EACVI Appropriateness Criteria for the use of Cardiovascular Imaging in Heart Failure

Derived from European National Imaging Societies Voting

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ABSTRACT

This paper presents the first European appropriateness criteria for the use of cardiovascular imaging in heart failure, derived from voting of the European national Imaging Societies representatives. The paper describes the development process and discusses the results.

INTRODUCTION

The European Association of Cardiovascular Imaging (EACVI) has recognised the need for the development of appropriateness criteria for the use of cardiovascular imaging (CVI) in clinical practice in Europe and have published a statement in this regard[1]. The evolving role of CVI in heart failure (HF) due to diversification of indications and to the rise in HF prevalence, partially due to better life expectancy and higher HF prevalence in the elderly[2,3,4] has driven the EACVI to commence with the development of appropriateness criteria for the use of CVI in HF.

METHODS

Development process

The process began with a review of the literature regarding the use of CVI in HF performed and reported in the European Heart Journal of Cardiovascular Imaging by the Expert Panel, which includes members of the Imaging Taskforce and invited authors, including one invited member of the ESC HF Association[2]. The aim of this document was to inform the process of definition of clinical indications for the use of CVI in HF and the process of scoring of appropriateness for each modality in each indication. The literature review was structured according to common HF clinical scenarios.

The next step, performed by members of the Expert Panel and of the Appropriateness Criteria Development Team, was the definition of clinical indications for the use of CVI in each HF clinical scenario and the development of scoring tables. The scoring tables, instructions and copies of the EACVI appropriateness criteria development need statement and of the published report of literature review were sent to the Voting Panel members for the first round of scoring. The instructions briefly explained the process already extensively detailed in the statement paper. Our appropriateness criteria development process was the first to offer the voters a literature review purposely written by the Expert Panel and published prior to commencement of the voting process.

The Voting Panel members were individuals recommended as representatives by the European National Imaging Societies and Working Groups collaborating with the EACVI when the process began (April 2014). The Voting Panel covered all geographic areas of Europe and the range of European realities regarding healthcare systems, needs and availabilities.

Statistical analysis of the first round of scores and feedback from the Voting Panel members regarding the scoring tables and the clarity of the questionnaire revealed the need for simplification of the scoring tables to eliminate repetitions and unnecessary expansions together with the need for improvement of the questionnaire to eliminate ambiguities. Following the face-to-face meeting with the Voting Panel members (appendix), a second round of scoring was performed using the optimised scoring tables.

Transparency and the inclusive nature of the process were ensured by interaction with the National Societies' representatives at the EACVI Summit in June 2015. The Consensus Meeting organised at the ESC Congress in August 2015 made the development process more robust, supporting the final interpretation of results by the Appropriateness Criteria Development Team.

Clinical scenarios and clinical indications

The common HF clinical scenarios are diagnosis, treatment planning and follow-up, each of them having two distinct sub-scenarios, as shown in Figure 1. The clinical scenarios were defined based on the clinical experience of the Expert Panel, on the ESC guidelines for the diagnosis and treatment of acute and chronic HF[5] and on the literature review. Clinical indications for the use of CVI in each HF clinical scenario and sub-scenario are detailed in Figures 2, 3, 4 and 5. They represent common clinical scenarios seen in contemporary practice, but do not include every conceivable clinical situation. Thus, some patients seen in clinical practice are not represented in this document or have additional extenuating features compared with the clinical scenarios presented.

Analysis of the scores

The appropriateness criteria were developed using the RAND-UCLA method, a two-round modified Delphi exercise[6]. Ratings of 1–3 were classified as inappropriate, with a rating of one indicating the greatest degree of inappropriateness. Ratings of 7–9 were classified as appropriate, with a rating of nine indicating the greatest degree of appropriateness. Ratings of 4–6 were classified as uncertain, being neither appropriate nor inappropriate. Scores in the "uncertain" category resulted mainly from the scoring of the use of a modality for a certain clinical indication in the appropriate range by some voters and lower by other voters. High scores were given by voters already using or still using that modality for the given clinical indication, whilst low scores were given by voters not yet using or no longer using the modality for that clinical indication.

Upon return of the scoring tables from voters, the scores were tabulated and statistical analyses were performed to calculate the median numerical score for each indication. The level of agreement among voting panel members was subsequently determined. Agreement was based on four or fewer panellists rating outside the three-point region containing the median (1–3; 4–6; 7–9), and disagreement was based on five or more panellists rating in each extreme (1–3 and 7–9), as per the RAND/UCLA protocol for a 15-member panel. The ratings from each panellist had equal weight in producing the final result for the indications.

The characterisation of the use of a certain CVI modality for a certain clinical indication as appropriate (A), inappropriate (I) or of unknown appropriateness (U) as described in the appropriateness criteria development methodology, reduced the differences in between modalities and indications observed in the initial scores. The characterisation was made when the median score value was in the 3 point range category (A for 7-9, U for 4-6, I for 1-3). The characterisation U is also classically attributed when there is disagreement in between voting panel members, despite the median score falling within one of the two other categories.

The heterogeneous European reality, with differences in current clinical practice[7] reflected in scoring, had a major impact in the final results despite the action taken to help resolve disagreement. In the case of some modalities and some clinical indications, the disagreement was favourable, bringing up the characterisation from I to U and encouraging future acquisition of further evidence in this regard. In the case of other modalities and clinical indications, the disagreement was unfavourable, bringing down the characterisation from A to U; however, the characterisation U does not discourage clinical use following locally established patterns, it only again encourages the acquisition of further evidence.

Analysis of the results to identify the outlier voters generating the most disagreement, found them to belong to the most developed countries and to the medical societies owning the larger volume of advanced technology for the longer period of time. These medical societies have been at the centre of research regarding clinical implementation of modern techniques and technologies and they have the higher density of opinion leaders in the field. We found that, despite creating disagreement, the outliers actually raised the median score regarding the use of modern techniques in the majority of clinical indications.

Given the higher perceived likelihood of disagreement in the context of heterogeneous European reality, the Appropriateness Criteria Development Team decided to present the results based on the median

score range which, regardless of this heterogeneity, may reflect more directly the opinion of the voting panel; the existence of disagreement is highlighted by an associated “d”. The reader is invited to consider the result with an associated “d” as a “U” within the current heterogeneous European context, bearing in mind though that in a more homogeneous context there may have been no disagreement. Despite this attempt to rationalise the results, there are situations in which similar clinical indications were scored differently for the same imaging modality. One example is that of cardiac magnetic resonance (CMR) for non-urgent (delayed) assessment for first diagnosis of HF, which scored within “A” range with or without a “d” depending on whether the initial symptomatic presentation was as an emergency or elective, which should make no difference in this case.

SCENARIOS AND CVI INDICATIONS

The appropriateness criteria for the use of CVI in HF are displayed in tables 1-5. Tables 1-4 present a detailed description of the appropriate use of CVI in HF per clinical indication, to support decision-making in clinical practice, taking into consideration further diversification of clinical scenarios for a particular patient, availability, coexistent situation influencing the decision (for example implanted non-CMR compatible device excludes CMR) or the choice of invasive coronary angiography instead of non-invasive CVI in the assessment of HF aetiology. Table 5 shows a summary of the appropriate use of CVI in a HF patient broadly, per clinical scenario, without considering sub-scenarios, by combining the clinical indications and keeping the higher reached score. This approach justifies the need for availability of a certain CVI modality. For example, whilst stress echocardiography is inappropriate for the urgent first diagnosis of HF in the symptomatic patient with emergency presentation, it is appropriate in the diagnosis of HF aetiology, so, it is appropriate for use in HF.

CVI use in the first diagnosis of HF

HF is a syndrome consisting of symptoms and signs resulting from an abnormality of cardiac structure and/or function[2, 5]. The symptoms are non-specific and the signs can be absent in patients receiving treatment, so the demonstration of an abnormality of cardiac structure and/or function is essential for HF diagnosis[2, 5]. Non-invasive CVI is used in the first diagnosis of HF to detect abnormalities of cardiac structure and/or function, which can explain the symptoms and signs[5]. The first diagnosis can be made in symptomatic patients presenting as an emergency for hospital admission or presenting electively as outpatients. It can also be made in asymptomatic patients, without heart failure, as an incidental finding during assessment performed for a different reason. Echocardiography is the CVI modality usually

underpinning the first diagnosis of HF in urgent, elective or screening settings. As seen from their final scores, the multinational European voting panel members agreed that the use of the available CVI modalities could differ in these settings, because of practicalities.

Together with bedside portability, wide availability of both equipment and expertise is needed for modalities used in urgent cases. The expertise has to be available day and night on-call to cover such an application. Echocardiography has all the needed characteristics and had unanimous maximal scoring. It was also unanimously agreed that there is no role in these settings for stress echocardiography, radionuclide angiography (RNA), single-photon emission computed tomography (SPECT) and positron emission tomography (PET). Cardiac magnetic resonance (CMR) and cardiovascular computed tomography (CT) scored within the “I” range; however, the opinion of some voters that there may be a role for these methods in the acute settings of the emergency department created disagreement, highlighting a potential future role of “on-call” for these modalities.

When not urgent, the ability to offer a certain CVI modality before discharge or in a “one-stop” basis in outpatient clinics, depends on availability of resources; the clinical indications we defined account for this practical reality, and the results differed for the two types of priority (urgent and non-urgent or delayed assessment). CT scored in the “U” range, whilst CMR scored within the “A” range for delayed first diagnosis of HF. The disagreement in regard with CMR use in delayed first diagnosis of HF in patients presenting as an emergency seems to originate from pure misunderstanding, because the delayed use should not depend upon the type of initial presentation. The same should be the case for the use of SPECT and PET in these settings.

There are situations in which the use of a modality is inappropriate in acute settings because of the potential complications, as for example the use of stress echocardiography in the urgent assessment of the patient presenting with HF symptoms, and this indication scored in the “I” range. However, as already mentioned in the general description of the results section, there is a role for stress echocardiography in the delayed assessment of patients presenting with HF.

Asymptomatic patients may be found during screening or assessment for other reasons, usually with echocardiography, to have abnormalities which could lead to HF. Cardiomyopathy screening may need CMR, which scored U in these settings of screening cardiomyopathy patients for heart failure, rather than screening for cardiomyopathy. Baseline and periodic screening of systolic function is performed in patients on cardiotoxic chemotherapy, usually with echocardiography. However, in case of poor

echocardiography window or uncertain results, CMR is essential; furthermore, in the absence of CMR or sometimes in the absence of high-resolution echocardiography with contrast, if needed, RNA could be used. This reality is reflected in the results. Considerations regarding contrast echocardiography, as well as all other echocardiography techniques are included under “echocardiography”. Asymptomatic patients with diabetes are offered left ventricular systolic function screening with echocardiography (A) or CMR in cases with poor echocardiography window (U); the voting panel took into consideration coronary disease screening in these patients too, scoring U for the relevant tests (stress echo, CMR, CT, SPECT).

The case of the patient with cardiac history of myocardial infarction, coronary artery disease or structural heart disease was separately and extensively considered, because of inherent particularities. For example, the ESC HF guidelines[5] recommend direct referral for echocardiography, without a natriuretic peptide assessment in patients with history of myocardial infarction and presentation with suspected HF, because of high pre-test likelihood of HF in these patients.

The patient with myocardial infarction and HF may represent a more stringent emergency, if urgent revascularisation is needed with or without treatment of potential mechanical complications[5]. Consequently, both non-invasive and invasive CVI should be provided with priority. In some situations, even CMR may be more likely needed as an urgent test, in preparation for surgery, and this was recognised by the voting panel by scoring CMR in the U rather than I range for this indication. The ESC HF guidelines[5] recommend coronary angiography in case of heart failure and coexistent coronary disease. Urgent invasive coronary angiography may be needed in case of acute presentation with heart failure and acute coronary syndrome. In patients with history of myocardial infarction or known coronary artery disease, in the absence of an acute coronary syndrome at the time of presentation, CT coronary angiography rather than invasive coronary angiography is increasingly used. Consequently, the assessment of existence of inducible ischaemia as reason for HF is often performed following coronary angiography when uncertainty regarding the functional severity of coronary disease persists. Similarly, the assessment of existence of viability in this patient category is performed in knowledge of coronary anatomy, to plan revascularisation. In the above-described circumstances, all relevant methods scored highly appropriate. Stress echocardiography refers both to pharmaceutical stress and exercise; the role of stress echo in HF of ischaemic aetiology comprises exercise echocardiography to detect dynamic mitral regurgitation and assess mitral regurgitation severity.

The patient with history of valve disease has first diagnosis of HF made by echocardiography and all other tests scored inappropriate in urgent settings, with some disagreement in the case of CMR. As a delayed test, stress echocardiography was scored as appropriate; this is obviously true in case the severity of valvular disease at rest does not explain HF symptoms and can be used to re-evaluate the severity of valve disease based on stress findings or to detect ischaemia. As a delayed test, CMR scored appropriate with some disagreement. CT scored U, given the emerging evidence regarding the role of calcium scoring in the assessment of aortic stenosis severity.

The patient with a history of congenital heart disease often benefits from CMR or CT for diagnosis, and this is mirrored in the results.

CVI use for diagnosis of HF aetiology

The diagnosis of HF aetiology may be made concomitantly with the first diagnosis of HF or subsequently, based on a separate second test.

The diagnosis of ischaemic aetiology can be suggested by invasive coronary angiography combined with fractional flow assessment (FFR) when needed, particularly in cases presenting with HF and acute coronary syndrome, in cases with a history of myocardial infarction, in cases with history of coronary disease without myocardial infarction or in cases with multiple risk factors for coronary artery disease and left ventricular systolic dysfunction with regional wall motion abnormalities typical for ischaemic heart disease. Coronary artery disease resulting in HF is more likely to be severe, extensive, proximal disease, which could involve the left main stem or all three coronary vessels. Consequently, induced ischaemia during a functional imaging study is likely to be extensive and potentially associated with complications at a higher than average incidence. Caution is required particularly for dobutamine stress echocardiography, especially in case of severe left ventricular systolic dysfunction at rest and/or in case of an already existing extensive scar of myocardial infarction. The risk is smaller for a vasodilator drug based functional imaging test. Stress echocardiography, CMR or SPECT based functional studies were all scored as appropriate. There was some disagreement for SPECT, mirroring the known possibility of a negative test in case of balanced ischaemia in patients with three-vessel coronary artery disease, however, balanced ischaemia has been previously demonstrated to be rare[8]. There was also disagreement in regard to appropriateness of stress echocardiography in patients already having had a coronary angiogram. This is because in such cases the test is rarely needed to assess ischaemia and consequently diagnose ischaemic aetiology of HF, but rather to assess viability. Currently, in clinical practice fractional flow reserve is used when necessary

to determine the significance of coronary artery lesions in HF patients, avoiding the risk of high dose dobutamine stress echocardiography in these patients. Furthermore, the stress echocardiography score was lower (7) in case of existence of regional wall motion abnormalities at rest typical for ischaemic aetiology (scar of myocardial infarction), acknowledging the relatively higher risk of the test in these settings. CT coronary angiography can be used to assess existence of coronary artery disease in HF patients; the test scored A with some disagreement in the patient with normal echocardiographic findings, and it scored U in case of systolic dysfunction with regional wall motion abnormalities at rest, if an invasive coronary angiogram was not already performed. We have to highlight that CT coronary angiography has to be performed at a heart rate of less than 65 beats per minute and beta-blockers are administrated prior to the test to immediately lower the heart rate if needed; this may be poorly tolerated by patients with decompensated HF, in need of gradual optimisation of treatment. Despite limited availability, there is an established role for PET in the diagnosis of ischaemic aetiology and this is reflected in the “U” score and even “A” score with some disagreement following coronary angiography.

The diagnosis of non-ischaemic aetiology was the subject of separate extensive consideration and scoring. In the case of valve disease with severity (diagnosed with echocardiography) explaining the symptoms, further tests scored “I”, with some disagreement in regard with stress echocardiography and CMR thought by some voters to have potential added value. Stress echocardiography and CMR scored “A” in case the valve disease severity does not explain the symptoms; all other tests scored “I” in this case. However, there was some disagreement regarding CT and PET, thought by some voters to play a role in this case. In the opinion of this writing group, CT coronary angiography is very good for exclusion of coronary artery disease in valve disease patients, however, the immediate lowering of heart rate for the test described above may be poorly tolerated by valve disease patients presenting with HF.

CMR and, with some disagreement, cardiac CT scored “A” in the assessment of HF patients with cardiac tumour, pericardial disease or congenital heart disease on an initial echocardiogram. PET scored “U” for further diagnosis of cardiac tumour and stress echocardiography scored “U” in the case of congenital heart disease, reflecting evolving roles for these modalities in the above-mentioned indications. The opinion of this writing group is that PET plays an important role in the assessment of cardiac tumours, and the score “U” rather than “A” should mirror the limited availability of this test around Europe.

The diagnosis of diastolic dysfunction as a reason for HF is extremely important, because of the increasing prevalence of HF with preserved left ventricular ejection fraction, which represents about 50% of the HF

population[2, 9]. The diagnosis is made primarily by echocardiography ("A"), with an evolving role for stress echocardiography in the borderline cases based on echo at rest ("U") and for CMR ("U"). The diagnosis of diastolic dysfunction aetiology can benefit from CMR ("A") to diagnose hypertrophy and infiltration. The use of cardiac CT for assessment for diastolic function is complex and currently not realistic for routine clinical use, explaining the "I" score. In regard with diagnosis of diastolic dysfunction aetiology, recent applications of CT and SPECT to diagnose amyloidosis could justify the "U" and "I^d" scores instead of "I".

CVI use for HF treatment planning

All non-invasive CVI modalities may play a role in HF treatment planning.

For revascularisation planning, echocardiography scored "A" for all indications, except for the assessment of inducible ischaemia. There was a disagreement in regard with the role of echocardiography at rest to diagnose viability, given the fact that echocardiography suffices for this diagnosis only in case of existence of at least partially preserved contractility and myocardial thickness in the segments assessed. Stress echocardiography scored "A" for viability and inducible ischaemia assessment; caution is however particularly required in the case of assessment of inducible ischaemia, which implies administration of high dose dobutamine. CMR scored "A" for all revascularisation related clinical indications, with or without aneurysmectomy. Continuing to be used in some centres for volumes and systolic function assessment, RNA scored "U". SPECT scored "A" for inducible ischaemia and viability assessment. CT scored "A" with some disagreement for preoperative assessment before aneurysmectomy. PET scored "A" for viability assessment and, with some disagreement, for assessment of inducible ischaemia as well; the disagreement should be again explained by the limited availability of PET around Europe, rather than by the value of the test, because PET has excellent diagnostic value for detection of ischaemia and, furthermore, it is the only technique providing true quantitative assessment.

For ICD planning, echocardiography and CMR scored "A" for LV systolic function assessment and echocardiography (with some disagreement reflecting the need for further testing in case of lack of diagnostic findings), stress echocardiography, CMR and SPECT scored "A" for diagnosis of ischaemic aetiology. CT and PET scored "U" for diagnosis of ischaemic aetiology. However, it is highly likely that a patient for whom ICD implantation is planned will have invasive coronary angiography performed for diagnosis of ischaemic aetiology of HF, rather than non-invasive CVI.

For CRT planning, echocardiography and CMR scored “A” because they provide a complete comprehensive cardiac assessment (echocardiography), LV systolic function assessment, LV lead placement guiding and assessment of the right ventricle (echocardiography and CMR). Whilst stress echocardiography scored “I”, there was disagreement from voters aware of the role stress echocardiography played in the assessment of viability of the postero-lateral wall, which is paced by the pacemaker LV lead for CRT. All other modalities scored “U”, given their role in the assessment of LV systolic function (RNA, SPECT), viability (SPECT, PET) or visualisation of the cardiac veins (CT).

For LVAD planning, echocardiography scored “A”, providing a complete cardiac assessment together with the assessment of LV systolic function. Accurate LV systolic function evaluation can be also performed with CMR (A_d) or RNA (U).

CVI use for HF follow-up

The planned follow-up of HF patients should be based primarily on echocardiographic assessment (“A”) with all other imaging modalities playing a role in further assessment, when necessary, because of echocardiographic findings in need of elucidation. In clinical practice, further assessment using alternative modalities is rarely needed during follow-up, because usually a complete diagnosis is already available at this stage. The main exception is the case of patients with poor echocardiographic window, in which the planned follow-up may have to be based on CMR or RNA.

The planned follow-up of CRT is usually based on echocardiography, which scored “A”.

In case of new symptoms, the HF patient will be initially assessed with echocardiography (“A”). However, all CVI modalities play a role in further assessment if this becomes necessary as a result of initial echocardiography. CMR scored “A” for further assessment; with some disagreement, stress echocardiography scored “A” too, mainly as a result of the evolving role of exercise echocardiography in the assessment of the HF patient. All other modalities scored “U”, acknowledging that their role depends on patient or service particularities. For example, in case of poor echocardiographic window and in the absence of available CMR, RNA can be used for assessing LV systolic function.

CLINICAL IMPLICATIONS

As highlighted in the present report, non-invasive CVI plays an important role in patients with HF, with all types of modalities being used according to the mode of presentation, for the diagnosis, treatment

planning and follow-up. This document provides a framework for decisions regarding judicious utilisation of imaging in the management of patients with HF seen in clinical practice. However, the reported data also reflect practice heterogeneity across Europe, with broad variations in access to modern technology and imaging facilities, educational platform, training requirements, certification guidelines, and reimbursement systems.

Unlike guidelines, which are solely based on scientific evidence, the present appropriateness criteria are thus also based on socio-economic considerations influencing the clinical practice of the voting panel members, as reflected in their scores. Hence, the present criteria are intended to provide guidance for patients and clinicians, but are not intended to diminish the acknowledged difficulty or uncertainty of clinical decision-making and cannot act as substitutes for sound clinical judgment and practice experience. This means that whilst a certain CVI modality may be inappropriate for a certain clinical indication in principle, it may still be appropriate for use in certain circumstances.

Also, the present appropriateness criteria do not pertain to non-European communities and can be somewhat different to those published by the American Society of the American College of Radiology and the American College of Cardiology Foundation[10], which derived from a more homogeneous society, with similar clinical practice and access to modern technology between voting panel members.

Finally, the writing group also acknowledges that HF represents a rapidly evolving field with increasing evidence for effective therapies and diagnostic tests, and therefore anticipates that this document should be updated in a timely fashion.

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Figure 1: Clinical scenarios in which cardiovascular imaging is used in heart failure

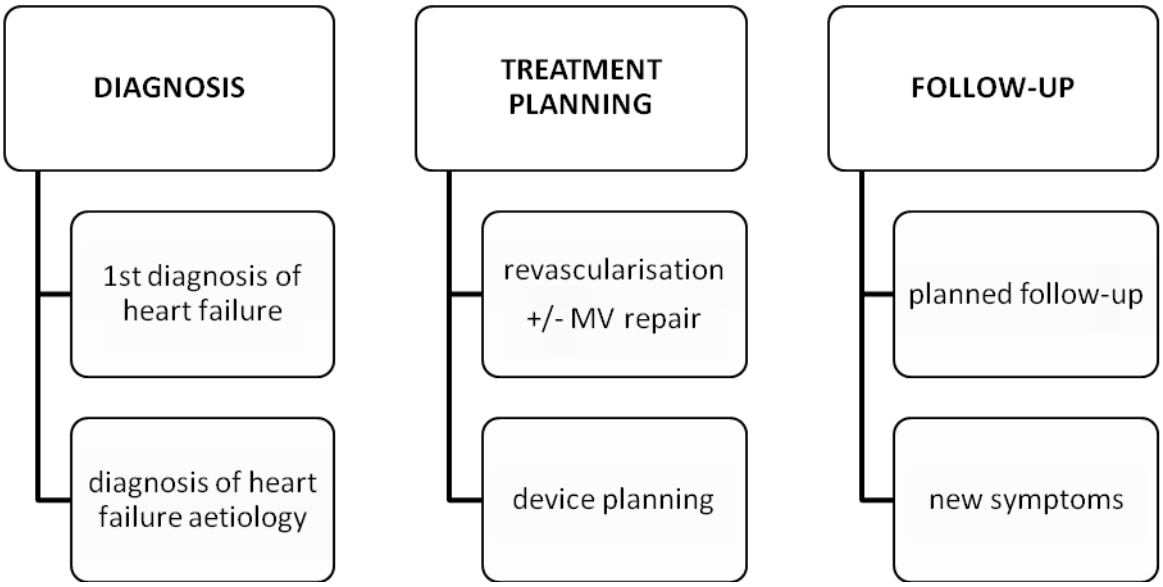

Figure 2: Clinical indications for cardiovascular imaging use for first diagnosis of heart failure

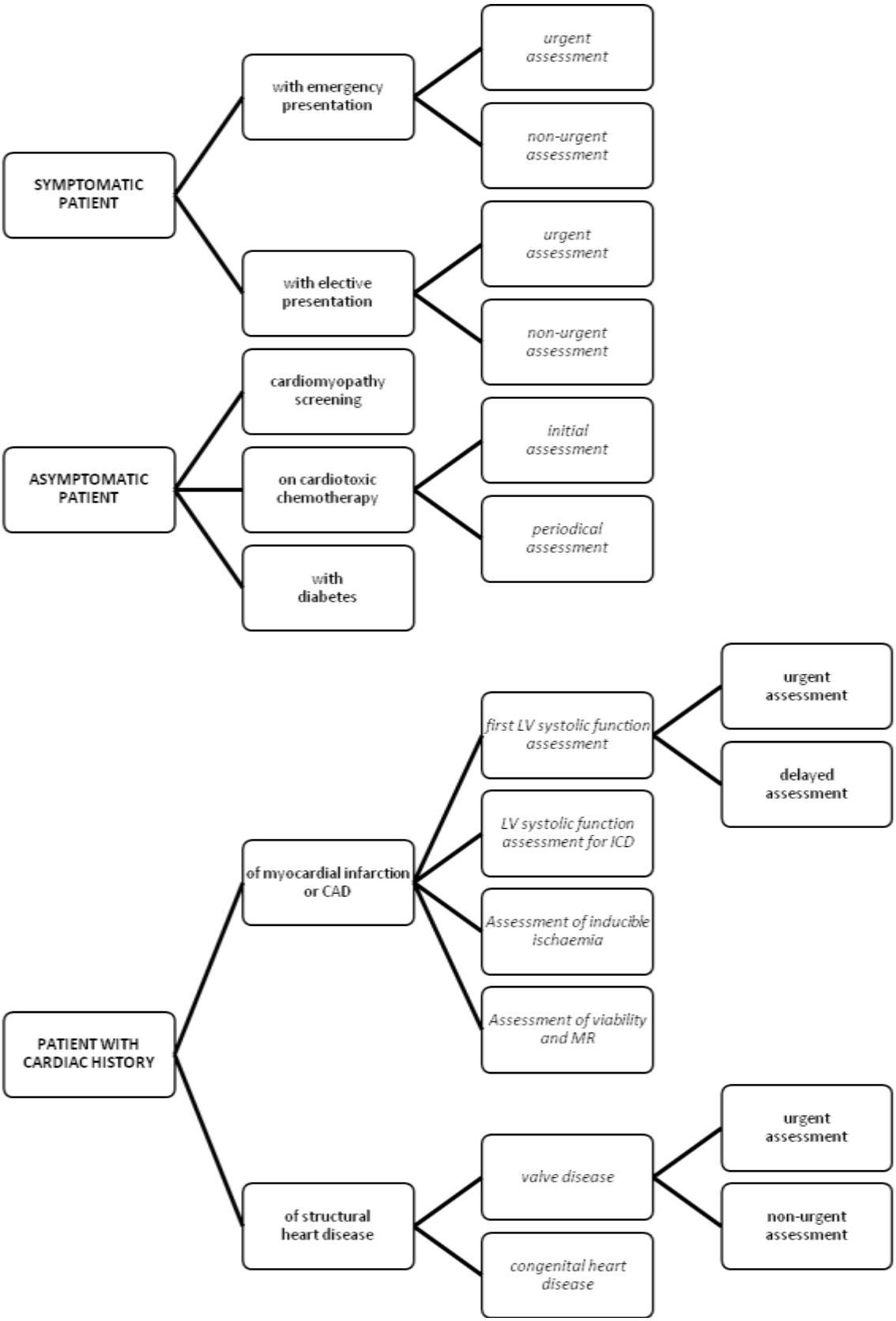

Figure 3: Clinical indications for cardiovascular imaging use to diagnose the aetiology of heart failure

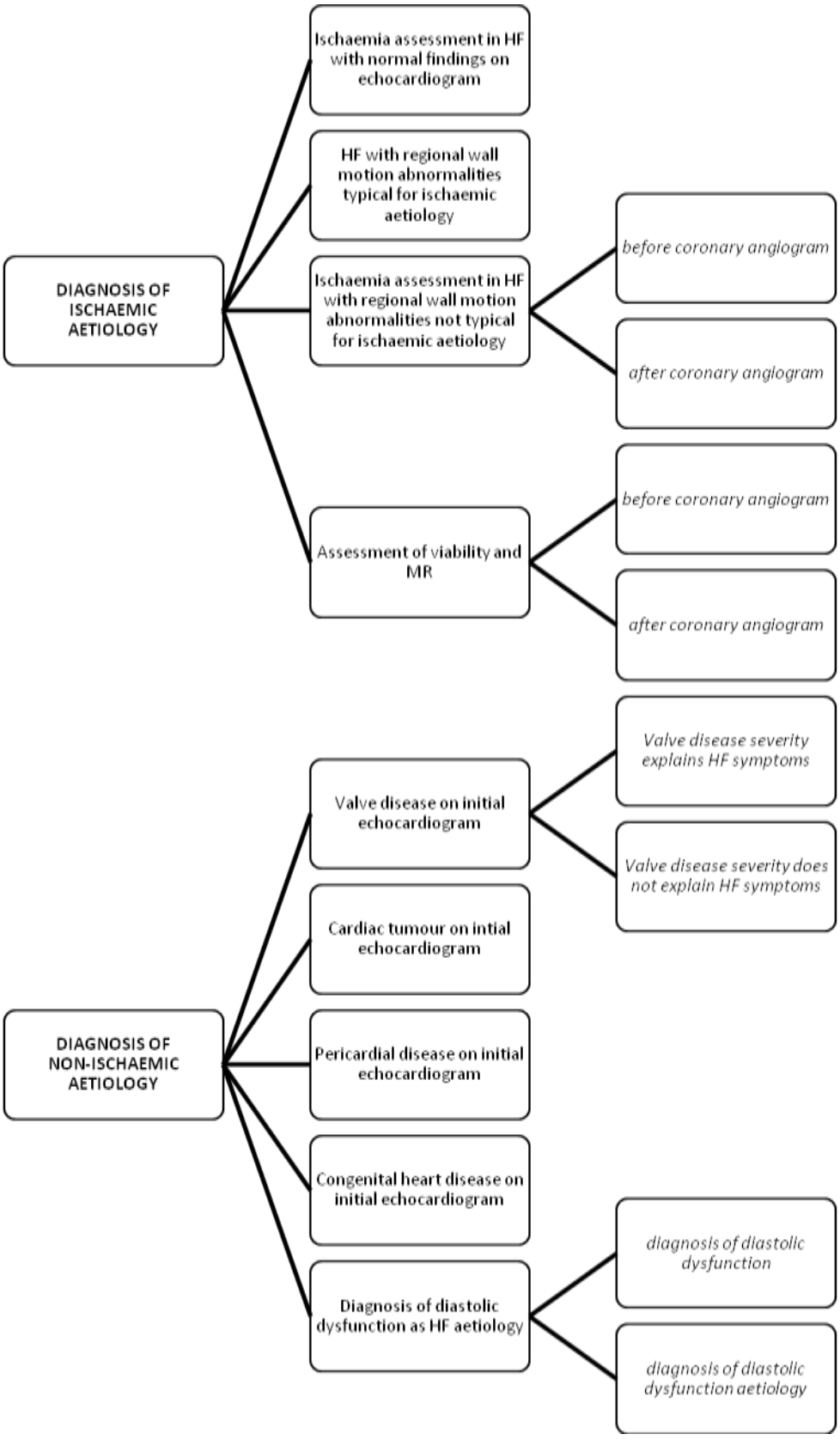

Figure 4: Clinical indications for cardiovascular imaging use for heart failure treatment planning

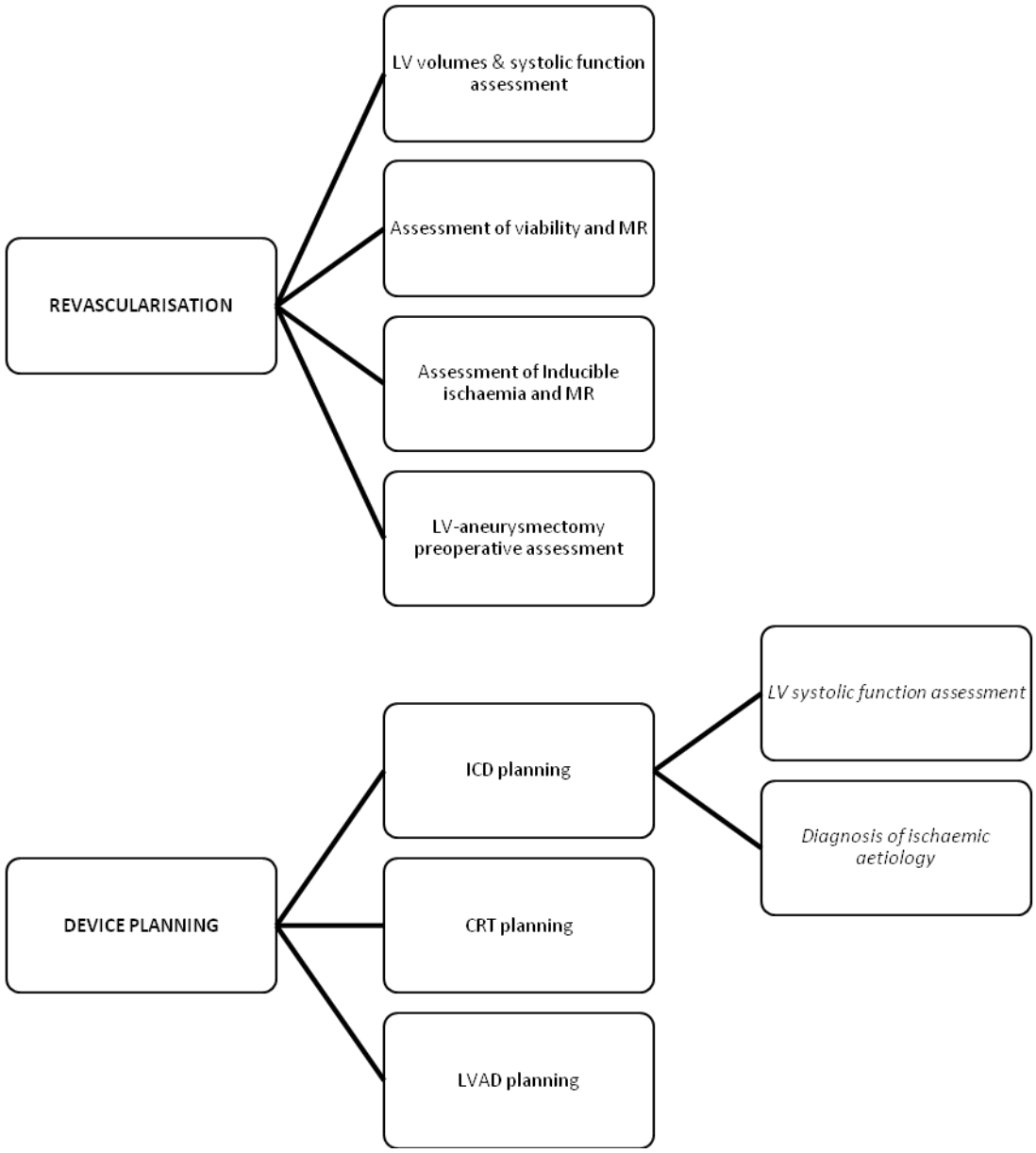

Figure 5: Clinical indications for cardiovascular imaging use in heart failure follow-up

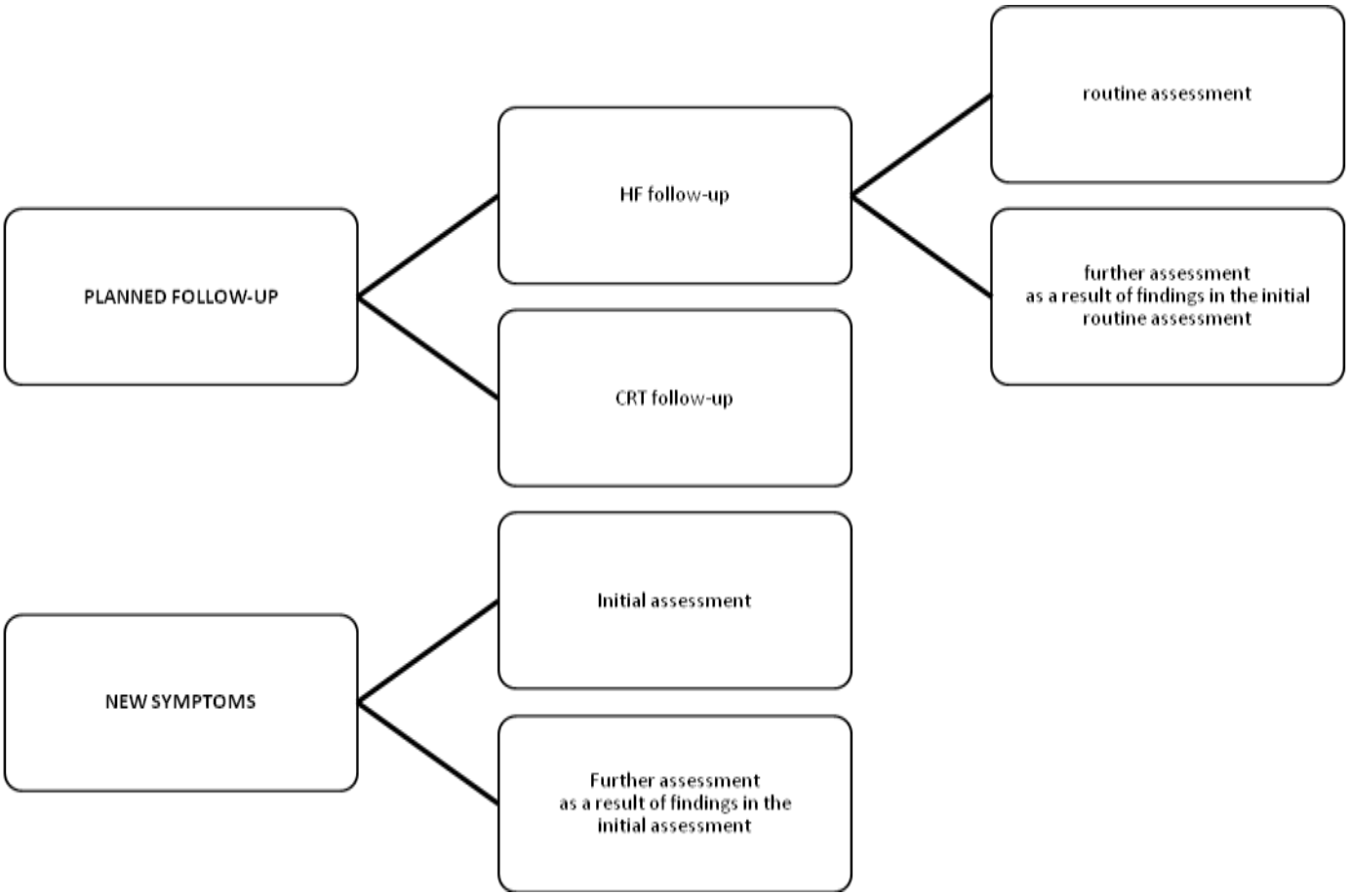

Table 1: Appropriateness criteria for the use of CVI in the first diagnosis of HF to detect abnormalities of cardiac structure and/or function, which could explain symptoms and signs

Clinical indications				Cardiovascular imaging modalities						
				Echo	**Stress Echo**	**CMR**	**RNA**	**SPECT**	**CT**	**PET**
Symptomatic patients	with emergency presentation	Urgent assessment		**A**	**I**	**I^{d}**	**I**	**I**	**I^{d}**	**I**
		Non-urgent assessment		**A**	**U**	**A^{d}**	**I**	**I^{d}**	**U**	**I^{d}**
	with elective presentation	Urgent assessment		**A**	**I**	**I^{d}**	**I**	**I**	**I^{d}**	**I**
		Non-urgent assessment		**A**	**U**	**A**	**I^{d}**	**U**	**U**	**U**
Asymptomatic patients	Cardiomyopathy screening			**A**	**I**	**U**	**I**	**I**	**I**	**I**
	On cardiotoxic chemotherapy	Initial screening		**A**	**I**	**A^{d}**	**U**	**I**	**I**	**I**
		Periodical screening		**A**	**I**	**U**	**U**	**I**	**I**	**I**
	Screening of patient with diabetes			**A**	**U**	**U**	**I^{d}**	**U**	**U**	**I^{d}**
Patients with a cardiac history	History of myocardial infarction or known CAD	First LV systolic function assessment	Urgent assessment	**A**	**I**	**U**	**I**	**I**	**I**	**I**
			Delayed assessment	**A**	**I^{d}**	**A^{d}**	**I^{d}**	**U**	**I**	**I^{d}**
		LV systolic function assessment for ICD		**A**	**I^{d}**	**A**	**U**	**U**	**I^{d}**	**I^{d}**
		Assessment of inducible ischaemia		**I^{d}**	**A**	**A**	**I^{d}**	**A**	**I^{d}**	**A^{d}**
		Assessment of viability		**U**	**A**	**A**	**I**	**A^{d}**	**I**	**A**
	History of structural heart disease	Valve disease	Urgent assessment	**A**	**I**	**I^{d}**	**I**	**I**	**I**	**I**
			Non-urgent assessment	**A**	**A**	**A^{d}**	**I^{d}**	**I**	**U**	**I**
		Congenital heart disease		**A**	**I^{d}**	**A**	**I**	**I**	**U**	**I**

A: appropriate, d: existence of disagreement in scores, I: inappropriate, ICD: Implantable Cardioverter Defibrillator, LV: left ventricle, U unknown appropriateness

Table 2: Appropriateness criteria for the use of CVI for diagnosis of HF aetiology

Clinical indications			Cardiovascular imaging modalities						
			Echo	**Stress Echo**	**CMR**	**RNA**	**SPECT**	**CT**	**PET**
Diagnosis of ischaemic aetiology	HF with normal findings on echocardiogram		-	**A**	**A**	**I**[d]	**A**[d]	**A**[d]	**U**
	HF with regional wall motion abnormalities (RWMA) typical for ischaemic aetiology		-	**A**	**A**	**I**	**A**[d]	**U**	**U**
	HF with RWMA not typical for ischaemic aetiology	Before coronary angiogram	-	**A**	**A**	**I**	**A**[d]	**U**	**U**
		After coronary angiogram	-	**A**[d]	**A**	**I**	**A**[d]	**I**[d]	**A**[d]
	Viability assessment	Before coronary angiogram	**A**[d]	**A**	**A**	**I**	**A**[d]	**I**	**A**[d]
		After coronary angiogram	**U**	**A**	**A**	**I**	**A**[d]	**I**	**A**[d]
Diagnosis of non-ischaemic aetiology	Valve disease on initial echo	Valve disease severity explains HF symptoms	-	**I**[d]	**I**[d]	**I**	**I**	**I**	**I**
		Valve disease severity does not explain HF symptoms	-	**A**	**A**	**I**	**I**	**I**[d]	**I**[d]
	Cardiac tumour on initial echo		-	**I**	**A**	**I**	**I**	**A**[d]	**U**
	Pericardial disease on initial echo		-	**I**	**A**	**I**	**I**	**A**	**I**[d]
	Congenital heart disease on initial echo		-	**U**	**A**	**I**	**I**	**A**[d]	**I**
	Diagnosis of diastolic dysfunction as HF aetiology	Diagnosis of diastolic dysfunction	**A**	**U**	**U**	**I**	**I**	**I**	**I**
		Diagnosis of diastolic dysfunction aetiology	**A**	**U**	**A**	**I**	**I**[d]	**U**	**I**

Abbreviations: see above

Table 3: Appropriateness criteria for the use of CVIin HF treatment planning clinical indications

Clinical indications			Cardiovascular imaging modalities						
			Echo	**Stress Echo**	**CMR**	**RNA**	**SPECT**	**CT**	**PET**
Revascularisation	LV volumes and systolic function assessment		**A**	**I[d]**	**A**	**U**	**U**	**U**	**I[d]**
	Assessment of viability and MR		**A[d]**	**A**	**A**	**I**	**A**	**I**	**A**
	Assessment of inducible ischaemia and MR		**I[d]**	**A**	**A**	**I**	**A**	**I**	**A[d]**
	LV-aneurysmectomy		**A**	**I[d]**	**A**	**I**	**I[d]**	**A[d]**	**U**
Device planning	ICD planning	LV systolic function assessment	**A**	**I**	**A**	**U**	**U**	**I[d]**	**I[d]**
		Ischaemic aetiology assessment	**A[d]**	**A**	**A**	**I[d]**	**A**	**U**	**U**
	CRT planning		**A**	**I[d]**	**A**	**U**	**U**	**U**	**U**
	LVAD planning		**A**	**I**	**A[d]**	**U**	**I[d]**	**U**	**I[d]**

Abbreviations: see above

Table 4: Appropriateness criteria for the use of CVI in HF follow-up clinical indications

Clinical indications			Cardiovascular imaging modalities						
			Echo	**Stress Echo**	**CMR**	**RNA**	**SPECT**	**CT**	**PET**
Planned follow-up	HF follow-up	Routine assessment	**A**	**I**	**U**	**I**[d]	**I**[d]	**I**	**I**
		Further assessment as a result of findings in the initial routine assessment	**A**	**A**[d]	**A**	**I**[d]	**U**	**U**	**U**
	CRT follow-up		**A**	**I**	**I**	**I**[d]	**I**	**I**[d]	**I**
New symptoms	Initial assessment		**A**	**I**[d]	**U**	**I**	**I**[d]	**I**[d]	**I**
	Further assessment as a result of findings in the initial assessment		**A**	**A**[d]	**A**	**U**	**U**	**U**	**U**

Abbreviations: see above

Table 5: Appropriateness criteria for the use of CVI in HF per clinical scenarios

Clinical scenarios	Cardiovascular imaging modalities						
	Echo	**Stress Echo**	**CMR**	**RNA**	**SPECT**	**CT**	**PET**
Diagnosis	**A**	**A**	**A**	**U**	**A**	**A**	**A**
Treatment planning	**A**	**A**	**A**	**U**	**A**	**A**[d]	**A**
Follow-up	**A**	**A**[d]	**A**	**U**	**U**	**U**	**U**

Abbreviations: see above

Appendix

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