






# BMJ Open Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease: a scoping review

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## ABSTRACT

**Objectives** In the care of coronary artery disease (CAD), evidence questions the adequate application of guidelines for cardiovascular procedures, particularly coronary angiographies (CA) and myocardial revascularisation. This review aims to examine how care providers' guideline adherence for CA and myocardial revascularisation in the care of chronic CAD was assessed in the literature.

**Design** Scoping review.

**Data sources** PubMed and EMBASE were searched through in June 2021 (rerun in September 2022).

**Eligibility criteria** We included studies assessing care providers' adherence to evidence-based guidelines for CA or myocardial revascularisation in the care of chronic CAD. Studies had to list the evaluation of guideline adherence as study objective, describe the evaluation methods used and report the underlying guidelines and recommendations.

**Data extraction and synthesis** Two independent reviewers used standardised forms to extract study characteristics, methodological aspects such as data sources and variables, definitions of guideline adherence and quantification methods and the extent of guideline adherence. To elucidate the measurement of guideline adherence, the main steps were described.

**Results** Twelve studies (311 869 participants) were included, which evaluated guideline adherence by (1) defining guideline adherence, (2) specifying the study population, (3) assigning (classes of) recommendations and (4) quantifying adherence. Thereby, primarily secondary data were used. Studies differed in their definitions of guideline adherence, where six studies each considered only recommendation class I/grade A/strong recommendations as adherent or additionally recommendation classes IIa/IIb. Furthermore, some of the studies reported a priori definitions and allocation rules for the assignment of recommendation classes. Guideline adherence results ranged from 10% for percutaneous coronary intervention with prior heart team discussion to 98% for coronary artery bypass grafting.

**Conclusion** Due to remarkable inconsistencies in the assessment, a cautious interpretation of the guideline adherence results is required. Future efforts should endeavour to establish a consistent understanding of the concept of guideline adherence.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ A robust methodology including a systematic literature search and data extraction conducted in duplicate.
- ⇒ This review synthesises the methods used to assess guideline adherence by summarising the four main steps of guideline adherence measurement.
- ⇒ Due to the absence of a validated instrument and focusing on examining the methods used to assess guideline adherence, no quality assessment of the methods used to measure guideline adherence could be conducted within this scoping review.

## INTRODUCTION

Coronary artery disease (CAD) is one of the most important widespread diseases,<sup>1</sup> and still the major cause of mortality at the global level.<sup>2</sup> With a lifetime prevalence of 8%<sup>1</sup> and a proportion of 16% of global deaths,<sup>2</sup> CAD is associated with a significant economic burden for healthcare systems all around the world.<sup>3</sup>

In order to improve the quality of CAD care, which is highly complex and varied in nature, many national and international scientific societies have developed evidence-based clinical practice guidelines.<sup>1 4 5</sup> By systematically providing the best evidence available, these guidelines aim to support health professionals in clinical decision-making and promote high-quality care.<sup>4 6</sup> Furthermore, due to concerns surrounding excessive utilisation of tests and procedures, appropriate use criteria (AUCs) have been developed in an effort to improve appropriate resource utilisation by providing a consensus judgement on the utility of a test or procedure in specific clinical scenarios. However, AUCs are derivations from the guidelines, and the guidelines remain the primary source of guidance for clinicians.<sup>7</sup>

Although there are established strategies for disseminating and implementing

evidence-based guidelines in clinical practice,<sup>8</sup> there is still some question as to whether guidelines for cardiovascular procedures, in particular, those for coronary angiography (CA) and myocardial revascularisation (eg, percutaneous coronary intervention (PCI)), are being applied adequately.<sup>9 10</sup>

There has been growing interest recently in evaluating the uptake among healthcare providers of clinical practice guidelines for patient treatment in chronic CAD care, that is, the adherence of healthcare providers to clinical guideline recommendations.<sup>11–14</sup> Since evidence on guideline adherence in clinical practice contributes to quantifying the quality of care<sup>15</sup> and may be used to stimulate activities that promote a more guideline-adherent use of cardiovascular procedures,<sup>14</sup> it is important to ensure that the concept of guideline adherence is measured accurately and consistently. To the best of our knowledge, there is no available evidence on the accuracy and comparability of the methods used to assess guideline adherence for invasive procedures in the field of chronic CAD care. The aim of this scoping review is thus (1) to examine the methods and results of studies that assessed guideline adherence for invasive diagnostic and therapeutic procedures in patients with chronic CAD and (2) to compile the general steps used to assess guideline adherence.

## METHODS

We performed a scoping review of methods used to assess guideline adherence for invasive diagnostic and therapeutic procedures in chronic CAD. The review was reported according to guidance in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews Statement.<sup>16</sup> The review was not registered, and no protocol was published. The study selection process was conducted in duplicate (HK and YS). In case of disagreement, a third reviewer (DM) was consulted. Two reviewers (HK and YS) performed subsequent data extraction using standardised extraction forms.

### Literature search

We conducted the search in the bibliographic databases PubMed and EMBASE (via Elsevier) using the search strategies presented in online supplemental file 1. Following removal of duplicates, studies were selected by examining the eligibility criteria stated below. The titles and abstracts were screened, and potentially relevant studies were subjected to a full-text review. In addition to this, cross-references and similar articles from the included articles were checked for inclusion. The search was conducted in June 2021 (and repeated in September 2022).

### Eligibility criteria

We selected studies that assessed guideline adherence among healthcare providers for invasive diagnostic or therapeutic procedures in the field of CAD care: CA,

PCI and coronary artery bypass grafting (CABG). Guideline adherence was defined as practitioners' decisions following clinical practice guidelines.<sup>14</sup> Thus, in this review, results presented as 'adherent care', 'compliant care',<sup>14</sup> 'care in agreement with the guidelines' and 'appropriate care' were included and summarised under the term 'adherent care'. In order to be considered, the studies had to be published in German or English, list the evaluation of guideline adherence as one of the respective study's objectives, and include a description of the evaluation methods used. In addition to this, the studies had to include patients with chronic CAD and report the corresponding results on guideline adherence. Furthermore, the studies had to list the specific guidelines and recommendations used as a basis for their assessment of adherence. Since evidence-based guidelines are the primary source of guidance for physicians,<sup>7</sup> the search only included studies that addressed adherence to this type of guidance.

Publications that focused on other decision aids, such as AUCs or performance measures, were excluded because these are derivatives from clinical practice guidelines.<sup>7</sup> Unlike evidence-based guidelines, performance measures aim to operationalise guideline recommendations, whereas AUCs only supplement guideline recommendations using specific clinical scenarios.<sup>7</sup> In addition to this, literature reviews and study protocols were excluded.

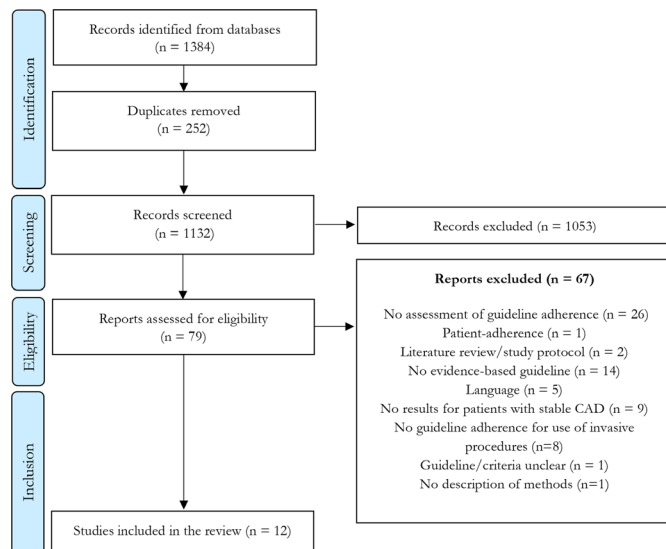
### Extraction and synthesis of data

Data on the main characteristics of the studies and their results were extracted (for consistency, the results of all the studies are presented in terms of adherence rather than non-adherence). In order to describe the methods used to assess guideline adherence in the field of chronic CAD care, we extracted information relating to the methodological aspects assumed to affect the assessment of guideline adherence,<sup>17</sup> that is, data source and collection, data variables, the study's definition of guideline adherence and the quantification method used. In addition to this, information regarding the underlying guideline recommendations and the target procedure/population was also extracted. Based on these factors, we summarised the main steps used to assess guideline adherence. Since most of data extracted were qualitative in nature, a narrative synthesis was conducted.<sup>18</sup>

## RESULTS

### Literature search

The search yielded 1384 publications. Following the removal of 252 duplicates, a total of 1132 titles and abstracts were screened and 79 potentially relevant studies were subsequently subjected to a full-text review. Based on the eligibility criteria, 67 of these studies were excluded. As the screening of cross-references and similar articles did not identify any additional relevant publications, 12 studies were ultimately included in this review



**Figure 1** Flowchart for the literature search.

(see flowchart in [figure 1](#) and online supplemental file 2 for details of the excluded studies).

### Study characteristics

Three of the 12 studies included in the review assessed guideline adherence for the invasive diagnostic CA,<sup>19–21</sup> while nine did so for therapeutic revascularisation by means of a PCI/percutaneous transluminal coronary angioplasty (PTCA) and/or CABG.<sup>22–30</sup> With one exception, all the studies were either based on a retrospective cross-sectional design (n=7)<sup>21 22 25–27 29 30</sup> or a prospective cohort design (n=4).<sup>19 20 24 28</sup> The studies evaluated both primary and specialised care (eg, catheterisation laboratory) over study periods ranging from 5 months<sup>19</sup> to 5 years<sup>27</sup> from 1991<sup>22 23</sup> to 2020.<sup>20</sup> The study populations varied with regards to care setting, disease state, prior treatment and patient demographics. An overview of the study characteristics is provided in online supplemental file 3.

### Assessment of guideline adherence

#### Methods and results

The majority of the studies (n=11) evaluated adherence to the guidelines published by the American College of Cardiology (ACC)/the American Heart Association (AHA) and the European Society of Cardiology. Specifically, the studies assessed adherence to recommendations on the performance of a revascularisation in general,<sup>23 30</sup> a CABG,<sup>22 24 29</sup> a PCI/PTCA,<sup>22 24 25 27</sup> an ad hoc PCI,<sup>25 26</sup> a PCI with prior heart team discussion<sup>26 28</sup> and a CA.<sup>19–21</sup>

Most of the studies were based on secondary data from registries,<sup>28–30</sup> patient records<sup>21–26</sup> or administrative data.<sup>22 23 27</sup> However, two studies were based on primary data obtained from prospective records of consecutive patients (eg, severity of stenosis, symptoms, procedures).<sup>19 20</sup> Eleven of the studies used clinical data variables, including information regarding the extent of CAD, the patients' symptoms, the diagnostic test results, the clinical history, risk factors and treatments provided.<sup>19–26 28–30</sup> In

one study, specific procedure codes and diagnoses within the utilised claims data were resorted.<sup>27</sup>

The studies' definitions of guideline adherence were based on recommendation classes/grades (used in USA, German and European guidelines) or levels of recommendation strengths (used in British guidelines). Recommendation classes/grades or levels of strengths indicate an estimate of the size of treatment effect that takes into account risks and benefits and evidence of and/or agreement on the effectiveness of a procedure.<sup>31 32</sup> In particular, the USA and European guidelines are based on three classes of recommendation: (1) class I=procedure is recommended, (2) class II=conflicting evidence/agreement; procedure is reasonable/should be considered (IIa) or may be reasonable/considered (IIb) or (3) class III=procedure is not recommended.<sup>33 34</sup> Similarly, the German guidelines categorise recommendations using three grades: (1) grade A=procedure shall (not) be performed, (2) grade B=procedure should (not) be performed or (3) grade 0=procedure could be performed.<sup>35</sup> In British guidelines, strong recommendations are applied where there is clear evidence of a benefit (ie, 'offer'), while a less certain recommendation indicates that the evidence of a benefit is less certain (ie, 'consider').<sup>36</sup>

All the studies determined guideline adherence on an individual basis for each patient and summed it up across the study population. Adherence was quantified using a nominal measure, either binary (adherent/non-adherent treatment),<sup>19 20 23–28 30</sup> multicategorically (useful/justified, uncertain and not useful/not indicated procedures)<sup>21</sup> or a combination of the two.<sup>22 29</sup>

The extent of guideline adherence depended on the procedure in question, and ranged from: 67% to 91% for PCI/PTCA,<sup>22 24 25 27</sup> 17% to 20% for ad hoc PCI,<sup>25 26</sup> 10% to 19% for PCI with prior heart team discussion,<sup>26 28</sup> 49% to 98% for CABG,<sup>22 24 29</sup> 40% to 94% for revascularisation in general<sup>23 30</sup> and 52% to 79% for CA.<sup>19–21</sup> An overview of the methods used to assess guideline adherence is presented in [table 1](#) (for detailed information, see online supplemental file 4).

#### Main steps used to assess guideline adherence

Four steps for assessing guideline adherence were identified, the first two of which could be undertaken simultaneously (see [figure 2](#)).

#### Definition of guideline adherence

In all of the studies, guideline adherence was defined as the proportion of procedures among patients who fulfilled all the criteria for a specific recommendation (class). The recommendations used in the studies varied. Several of the studies limited their definitions of adherent care to procedures corresponding to recommendation class I/grade A/strong recommendations (ie, 'is recommended'),<sup>20 23 26–28 30</sup> while others additionally considered recommendation class IIa (ie, 'is

**Table 1** Methods

Study	Guideline and treatment decision	Definition of guideline adherence	Quantification and level of measurement
Kiselev <i>et al</i> <sup>30</sup>	ESC/EACTS 2014 GL on myocardial revascularisation  Revascularisation	1. Adherence=revascularisation if indication 2. Non-adherence=indication without revascularisation Indication=class I recommendation	Proportion of adherent/non-adherent treatment  A binary measure
Epstein <i>et al</i> <sup>23</sup>	ACC/AHA 1988 GL on PTCA ACC/AHA 1991 GL on CABG  Revascularisation	1. Non-adherence=no revascularisation if indication Indication=recommendation class I 2. Non-adherence=revascularisation if no indication No indication=class III recommendation	Proportion of non-adherent treatment  A binary measure
O'Connor <i>et al</i> <sup>29</sup>	ACC/AHA 2004 GL on CABG  CABG	Useful procedure=Recommendation class I Evidence favours procedure=Recommendation class IIa Evidence less well established=Recommendation class IIb Procedure not useful=Recommendation class III Adherence=CABG if recommendation class I or II	Proportion of useful, evidence favours procedure, evidence less well established and not useful procedures + adherent and non-adherent to guidelines  A multi-categorical and a binary measure
Witberg <i>et al</i> <sup>24</sup>	ESC 2010 GL on myocardial revascularisation  PCI, CABG	Adherence=PCI/CABG according to indication Indication for PCI=recommendation class IIa No indication for PCI/Indication for CABG=recommendation class III for PCI	Proportion of adherent/non-adherent treatment  A binary measure
Leape <i>et al</i> <sup>22</sup>	ACC/AHA 1988/1993 GL on PTCA ACC/AHA 1991 GL on CABG  PTCA, CABG	Justified procedure=recommendation class I Uncertain procedure=recommendation class II No indication for procedure=recommendation class III Adherence=procedures rated as justified and uncertain	Proportion of justified, uncertain, not indicated procedures (and adherent and non-adherent to guidelines)  A multi-categorical and a binary measure
Linder <i>et al</i> <sup>27</sup>	NVL 2013 on chronic CAD (ESC/EACTS 2014 GL on myocardial revascularisation)  PCI	Adherence=no PCI if indication for CABG Indication=recommendation grade A (Class I recommendation for CABG and class III recommendation for PCI)	Proportion of adherent/non-adherent treatment  A binary measure
Marino <i>et al</i> <sup>25</sup>	ESC/EACTS 2018 GL on myocardial revascularisation (ACCF/AHA GL 2012 on stable ischaemic heart disease)  PCI, Ad hoc PCI	1. Adherence=PCI if strong recommendation for PCI or similar recommendation for PCI/CABG Strong recommendation=Class I recommendation for PCI and class IIb for CABG Similar recommendation=Class I recommendation for PCI and class I for CABG, class IIa recommendation for PCI and class I/II for CABG 2. Non-adherence=ad hoc PCI if indication for heart team discussion Indication=recommendation class I for CABG	Proportion of adherent/non-adherent treatment  A binary measure

Continued



Table 1 Continued

Study	Guideline and treatment decision	Definition of guideline adherence	Quantification and level of measurement
Leonardi <i>et al</i> <sup>26</sup>	ESC 2013 GL on stable CAD ESC/EACTS 2014 GL on myocardial revascularisation  Ad hoc PCI, PCI with heart team discussion	1. Adherence=heart team discussion if indication 2. Non-adherence=ad hoc PCI if indication for heart team discussion Indication=recommendation class I for heart team, recommendation class I for CABG	Proportion of adherent/non-adherent treatment  A binary measure
Yates <i>et al</i> <sup>28</sup>	ESC/EACTS 2010 GL on myocardial revascularisation  PCI with heart team discussion	Adherence=heart team discussion before revascularisation if indication Indication=recommendation class I	Proportion of adherent/non-adherent treatment  A binary measure
Morgan-Hughes <i>et al</i> <sup>20</sup>	NICE CG95 (2016)  CA	Non-adherence=Overuse of CA Surrogate: Overuse of CA=CA without strong recommendation and revascularisation	Proportion of adherent/non-adherent (overuse of CA) treatment  A binary measure
Leung <i>et al</i> <sup>19</sup>	ACC/AHA 1999 GL on CA  CA	Adherence=CA if recommendation class I or II (Non-adherence=CA if recommendation class III or no recommendation class I or II)	Proportion of adherent/non-adherent treatment  A binary measure
Rubboli <i>et al</i> <sup>21</sup>	ACC/AHA 1999 GL on CA  CA	Adherence=CA if recommendation class I (useful) or IIa (evidence favours procedure) Uncertain=CA if recommendation class IIb (evidence less well established) Non-adherence=CA if recommendation class III (not useful)	Proportion of useful, evidence favours procedure, evidence less well established and not useful procedures+adherent, uncertain and non-adherent procedures  A multi-categorical measure

ACC, American College of Cardiology; ACCF, American College of Cardiology Foundation; AHA, American Heart Association; CA, coronary angiography; CABG, coronary artery bypass grafting; CAD, coronary artery disease; EACTS, European Association for Cardio-Thoracic Surgery; ESC, European Society of Cardiology; GL, Guideline; NVL, National disease management guideline; PCI, percutaneous coronary intervention; PTCA, percutaneous transluminal coronary angioplasty.

probably recommended'),<sup>21 24 25</sup> or even recommendation class IIb (ie, 'might be considered')<sup>19 22 29</sup> to be adherent.

If the criteria for a specific recommendation (class) were not fulfilled, some of the studies additionally defined guideline-adherent care as 'doing nothing'.<sup>20 23 27 30</sup> Non-adherent care reflected both procedures offered to patients without a corresponding recommendation and cases where no procedure was performed despite revascularisation or diagnostic CA being recommended.

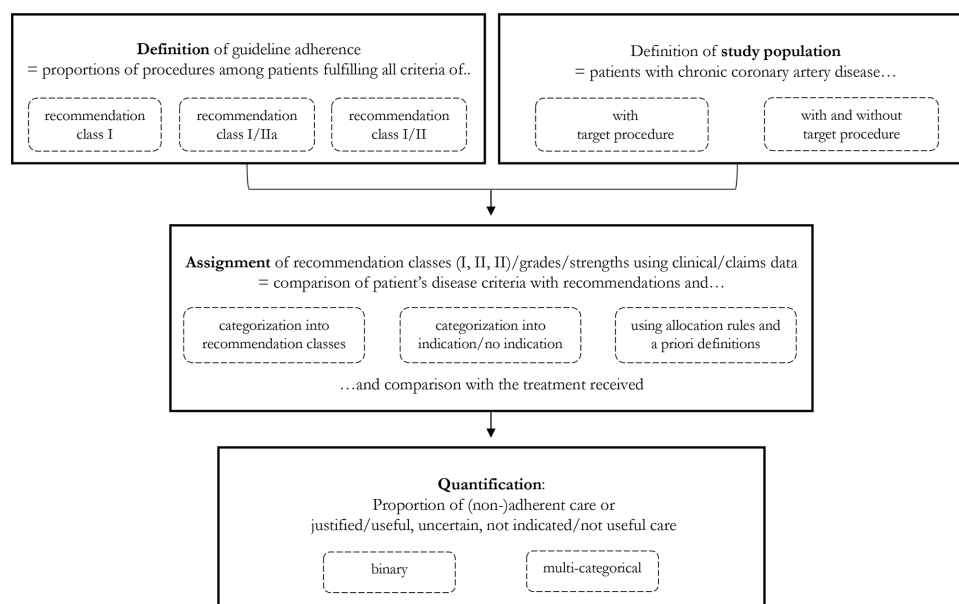
#### Definition of study population

While eight of the studies only considered patients who received a specific target procedure,<sup>19 21 22 24–26 28 29</sup> four included patients regardless of what treatment they had

received in order to examine guideline adherence for revascularisation or diagnostic CA.<sup>20 23 27 30</sup>

#### Assignment of recommendations and recommendation classes/grades/strengths

Using clinical data collected from different sources (see table 1), for each patient, it was checked (1) which class of recommendation or (2) whether the specific recommendation (class) under evaluation matched the patients' disease criteria (eg, symptoms, severity of disease). Six of the studies categorised patients into recommendation classes I, II (a,b) and III.<sup>19 21–23 25 29</sup> The remaining studies focused on specific recommendations or recommendation classes (eg, recommendation class I<sup>30</sup>) and merely categorised patients into two groups: 'procedure



**Figure 2** Main steps used to assess guideline adherence.

indicated' or 'procedure not indicated'.<sup>20 24–28 30</sup> Whether or not the care in question was guideline-adherent was ultimately determined by comparing the results of the assignment with the treatment received. For example, a PCI for a patient with a recommendation class I for PCI was considered adherent.

Overall, there were differences in terms of how the studies dealt with ambiguous assignments and cases of insufficient information for an explicit assignment of recommendation classes. Only one study reported a prespecified allocation rule for cases of an ambiguous assignment (ie, where a patient was assigned to more than one recommendation class).<sup>27</sup> In cases where guideline criteria had not been explicitly defined, four studies used a priori definitions of these criteria for an explicit assignment (eg, evidence of ischaemia, morbidity risk).<sup>22 23 29 30</sup>

#### Quantification of guideline adherence

Estimating the proportions of patients with adherent or non-adherent care, nine of the studies used a binary approach.<sup>19 20 23–28 30</sup>

Three of the studies quantified the results according to the considered guidelines using a multicategorical approach, reporting the proportions of procedures within each recommendation class that were defined as justified/useful (class I), uncertain (class II) and not indicated/not useful (class III).<sup>21 22 29</sup> Of these three studies, one adapted this rating to its own definition by quantifying adherent (class I and IIa), uncertain (class IIb) and non-adherent (class III) procedures.<sup>21</sup> The other two studies used an additional binary categorisation into adherent and non-adherent care by accordingly assigning the cases that had initially been classified as uncertain.<sup>22 29</sup>

## DISCUSSION

To the best of our knowledge, this is the first scoping review to summarise the methods used to assess guideline adherence in studies that evaluate invasive diagnostic and therapeutic procedures in patients with chronic CAD. Based on 12 studies investigating physicians' adherence to European, USA, German and British guidelines, we examined methods and results and identified the main steps used to assess guideline adherence. The studies included in the review used similar approaches to evaluate guideline adherence, that is, (1) defining guideline adherence, (2) specifying the study population, (3) assigning recommendations or recommendation classes/grades/strengths and (4) quantifying guideline adherence. However, differences were identified with regards to data sources and collection, the definition of guideline adherence, the assignment of recommendation classes/grades/strengths and the results on guideline adherence.

#### Data sources and collection

Although two of the studies prospectively collected primary data,<sup>19 20</sup> most used secondary data that had been collected retrospectively.<sup>21–30</sup> Even though secondary data often represent a more easily accessible and affordable data source, they are usually not collected for the purpose of assessing guideline adherence. As a result, the database may be non-specific (ie, information is available on a more aggregate level without providing clinical details) or incomplete (ie, required information is missing entirely).<sup>37</sup> This limits the informative value of the database, particularly given the complexity of treatment decisions.

Furthermore, the accuracy of information obtained from patient records, registries and claims data is highly dependent on the standard and quality of the documentation of the care providers.<sup>15 38</sup> In particular, the interpretation and documentation of patients' test results

(eg, extent/significance of coronary stenoses) and symptoms (eg, type of chest pain), which are key criteria for the assignment of recommendation classes, vary widely.<sup>19 20 24 25 29 39</sup> Moreover, secondary data often fail to provide information on contraindications or patient preferences that could justify deviations from the guidelines.<sup>22–24</sup> The appropriateness of claims data for assessing guideline adherence might additionally be affected by factors such as the complexity of coding or economic incentives (eg, coding higher disease severity in order to generate higher payments).<sup>40</sup>

Overall, these issues might have led to misclassification or exclusion of patients and procedures,<sup>15 22 23 26 29 30</sup> and, thus, contributed to a potential overestimation or underestimation of guideline adherence.<sup>22 23</sup>

A prospective collection of primary data alone or in combination with secondary sources (as reported in two studies<sup>19 20</sup>) may represent the first step towards obtaining a more reliable database. In addition to this, a priori definitions of all variables in order to ensure objective data collection, measures for ensuring data completeness and methods for handling missing data are requirements for an explicit assignment.

### Definition of guideline adherence

Half of the studies only considered recommendation class I/grade A/strong recommendations to be adherent,<sup>20 23 26–28 30</sup> while the others also included recommendation classes IIa and IIb. This difference has a significant impact on the overall results regarding guideline adherence and its interpretation and comparability. For example, excluding recommendation class II would decrease guideline adherence by 11%–12% in two of the studies, which assessed CABG,<sup>22 29</sup> and by 58% in one study that assessed PCI.<sup>22</sup> The recommendation classes I/strong recommendations<sup>20 22 23 26–28 30</sup> and IIa<sup>21 24 25</sup> are based on high-level evidence, which is associated with a strong or intermediate positive benefit–risk estimate.<sup>7</sup> In contrast, recommendation class IIb as a guideline-adherent scenario<sup>19 22 29</sup> is only associated with a marginal benefit–risk ratio or uncertain outcomes.<sup>7</sup> As such, an assessment of the impact of addressing different classes of recommendation on guideline adherence (eg, by means of sensitivity analyses) would be appropriate.

### Assignment of recommendation classes/grades/strengths

The differences found in the assignment of recommendation classes/grades/strengths relate to the use of a priori definitions of guideline criteria and allocation rules (explicitly assigning each patient to one recommendation (class)). Five of the studies only used these in case of difficulties in the interpretation of guideline criteria or an ambiguous assignment.<sup>22 23 27 29 30</sup> A priori definitions and allocation rules ensure a more objective and explicit assignment of recommendation classes/grades/strengths. However, different interpretations of assignment criteria and allocation rules in clinical practice and research are likely to affect the measurement of guideline

adherence. A consistent understanding of the guideline criteria for clinical implementation and research could be achieved by further establishing the clinical standard criteria developed by the ACC/AHA. The application of these criteria would aim to harmonise cardiovascular terminology, thus enabling improved clinical communication and facilitating research.<sup>41</sup>

### Results on guideline adherence

The study results differ in the extent of guideline adherence, particularly between studies that did not examine the same treatment decisions. The lowest extent of adherence was observed for a PCI with prior heart team discussion (10%)<sup>26 28</sup> and an ad hoc PCI (17%),<sup>25</sup> while the highest extent of adherence was observed for CABG (98%).<sup>29</sup> Since a high level of evidence has a positive impact on the implementation of guidelines in clinical practice,<sup>8 22</sup> this variation might be explained by the low level of evidence for the recommendations for PCI with prior heart team discussion and ad hoc PCI (ie, consensus of experts or small/retrospective studies and registries).<sup>33 42 43</sup> The providers' explanations and the patients' perceptions regarding the benefits and risks of the procedures in question may also contribute to this variation.<sup>44</sup> Patients may frequently request a PCI due to the invasiveness of CABG and the higher value assigned to the short-term benefit of PCI when compared with the long-term advantages of CABG.<sup>44</sup> This might lead to a lower adherence for (ad hoc) PCI.

Those studies that examined the same treatment decision showed less variation than those that evaluated different treatment decisions. The extent of adherence varied least for an ad hoc PCI (between 17% and 20%)<sup>25 26</sup> and most for revascularisation in general (between 40% and 94%).<sup>22 24 29</sup> In these studies, the observed variation may be the result of methodological differences (eg, different data sources or different definitions of guideline adherence).

Guideline adherence may also differ in the time of development and the temporal consistency of guideline recommendations. For example, the lowest extent of guideline adherence was observed for recommendations developed in 2010<sup>24 45</sup> (ie, heart team discussions before PCI and revascularisation decisions based on the Syntax Score<sup>24 26 28</sup>) and for recommendations that changed significantly over time<sup>46</sup> (ad hoc PCI<sup>26</sup>). This might indicate difficulties in the implementation of the evolving and more complex recommendations over time.<sup>8</sup> However, the heterogeneity of the included studies did not allow an analysis of a temporal trend.

Furthermore, the variation of results may be influenced by external factors.<sup>8</sup> For example, initiatives to improve the quality and cost-effectiveness of care using decision aids (eg, AUCs and performance measures) and financial incentives to encourage compliance with guidelines (eg, pay-for-performance models) are well established in the USA<sup>7 47</sup> and may have improved awareness of clinical guidelines among providers.<sup>48</sup>

In addition, guideline adherence results vary in terms of the interpretation of non-adherence. Because in most of the studies only the proportion of patients receiving a procedure without a corresponding indication was reported, the derived non-adherence could be primarily interpreted as potential overuse. However, both overuse and underuse of medical procedures reduce quality of care.<sup>49</sup> Therefore, to assess the proportion of patients not receiving a procedure with an indication (as reported in two studies<sup>23,30</sup>) would also be informative for developing targeted interventions to promote high quality care.

Some efforts will be needed in order to advance research on guideline adherence and improve the credibility of the results. First, prospective databases that comply with guideline criteria should be developed for an objective collection of relevant clinical data. Second, the establishment and use of consistent definitions for guideline criteria (eg, the clinical standard criteria published by the ACC/AHA) should be promoted in care and research. Third, in order to facilitate an adequate interpretation of results, we highly recommend the development of reporting standards for studies that evaluate guideline adherence.

### Limitations

This review should be interpreted in the context of the following limitations. First, the literature search was performed in two databases and was limited to studies available in German or English, so other studies relevant to the review may have been overlooked. However, this may only have a minor impact on the results of this review, as the screening of the reference lists of the studies included in the search did not yield additional methods.

Second, due to the absence of a validated instrument, it was not possible to conduct a quality assessment of the methods used to measure guideline adherence. However, since the primary objective of this review was to examine the methods used to assess guideline adherence, this might likely not affect the results of this review.

Third, most of the included studies were retrospective in design and used secondary data, so the credibility of the guideline adherence results is limited. However, we extensively discussed these methodological aspects among others to enable readers to adequately interpret results on guideline adherence.

### CONCLUSION

We observed inconsistencies in the assessment that limit the credibility and comparability of the guideline adherence results. For researchers, the four assessment steps identified in the review may serve as orientation for ensuring consistency. However, the data collection, the definitions, the assignments of recommendations and the methods of quantification require further standardisation. Since evidence on guideline adherence may be

used to set up tailored interventions in clinical practice patterns in efforts to improve care, the available evidence regarding guideline adherence should be interpreted with caution. As such, future efforts should endeavour to establish a consistent understanding of the concept of guideline adherence.

**Contributors** HK, YS and DM were involved in the conception and design of this review. The selection of articles was carried out by HK and YS, consulting DM as third reviewer in case of disagreement. The data extraction and analysis were conducted and guided by HK and YS. All the authors contributed to the data interpretation. HK and YS wrote the final manuscript. BW, DM and SS critically revised the final manuscript. All the authors read and approved the final manuscript. YS is responsible for the overall content as guarantor.

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## Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease – a scoping review: Supplementary Material

### Supplementary file 1: Electronic Database Searches

Database	Terms
MEDLINE via Pubmed	#1 guideline*[TIAB] #2 guideline adherence[MeSH Terms] #3 adherence [TIAB] #4 Compliance[TIAB] #5 Concordance[TIAB] #6 according[TIAB] #7 non-adherence[TIAB] #8 nonadherence[TIAB] #9 discrepancy[TIAB] #10 appropriate*[TIAB] #11 undertreatment[TIAB] #12 overtreatment[TIAB] #13 underuse[TIAB] #14 under-use[TIAB] #15 overuse[TIAB] #16 over-use #17 misuse[TIAB] #18 investigat*[TIAB] #19 examine[TIAB] #20 identify[TIAB] #21 evaluat*[TIAB] #22 assess*[TIAB] #23 measure*[TIAB] #24 analyz*[TIAB] #25 reliability[TIAB] #26 valid*[TIAB] #27 percutaneous coronary intervention[TIAB] #28 myocardial revascularization[TIAB] #29 coronary revascularization [TIAB] #30 coronary artery bypass graft[TIAB] #31 diagnostic catheterization[TIAB] #32 coronary angiography[TIAB] #33 systematic review[TIAB] #34 meta-analysis[TIAB] #35 (#2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10) #36 (#11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17) #37 (#17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26) #38 (#27 OR #28 OR #29 OR #30 OR #31 OR #32) #39 (#33 OR #34) #40 (#1 AND #35) #41 (#40 OR #36) #42 (#41 AND #37 AND #38) #43 (#42 NOT #39)

Database	Terms
EMBASE via Elsevier	#1 'guideline':ab,ti #2 'protocol compliance'/exp #3 'adherence':ab,ti #4 'Compliance':ab,ti #5 'Concordance':ab,ti #6 'according':ab,ti #7 'non-adherence':ab,ti #8 'nonadherence':ab,ti #9 'discrepancy':ab,ti #10 'appropriate*':ab,ti #11 'undertreatment':ab,ti #12 'overtreatment':ab,ti #13 'underuse':ab,ti #14 'under-use':ab,ti #15 'overuse':ab,ti #16 'over-use':ab,ti #17 'misuse':ab,ti #18 'investigat*':ab,ti #19 examine:ab,ti #20 identify:ab,ti #21 'evaluat*':ab,ti #22 'assess*':ab,ti #23 'measure*':ab,ti #24 'analyz*':ab,ti #25 'reliability':ab,ti #26 'valid*':ab,ti #27 'percutaneous coronary intervention':ab,ti #28 'myocardial revascularization':ab,ti #29 'coronary revascularization':ab,ti #30 'coronary artery bypass graft':ab,ti #31 'diagnostic catheterization':ab,ti #32 'coronary angiography':ab,ti #33 'systematic review':ab,ti #34 'meta-analysis':ab,ti #35 (#2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10) #36 (#11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17) #37 (#17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26) #38 (#27 OR #28 OR #29 OR #30 OR #31 OR #32) #39 (#33 OR #34) #40 (#1 AND #35) #41 (#40 OR #36) #42 (#41 AND #37 AND #38) #43 (#42 NOT #39) #44 (#43 AND [embase]/lim) #45 (#44 NOT ('conference abstract':it OR 'conference paper':ti OR 'conference review':ti OR 'review':it))



## Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease – a scoping review: Supplementary Material

### Supplementary file 2: Potentially relevant studies and exclusion criteria

No.	Author (Year)	Title	Exclusion criteria
1	Qanitha et al. 2019	Adherence to guideline recommendations for coronary angiography in a poor South-East Asian setting: Impact on short- and medium-term clinical outcomes	Patient adherence
2	Fink et al. 2019	Revascularization Strategies and Survival in Patients With Multivessel Coronary Artery Disease	Guideline adherence no result of the study
3	Ariyaratne et al. 2020	The cost-effectiveness of guideline-driven use of drug-eluting stents: propensity-score matched analysis of a seven-year multicentre experience	No adherence to evidence-based guidelines
4	Anderson et al. 2005	Relationship between procedure indications and outcomes of percutaneous coronary interventions by American College of Cardiology/American Heart Association Task Force Guidelines	No results for patients with chronic CAD
5	Masoudi et al. 2013	Cardiovascular care facts: a report from the national cardiovascular data registry: 2011	Guideline adherence no result of the study
6	Ueki et al. 2019	Validation of High-Risk Features for Stent-Related Ischemic Events as Endorsed by the 2017 DAPT Guidelines	Guideline adherence no result of the study
7	Ziskind et al. 1999	Assessing the appropriateness of coronary revascularization: the University of Maryland Revascularization Appropriateness Score (RAS) and its comparison to RAND expert panel ratings and American College of Cardiology/American Heart Association guidelines with regard to assigned appropriateness rating and ability to predict outcome	No results for patients with chronic CAD
8	Bernstein et al. 2002	Appropriateness of coronary revascularization for patients with chronic stable angina or following an acute myocardial infarction: multinational versus Dutch criteria	No adherence to evidence-based guidelines
9	Dalton et al. 2016	Practice Variation Among Hospitals in Revascularization Therapy and Its Association With Procedure-related Mortality	Guideline adherence no result of the study
10	Powell et al. 2018	Prior Authorization for Elective Diagnostic Catheterization: The Value of Reviewers in Cases with Clinical Ambiguity	No adherence to evidence-based guidelines
11	Sibai et al. 2008	The appropriateness of use of coronary angiography in Lebanon: implications for health policy	No results for patients with chronic CAD
12	De Lima et al. 2010	Treatment of coronary artery disease in hemodialysis patients evaluated for transplant-a registry study	Guideline adherence no result of the study
13	Lenzen et al. 2005	Management and outcome of patients with established coronary artery disease: the Euro Heart Survey on coronary revascularization	Guideline adherence no result of the study
14	Tillmanns et al. 2009	Treatment of chronic CAD--do the guidelines (ESC, AHA) reflect daily practice?	Literature Review

No.	Author (Year)	Title	Exclusion criteria
15	Schilling et al. 2003	Assessment of indications in interventional cardiology: appropriateness and necessity of coronary angiography and revascularization	No adherence to evidence-based guidelines
16	Ormerod et al. 2015	Implementation of NICE clinical guideline 95 on chest pain of recent onset: experience in a district general hospital	Guideline adherence no result of the study
17	Bernardi et al. 2002	The appropriateness of diagnostic angiography in cardiology	No full-text available in English or German
18	Gualano et al. 2010	Temporal trends in the use of drug-eluting stents for approved and off-label indications: a longitudinal analysis of a large multicenter percutaneous coronary intervention registry	Guideline adherence no result of the study
19	Laouri et al. 1997	Underuse of coronary revascularization procedures: application of a clinical method	No adherence to evidence-based guidelines
20	Luciano et al. 2019	Analysis of the appropriate use criteria for coronary angiography in two cardiology services of southern Brazil	No adherence to evidence-based guidelines (AUC)
21	Daly et al. 2005	The initial management of stable angina in Europe, from the Euro Heart Survey: a description of pharmacological management and revascularization strategies initiated within the first month of presentation to a cardiologist in the Euro Heart Survey of Stable Angina	Guideline adherence no result of the study
22	Hatam et al. 2013	Adherence to American Heart Association and American College of Cardiology standard guidelines of angiography in Shiraz, Iran	No results for patients with chronic CAD
23	Bressan et al. 1998	Coronary angiography in two defined populations: Padua and Citadella	No full-text available in English or German
24	Bressan et al. 1993	Coronary angiography in a defined population: a pilot study of the residents of Padua	No full-text available in English or German
25	Daly et al. 2008	Differences in presentation and management of stable angina from East to West in Europe: a comparison between Poland and the UK	Guideline adherence no result of the study
26	Dudley et al. 2002	Age- and sex-related bias in the management of heart disease in a district general hospital	Guideline/Recommendations not clear
27	Casale et al. 2007	"ProvenCareSM": a provider-driven pay-for-performance program for acute episodic cardiac surgical care	No guideline adherence for invasive procedures in the care of CAD
28	Lee et al. 1990	Feasibility and cost-saving potential of outpatient cardiac catheterization	Guideline adherence no result of the study
29	De Luca et al. 2018	Characteristics, treatment and quality of life of stable coronary artery disease patients with or without angina: Insights from the START study	Guideline adherence no result of the study
30	Yelavarthy et al. 2021	The DISCO study-Does Interventionalists' Sex impact Coronary Outcomes?	No adherence to evidence-based guidelines

No.	Author (Year)	Title	Exclusion criteria
31	De Barros E Silva et al. 2018	Improvement in quality indicators using NCDR® registries: First international experience	No adherence to evidence-based guidelines
32	LaVeist et al. 2003	The cardiac access longitudinal study. A study of access to invasive cardiology among African American and white patients	No results for patients with chronic CAD
33	Cho et al. 2020	Practice Pattern, Diagnostic Yield, and Long-Term Prognostic Impact of Coronary Computed Tomographic Angiography	No adherence to evidence-based guidelines
34	Domingues et al. 2019	Heart Team decision making and long-term outcomes for 1000 consecutive cases of coronary artery disease	Guideline adherence no result of the study
35	Sanei et al. 2017	Evaluation of coronary angioplasty results in patients referring to Isfahan cardiac centers, Iran, and comparing with clinical guidelines	No full-text available in English or German
36	Reid et al. 2014	Is angiography overused for the investigation of suspected coronary disease? A single-centre study	Guideline adherence no result of the study
37	Karthikeyan et al. 2017	Appropriateness-based reimbursement of elective invasive coronary procedures in low- and middle-income countries: Preliminary assessment of feasibility in India	No adherence to evidence-based guidelines (AUC)
38	Berry et al. 2009	ProvenCare: quality improvement model for designing highly reliable care in cardiac surgery	No guideline adherence for invasive procedures in the care of CAD
39	Anderson et al. 2002	A Contemporary Overview of Percutaneous Coronary Interventions	Guideline adherence no result of the study
40	Adamson et al. 2018	Comparison of International Guidelines for Assessment of Suspected Stable Angina: Insights From the PROMISE and SCOT-HEART	Guideline adherence no result of the study
41	Eccleston et al. 2017	Improving Guideline Compliance in Australia With a National Percutaneous Coronary Intervention Outcomes Registry	No guideline adherence for invasive procedures in the care of CAD
42	Din et al. 2017	Variation in practice and concordance with guideline criteria for length of stay after elective percutaneous coronary intervention	No guideline adherence for invasive procedures in the care of CAD
43	Sanchez et al. 2016	Revascularization heart team recommendations as an adjunct to appropriate use criteria for coronary revascularization in patients with complex coronary artery disease	No adherence to evidence-based guidelines (AUC)
44	Greenwood et al. 2016	Effect of care guided by cardiovascular magnetic resonance, myocardial perfusion scintigraphy, or NICE guidelines on subsequent unnecessary angiography rates: The CE-MARC 2 randomized clinical trial	Guideline adherence no result of the study
45	Demarco et al. 2015	Pre-test probability risk scores and their use in contemporary management of patients with chest pain: One year stress echo cohort study	Guideline adherence no result of the study
46	Cubukcu et al. 2015	What's the risk? Assessment of patients with stable chest pain. Echo research and practice	Guideline adherence no result of the study

No.	Author (Year)	Title	Exclusion criteria
47	Back et al. 2003	Critical appraisal of cardiac risk stratification before elective vascular surgery	Guideline adherence no result of the study
48	Kim et al. 2014	Rate of percutaneous coronary intervention for the management of acute coronary syndromes and stable coronary artery disease in the United States (2007 to 2011)	Guideline adherence no result of the study
49	Gandhi et al. 2014	Characteristics and evidence-based management of stable coronary artery disease patients in Canada compared with the rest of the world: insights from the CLARIFY registry	No guideline adherence for invasive procedures in the care of CAD
50	Chan et al. 2013	Patient and hospital characteristics associated with inappropriate percutaneous coronary interventions	No adherence to evidence-based guidelines (AUC)
51	Athauda-Arachchi et al. 2013	Assessing the implications of implementing the NICE guideline 95 for evaluation of stable chest pain of recent onset: A single centre experience	Guideline adherence no result of the study
52	Hannan et al. 2010	Adherence of catheterization laboratory cardiologists to American College of Cardiology/American Heart Association guidelines for percutaneous coronary interventions and coronary artery bypass graft surgery: what happens in actual practice?	No results for patients with chronic CAD
53	Mazzarotto et al. 2009	The use of functional tests and planned coronary angiography after percutaneous coronary revascularization in clinical practice. Results from the AFTER multicenter study	No results for patients with chronic CAD
54	Hemingway et al. 2008	Appropriateness criteria for coronary angiography in angina: Reliability and validity	No adherence to evidence-based guidelines
55	Ugalde et al. 2007	Coronary angiography: indications, results and complications in 5.000 consecutive patients	No full-text available in English or German
56	Darvish et al. 2015	Adherence to practice guidelines for coronary artery bypass graft surgery in Shiraz, Iran	No results for patients with chronic CAD
57	Dworsky et al. 2020	Older veterans undergoing inpatient surgery: What is the compliance with best practice guidelines?	No guideline adherence for invasive procedures in the care of CAD
58	Toth et al. 2021	Revascularization decisions in patients with chronic coronary syndromes: Results of the second International Survey on Interventional Strategy (ISIS-2)	No guideline adherence for invasive procedures in the care of CAD
59	Green et al. 2016	Implementation of a modified version of NICE CG95 on chest pain of recent onset: Experience in a DGH	No guideline adherence for invasive procedures in the care of CAD
60	Komajda et al. 2021	The ESC-EORP Chronic Ischaemic Cardiovascular Disease Long Term (CICD LT) registry	Study Protocol
61	Müller et al. 2001	Referral pattern of the heart catheterization laboratory at the Bern Island University Hospital	No adherence to evidence-based guidelines



No.	Author (Year)	Title	Exclusion criteria
62	Hoffman et al. 2007	Triage of patients with suspected coronary artery disease using multislice computed tomography	No description of the methods for evaluation of guideline adherence
63	Washington et al. 2003	Reliability of clinical guideline development using mail-only versus in-person expert panels	Guideline adherence no result of the study
64	Chmiel et al. 2015	Appropriateness of diagnostic coronary angiography as a measure of cardiac ischemia testing in non-emergency patients - a retrospective cross-sectional analysis	Guideline adherence no result of the study
65	Lurati Buse et al. 2021	Adherence to the European Society of Cardiology/European Society of Anaesthesiology recommendations on preoperative cardiac testing and association with positive results and cardiac events: a cohort study	No results for patients with chronic CAD
66	Orsini et al. 2022	Clinical outcomes of newly diagnosed, stable angina patients managed according to current guidelines. The ARCA (Arca Registry for Chronic Angina) Registry: A prospective, observational, nationwide study	Guideline adherence no result of the study
67	Raposo et al. 2021	Adoption and patterns of use of invasive physiological assessment of coronary artery disease in a large cohort of 40 821 real-world procedures over a 12-year period	Guideline adherence no result of the study

AUC = Appropriate Use Criteria, CAD = Coronary Artery Disease

## Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease – a scoping review: Supplementary Material

### Supplementary file 3: Study characteristics

Study	Procedure	Study design and setting	Study period	Study population
Kiselev et al. 2019 [1]	PCI/CABG	Retrospective cross-sectional study  RUS, Primary care [2]	Jan 2012 – Dec 2015	1,522 randomly selected patients with stable CAD (stable angina, previous MI, other chronic ischemic heart disease (ICD-10)), CA result and echocardiography including LVEF (exclusion, if ACS within previous 30 days)
Epstein et al. 2003 [3]	PTCA/CABG	Retrospective cohort study  US, Care in Medicare Insurance	Jan 1991 – Dec 1992	3,209 randomly selected Medicare beneficiaries aged 65 to 75 with inpatient CA for suspected CAD and diagnosis of chronic stable angina, asymptomatic coronary artery disease, previous MI
O'Connor et al. 2008 [4]	CABG	Retrospective, multicentre cross-sectional study  US, cardiac surgery programs in Northern New England	Jan 2004 – Dec 2005	806 patients with CABG and stable angina
Witberg et al. 2014 [5]	PCI, CABG	Prospective single-centre cohort study  ISR, medical centre	Jan 2009 – Dec 2010	290 patients referred for PCI or CABG because of LM/3VD without indication for valve surgery or previous CABG/heart transplantation
Leape et al. 2003 [6]	PTCA, CABG	Retrospective cross-sectional study  US, Care in Medicare Insurance	Jan 1991 – Dec 1992	819 randomly selected Medicare beneficiaries aged 65 to 75 with CA for suspected CAD and diagnosis of single or multi vessel CAD with class I-V angina and PTCA within 90 days or ischemic heart disease without symptoms, stable angina or post MI and CABG within 90 days
Linder et al. 2018 [7]	PCI	Retrospective cross-sectional analysis  GER, Care in statutory health insurance	2008 – 2013	298,574 patients insured by the German statutory health insurance fund with CAD
Marino et al. 2020 [8]	PCI	Retrospective, multicentre cross-sectional pilot study	N/A	336 patients with stable CAD

Study	Procedure	Study design and setting	Study period	Study population
		ITA, PCI-performing hospitals		
Leonardi et al. 2017 [9]	(ad hoc) PCI	Retrospective, multicentre cross-sectional pilot study	N/A	148 randomly selected patients with PCI for stable complex CAD and no previous CABG, partly with diabetes mellitus
Yates et al. 2014 [10]	PCI	ITA, PCI-performing hospitals Prospective, single-centre cohort study with historical control-group	Jan – Jun 2011, Jan – Jun 2010	115 patients with stable complex CAD and PCI
Leung et al. 2007 [11]	CA	UK, hospital (cardiothoracic unit) Prospective single-centre cohort study	5 months in 2002	491 consecutive patients with CA for assessment of chest pain
Morgan-Hughes et al. 2021 [12]	CA	AUS, Tertiary referral centre (catheterization laboratory) Prospective, multicentre cohort study (national audit and service evaluation)	Jan 2018 – Mar 2020	5,293 patients with CTCA for suspected CAD (recent-onset chest pain symptoms); 618 underwent CA
Rubboli et al. 2001 [13]	CA	UK, CTCA-performing Medical centres Retrospective, single-centre cross-sectional study	Jan 1999 – Dec 1999	266 patients with CA for CAD (stable angina, previous MI)
		IT, hospital (catheterization laboratory)		

ACS = Acute Coronary Syndrome, MI = Myocardial Infarction, CA = Coronary Angiography, CABG = Coronary Artery Bypass Grafting, CAD = Coronary Artery Disease, CTCA = Computed Tomography Coronary Angiography, ICD = International Classification of Diseases, LM = Left Main, LVEF = Left Ventricular Ejection Fraction, N/A = Not available, PCI = Percutaneous Coronary Intervention, PTCA = Percutaneous Transluminal Angioplasty, 3VD = 3-Vessel Disease

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Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease – a scoping review:  
Supplementary Material

Supplementary file 4: Methods and results

Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence
Kiselev et al. 2019 [1]	ESC/EACTS 2014 GL on myocardial revascularization	Russian registry	- Coronary anatomy	a) Adherence = revascularization if indication	Proportion of adherent/non-adherent treatment	a) Procedure performed: 81% adherence
		Retrospective data entry from patient charts by trained study personnel	- Extent of stenosis - LVEF - Clinical history - Symptom status - Therapy	b) Non-adherence = indication without revascularization	A binary measure	b) Procedure indicated: 40% adherence
	Revascularization			Indication = class I recommendation		
Epstein et al. 2003 [2]	ACC/AHA 1988 GL on PTCA	Medicare data + patient charts	- Extent of coronary artery occlusion	a) Non-adherence = no revascularization if indication	Proportion of non-adherent treatment	a) Procedure indicated: ≈ 76% adherence
	ACC/AHA 1991GL on CABG	Review of coronary angiography report and charts by trained study personnel	- Indication for angiography - Severity of angina - Comorbid conditions and risk factors - Medical/surgical history - Medication - Allergies/intolerances - Results of stress tests	Indication = recommendation class I  b) Non-adherence = revascularization if no indication	A binary measure	b) Procedure not indicated: ≈ 94% adherence
	Revascularization			No indication = class III recommendation		

Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence
O'Connor et al. 2008 [3]	ACC/AHA 2004 GL on CABG	American registry	- Coronary anatomy	Useful procedure = Recommendation class I	Proportion of useful, evidence favours procedure, evidence less well established and not useful procedures + adherent and non-adherent to guidelines	87% useful (class I) 11% procedure favoured (class IIa) 2% not useful (class III)  Overall: 98% adherence
	CABG	Data contribution by centres	- Extent of stenosis - Extent of ischemia - Symptom status - Shock - Prior treatment - Suitability for surgery/PCI - Hemodynamic stability - Cardiac history (e.g. STEMI) - Area of viable myocardium - Results of non-invasive testing	Evidence favours procedure = Recommendation class IIa  Evidence less well established = Recommendation class IIb  Procedure not useful = Recommendation class III  Adherence = CABG if recommendation class I or II		
Witberg et al. 2014 [4]	ESC 2010 GL on myocardial revascularization	Chart review by study personnel	- Clinical, laboratory, angiographic characteristics	Adherence = PCI/CABG according to indication	Proportion of adherent/non-adherent treatment	PCI: 78% adherence
	PCI, CABG	Calculation of SS (and cSS) by a study physician not blinded to mode of revascularization using a web-based calculator	- SS/cSS	Indication for PCI = recommendation class IIa  No indication for PCI/Indication for CABG = recommendation class III for PCI	A binary measure	CABG: 49% adherence

Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence	
Leape et al. 2003 [5]	ACC/AHA 1988/1993 GL on PTCA	Medicare data + patient charts	Clinical and laboratory data (e.g. symptoms, extent of CAD)	Justified procedure = recommendation class I	Proportion of justified, uncertain, not indicated procedures (and adherent and non-adherent to guidelines)	PTCA, 1988 GL: - 18% justified (class I), - 55% uncertain (class II) - 27% not indicated (class III) - Overall: 73% adherence	
	ACC/AHA 1991 GL on CABG	Review of coronary angiography report and charts by trained study personnel		Uncertain procedure = recommendation class II			
	PTCA, CABG			No indication for procedure = recommendation class III			
				Adherence= procedures rated as justified and uncertain			A multi-categorical and a binary measure
						PTCA, 1993 GL: - 15% justified (class I), - 58 % uncertain (class II) - 27 % not indicated (class III) - Overall: 73% adherence	
						CABG: - 86% justified (class I), - 12% uncertain (class II) - 2% not indicated (class III) - Overall: 98% adherence	
Linder et al. 2018 [6]	NVL 2013 on chronic CAD	Claims data	- ICD-Code (diagnosis, number of lesioned vessels)  - EBM/OPS codes for stents implantation	Adherence = no PCI if indication for CABG	Proportion of adherent/non-adherent treatment	67% adherence	
	(ESC/EACTS 2014 GL on myocardial revascularization)	Data record review using ICD-/OPS-/EBM-Codes by study personnel		Indication = recommendation grade A (/Class I recommendation for CABG and class III recommendation for PCI)			A binary measure
		PCI					



Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence
Marino et al. 2020 [7]	ESC/EACTS 2018 GL on myocardial revascularization	Patient charts	- SS - Coronary anatomy - Significance of stenoses	a) Adherence = PCI if strong recommendation for PCI or similar recommendation for PCI/CABG	Proportion of adherent/non-adherent treatment	a) PCI: 91% adherence
	(ACCF/AHA GL 2012 on stable ischemic heart disease)	Review of chart and coronary angiogram and determination of PTP by study personnel		Strong recommendation = Class I recommendation for PCI and class IIb for CABG	A binary measure	b) Ad hoc PCI: 17% adherence
	PCI, Ad hoc PCI	Definition of SS and SYNTAX Revascularization Index, coronary anatomy and presence of 'borderline' stenosis by study personnel		Similar recommendation = Class I recommendation for PCI and class I for CABG, class IIa recommendation for PCI and class I/II for CABG		
				b) Non-adherence = ad hoc PCI if indication for heart team discussion		
Leonardi et al. 2017 [8]	ESC 2013 GL on stable CAD	Review of chart and coronary angiogram and determination of PTP by study personnel	- Coronary anatomy - Significance of stenoses - SS	a) Adherence = heart team discussion if indication	Proportion of adherent/non-adherent treatment	a) Heart team discussion: 11% adherence
	ESC/EACTS 2014 GL on myocardial revascularization	Definition of SS, coronary anatomy and presence of 'borderline' stenosis by study personnel	- Evidence of heart team discussion	b) Non-adherence = ad hoc PCI if indication for heart team discussion	A binary measure	b) Ad hoc PCI: 20% adherence
	Ad hoc PCI, PCI with heart team discussion			Indication = recommendation class I for heart team, recommendation class I for CABG		

Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence
Yates et al. 2014 [9]	ESC/EACTS 2010 GL on myocardial revascularization	British registry, records on heart team discussion	<ul style="list-style-type: none"><li>- Coronary anatomy</li><li>- Significance of stenoses</li><li>- Diagnosis</li><li>- Management plan</li><li>- Reasons for deviation from expected practice</li></ul>	Adherence = heart team discussion before revascularization if indication	Proportion of adherent/non-adherent treatment	2010: 10% adherence
	PCI with heart team discussion	Prospective data collection during PCI in registry by care providers		Indication = recommendation class I	A binary measure	2011: 19% adherence
Morgan-Hughes et al. 2021 [10]	NICE CG95 (2016)	Review of database of all patients discussed by the heart team by study personnel, minutes recorded at each meeting				
	CA	Prospective data collection at participating centres in patient records and picture archiving/communication systems and anonymized collation at audit centre	<ul style="list-style-type: none"><li>- Demographic information</li><li>- CTCA results</li><li>- Diagnostic tests</li><li>- Revascularization</li></ul>	Non-adherence = Overuse of CA  Surrogate: Overuse of CA = CA without strong recommendation and revascularization	Proportion of adherent/non-adherent (overuse of CA) treatment  A binary measure	52% adherence
		Definition of CTCA as diagnostic or not by reporting cardiologist/radiologist using own criteria				

Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence
Leung et al. 2007 [11]	ACC/AHA 1999 GL on CA	N/A	<ul style="list-style-type: none"><li>- Clinical history</li><li>- Coronary risk factors (e.g. diabetes mellitus, smoking)</li></ul>	Adherence = CA if recommendation class I or II	Proportion of adherent/non-adherent treatment	53% adherence
	CA	<p>Prospective data recording by study personnel</p> <p>Classification (visual) of chest pain and estimation of the degree of coronary stenosis by experienced study personnel</p>	<ul style="list-style-type: none"><li>- Symptoms</li><li>- Results of electrocardiograms and laboratory tests</li><li>- Extent of stenosis</li><li>- Prior treatment</li></ul>	(Non-adherence = CA if recommendation class III or no recommendation class I or II)	A binary measure	
Rubboli et al. 2001 [12]	ACC/AHA 1999 GL for CA	Chart review by study personnel	<ul style="list-style-type: none"><li>- Clinical diagnosis (indication)</li><li>- Comorbidities</li></ul>	Useful procedure = recommendation class I	Proportion of useful, evidence favours procedure, evidence less well established and not useful	Approx. 71% useful Approx. 8% favoured (class IIa) 21% less established (class IIb)
	CA	Charts filled out by catheterization cardiologist	<ul style="list-style-type: none"><li>- Cardiovascular risk factors</li><li>- Laboratory test results</li><li>- Instrumental examination results</li><li>- Ongoing treatment</li></ul>	<p>Evidence favours procedure = recommendation class IIa</p> <p>Evidence less well established = recommendation class IIb</p> <p>Non-useful procedure = recommendation class III</p> <p>Adherence = CA if recommendation class I (useful) or IIa (evidence favours procedure)</p> <p>Uncertain = CA if recommendation class IIb (evidence less well established)</p>	<p>procedures + adherent, uncertain and non-adherent procedures</p> <p>A multi-categorical measure</p>	<p>Overall: 79% adherent (class I /IIa) 21% uncertain (class IIb) 0% non-adherent (class III)</p>

Study	Guideline and treatment decision	Data source and collection	Data and variables	Definition of guideline adherence	Quantification and level of measurement	Extent of guideline adherence
				Non-adherence = CA if recommendation class III (not useful)		

ACC = American College of Cardiology, ACCF = American College of Cardiology Foundation, AHA = American Heart Association, CA = Coronary Angiography, CABG = Coronary Artery Bypass Grafting, CAD = Coronary Artery Disease, cSS = clinical Syntax Score, CTCA = Computed Tomography – CA, DM = Diabetes mellitus, EBM = Common Assessment Scale, ESC = European Society of Cardiology, EACTS = European Association for Cardio-Thoracic Surgery, GL = Guideline, ICD = International Classification of Diseases, (LV)EF = (Left Ventricular) Ejection Fraction, LVF = Left Ventricular Function, (N)STEMI = (non-)ST-segment Elevation Myocardial Infarction, NVL = National disease management guideline, OPS = Operation and procedure codes, PCI = Percutaneous Coronary Intervention, PTCA = Percutaneous Transluminal Coronary Angioplasty, PTP = Pre-Test Probability, SS = Syntax Score

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