. Distribution of appropriate, uncertain, and inappropriate indication rates.

Appropriate	**Score 9**	**Score 8**	**Score 7**	374 (74.65%)
	319 (63.67%)	50 (9.98%)	5 (0.99%)	
Uncertain	**Score 6**	**Score 5**	**Score 4**	20 (3.99%)
	5 (0.99%)	9 (1.79%)	6 (1.19%)	
Inappropriate	**Score 3**	**Score 2**	**Score 1**	85 (16.96%)
	56 (11.17%)	25 (4.99%)	4 (0.79%)	
Unclassified	22 (4.39%)			22 (4.39%)
Total 501 (100%)				

Notes: The indication rates with the variable scores (1–9) were used according to the AUC 2011; this reflects a gradual value of the related indication: (1–3) for inappropriate indications with score 1 indicating a "more inappropriate" indication than scores 2 and 3, (4–6) for uncertain indications with score 4 indicating a "more uncertain" indication than scores 5 and 6, and (7–9) for appropriate indications with score 7 indicating a "less appropriate" indication than score 8 and score 8 "less appropriate" than score 9.

Of the 34 indications, there were 20 appropriate (58.83%), 10 inappropriate (29.41%), and 4 uncertain (11.76%) indications. Such results imply that there were 64 TTE indications not implemented in this study population, and most importantly, there were 37 appropriate TTE indications that were not found in this study population.

The "presence of symptoms or conditions potentially related to suspected cardiac etiology including but not limited to chest pain, shortness of breath, palpitations, transient ischemic attack, stroke or peripheral embolic event" was the most common appropriate indication (prevalence rate: 53.89%, score 9). This was immediately followed by the "initial evaluation of suspected hypertensive heart disease" (prevalence rate: 9.18%, score 8).

The lowest rate of appropriate indication present in this study population was for the "re-evaluation of known ascending aortic dilation or history of aortic dissection with a change in clinical status or cardiac exam or when findings may alter management or therapy" (prevalence rate: 0.19%, score 9). Finally, the most common inappropriate indication was "lightheadedness/presyncope when there are no other symptoms or signs of cardiovascular disease" (prevalence rate: 5.39%, score 3). Table 3 summarizes these results with respect to the AUC 2011 indications.

Discussion

As the field of echocardiography continues to advance, the health-care community needs to understand how to best incorporate this technology into daily clinical care.[5,6] In the present study, we provide an estimate of whether TTE indications in a university hospital in Lebanon were appropriate according to the AUC 2011. The particularity of this study is its pilot nature in Lebanon, and the location is also of note because this study was conducted outside the USA, where AUC 2011 were established. From a scientific point of view, the suitability of the labels of *appropriate, uncertain, and inappropriate* for indications for echocardiography should be expected to be similar in different countries, although these countries may have different health-care budgets, different medical backgrounds of physicians, and different third-party statuses. In this perspective, Gurzun and Ionescu reported that the assessment of AUC in the UK showed results that were similar to those reported in the USA and that 1 in 10 TTE indications could be avoided.[7]

The rate of appropriateness of requisitions was found to be 74.66% (374/501) in this studied population. Although it is not optimal, we estimate that it is a relatively satisfactory rate as the first AUC evaluation in a single academic facility in Lebanon. Other studies reported relatively similar proportions of appropriate, uncertain, and inappropriate TTE indications.[8,9] Al-Kaisey et al conducted a study in an Australian regional center and reported 77% appropriate, 20.3% inappropriate, and 2.7% uncertain TTE indications.[8] Similarly, Patil et al reported that TTE was appropriate in 82%, inappropriate in 12.3%, uncertain in 5.3%, and nonfitting in 0.4% of the cases studied.[10] Interestingly, Bailey et al found that adherence to AUC 2011 regarding inpatients in a regional hospital was consistent with that encountered in university hospitals.[11]

In our study population, we counted 270 (53.89%) appropriate indications (AUC 2011, indication #1, score 9): "presence of symptoms or conditions potentially related to suspected cardiac etiology..."; this was the most common appropriate cause in this study population, a logical finding given that most of the inpatients in our hospital community, and particularly in the cardiology division, are admitted for cardiac or cardiac-like symptom(s), and echocardiography represents a universally available and useful paraclinical test to assess this category of patients in order to finalize diagnosis. Similarly, Al-Kaisey et al reported that "evaluation of symptoms potentially related to a cardiac etiology" was the most common indication for ordering TTE.[8]

Moreover, 46 patients (9.18%) had their echo indication listed as "initial evaluation of suspected hypertensive heart disease" (AUC 2011, indication #67, score 8); this was the second most common appropriate indication. We consider this a logical finding, given the relatively high prevalence rate of hypertension in our community and in our study population (61.67%, $n = 309$). However, not all of these patients had their hypertension diagnosed at the time of this study, and many of them had already been diagnosed and treated for hypertension.

The echo indication labeled as the most inappropriate one (AUC 2011, indication #36, score 1) was "re-evaluation in a patient without valvular disease on prior echocardiogram and no change in clinical status or cardiac exam," and we counted two patients (0.39%) in this category in this study population. We estimate that such routine evaluations or reevaluations do not affect the clinical course and may lead to unnecessary health-care expenses; moreover, a suitable history taking with physical examination, along with chest X-rays and electrocardiogram, is usually sufficient to rule out active cardiovascular conditions in such cases.

Table 3A. Appropriate indications.

	N (%)	TYPE, SCORE
(1) Symptoms or conditions potentially related to suspected cardiac etiology including but not limited to chest pain, shortness of breath, palpitations, TIA, stroke, or peripheral embolic event.	270 (53.89%)	A9
(67) Initial evaluation of suspected hypertensive heart disease.	46 (9.18%)	A8
(24) Initial evaluation of ventricular function following ACS.	9 (1.79%)	A9
(5) Sustained or non-sustained atrial fibrillation, SVT, or VT.	8 (1.59%)	A9
(70) Initial evaluation of known or suspected HF (systolic or diastolic) based on symptoms, signs, or abnormal test results.	6 (1.19%)	A9
(34) Initial evaluation when there is a reasonable suspicion of valvular or structural heart disease.	6 (1.19%)	A9
(7) Clinical symptoms or signs consistent with a cardiac diagnosis known to cause lightheadedness/pre-syncope/syncope (including but not limited to aortic stenosis, hypertrophic cardiomyopathy, or HF).	5 (0.99%)	A9
(9) Syncope when there are no other symptoms or signs of cardiovascular disease.	4 (0.79%)	A7
(59) Suspected pericardial conditions	3 (0.59%)	A9
(76) Initial evaluation or re-evaluation after revascularization and/or optimal medical therapy to determine candidacy for device therapy and/or to determine optimal choice of device.	3 (0.59%)	A9
(22) Evaluation of a patient without chest pain but with other features of an ischemic equivalent or laboratory markers indicative of ongoing MI.	2 (0.39%)	A8
(29) Known acute pulmonary embolism to guide therapy (eg, thrombectomy and thrombolytics).	2 (0.39%)	A8
(52) Initial evaluation of suspected infective endocarditis with positive blood cultures or a new murmur.	2 (0.39%)	A9
(73) Re-evaluation of known HF (systolic or diastolic) to guide therapy.	2 (0.39%)	A9
(17) Routine surveillance (<1 y) of known pulmonary hypertension without change in clinical status or cardiac exam.	1 (0.19%)	A7
(18) Re-evaluation of known pulmonary hypertension if change in clinical status or cardiac exam or to guide therapy.	1 (0.19%)	A9
(47) Initial postoperative evaluation of prosthetic valve for establishment of baseline.	1 (0.19%)	A9
(58) Suspected cardiovascular source of embolus.	1 (0.19%)	A9
(64) Re-evaluation of known ascending aortic dilation or history of aortic dissection to establish a baseline rate of expansion or when the rate of expansion is excessive.	1 (0.19%)	A9
(65) Re-evaluation of known ascending aortic dilation or history of aortic dissection with a change in clinical status or cardiac exam or when findings may alter management or therapy.	1 (0.19%)	A9

Note: Results and prevalence of Appropriateness along with their scores according to AUC 2011.
Abbreviations: A, Appropriate; I, Inappropriate; U, Uncertain; N, number; %, percentage.

Only 331 requests (66.06%) were done by cardiologists, and there were also 290 discordant requests (58%); we surmise that such a high rate of discordant requests is consecutive to inappropriate or arbitrary request form filling, frequently done by nurses, interns, or even cardiology fellows. Accordingly, we hypothesize that a more active participation and supervision of cardiologists in this process would help to decrease the discordance rate.

Of note, 22 patients (4.39%) belong to the nonfitting group, and we estimate that most of these patients presented to the echo laboratory in the setting of extracardiac conditions, with the cardiac echo requested as a parallel adjunct during the hospital stay, when the examination is financially covered by a third-party payer. Therefore, we estimate that such practices are relatively frequent for inpatients. In this regard, it is essential to highlight the value of cost efficiency in such practice, and we estimate that standards must be applied increasingly for an appropriate use of cardiovascular imaging.[12] Twenty patients (3.99%) belong to the uncertain category of indications. Such patients often require individual physician judgment and an extensive understanding of the patient's condition in order to better determine the usefulness of a TTE in a particular scenario. In this perspective, we focus on the importance that echo indication be assessed by a certified cardiologist especially when the indication is in a gray zone. Such practice would not only allow the preservation of financial resources but also allow the facilitation of access to echocardiographic procedures for many patients, by avoiding unnecessary tests for others and therefore reducing waiting lists on the basis of clinical priorities.[13,14]

Table 3B. "Non-appropriate" indications: Uncertain, Inappropriate, non-fitting.

	N (%)	TYPE, SCORE
(69) Re-evaluation of known hypertensive heart disease without a change in clinical status or cardiac exam HF With TTE.	6 (1.19%)	U4
(27) Respiratory failure or hypoxemia when a non-cardiac etiology of respiratory failure has been established.	5 (0.99%)	U5
(45) Routine surveillance (<1 y) of moderate or severe valvular regurgitation without a change in clinical status or cardiac exam.	5 (0.99%)	U6
(89) Routine surveillance (<1 y) of known cardiomyopathy without a change in clinical status or cardiac exam.	4 (0.79%)	U5
(8) Lightheadedness/presyncope when there are no other symptoms or signs of cardiovascular disease.	27 (5.39%)	I3
(68) Routine evaluation of systemic hypertension without symptoms or signs of hypertensive heart disease.	20 (3.99%)	I3
(53) Transient fever without evidence of bacteremia or a new murmur.	13 (2.59%)	I2
(11) Routine surveillance of ventricular function with known CAD and no change in clinical status or cardiac exam.	5 (0.99%)	I3
(13) Routine perioperative evaluation of ventricular function with no symptoms or signs of cardiovascular disease.	4 (0.79%)	I2
(35) Initial evaluation when there are no other symptoms or signs of valvular or structural heart disease.	4 (0.79%)	I2
(74) Routine surveillance (<1 y) of HF (systolic or diastolic) when there is no change in clinical status or cardiac exam.	4 (0.79%)	I2
(36) Re-evaluation in a patient without valvular disease on prior echocardiogram and no change in clinical status or cardiac exam.	2 (0.39%)	I1
(80) Routine surveillance (<1 y) of implanted device without a change in clinical status or cardiac exam.	1 (0.19%)	I3
(95) Routine surveillance (<2 y) of adult congenital heart disease following complete repair, without a residual structural or hemodynamic abnormality, without changes in clinical status or cardiac exam.	1 (0.19%)	I3
Non-fitting group	22 (4.39%)	NC

Note: Results and prevalence of "Non-Appropriateness" along with their scores according to AUC 2011.
Abbreviations: A, Appropriate; I, Inappropriate; U, Uncertain; NC, non classified; "non appropriate" = U, I, or NC; N, number; %, percentage; the digit between parentheses refers to the indication number as it appears in the AUC 2011.

Clinical Implication and QIP

Improvement of practice through the creation of a QIP is expected through sensitizing practitioners to AUC. In this respect, a QIP is expected to be beneficial in terms of sensitizing practitioners, namely, cardiologists, to a tailored, individualized, and evidence-based approach in cardiovascular imaging, and particularly echocardiography.[5]

Many approaches may be used, and we adopted the following processes for a practical QIP:

1. control of echo requests by a cardiologist prior to the echo examination;
2. regular lectures for the medical staff, including cardiology fellows and interns concerning the AUC 2011;
3. placement of large posters summarizing all AUC 2011 in the medical staff meeting room and in the echo laboratory;
4. performance of daily auditing by the cardiology fellows in the echo laboratory regarding echo requisitions; and
5. monthly feedback regarding ordering behavior sent through e-mail to all cardiologists.

Of note, educational intervention has proven to be efficient in terms of reduction in inappropriate TTE and increase in appropriate TTE.[15] Bhave et al reported that a web-based educational program using electronic application allows rapid and accurate implementation of the AUC for TTE.[16]

AUC represent the first step of the chain of quality improvement in cardiovascular ultrasound.[17] For a better clinical outcome, there must be adherence to AUC appropriateness and adherence to best practices in image acquisition, image interpretation and results communication, and incorporation of findings into the clinical setting, given that inappropriate echo indication or performance may lead to irrelevant diagnosis and potentially to inappropriate management.[18,19]

Finally, the right implementation of AUC may produce a positive impact on third-party payers, and consequently, it will improve the whole health-care system in a relatively restricted health-care budget worldwide.[20]

Study Limitations

This study design is observational, cross-sectional, and involving a single center. In addition, the number of this study

population is limited. Many of the criteria reported in the AUC 2011 are based on a consensus, and the scientific basis of some criteria exhibits a relative weakness, with the level of evidence B or C.[20] Accordingly, AUC may represent a useful tool to evaluate appropriate use of echocardiography; however, they should not be regarded as the gold standards to assess the clinical relevance of practice in echocardiography. It is up to the medical practitioner to apply independent clinical judgment in each particular case for appropriate diagnosis and management.[20]

Conclusion

In this study, 74.66% of patients were found fitting into the appropriate category, 16.96% of patients into the inappropriate category, 3.99% of patients into the uncertain category, and 4.39% of patients in the nonfitting group. The appropriateness of *appropriate* in the AUC is not an absolute golden rule, and the physician has to deal with each patient individually. At all times, it is the physician's professional responsibility to exercise independent clinical judgment in each particular situation. AUC are expected to be useful for clinicians, healthcare facilities, and third-party payers engaged in the delivery of cardiovascular imaging. Moreover, AUC serve as general guidelines to assess practice in TTE, preserve health-care resources, improve clinical outcome, and, most importantly, create a QIP.

Acknowledgment

The authors would like to express their gratitude to CWM Staff (Department of Research, Institute of Research and Development, 14000 Caen, France) for assistance in editing this paper.

Author Contributions

Conceived and designed the experiments: VR. Analyzed the data: VR, AK. Wrote the first draft of the manuscript: VR. Contributed to the writing of the manuscript: VR, AK. Agree with manuscript results and conclusions: VR, AK. Jointly developed the structure and arguments for the paper: VR, AK. Made critical revisions and approved final version: VR, AK. Both authors reviewed and approved of the final manuscript.

REFERENCES

1. Douglas PS, Garcia MJ, Haines DE, et al. 2011 appropriate use criteria for echocardiography. *J Am Soc Echocardiogr*. 2011;24(3):229–67.
2. Douglas PS, Khandheria B, Stainback RF, et al. 2007 appropriateness criteria for transthoracic and transesophageal echocardiography. *J Am Soc Echocardiogr*. 2007;20(7):787–805.
3. Douglas PS, Khandheria B, Stainback RF, et al. 2008 appropriateness criteria for stress echocardiography. *J Am Coll Cardiol*. 2008;51(11):1127–47.
4. Banihashemi B, Maftoon K, Chow BJ, Bernick J, Wells GA, Burwash IG. Limitations of free-form-text diagnostic requisitions as a tool for evaluating adherence to appropriate use criteria for transthoracic echocardiography. *Cardiovasc Ultrasound*. 2015;13:4.
5. Kossaify A, Grollier G. Echocardiography practice: insights into appropriate clinical use, technical competence and quality improvement program. *Clin Med Insights Cardiol*. 2014;8:1–7.
6. Hendel RC, Patel MR, Allen JM, et al. Appropriate use of cardiovascular technology: 2013 ACCF appropriate use criteria methodology update. *J Am Coll Cardiol*. 2013;61(12):1305–17.
7. Gurzun MM, Ionescu A. Appropriateness of use criteria for transthoracic echocardiography: are they relevant outside the USA? *Eur Heart J Cardiovasc Imaging*. 2014;15(4):450–5.
8. Al-Kaisey A, Jones E, Nadurata V, Farouque O, De Silva D, Ramchand J. Appropriateness use of echocardiography in an Australian Regional Centre. *Intern Med J*. 2015;45(11):1128–33.
9. Ballo P, Bandini F, Capecchi I, et al. Application of 2011 American College of Cardiology Foundation/American Society of Echocardiography appropriateness use criteria in hospitalized patients referred for transthoracic echocardiography in a community setting. *J Am Soc Echocardiogr*. 2012;25(6):589–98.
10. Patil HR, Coggins TR, Kusnetzky LL, Main ML. Evaluation of appropriate use of transthoracic echocardiography in 1,820 consecutive patients using the 2011 revised appropriate use criteria for echocardiography. *Am J Cardiol*. 2012;109(12):1814–7.
11. Bailey SA, Mosteanu I, Tietjen PA, Petrini JR, Alexander J, Keller AM. The use of transthoracic echocardiography and adherence to appropriate use criteria at a regional hospital. *J Am Soc Echocardiogr*. 2012;25(9):1015–22.
12. Shaw LJ. Cost-effectiveness and future implications for cardiovascular imaging. *Can J Cardiol*. 2013;29(3):350–7.
13. Matulevicius SA, Rohatgi A, Das SR, Price AL, DeLuna A, Reimold SC. Appropriate use and clinical impact of transthoracic echocardiography. *JAMA Intern Med*. 2013;173(17):1600–7.
14. Mandorla S, Trambaiolo P, De Cristofaro M, et al. Appropriateness in echocardiography and clinical priority classification criteria: a proposal from the Italian Society of Cardiovascular Echography. *G Ital Cardiol (Rome)*. 2010;11(6):503–33.
15. Bhatia RS, Milford CE, Picard MH, Weiner RB. An educational intervention reduces the rate of inappropriate echocardiograms on an inpatient medical service. *JACC Cardiovasc Imaging*. 2013;6(5):545–55.
16. Bhave NM, Mansour IN, Veronesi F, Razi RR, Lang RM, Ward RP. Use of a web-based application of the American College of Cardiology Foundation/American Society of Echocardiography appropriateness use criteria for transthoracic echocardiography: a pilot study. *J Am Soc Echocardiogr*. 2011;24(3):271–6.
17. Ward RP. Appropriateness criteria for echocardiography: an important step toward improving quality. *J Am Soc Echocardiogr*. 2009;22(1):60–2.
18. Redberg RF. Appropriate use guidelines in echocardiography and beyond. *JAMA Intern Med*. 2013;173(17):1611.
19. Ioannidis JP. Appropriate vs clinically useful diagnostic tests. *JAMA Intern Med*. 2013;173(17):1607–9.
20. Fonseca R, Marwick TH. How I do it: judging appropriateness for TTE and TEE. *Cardiovasc Ultrasound*. 2014;12:22.