



A systematic review of Appropriate Use Criteria for transthoracic echocardiography: are they relevant outside the United States?

Robert N. Kerley¹ · Siun O'Flynn¹

Received: 2 June 2017 / Accepted: 7 June 2018 / Published online: 18 June 2018
© Royal Academy of Medicine in Ireland 2018

Abstract

Introduction The 2011 Appropriate Use Criteria (AUC) were developed by the American Society of Echocardiography (ASE) to provide guidance for referring physicians in response to growing concerns about unnecessary transthoracic echocardiogram (TTE) requests. Very few studies have assessed how medical centers overseas perform against AUC. Evidence is now emerging that inappropriate referral rates in Europe are similar to those reported in the US.

Objective This study systematically reviewed published evidence to identify (1) whether the 2011 AUC are applicable to medical centers outside the US (2) the level of adherence to the AUC across multiple centers, (3) the main factors which cause deviation from AUC, (4) any changes in referral rates since the publication of AUC, and (5) any factors and/or intervention strategies which promote adherence to AUC.

Methods and results Electronic databases were systematically searched for papers related to AUC and cardiac imaging. Following screening and application of eligibility criteria, data was extracted from ten reports involving 8561 TTE studies. Classification rates were 99.5 and 98% for US studies and studies outside the US respectively. Overall, 7119 TTE studies were classified as appropriate (83.1%) of which 3724 were US referrals (84.7%) and 3395 originated outside the US (81.5%). Six of the included studies independently observed significantly more appropriate referrals among inpatients compared to outpatients ($p < 0.001$). US centers observed no significant difference in appropriate referral rates between physician specialties while one UK study showed cardiac surgeons ordered inappropriate TTEs more frequently than other specialties ($p < 0.05$). This review found no obvious trend in appropriate referral rates between 2012 and 2015 indicating no temporal change in physician ordering patterns. Only one educational interventional study met the author's criteria which showed that while intervention was effective during its implantation (26% reduction in TTEs ordered per day), TTE referral rates regressed to pre-intervention levels overtime.

Conclusions In conclusion, the American guideline AUC are applicable to centers outside the US and their implementation across five international centers suggest almost 1 in 5 scans could be avoided.

Keywords Appropriate Use Criteria · Transthoracic echocardiography

This work was carried out at the Department of Medicine, Cork University Hospital (CUH), Cork, Ireland.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s11845-018-1843-9>) contains supplementary material, which is available to authorized users.

✉ Robert N. Kerley
r.kerley@umail.ucc.ie

¹ School of Medicine, Brookfield Health Sciences Complex, University College Cork, College Road, Cork, Ireland

Introduction

Transthoracic echocardiography (TTE) is a versatile, widely available, and overall invaluable asset in the assessment of unwell patients. However, these same characteristics coupled with the negligible risk associated with the diagnostic tool may encourage overuse. In the United States (US), TTE referrals have doubled in the past decade constituting approximately half of all cardiac imaging services [1]. In 2010, TTE accounted for 11% and more than \$1.1 billion of Medicare diagnostic imaging spending [2]. In response to the increased use of cardiac imaging, the American College of Cardiology Foundation (ACCF) in collaboration with the American

Society of Echocardiography (ASE) and other subspecialty societies published Appropriate Use Criteria (AUC) for TTE in 2007 and a second updated version was released in 2011 [3, 4].

The revised 2011 Appropriate Use Criteria for echocardiography

The revised criteria classified 98 potential indications for TTE each with an appropriate use score determined by a technical panel of cardiovascular, imaging, and primary care specialists. Scores of 7–9 were considered “appropriate”, scores of 4–6 were classified as “unsure”, while scores of 1–3 were considered “inappropriate” studies. When applied across multiple settings, the rate of inappropriate referrals was as high 22% [5–11]. Reported factors that cause deviation from the AUC include outpatient settings and non-cardiologist referrals while routine TTE monitoring in the absence of a change in clinical status or clinical evidence of cardiovascular disease is the main cause of inappropriate referrals [11, 12]. Furthermore, a number of studies have reported that appropriate TTEs have a higher prevalence of new, unexpected, or treatable findings compared to inappropriate TTEs [13, 14]. These findings, coupled with the high rate of inappropriate referrals reported throughout the US, suggest a strict compliance to the 2011 AUC could address current demands on echocardiography services and reduce diagnostic imaging spending.

Are they relevant outside the US?

There is limited data available on how clinical requests for TTE compare with the AUC and most studies have been performed in single academic centers throughout the US [11–15]. Very few studies have assessed how medical centers overseas perform against the AUC. Evidence is now emerging that inappropriate referral rates in Europe are similar to those reported from the US [10, 16–18]. These studies found over 95% of its TTE studies were captured by the 2011 AUC indicating these criteria could be applied to centers outside the US.

Aims and objectives

The aim of this paper is to systematically review the current literature on the appropriate use of TTE according to the 2011 AUC with a view to establishing the following:

1. How applicable are the 2011 AUC to medical centers outside the US?
2. How many TTE studies are appropriate, inappropriate, or uncertain, and is there a difference between US and non-US centers?
3. What are the main factors reported in the literature which cause deviation from the 2011 AUC?

4. Are there any factors and/or intervention strategies reported in the literature which promote adherence to the 2011 AUC and reduce overall TTE studies ordered?

This review will inform clinicians as to the applicability of AUC to an Irish hospital setting with the overall aim of reducing the demand placed on non-interventional cardiology through rational use of imaging services. Additionally, the identification of factors which cause deviation from AUC could inform education intervention strategies in the future.

Materials and methods

Literature search strategy

Relevant literature to the research objective was identified by a systematic search of Medline through PubMed. The last search date was 21 January 2016. The literature search was performed using the following strategy:

- (i) One or more imaging term: “echocardiography” [All Fields] OR “echocardiogram” [All Fields] OR “transthoracic echocardiography” [All Fields] OR “transthoracic echocardiogram” [All Fields] OR “echocardiography studies” [All Fields] OR “cardiac ultrasound” [All Fields] OR “cardiac imaging” [All Fields]

AND

- (ii) One or more rational use of imaging term: “appropriate use” [All Fields] OR “appropriate use criteria” [All Fields] OR “appropriate use criteria auc” [All Fields] OR “misuse” [All Fields] OR “rational use” [All Fields] OR “2011 appropriate use criteria” [All Fields] OR “2011 revised appropriate use criteria” [All Fields]

AND

- (iii) One or more population sample term: “inpatient” [All Fields] OR “inpatients” [All Fields] OR “outpatient” [All Fields] OR “outpatients” [All Fields] OR “patient” [All Fields] OR “patients” [All Fields]

AND

- (iv) One or more hospital setting term: “academic” [All Fields] OR “community” [All Fields] OR “tertiary” [All Fields] OR “regional” [All Fields]

Study inclusion criteria

To be included studies must

- (i) Study adult patients ≥ 18 years old
- (ii) Examine use of transthoracic echocardiography
- (iii) Examine adherence to the 2011 ACCF/ASE Appropriate Use Criteria
- (iv) Be available as a full text

Study exclusion criteria

All published, peer-reviewed studies were eligible for inclusion, no date limits were imposed, but due to feasibility, studies that were not available in English were excluded. Studies were excluded if they did not report:

- (i) Most frequent AUC-classified appropriate indications
- (ii) Most frequent AUC-classified inappropriate indications
- (iii) The percentage of echocardiography studies classifiable by the AUC

Selection of studies

The above inclusion and exclusion criteria were systematically applied in sequence to arrive at the final set of original articles. From the initial search result, article titles were reviewed. If it was obvious from the title that the study did not meet the inclusion criteria, the article was excluded. The abstracts of remaining studies were reviewed by the author of this literature review and excluded if they did not meet the inclusion criteria. Full text articles were subsequently assessed by the same author and excluded based on the above exclusion criteria. All remaining articles were individually critiqued and checked for validity with the EBL Critical Appraisal Checklist (Supplementary Table 1).

Data extraction and analysis

Data was extracted from the final set of articles and presented in tables. Table 5 describes the hospital setting in which the 2011 ACCF/ASE Appropriate Use Criteria were applied which included the number of hospitals, type of hospital (e.g., academic), and country of origin. The study type was noted as well as the population being studied (e.g., inpatients) and sample size (*n*). In terms of AUC classification findings, only 2011 AUC classifications were reported in studies which compared the revised 2011 AUC to the 2007 criteria. For studies which assessed the effect of an educational intervention on appropriate referral rates, the pre-intervention findings were reported to maintain comparability with other studies.

The most common inappropriate indication(s) were noted as reported by studies including any differences observed between population samples.

Results

Figure 1 illustrates the flow diagram used for study inclusion and exclusion. Of the 38 articles initially identified, 17 publications met inclusion criteria and required full-text evaluation. Seven publications were excluded as five studies did not report the most common appropriate or inappropriate indications while another two studies did not report the percentage of echocardiography studies classifiable by the AUC. Overall, ten studies were identified that met the criteria and were included in this literature review.

Applicability of the 2011 Appropriate Use Criteria across multiple centers

Figure 2 illustrates the applicability of the 2011 AUC to five studies conducted in the US: one in Canada, three in the European Union (UK, Portugal, Italy), and one in Australia [9–15, 17, 19, 20]. Overall, 8561 studies were extracted from the included studies of which 8460 were classifiable (98.8%). In terms of region, 4396 US studies were identified with 4378 classifiable (99.5%) while 4165 non-US studies were identified with 4082 classifiable (98.0%).

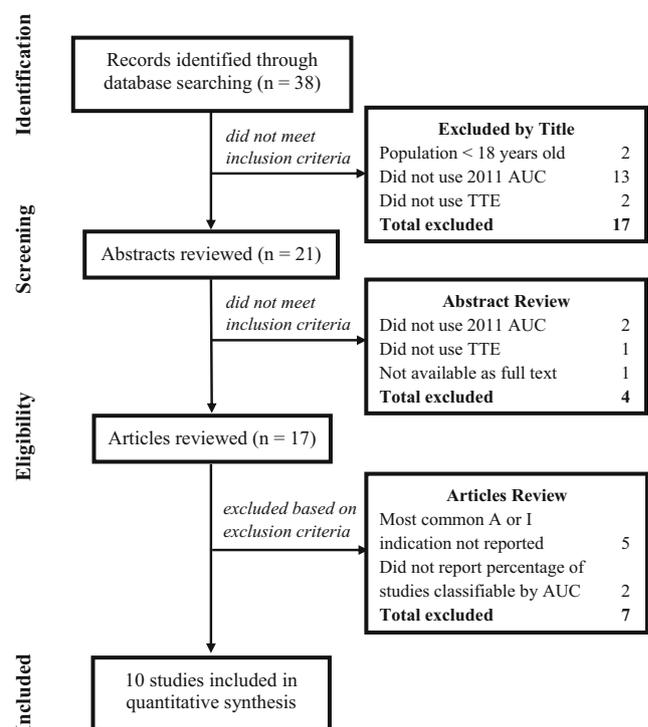


Fig. 1 Flowchart of articles included and excluded by applying the search strategy

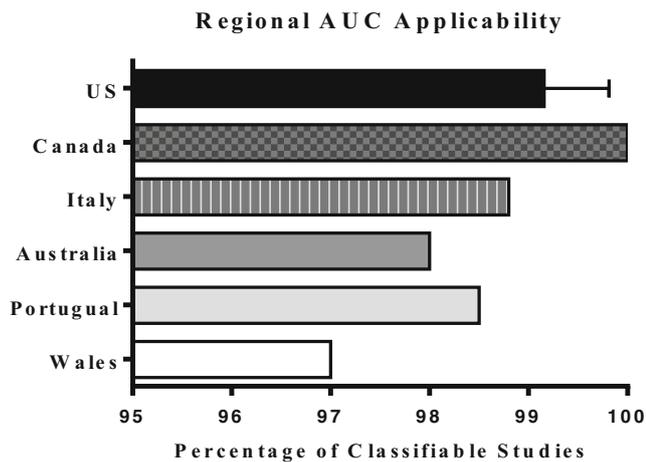


Fig. 2 Percentage of referrals classifiable by the 2011 AUC in US/non-US regions. US studies ($n = 5$) represented as mean \pm SEM. Non-US studies ($n = 5$) are represented independently

Reported Appropriate Use Criteria classifications

Rates of appropriate use

Table 5 shows the appropriate use rates reported across the ten studies. Overall, 7119 TTE studies were classified as appropriate (83.1%), 1067 as inappropriate (12.5%), and 367 as unsure (4.2%). In the US, 3724 referrals were appropriate (84.7%), 462 inappropriate (10.5%), and 203 unsure (4.6%), while 3395 referrals outside the US were appropriate (81.5%), 605 inappropriate (14.5%), and 165 unsure (4%) (Tables 1 and 2).

Most common inappropriate TTE referrals

Table 3 shows the most frequent inappropriate TTE indications extracted from the included studies. Overall, the most inappropriate TTE referral was Indication 11 (108 studies). The most common inappropriate TTE referral in the US regions was Indication 53 (63 TTE studies) and Indication 11 in non-US regions (108 TTE studies) (see Supplementary Table 2).

Table 1 Appropriate use rates reported from centers outside the United States

(a)		TTE studies			Percentage of n (%)			
		n	A	U	I	A	U	I
Gurzon et al. (2014)	UK	1070	920	32	118	86	3	11
Fonseca et al. (2015)	PRT	799	629	48	122	78.7	6	15.3
Al-Kaisey et al. (2015)	AUS	1000	770	27	203	77	2.7	20.3
Remfry et al. (2015)	CAN	365	329	11	26	90	3	7
Ballo et al. (2012)	ITA	931	748	47	137	80.3	5	14.7
Total non-US studies		4165	3395	165	605	81.5	4.0	14.5

TTE, transthoracic echocardiography; n , sample size; A, appropriate; U, unsure; I, inappropriate; UK, United Kingdom; PRT, Portugal; AUS, Australia; CAN, Canada; ITA, Italy

Reported factors that influence deviation from Appropriate Use Criteria

Three major factors were considered when examining deviation from the AUC including inpatient versus outpatient setting, specialty of referring physician, and time from 2011 AUC publication.

Outpatient versus inpatient referrals

Six out of the ten studies included both inpatient and outpatient TTE referrals in their analysis [10–13, 17, 19]. All studies showed significantly more appropriate referrals among inpatient populations compared to outpatient populations. The most common inappropriate TTE referral among outpatients was Indication 11 (108 TTE studies). Two studies independently showed Indication 11 was significantly more prevalent among outpatient referrals compared to inpatients ($p < 0.001$) [17, 19]. The most common inappropriate TTE referral among inpatients was Indication 53 (74 TTE studies). Statistical comparisons between inpatient and outpatient populations were variable with one study reporting Indication 53 and another reporting Indication 13 being significantly more prevalent among inpatients [17, 19]. Of the six studies that included inpatient and outpatient populations, four found the most common inappropriate indications were similar between the two groups [10–13]. Table 4 shows the most frequent inappropriate TTE indications among inpatient and outpatient populations extracted from the included studies.

Specialty of the referring physician

Eight of the ten studies reported appropriate referrals by specialty of the referring physician. Five of these studies found no significant difference in appropriate referral rates between specialties [11–14, 20]. A study by Fonseca et al. found cardiologists ordered inappropriate

Table 2 Appropriate use rates reported from centers within the United States

(b)		TTE studies				Percentage of <i>n</i> (%)		
		<i>n</i>	A	U	I	A	U	I
Bhatia et al. (2012)	USA	1318	1107	40	171	84	3	13
Matulevicius et al. (2013)	USA	535	491	21	23	91.8	3.9	4.3
Patil et al. (2012)	USA	1825	1497	97	224	82	5.3	12.3
Alqarqaz et al. (2012)	USA	170	131	24	15	77	14	9
Koshy et al. (2015)	USA	548	499	22	27	91	4	5
Total US studies		4396	3724	203	462	84.7	4.6	10.5

TTE, transthoracic echocardiography; *n*, sample size; A, appropriate; U, unsure; I, inappropriate; USA, United States of America

TTEs more frequently than any other specialty ($p < 0.05$) while another study by Ballo et al. found cardiologists ordered significantly more appropriate TTEs compared to other specialties ($p < 0.001$) [9, 19]. Gurzon et al. reported cardiac surgeons ordered inappropriate TTEs more frequently than any other specialty ($p < 0.05$) [10].

Role for education intervention?

A study by Bhatia et al. examined the effect of an AUC-guided educational intervention on the proportion of inappropriate TTE referrals ordered at an academic medical center [15]. During the intervention period, there was a significant 26% reduction in the number of TTEs ordered per day (3.9 versus 2.9 TTEs, $p < 0.001$). Additionally, there was a significant decrease in inappropriate TTEs ordered (5 versus 13%, $p < 0.001$) and a significant increase in appropriate TTEs ordered (93 versus 84%, $p < 0.001$). During the post-intervention period, the rate of inappropriate TTEs increased (5 versus 11%, $p < 0.05$) and appropriate TTEs decreased (93 versus 86%, $p < 0.05$) compared to the intervention period. The post-intervention rate of inappropriate TTEs was similar to the pre-intervention control period (11 versus 13%, $p > 0.05$) (Table 5).

Discussion

Are the Appropriate Use Criteria for echocardiography relevant outside the US?

The results of this systematic review suggest the AUC are applicable to centers outside the US with 98% of extracted studies classifiable according to the 2011 revised document. The lowest classifiable rate was observed in a Welsh cross-sectional study (97%) which could be explained by the study protocol [10]. Data was collected based on questionnaires filled in by participating centers which carries a risk that the clinical indication may not be fully captured. This limitation coupled with the reported classification rates from the other four non-US studies ($\geq 98\%$) suggests the AUC are relevant outside the US [9, 17, 19, 20].

Medical center adherence to Appropriate Use Criteria

Rates of appropriate use

Overall, slightly more than eight in ten TTE studies were considered appropriate (83.1%) with slightly higher appropriate referrals seen in US regions (84.7%) compared to those

Table 3 Frequency of inappropriate TTE indications

Indication	Description	No. of studies
11	Routine surveillance of ventricular function with known CAD and no change in clinical status or cardiac exam	108
74	Routine surveillance (< 1 year) of HF (systolic or diastolic) when there is no change in clinical status or cardiac exam	88
53	Transient fever without evidence of bacteremia or a new murmur	74
35	Initial evaluation when there are no other symptoms or signs of valvular or structural heart disease	29
13	Routine perioperative evaluation of ventricular function with no symptoms or signs of cardiovascular disease	12
8	Lightheadedness/presyncope when there are no other symptoms or signs of cardiovascular disease	4

CAD, coronary artery disease; HF, heart failure; TTE, transthoracic echocardiography

Table 4 Frequency of inappropriate TTE indications among inpatients and outpatients

Indication	OP	IP
11 Routine surveillance of ventricular function with known CAD and no change in clinical status or cardiac exam	108	0
53 Transient fever without evidence of bacteremia or a new murmur	0	74
74 Routine surveillance (< 1 year) of HF (systolic or diastolic) when there is no change in clinical status or cardiac exam	47	41
35 Initial evaluation when there are no other symptoms or signs of valvular or structural heart disease	25	4
13 Routine perioperative evaluation of ventricular function with no symptoms or signs of cardiovascular disease	19	9
8 Lightheadedness/presyncope when there are no other symptoms or signs of cardiovascular disease	0	4

CAD, coronary artery disease; HF, heart failure; OP, outpatients; IP, inpatients; TTE, transthoracic echocardiography

outside the US (81.5%). In the US, compliance with the AUC is essential as requests for tests are only authorized if they comply with the radiology manager's pre-certification criteria which are in line with the AUC [10]. This could explain the observed difference in adherence between regions and may suggest a potential role for strict application of the AUC in the international setting. The overall 83% appropriate use rate is comparable to the largest study to date performed in 1820 patients (82%) in a single US academic center [11].

Inappropriate TTE referrals

The most common reason for inappropriate TTE referral was "routine surveillance of ventricular function with known CAD and no change in clinical status" of which all 108 studies came from outpatient TTE referrals performed outside the US, primarily in Portugal and Australia [17, 19] (see Supplementary Table 2). Al-Kaisey et al. reported over 50% of these outpatient referrals had a TTE in the preceding 12 months [17]. This represents an important group of patients to target for future improvement in TTE requesting. In the US "transient fever without evidence of bacteremia or a new murmur" was the most common inappropriate indication. Interestingly, all 74 extracted studies were from inpatient populations, 63 of which were extracted from US studies. A study by Bhatia et al. showed a significant reduction in inappropriate TTE studies to evaluate infective endocarditis through educational intervention (7 versus 3%, $p < 0.05$) [15]. These findings suggest a role for educational intervention particularly in the inpatient setting and suggest a need for pilot intervention in outpatient settings.

Investigation into factors which cause deviation from Appropriate Use Criteria

Outpatient versus inpatient?

The results of this systematic review show a lower proportion of appropriate referrals among outpatients [10–13,

17, 19]. This is not unexpected as outpatient requests usually refer to routine TTE in patients with no change in clinical status (typically rated inappropriate), whereas inpatients commonly present with new symptoms or signs suggesting cardiac disease or known cardiovascular disease (typically rated appropriate).

Specialty of the referring physician

The majority of studies showed no significant effect of medical specialty on appropriate referral rates. Interestingly, an Italian study of five community hospitals found cardiologists ordered significantly more appropriate TTEs compared to other specialties while a study conducted in Portugal found cardiologists ordered significantly more inappropriate TTEs [9, 19]. All US studies that reported appropriate referrals by specialty found no significant difference between specialties [11–14]. The authors of the Italian study suggested Italy's health care payment criteria which is diagnosis-related rather than pay-for-performance reimbursement as a potential explanation for conflicting results with US reports.

Potential strategies to improve adherence to the criteria

This review examined a single educational intervention study which showed while intervention was effective during its implementation, TTE referral rates regressed to pre-intervention levels over time [15]. This suggests that long-term success requires a sustained effort of education and feedback. An alternative strategy could examine the use of the plasma biomarker brain natriuretic peptide (BNP) as a sequential testing strategy to TTE. In the primary care setting, the use of BNP as a sequential strategy significantly reduced the cost for diagnostic workup of patients with suspected heart failure [21].

Table 5 Summary of studies included in quantitative research synthesis

Author, (date), country	Methods	Findings				Most common inappropriate indication (number of referrals, % of <i>n</i>)	Limitations	Comments
		NC	A	U	I			
Gurzon et al. (2014), Wales (UK)	Setting: 14 hospitals Study: Cross-sectional analysis over 1 week (June 12) Population sample: In- and outpatients <i>n</i> = 1070	3	86	3	11	Indication 35: “initial evaluation for a murmur without symptoms/signs of structural heart disease” (29 TTEs, 2.7%) No difference between inpatients and outpatients	AUC developed in the US and this is a UK study. Data collection based on questionnaires. Cardiac surgeons ordered inappropriate TTEs more frequently than other specialties (<i>p</i> < 0.05) 1 in 10 scans could be avoided	Significantly more appropriate referrals among inpatients (94.4%) than in outpatients (83.5%, <i>p</i> < 0.05) Cardiac surgeons ordered inappropriate TTEs more frequently than other specialties (<i>p</i> < 0.05) 1 in 10 scans could be avoided
Fonseca et al. (2015), Portugal	Setting: Regional hospital Study: 1 month prospective analysis Population sample: In- and outpatients <i>n</i> = 799	2.5	78.7	6	15.3	Outpatient: “routine surveillance of the ventricular function in known CAD with no change in clinical status” (#11, 61 TTEs, 7.6%) Inpatient: “routine perioperative evaluation of ventricular function with no symptoms or signs of cardiovascular disease” (#13, 4 TTEs, 0.5%)	Single-center study therefore the results cannot be extrapolated to different settings in Portugal.	Significantly more appropriate referrals among inpatients (93%) than in outpatients (74.2%, <i>p</i> < 0.05) Cardiologists ordered inappropriate TTEs more frequently than other specialties (<i>p</i> < 0.05)
Al-Kaisey et al. (2015), Australia	Setting: Regional hospital Study: 6-month retrospective analysis Population sample: In- and outpatients <i>n</i> = 1000	2	77	2.7	20.3	Outpatient: “routine surveillance of the ventricular function in known CAD with no change in clinical status” (#11, 11 TTEs, 1.1%) Inpatient: “transient fever without evidence of bacteremia or a new murmur” (#53, 47 TTEs, 4.7%)	Single-center study therefore the results cannot be extrapolated to different settings in Australia. Retrospective analysis carries a risk that the clinical indication may not fully be captured.	Significantly more inappropriate referrals among outpatients (24.4%) than in inpatients (9.6%, <i>p</i> < 0.001) 1 in 5 scans could be avoided
Remfry et al. (2015), Canada	Setting: 3 academic hospitals Study: 2-month retrospective analysis Population sample: Inpatients <i>n</i> = 365	0	90	3	7	Indication 8: “lightheadedness/presyncope when there are no other symptoms or signs of cardiovascular disease” (4 TTEs, 3.1%)	Results from academic centers may not be applicable to community centers. Retrospective analysis carries a risk that the clinical indication may not fully be captured.	No significant difference in appropriate referral rates between specialties.
Ballo et al. (2012), Italy	Setting: 5 community hospitals Study: 6-week prospective analysis Population sample: Inpatients <i>n</i> = 931	1.2	80.3	5	14.7	Indication 74: “routine surveillance (<1 year) of HF (systolic or diastolic) when there is no change in clinical status or cardiac exam” (32 TTEs, 3.4%)	AUC developed in the US and this is an Italian study. Results from a single community center may not be applicable to other Italian healthcare settings.	Cardiologists had a higher rate of appropriate referrals compared to non-cardiologists (91.5 vs. 69.7%, <i>p</i> < 0.001). Appropriate indications showed a significantly higher prevalence of clinically useful studies compared to inappropriate indications (86.7 vs. 14.1%, <i>p</i> < 0.001)

Table 5 (continued)

Author, (date), country	Methods	Findings				Most common inappropriate indication (number of referrals, % of <i>n</i>)	Limitations	Comments
		NC	A	U	I			
Bhatia et al. (2014), United States	Setting: Academic hospital Study: 11-month prospective analysis Population sample: Inpatients <i>n</i> = 1318	0.8	84	3	13	Indication 53: “transient fever without evidence of bacteremia or a new murmur” (63 TTEs, 4.7%) No difference between pre- and post-intervention	Results from a single academic center may not be applicable to other practice settings. Intervention aimed at junior staff so may not be applied to senior staff.	AUC classification during intervention: NC (2) A (93**) U (2) I (5**) AUC classification post-intervention: NC (0) A (86) U (3) I (11) After completion of a successful AUC-based educational and feedback intervention, the rate of inappropriate TTEs regresses to pre-intervention levels.
Matulevicius et al. (2013), United States	Setting: Academic hospital Study: 1-month retrospective analysis Population sample: In- & outpatients <i>n</i> = 535	0	91.8	3.9	4.3	Indication 13: “routine perioperative evaluation of ventricular function with no symptoms or signs of cardiovascular disease” (13 TTEs, 2.4%) No difference between inpatients and outpatients	Results from a single academic center may not be applicable to other practice settings. Retrospective analysis carries a risk that the clinical indication may not fully be captured.	Significantly more appropriate referrals among inpatients (95.7%) than in outpatients (86.5%, <i>p</i> < 0.001) No significant difference in appropriate referral rates between specialties. Although 9 in 10 TTEs were appropriate by 2011 AUC, fewer than 1 in 3 TTEs resulted in an active change in care, nearly half resulted in continuation of care and slightly more than 1 in 5 resulted in no change in care
Patil et al. (2012), United States	Setting: Regional hospital Study: 2-month prospective analysis Population sample: Inpatients <i>n</i> = 1825	0.4	82	5.3	12.3	Indication 74: “routine surveillance (< 1 year) of HF (systolic or diastolic) when there is no change in clinical status or cardiac exam” (46 TTEs, 2.5%) No difference between inpatients and outpatients	Single-center design may not be applicable to other settings.	First study performed which evaluated the revised 2011 criteria Significantly more appropriate referrals among inpatients (88.7%) than in outpatients (76.2%, <i>p</i> < 0.001) No significant difference in appropriate referral rates between specialties.
Alqarqaz et al. (2012), United States	Setting: Academic hospital Study: 2-month prospective analysis Population sample: Outpatients <i>n</i> = 170	0	77	14	9	Indication 74: “routine surveillance (< 1 year) of HF (systolic or diastolic) when there is no change in clinical status or cardiac exam” (10 TTEs, 5.3%)	Single-center design may not be applicable to other settings. Relatively small sample size.	No significant difference in appropriate referral rates between specialties. Echo studies classified as appropriate were more likely to be associated with new

Table 5 (continued)

Author, (date), country	Methods	Findings					Most common inappropriate indication (number of referrals, % of <i>n</i>)	Limitations	Comments
		NC	A	U	I				
Koshy et al. (2015), United States	Setting: Academic hospital Study: 1-month retrospective analysis Population sample: In- and outpatients <i>n</i> = 548	0.02	91	4	5	Indication 13: “routine perioperative evaluation of ventricular function with no symptoms or signs of cardiovascular disease” (4 TTEs, 0.7%) No difference between inpatients and outpatients	Single-center design may not be applicable to other settings Retrospective analysis carries a risk that the clinical indication may not fully be captured.	(<i>p</i> < 0.05) and major findings (<i>p</i> < 0.05) when compared with other studies. Patient care intervention was significantly associated with appropriate studies compared to other studies (<i>p</i> < 0.05). Significantly more appropriate referrals among inpatients (96%) than in outpatients (85%, <i>p</i> < 0.001) No significant difference in appropriate referral rates between specialties. Significantly more abnormal findings among appropriate referrals (51%) compared with inappropriate (38%, <i>p</i> < 0.05) The prevalence of a new abnormality was similar between inappropriate (25%) and appropriate (26%) repeat TTEs (<i>p</i> > 0.05)	

NC, not classifiable; A, appropriate; U, unsure; I, inappropriate; TTE, transthoracic echocardiography; AUC, Appropriate Use Criteria; CAD, coronary artery disease; HF, heart failure
**Significant difference from the pre-intervention/control group, *p* < 0.001

Limitations of the study

Firstly, this study only used one database to obtain original articles which may have limited the available literature for systematic review. Secondly, the literature search, study selection, assessment of study validity, and data extraction were performed by a single author which could potentially lead to a misinterpretation of results. Finally, statistical analysis of extracted TTE studies was purely descriptive which hinders objective comparison between other systematic reviews and original article reports. This could be addressed through meta-analysis with the appropriate software, statistical model, and expertise.

Future research perspectives

This review highlights the limited literature available on TTE appropriate use rates according to the 2011 AUC. Furthermore, there is very little data available on intervention strategies to reduce yearly TTE rates. As the overall purpose of AUC is reduce, cardiac imaging demands further research should (1) assess the effect of educational intervention on adherence to the 2011 AUC, (2) examine alternative strategies such as screening with plasma biomarkers (troponin and natriuretic peptide levels), and (3) continue auditing efforts to ensure strict hospital adherence to AUC.

Conclusion

In conclusion, the American guideline AUC are applicable to centers outside the USA and their implementation across five international centers suggest almost 1 in 5 scans could be avoided. The high classification rates observed suggest that applying the AUC for TTE screening outside the USA might be feasible. Their strict application has the potential to reduce cardiac imaging demands and decrease spending on diagnostic imaging. Further study is needed to determine its applicability to an Irish medical center and assess factors which could aid in adherence to the criteria.

References

1. Andrus BW, Welch HG (2012) Medicare services provided by cardiologists in the United States: 1999–2008. *Circ Cardiovasc Qual Outcomes* 5(1):31–36
2. (2012) A data book: health care spending and the Medicare program
3. Douglas PS, Garcia MJ, Haines DE, Lai WW, Manning WJ, Patel AR et al (2011) ACCF/AHA/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 Appropriate Use Criteria for echocardiography. A report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Society of Echocardiography, American Heart Association, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance American College of Chest Physicians. *J Am Soc Echocardiogr* 24(3):229–267
4. Douglas PS, Khandheria B, Stainback RF, Weissman NJ, Brindis RG, Patel MR, Khandheria B, Alpert JS, Fitzgerald D, Heidenreich P, Martin ET, Messer JV, Miller AB, Picard MH, Raggi P, Reed KD, Rumsfeld JS, Steimle AE, Tonkovic R, Vijayaraghavan K, Weissman NJ, Yeon SB, Brindis RG, Douglas PS, Hendel RC, Patel MR, Peterson E, Wolk MJ, Allen JM, American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American Society of Echocardiography, American College of Emergency Physicians, American Society of Nuclear Cardiology, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, American College of Chest Physicians, Society of Critical Care Medicine (2007) ACCF/AHA/ACEP/ASNC/SCAI/SCCT/SCMR 2007 appropriateness criteria for transthoracic and transesophageal echocardiography: a report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American Society of Echocardiography, American College of Emergency Physicians, American Society of Nuclear Cardiology, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, and the Society for Cardiovascular Magnetic Resonance endorsed by the American College of Chest Physicians and the Society of Critical Care Medicine. *J Am Coll Cardiol* 50(2):187–204
5. Bhatia RS, Carne DM, Picard MH, Weiner RB (2012) Comparison of the 2007 and 2011 appropriate use criteria for transthoracic echocardiography in various clinical settings. *J Am Soc Echocardiogr* 25(11):1162–1169
6. Mansour IN, Razi RR, Bhavne NM, Ward RP (2012) Comparison of the updated 2011 appropriate use criteria for echocardiography to the original criteria for transthoracic, transesophageal, and stress echocardiography. *J Am Soc Echocardiogr* 25(11):1153–1161
7. Parikh PB, Asheld J, Kort S (2012) Does the revised appropriate use criteria for echocardiography represent an improvement over the initial criteria? A comparison between the 2011 and the 2007 appropriateness use criteria for echocardiography. *J Am Soc Echocardiogr* 25(2):228–233
8. Bailey SA, Mosteanu I, Tietjen PA, Petrini JR, Alexander J, Keller AM (2012) The use of transthoracic echocardiography and adherence to appropriate use criteria at a regional hospital. *J Am Soc Echocardiogr* 25(9):1015–1022
9. Ballo P, Bandini F, Capecchi I, Chiodi L, Ferro G, Fortini A, Giuliani G, Landini G, Laureano R, Milli M, Nenci G, Pizzarelli F, Santoro GM, Vannelli P, Cappelletti C, Zuppiroli A, American College of Cardiology Foundation, American Society of Echocardiography (2012) 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* 25(6):589–598
10. Gurzun MM, Ionescu A (2014) Appropriateness of use criteria for transthoracic echocardiography: are they relevant outside the USA? *Eur Heart J Cardiovasc Imaging* 15(4):450–455
11. Patil HR, Coggins TR, Kusnetzky LL, Main ML (2012) Evaluation of appropriate use of transthoracic echocardiography in 1,820 consecutive patients using the 2011 revised appropriate use criteria for echocardiography. *Am J Cardiol* 109(12):1814–1817

12. Matulevicius SA, Rohatgi A, Das SR, Price AL, DeLuna A, Reimold SC (2013) Appropriate use and clinical impact of transthoracic echocardiography. *JAMA Intern Med* 173(17):1600–1607
13. Koshy TP, Rohatgi A, Das SR, Price AL, deLuna A, Reimold N, Willett K, Reimold SC, Matulevicius SA (2015) The association of abnormal findings on transthoracic echocardiography with 2011 Appropriate Use Criteria and clinical impact. *Int J Cardiovasc Imaging* 31(3):521–528
14. Alqarqaz M, Koneru J, Mahan M, Ananthasubramaniam K (2012) Applicability, limitations and downstream impact of echocardiography utilization based on the Appropriateness Use Criteria for transthoracic and transesophageal echocardiography. *Int J Cardiovasc Imaging* 28(8):1951–1958
15. Bhatia RS, Dudzinski DM, Milford CE, Picard MH, Weiner RB (2014) Educational intervention to reduce inappropriate transthoracic echocardiograms: the need for sustained intervention. *Echocardiography (Mount Kisco, NY)* 31(8):916–923
16. Vijayan S, Khanji M, Ionescu A (2011) Can application of appropriateness of use criteria reduce the workload in a tertiary echocardiographic laboratory? A single centre experience. *Eur J Echocardiogr* 12
17. Al-Kaisey A, Jones E, Nadurata V, Farouque O, De Silva D, Ramchand J (2015) Appropriate use of echocardiography in an Australian regional centre. *Intern Med J* 45(11):1128–1133
18. Fonseca R, Negishi K, Otahal P, Marwick TH (2015) Temporal changes in appropriateness of cardiac imaging. *J Am Coll Cardiol* 65(8):763–773
19. Fonseca P, Sampaio F, Ribeiro J, Goncalves H, Gama V (2015) Appropriate use criteria for transthoracic echocardiography at a tertiary care center. *Rev Port Cardiol* 34(12):713–718
20. Remfry A, Abrams H, Dudzinski DM, Weiner RB, Bhatia RS (2015) Assessment of inpatient multimodal cardiac imaging appropriateness at large academic medical centers. *Cardiovasc Ultrasound* 13(1):44
21. Khezri BS, Helmersson-Karlqvist J, Larsson A (2014) Estimation of the possible economic effects of a sequential testing strategy with NT-proBNP before echocardiography in primary care. *Clin Lab* 60(6):881–886