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

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# 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 revascularization. This review aims to examine how care providers' guideline adherence for CA and myocardial revascularization in the care of chronic CAD was assessed in the literature.

Design:

Scoping Review.

Methods:

A systematic literature search was conducted. We included studies assessing care providers' adherence to evidence-based guidelines for CA or myocardial revascularization in the care of chronic CAD. Methodological aspects such as data sources, definitions of guideline adherence and quantification methods, and the extent of guideline adherence were extracted. To elucidate the measurement of guideline adherence, the main steps were described.

Results:

Twelve studies were included, which evaluated guideline adherence by i) defining guideline adherence, ii) specifying the study population, iii) assigning (classes of) recommendations, and iv) quantifying adherence. Thereby, primarily secondary data were used. The 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, allocation rules and tools for the assignment of recommendation classes. The guideline adherence results ranged from 10% for

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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.

**Keywords**

coronary heart disease, coronary intervention, quality in health care, cardiology

**Strengths and limitations of this study**

- A robust methodology including a systematic literature search and data extraction conducted in duplicate
- This review synthesizes the methods used to assess guideline adherence by summarizing the four main steps of guideline adherence measurement
- Due to the absence of a validated instrument and focussing 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

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# INTRODUCTION

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

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.[e.g. 1,4,5] By systematically providing the best evidence available, these guidelines aim to support health professionals in clinical decision-making and promote high-quality care.[4,6] Furthermore, due to concerns surrounding excessive utilization of tests and procedures, Appropriate Use Criteria (AUCs) have been developed in an effort to improve appropriate resource utilization 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.[7]

Although there are established strategies for disseminating and implementing evidence-based guidelines in clinical practice,[8] there is still some question as to whether guidelines for cardiovascular procedures, in particular those for coronary angiography (CA) and myocardial revascularization (e.g. percutaneous coronary intervention (PCI)), are being applied adequately.[9,10]

There has been growing interest recently in evaluating the uptake among healthcare providers of clinical practice guidelines for patient treatment in chronic CAD care, i.e. the adherence of healthcare providers to clinical guideline recommendations.[11-14] Since evidence on guideline adherence in clinical practice contributes to quantifying the quality of care[15] and may be used to stimulate activities that promote a more guideline-adherent use of cardiovascular procedures,[14] it is important to ensure that the concept of guideline adherence is measured accurately and



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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 i) to examine the methods and results of studies that assess guideline adherence for invasive diagnostic and therapeutic procedures in patients with chronic CAD and ii) to compile the general steps used to assess guideline adherence.

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# 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 (PRISMA-ScR) Statement.[16] 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 standardized extraction forms.

## Literature search and eligibility criteria

We conducted the search in the bibliographic databases MEDLINE (via PubMed) and EMBASE (via Elsevier) using the search strategies presented in the supplementary 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 (rerun 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.[14] Thus, in this review, results presented as 'adherent care', 'compliant care',[14] 'care in agreement with the guidelines' and 'appropriate care' were included and



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summarized 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, 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.[7] Unlike evidence-based guidelines, performance measures aim to operationalize guideline recommendations, whereas AUCs only supplement guideline recommendations using specific clinical scenarios.[7] 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,[17] i.e. 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 summarized the main steps used to assess guideline adherence. Since most of data extracted was qualitative in nature, a narrative synthesis was conducted.[18]



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## Patient and public involvement

No patients were involved in this study.

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# 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, twelve studies were ultimately included in this review (see flow chart in Fig. 1 and supplementary file 2 for details of the excluded studies).

[Insert Figure 1: Flow chart for the literature search]

## Study characteristics

Three of the twelve studies included in the review assessed guideline adherence for the invasive diagnostic CA,[19-21] while nine did so for therapeutic revascularization by means of a PCI/percutaneous transluminal coronary angioplasty (PTCA) and/or CABG.[22-30] With one exception, all the studies were either based on a retrospective cross-sectional design (n=7)[21,22,25-27,29,30] or a prospective cohort design (n=4).[19,20,24,28] The studies evaluated both primary and specialized care (e.g. catheterization laboratory) over study periods ranging from five months[19] to five years.[27] The study populations varied with regard to care setting, disease state, prior treatment and patient demographics. An overview of the study characteristics is provided in the supplementary file 3.



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## 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 (ESC). Specifically, the studies assessed adherence to recommendations on the performance of a revascularization in general,[23,30] a CABG,[22,24,29] a PCI/PTCA,[22,24,25,27] an ad hoc PCI,[25,26] a PCI with prior heart team discussion[26,28] and a CA.[19-21]

Most of the studies were based on secondary data from registries,[28-30] patient records,[21-26] or administrative data.[22,23,27] However, two studies were based on primary data obtained from prospective records of consecutive patients (e.g. severity of stenosis, symptoms, procedures).[19,20] 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.[19-26,28-30] In one study, specific procedure codes and diagnoses within the utilized claims data were resorted.[27]

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.[31,32] In particular, the USA and European guidelines are based on three classes of recommendation: i) class I = procedure is recommended, ii) class II = conflicting evidence/agreement; procedure is reasonable/should be considered (IIa) or may be reasonable/considered (IIb) or iii) class III = procedure is not recommended.[33,34] Similarly, the German guidelines categorize recommendations using three grades: i) grade A = procedure shall (not) be performed, ii) grade B = procedure should (not) be performed or iii) grade



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0 = procedure could be performed.[35] In British guidelines, strong recommendations are applied where there is clear evidence of a benefit (i.e. 'offer'), while a less certain recommendation indicates that the evidence of a benefit is less certain (i.e. 'consider').[36]

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),[19,20,23-28,30] multi-categorically (useful/justified, uncertain and not useful/not indicated procedures),[21] or a combination of the two.[22,29]

The extent of guideline adherence depended on the procedure in question, and ranged from: 67% to 91% for PCI/PTCA,[22,24,25,27] 17% to 20% for ad hoc PCI,[25,26] 10% to 19% for PCI with prior heart team discussion,[26,28] 49% to 98% for CABG,[22,24,29] 40% to 94% for revascularization in general,[23,30] and 52% to 79% for CA.[19-21] An overview of the methods used to assess guideline adherence is presented in Table 1. For detailed information on the methods and results of the included studies see supplementary file 4.

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Table 1: Methods

| Study | Guideline and treatment decision | Definition of guideline adherence | Quantification and level of measurement |
|---|---|---|---|
| Kiselev et al. 2019 [30] | ESC/EACTS 2014 GL on myocardial revascularization<br><br>Revascularization | a) Adherence = revascularization if indication<br><br>b) Non-adherence = indication without revascularization<br><br>Indication = class I recommendation | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Epstein et al. 2003 [23] | ACC/AHA 1988 GL on PTCA<br><br>ACC/AHA 1991 GL on CABG<br><br>Revascularization | a) Non-adherence = no revascularization if indication<br><br>Indication = recommendation class I<br><br>b) Non-adherence = revascularization if no indication<br><br>No indication = class III recommendation | Proportion of non-adherent treatment<br><br>A binary measure |
| O'Connor et al. 2008 [29] | ACC/AHA 2004 GL on CABG<br><br>CABG | Useful procedure = Recommendation class I<br><br>Evidence favours procedure = Recommendation class IIa<br><br>Evidence less well established = Recommendation class IIb<br><br>Procedure not useful = Recommendation class III<br><br>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<br><br>A multi-categorical and a binary measure |
| Witberg et al. 2014 [24] | ESC 2010 GL on myocardial revascularization<br><br>PCI, CABG | Adherence = PCI/CABG according to indication<br><br>Indication for PCI = recommendation class IIa<br><br>No indication for PCI/Indication for CABG = recommendation class III for PCI | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Leape et al. 2003 [22] | ACC/AHA 1988/1993 GL on PTCA<br><br>ACC/AHA 1991 GL on CABG<br><br>PTCA, CABG | Justified procedure = recommendation class I<br><br>Uncertain procedure = recommendation class II<br><br>No indication for procedure = recommendation class III<br><br>Adherence= procedures rated as justified and uncertain | Proportion of justified, uncertain, not indicated procedures (and adherent and non-adherent to guidelines)<br><br>A multi-categorical and a binary measure |
| Linder et al. 2018 [27] | NVL 2013 on chronic CAD<br><br>(ESC/EACTS 2014 GL on myocardial revascularization)<br><br>PCI | Adherence = no PCI if indication for CABG<br><br>Indication = recommendation grade A (/Class I recommendation for CABG and class III recommendation for PCI) | Proportion of adherent/non-adherent treatment<br><br>A binary measure |



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| Study | Guideline and treatment decision | Definition of guideline adherence | Quantification and level of measurement |
|---|---|---|---|
| Marino et al. 2020 [25] | ESC/EACTS 2018 GL on myocardial revascularization<br><br>(ACCF/AHA GL 2012 on stable ischemic heart disease)<br><br>PCI, Ad hoc PCI | a) Adherence = PCI if strong recommendation for PCI or similar recommendation for PCI/CABG<br><br>Strong recommendation = Class I recommendation for PCI and class IIb for CABG<br><br>Similar recommendation = Class I recommendation for PCI and class I for CABG, class IIa recommendation for PCI and class I/II for CABG<br><br>b) Non-adherence = ad hoc PCI if indication for heart team discussion<br><br>Indication = recommendation class I for CABG | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Leonardi et al. 2017 [26] | ESC 2013 GL on stable CAD<br><br>ESC/EACTS 2014 GL on myocardial revascularization<br><br>Ad hoc PCI, PCI with heart team discussion | a) Adherence = heart team discussion if indication<br><br>b) Non-adherence = ad hoc PCI if indication for heart team discussion<br><br>Indication = recommendation class I for heart team, recommendation class I for CABG | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Yates et al. 2014 [28] | ESC/EACTS 2010 GL on myocardial revascularization<br><br>PCI with heart team discussion | Adherence = heart team discussion before revascularization if indication<br><br>Indication = recommendation class I | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Morgan-Hughes et al. 2021 [20] | NICE CG95 (2016)<br><br>CA | Non-adherence = Overuse of CA<br><br>Surrogate:<br>Overuse of CA = CA without strong recommendation and revascularization | Proportion of adherent/non-adherent (overuse of CA) treatment<br><br>A binary measure |
| Leung et al. 2007 [19] | ACC/AHA 1999 GL on CA<br><br>CA | Adherence = CA if recommendation class I or II<br><br>(Non-adherence = CA if recommendation class III or no recommendation class I or II) | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Rubboli et al. 2001 [21] | ACC/AHA 1999 GL for CA<br><br>CA | Adherence = CA if recommendation class I (useful) or IIa (evidence favours procedure)<br><br>Uncertain = CA if recommendation class IIb (evidence less well established)<br><br>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<br><br>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, ESC = European Society of Cardiology, EACTS = European Association for Cardio-Thoracic Surgery, GL = Guideline, NVL = National disease management guideline, PCI = Percutaneous Coronary Intervention, PTCA = Percutaneous Transluminal Coronary Angioplasty



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## 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 Fig. 2).

[Insert Figure 2: Main steps used to assess guideline adherence]

### *Definition of guideline adherence*

In all of the studies, guideline adherence was defined as the proportion of procedures among patients that 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 (i.e. 'is recommended'),[20,23,26-28,30] while others additionally considered recommendation class IIa (i.e. 'is probably recommended'),[21,24,25] or even recommendation class IIb (i.e. 'might be considered')[19,22,29] 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'.[20,23,27,30] Non-adherent care reflected both procedures offered to patients without a corresponding recommendation and cases where no procedure was performed despite revascularization or diagnostic CA being recommended.

### *Definition of study population*

While eight of the studies only considered patients who received a specific target procedure,[19,21,22,24-26,28,29] four included patients regardless of what treatment they had received in order to examine guideline adherence for revascularization or diagnostic CA.[20,23,27,30]



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

Using clinical data collected from different sources (see Table 1), for each patient it was checked i) which class of recommendation or ii) whether the specific recommendation (class) under evaluation matched the patients' disease criteria (e.g. symptoms, severity of disease). Six of the studies took all the recommendation classes into consideration for this process and categorized patients into recommendation classes I, II (a,b) and III.[19,21-23,25,29] The remaining studies focused on specific recommendations or recommendation classes (e.g. recommendation class I[30]) and merely categorized patients into two groups: 'procedure indicated' or 'procedure not indicated'.[20,24-28,30] 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 pre-specified allocation rule for cases of an ambiguous assignment (i.e. where a patient was assigned to more than one recommendation class).[27] In cases where guideline criteria had not been explicitly defined, four studies used a priori definitions of these criteria for an explicit assignment (e.g. evidence of ischemia, morbidity risk).[22,23,29,30] Some of these definitions were reviewed and revised by an expert panel of cardiologists (including cardiologists from the guideline panel),[22,23] or corresponded to established definitions.[30]

*Quantification of guideline adherence*

Estimating the proportions of patients with adherent or non-adherent care, nine of the studies used a binary approach.[19,20,23-28,30] Among this number, two studies focused on non-adherent care in order to assess potential overuse (i.e. application of a procedure without a corresponding indication) or underuse (i.e. an indication without a corresponding procedure).[20,23]



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Three of the studies quantified the results according to the considered guidelines using a multi-categorical 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).[21,22,29] 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.[21] The other two studies used an additional binary categorization into adherent and non-adherent care by accordingly assigning the cases that had initially been classified as uncertain.[22,29]

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# DISCUSSION

To the best of our knowledge, this is the first scoping review to summarize 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, i.e.: i) defining guideline adherence, ii) specifying the study population, iii) assigning recommendations or recommendation classes/grades/strengths, and iv) quantifying guideline adherence. However, differences were identified with regard 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,[19,20] most used secondary data that had been collected retrospectively.[21-30] 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 data base may be non-specific (i.e. information is available on a more aggregate level without providing clinical details) or incomplete (i.e. required information is missing entirely).[37] This limits the informative value of the data base.

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.[15,38] In particular, the interpretation and documentation of patients' test results (e.g. extent/significance of coronary stenoses) and symptoms (e.g. type of chest pain), which are key criteria for the assignment of recommendation classes, varies widely.[19,20,24,25,29,39] Moreover, secondary data often fail to provide information on contra-indications or patient preferences that could justify



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deviations from the guidelines.[22-24] The appropriateness of claims data for assessing guideline adherence might additionally be affected by factors such as the complexity of coding or economic incentives (e.g. coding higher disease severity in order to generate higher payments).[40]

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

A prospective collection of primary data alone or in combination with secondary sources (as reported in two studies[19,20]) may represent the first step towards obtaining a more reliable data base. 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,[20,23,26-28,30] 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[22,29], and by 58% in one study that assessed PCI.[22] The recommendation classes I/strong recommendations[20,22,23,26-28,30] and IIa[21,24,25] are based on high-level evidence, which is associated with a strong or intermediate positive benefit-risk estimate.[7] In contrast, recommendation class IIb as a guideline-adherent scenario[19,22,29] is only associated with a marginal benefit-risk ratio or uncertain outcomes.[7] As such, an assessment of the impact of addressing different classes of recommendation on guideline adherence (e.g. by means of sensitivity analyses) would be appropriate.



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### 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.[22,23,27,29,30] 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 harmonize cardiovascular terminology, thus enabling improved clinical communication and facilitating research.[41]

Moreover, the studies differed in their use of assignment tools. Most of the studies did not report information on their methods of assignment.[19-21,24-28,30] If we assume that these studies assigned recommendation classes/grades/strengths manually, this limits the reliability of the results. Manual assignments are susceptible to error and variation in cases where multiple investigators are used, especially if the persons carrying out the ratings are not adequately trained and the process is not standardized.[42,43] In order to address this issue, the development of standardized tools should be enhanced, e.g. by using an automatic computer algorithm and a decision table such as that used in three of the studies.[22,23,29]

### Results on guideline adherence

The results on guideline adherence differ, particularly between studies that do not examine the same treatment decisions. The lowest extent of adherence was observed for a PCI with prior heart team discussion (10%)[26,28] and an ad hoc PCI (17%),[25] while the highest extent of adherence



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was observed for CABG (98%).[29] Since a high level of evidence has a positive impact on the implementation of guidelines in clinical practice,[8,22] 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 (i.e. consensus of experts or small/retrospective studies and registries).[33,44,45] The providers' explanations and the patients' perceptions regarding the benefits and risks of the procedures in question may also contribute to this variation.[46] 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.[46] This might lead to a lower proportion of adherence for 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%)[25,26] and most for revascularization in general (between 40% and 94%).[22,24,29] In these studies, the observed variation may be the result of methodological differences (e.g. different data sources or different definitions of guideline adherence).

In addition to this, the variation of results may be influenced by external factors.[8] For example, initiatives to improve the quality and cost-effectiveness of care using decision aids (e.g. AUCs and performance measures) and financial incentives to encourage compliance with guidelines (e.g. pay-for-performance models) are well established in the United States,[7,47] and may have improved awareness of clinical guidelines among providers.[48]

Some effort will be needed in order to advance research on guideline adherence and improve the credibility of the results. Firstly, prospective databases that comply with guideline criteria should be developed for an objective collection of relevant clinical data. Ideally, these would be integrated into digital documentation systems and include an automatic mechanism for the patient-level assignment of recommendations and the corresponding classes/grades/strengths of recommendation. Secondly, the establishment and use of consistent definitions for guideline



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criteria (e.g. the clinical standard criteria published by the ACC/AHA) should be promoted in care and research. Finally, 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. Firstly, 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.

Secondly, 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.

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# CONCLUSION

The inconsistencies observed in the assessment 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 standardization. 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.

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Supplementary material

The supplementary material associated with this article is available online. File 1: Search strategies; File 2: Potentially relevant studies and exclusion criteria; File 3: Study characteristics, File 4: Methods and results of the included studies.

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Conflicts of interest

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Author contributions

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



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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.

## Data availability

No new data were generated or analysed in support of this research.

## Patient consent for publication

This study does not contain patient personal data.

## Ethics approval

Since this study does not involve human participants, no ethics approval is required.

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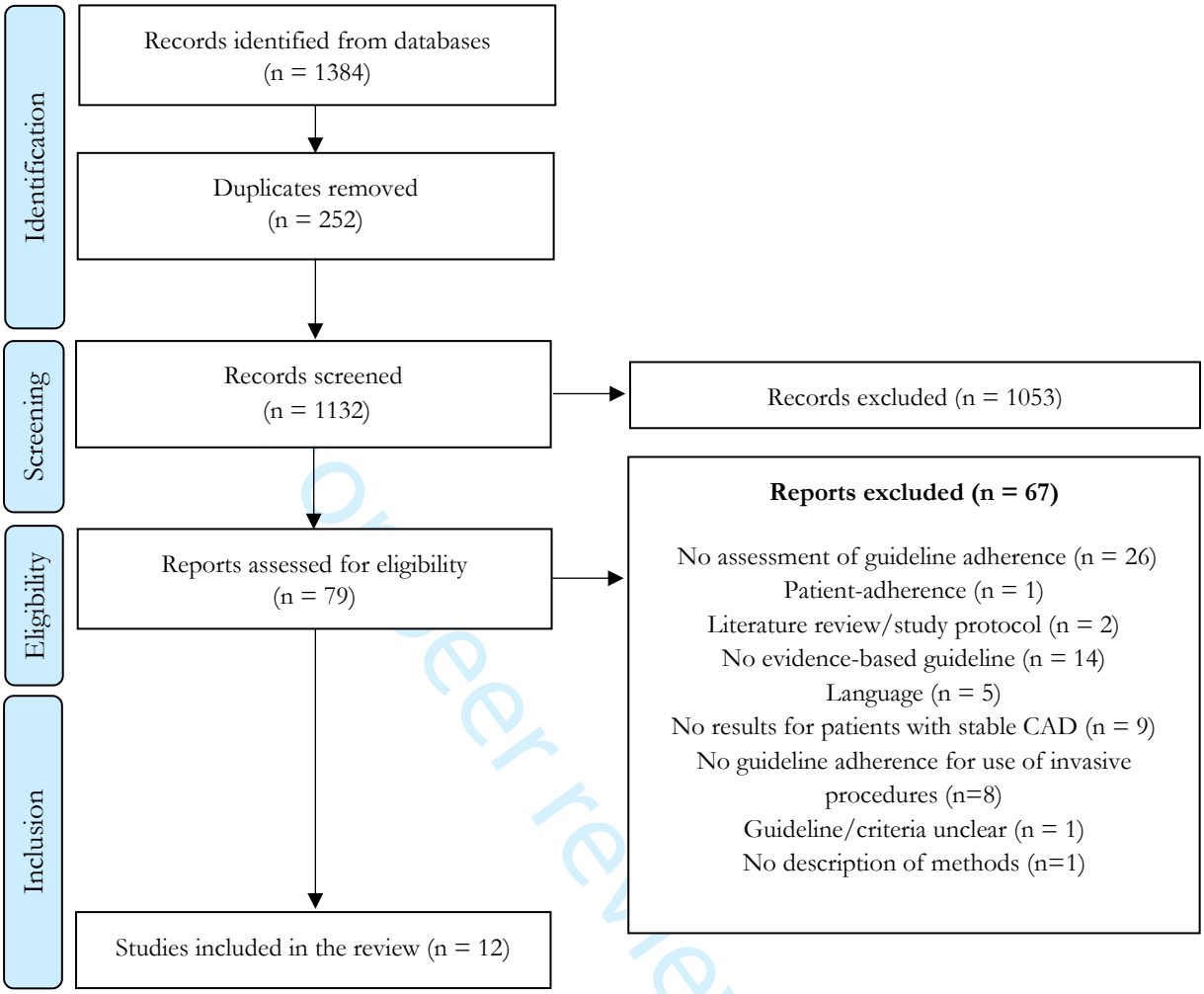


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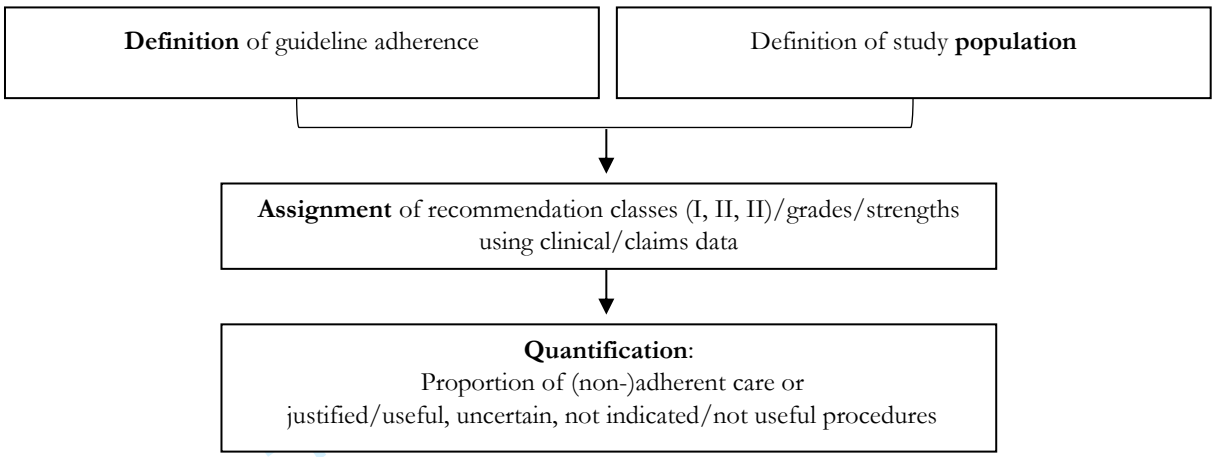


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**Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease – a scoping review: Supplementary Material**

Supplementary file 1: Electronic Database Searches

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

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| 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)) |

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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 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 |

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| | | | |
|---|---|---|---|
| 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 |
| 31 | De Barros E Silva et al. 2018 | Improvement in quality indicators using NCDR® registries: First international experience | No adherence to evidence-based guidelines |

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| | | | |
|---|---|---|---|
| 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 |
| 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 |

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| | | | |
|---|---|---|---|
| 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 |
| 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 |

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| | | | |
|---|---|---|---|
| 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

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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 3: Study characteristics

| Study | Procedure | Study design and setting | Study period | Study population |
|---|---|---|---|---|
| Kiselev et al. 2019 [1] | PCI/CABG | Retrospective cross-sectional study<br><br>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<br><br>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<br><br>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<br><br>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<br><br>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<br><br>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 |

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| | | | | | |
|---|---|---|---|---|---|
| | | | ITA, PCI-performing hospitals | | |
| Leonardi et al. 2017 [9] | (ad hoc) PCI | | Retrospective, multicentre cross-sectional pilot study<br><br>ITA, PCI-performing hospitals | 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 | | Prospective, single-centre cohort study with historical control-group<br><br>UK, hospital (cardiothoracic unit) | Jan – Jun 2011, Jan – Jun 2010 | 115 patients with stable complex CAD and PCI |
| Leung et al. 2007 [11] | CA | | Prospective single-centre cohort study<br><br>AUS, Tertiary referral centre (catheterization laboratory) | 5 months in 2002 | 491 consecutive patients with CA for assessment of chest pain |
| Morgan-Hughes et al. 2021 [12] | CA | | Prospective, multicentre cohort study (national audit and service evaluation)<br><br>UK, CTCA-performing Medical centres | 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 | | Retrospective, single-centre cross-sectional study<br><br>IT, hospital (catheterization laboratory) | Jan 1999 – Dec 1999 | 266 patients with CA for CAD (stable angina, previous MI) |

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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2. Gridnev VI, Kiselev AR, Posnenkova OM, et al. Objectives and design of Russian Registry of Hypertension, Coronary Artery Disease, and Chronic Heart Failure. *Russian Open Medical Journal.* 2017;6(2). doi: 10.15275/rusomj.2017.0201

3. Epstein AM, Weissman JS, Schneider EC, et al. Race and gender disparities in rates of cardiac revascularization: do they reflect appropriate use of procedures or problems in quality of care? *Med Care* 2003 Nov;41(11):1240-55. doi: 10.1097/01.mlr.0000093423.38746.8c

4. O'Connor GT, Olmstead EM, Nugent WC, et al. Appropriateness of Coronary Artery Bypass Graft Surgery Performed in Northern New England. *J Am Coll Cardiol* 2008;51(24):2323-8. doi: 10.1016/j.jacc.2008.01.067

5. Witberg G, Lavi I, Gonen O, et al. Long-term outcomes of patients with complex coronary artery disease according to agreement between the SYNTAX score and revascularization procedure in contemporary practice. *Coron Artery Dis* 2014 Jun;25(4):296-303. doi: 10.1097/mca.0000000000000106

6. Leape LL, Weissman JS, Schneider EC, et al. Adherence to practice guidelines: The role of specialty society guidelines. *Am Heart J* 2003;145(1):19-26. doi: 10.1067/mhj.2003.35

7. Linder R, Zeidler J, Verheyen F, et al. Guidelines versus reality: is coronary stent application in three-vessel disease standard or the exception? *Eur J Health Econ* 2018 Jul;19(6):821-30. doi: 10.1007/s10198-017-0924-4

8. Marino M, Leonardi S, Crimi G, et al. Lack of implementation of guidelines recommendations for coronary revascularization in stable patients with complex disease is associated with high rates of incomplete revascularization: Analysis from the Apache study. *Heart Vessels* 2020 Jan;35(1):30-7. doi: 10.1007/s00380-019-01459-1

9. Leonardi S, Marino M, Crimi G, et al. APpropriAteness of percutaneous Coronary interventions in patients with ischaemic HEart disease in Italy: the APACHE pilot study. *BMJ Open* 2017 Sep 5;7(9):e016909. doi: 10.1136/bmjopen-2017-016909

10. Yates MT, Soppa GK, Valencia O, et al. Impact of European Society of Cardiology and European Association for Cardiothoracic Surgery Guidelines on Myocardial Revascularization on

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the activity of percutaneous coronary intervention and coronary artery bypass graft surgery for stable coronary artery disease. *J Thorac Cardiovasc Surg* 2014 Feb;147(2):606-10. doi: 10.1016/j.jtcvs.2013.01.026

11. Leung DY, Hallani H, Lo ST, et al. How compliant are we with guidelines for coronary angiography in clinical practice? *Intern Med J* 2007;37(10):699-704. doi: 10.1111/j.1445-5994.2007.01390.x

12. Morgan-Hughes G, Williams MC, Loudon M, et al. Downstream testing after CT coronary angiography: time for a rethink? *Open heart* 2021 Feb;8(1). doi: 10.1136/openhrt-2021-001597

13. Rubboli A, La Vecchia L, Casella G, et al. Appropriateness of the use of coronary angiography in a population of patients with ischemic heart disease. *Ital Heart J* 2001 Sep;2(9):696-701.

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

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

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

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

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| 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<br><br>PCI with heart team discussion | British registry, records on heart team discussion<br><br>Prospective data collection during PCI in registry by care providers<br><br>Review of database of all patients discussed by the heart team by study personnel, minutes recorded at each meeting | - Coronary anatomy<br>- Significance of stenoses<br>- Diagnosis<br>- Management plan<br>- Reasons for deviation from expected practice | Adherence = heart team discussion before revascularization if indication<br><br>Indication = recommendation class I | Proportion of adherent/non-adherent treatment<br><br>A binary measure | 2010:<br>10% adherence<br><br>2011:<br>19% adherence |
| Morgan-Hughes et al. 2021 [10] | NICE CG95 (2016)<br><br>CA | Prospective data collection at participating centres in patient records and picture archiving/communication systems and anonymized collation at audit centre<br><br>Definition of CTCA as diagnostic or not by reporting cardiologist/radiologist using own criteria | - Demographic information<br>- CTCA results<br>- Diagnostic tests<br>- Revascularization | Non-adherence = Overuse of CA<br><br>Surrogate:<br>Overuse of CA = CA without strong recommendation and revascularization | Proportion of adherent/non-adherent (overuse of CA) treatment<br><br>A binary measure | 52% adherence |

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| 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<br><br>CA | N/A<br><br>Prospective data recording by study personnel<br><br>Classification (visual) of chest pain and estimation of the degree of coronary stenosis by experienced study personnel | - Clinical history<br>- Coronary risk factors (e.g. diabetes mellitus, smoking)<br>- Symptoms<br>- Results of electrocardiograms and laboratory tests<br>- Extent of stenosis<br>- Prior treatment | Adherence = CA if recommendation class I or II<br><br>(Non-adherence = CA if recommendation class III or no recommendation class I or II) | Proportion of adherent/non-adherent treatment<br><br>A binary measure | 53% adherence |
| Rubboli et al. 2001 [12] | ACC/AHA 1999 GL for CA<br><br>CA | Chart review by study personnel<br><br>Charts filled out by catheterization cardiologist | - Clinical diagnosis (indication)<br>- Comorbidities<br>- Cardiovascular risk factors<br>- Laboratory test results<br>- Instrumental examination results<br>- Ongoing treatment | Useful procedure = recommendation class I<br><br>Evidence favours procedure = recommendation class IIa<br><br>Evidence less well established = recommendation class IIb<br><br>Non-useful procedure = recommendation class III<br><br>Adherence = CA if recommendation class I (useful) or IIa (evidence favours procedure)<br><br>Uncertain = CA if recommendation class IIb (evidence less well established) | Proportion of useful, evidence favoured procedure, evidence less well established and not useful procedures adherent, uncertain and non-adherent procedures<br><br>A multi-categorical measure | Approx. 71% useful<br>Approx. 8% favoured (class IIa)<br>21% less established (class IIb)<br><br>Overall:<br>79% adherent (class I /IIa)<br>21% uncertain (class IIb)<br>0% non-adherent (class III) |

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| 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 code, PCI = Percutaneous Coronary Intervention, PTCA = Percutaneous Transluminal Coronary Angioplasty, PTP = Pre-Test Probability, SS = Syntax Score

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**Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist**

| SECTION | ITEM | PRISMA-ScR CHECKLIST ITEM | REPORTED ON PAGE # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a scoping review. | Title page |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives. | Abstract page |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach. | 1-2 |
| Objectives | 4 | Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives. | 2 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number. | 3 |
| Eligibility criteria | 6 | Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale. | 3-4 |
| Information sources* | 7 | Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed. | 3 |
| Search | 8 | Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated. | Supplementary file 1 |
| Selection of sources of evidence† | 9 | State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review. | 3 |
| Data charting process‡ | 10 | Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators. | 3 |
| Data items | 11 | List and define all variables for which data were sought and any assumptions and simplifications made. | 4 |
| Critical appraisal of individual | 12 | If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe | - |

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| SECTION | ITEM | PRISMA-ScR CHECKLIST ITEM | REPORTED ON PAGE # |
|---|---|---|---|
| sources of evidence§ | | the methods used and how this information was used in any data synthesis (if appropriate). | |
| Synthesis of results | 13 | Describe the methods of handling and summarizing the data that were charted. | 4 |
| **RESULTS** | | | |
| Selection of sources of evidence | 14 | Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram. | 6, Supplementary file 2 |
| Characteristics of sources of evidence | 15 | For each source of evidence, present characteristics for which data were charted and provide the citations. | 6, Supplementary file 3 |
| Critical appraisal within sources of evidence | 16 | If done, present data on critical appraisal of included sources of evidence (see item 12). | - |
| Results of individual sources of evidence | 17 | For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives. | 9-10 (Table 1), Supplementary file 4 |
| Synthesis of results | 18 | Summarize and/or present the charting results as they relate to the review questions and objectives. | 7-8, 11-13 |
| **DISCUSSION** | | | |
| Summary of evidence | 19 | Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups. | 14 |
| Limitations | 20 | Discuss the limitations of the scoping review process. | 18 |
| Conclusions | 21 | Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps. | 19 |
| **FUNDING** | | | |
| Funding | 22 | Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review. | 20 |

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

*From:* Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

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

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# 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 revascularization. This review aims to examine how care providers' guideline adherence for CA and myocardial revascularization 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 revascularization 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 standardized 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:


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Twelve studies (311,869 participants) were included, which evaluated guideline adherence by i) defining guideline adherence, ii) specifying the study population, iii) assigning (classes of) recommendations, and iv) 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, allocation rules and tools 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.

**Keywords**

coronary heart disease, coronary intervention, quality in health care, cardiology

**Strengths and limitations of this study**

- A robust methodology including a systematic literature search and data extraction conducted in duplicate
- This review synthesizes the methods used to assess guideline adherence by summarizing the four main steps of guideline adherence measurement

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- Due to the absence of a validated instrument and focussing 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

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# INTRODUCTION

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

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.[e.g. 1,4,5] By systematically providing the best evidence available, these guidelines aim to support health professionals in clinical decision-making and promote high-quality care.[4,6] Furthermore, due to concerns surrounding excessive utilization of tests and procedures, Appropriate Use Criteria (AUCs) have been developed in an effort to improve appropriate resource utilization 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.[7]

Although there are established strategies for disseminating and implementing evidence-based guidelines in clinical practice,[8] there is still some question as to whether guidelines for cardiovascular procedures, in particular those for coronary angiography (CA) and myocardial revascularization (e.g. percutaneous coronary intervention (PCI)), are being applied adequately.[9,10]

There has been growing interest recently in evaluating the uptake among healthcare providers of clinical practice guidelines for patient treatment in chronic CAD care, i.e. the adherence of healthcare providers to clinical guideline recommendations.[11-14] Since evidence on guideline adherence in clinical practice contributes to quantifying the quality of care[15] and may be used to stimulate activities that promote a more guideline-adherent use of cardiovascular procedures,[14] it is important to ensure that the concept of guideline adherence is measured accurately and



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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 i) to examine the methods and results of studies that assess guideline adherence for invasive diagnostic and therapeutic procedures in patients with chronic CAD and ii) to compile the general steps used to assess guideline adherence.

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# 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 (PRISMA-ScR) Statement.[16] 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 standardized extraction forms.

## Literature search

We conducted the search in the bibliographic databases PubMed and EMBASE (via Elsevier) using the search strategies presented in the supplementary 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.[14] Thus, in this review, results presented as 'adherent care', 'compliant care',[14] 'care in agreement with the guidelines' and 'appropriate care' were included and



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summarized 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,[7] 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.[7] Unlike evidence-based guidelines, performance measures aim to operationalize guideline recommendations, whereas AUCs only supplement guideline recommendations using specific clinical scenarios.[7] 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,[17] i.e. 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 summarized the main steps used to assess guideline adherence. Since most of data extracted was qualitative in nature, a narrative synthesis was conducted.[18]



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## Patient and public involvement

No patients were involved in this study.

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# 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, twelve studies were ultimately included in this review (see flow chart in Fig. 1 and supplementary file 2 for details of the excluded studies).

[Insert Figure 1: Flow chart for the literature search]

## Study characteristics

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



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## 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 (ESC). Specifically, the studies assessed adherence to recommendations on the performance of a revascularization in general,[23,30] a CABG,[22,24,29] a PCI/PTCA,[22,24,25,27] an ad hoc PCI,[25,26] a PCI with prior heart team discussion[26,28] and a CA.[19-21]

Most of the studies were based on secondary data from registries,[28-30] patient records,[21-26] or administrative data.[22,23,27] However, two studies were based on primary data obtained from prospective records of consecutive patients (e.g. severity of stenosis, symptoms, procedures).[19,20] 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.[19-26,28-30] In one study, specific procedure codes and diagnoses within the utilized claims data were resorted.[27]

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.[31,32] In particular, the USA and European guidelines are based on three classes of recommendation: i) class I = procedure is recommended, ii) class II = conflicting evidence/agreement; procedure is reasonable/should be considered (IIa) or may be reasonable/considered (IIb) or iii) class III = procedure is not recommended.[33,34] Similarly, the German guidelines categorize recommendations using three grades: i) grade A = procedure shall (not) be performed, ii) grade B = procedure should (not) be performed or iii) grade



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0 = procedure could be performed.[35] In British guidelines, strong recommendations are applied where there is clear evidence of a benefit (i.e. 'offer'), while a less certain recommendation indicates that the evidence of a benefit is less certain (i.e. 'consider').[36]

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),[19,20,23-28,30] multi-categorically (useful/justified, uncertain and not useful/not indicated procedures),[21] or a combination of the two.[22,29]

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

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Table 1: Methods

| Study | Guideline and treatment decision | Definition of guideline adherence | Quantification and level of measurement |
|---|---|---|---|
| Kiselev et al. 2019 [30] | ESC/EACTS 2014 GL on myocardial revascularization<br><br>Revascularization | a) Adherence = revascularization if indication<br><br>b) Non-adherence = indication without revascularization<br><br>Indication = class I recommendation | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Epstein et al. 2003 [23] | ACC/AHA 1988 GL on PTCA<br><br>ACC/AHA 1991 GL on CABG<br><br>Revascularization | a) Non-adherence = no revascularization if indication<br><br>Indication = recommendation class I<br><br>b) Non-adherence = revascularization if no indication<br><br>No indication = class III recommendation | Proportion of non-adherent treatment<br><br>A binary measure |
| O'Connor et al. 2008 [29] | ACC/AHA 2004 GL on CABG<br><br>CABG | Useful procedure = Recommendation class I<br><br>Evidence favours procedure = Recommendation class IIa<br><br>Evidence less well established = Recommendation class IIb<br><br>Procedure not useful = Recommendation class III<br><br>Adherence = CABG if recommendation class I or II | Proportion of useful, evidence favours procedure, evidence less well established and not useful procedures<br>+ adherent and non-adherent to guidelines<br><br>A multi-categorical and a binary measure |
| Witberg et al. 2014 [24] | ESC 2010 GL on myocardial revascularization<br><br>PCI, CABG | Adherence = PCI/CABG according to indication<br><br>Indication for PCI = recommendation class IIa<br><br>No indication for PCI/Indication for CABG = recommendation class III for PCI | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Leape et al. 2003 [22] | ACC/AHA 1988/1993 GL on PTCA<br><br>ACC/AHA 1991 GL on CABG<br><br>PTCA, CABG | Justified procedure = recommendation class I<br><br>Uncertain procedure = recommendation class II<br><br>No indication for procedure = recommendation class III<br><br>Adherence= procedures rated as justified and uncertain | Proportion of justified, uncertain,<br>not indicated procedures<br>(and adherent and non-adherent to guidelines)<br><br>A multi-categorical and a binary measure |
| Linder et al. 2018 [27] | NVL 2013 on chronic CAD<br><br>(ESC/EACTS 2014 GL on myocardial revascularization)<br><br>PCI | Adherence = no PCI if indication for CABG<br><br>Indication = recommendation grade A (/Class I recommendation for CABG and class III recommendation for PCI) | Proportion of adherent/non-adherent treatment<br><br>A binary measure |

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| Marino et al. 2020 [25] | ESC/EACTS 2018 GL on myocardial revascularization<br><br>(ACCF/AHA GL 2012 on stable ischemic heart disease)<br><br>PCI, Ad hoc PCI | a) Adherence = PCI if strong recommendation for PCI or similar recommendation for PCI/CABG<br><br>Strong recommendation = Class I recommendation for PCI and class IIb for CABG<br><br>Similar recommendation = Class I recommendation for PCI and class I for CABG, class IIa recommendation for PCI and class I/II for CABG<br><br>b) Non-adherence = ad hoc PCI if indication for heart team discussion<br><br>Indication = recommendation class I for CABG | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Leonardi et al. 2017 [26] | ESC 2013 GL on stable CAD<br><br>ESC/EACTS 2014 GL on myocardial revascularization<br><br>Ad hoc PCI, PCI with heart team discussion | a) Adherence = heart team discussion if indication<br><br>b) Non-adherence = ad hoc PCI if indication for heart team discussion<br><br>Indication = recommendation class I for heart team, recommendation class I for CABG | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Yates et al. 2014 [28] | ESC/EACTS 2010 GL on myocardial revascularization<br><br>PCI with heart team discussion | Adherence = heart team discussion before revascularization if indication<br><br>Indication = recommendation class I | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Morgan-Hughes et al. 2021 [20] | NICE CG95 (2016)<br><br>CA | Non-adherence = Overuse of CA<br><br>Surrogate:<br>Overuse of CA = CA without strong recommendation and revascularization | Proportion of adherent/non-adherent (overuse of CA) treatment<br><br>A binary measure |
| Leung et al. 2007 [19] | ACC/AHA 1999 GL on CA<br><br>CA | Adherence = CA if recommendation class I or II<br><br>(Non-adherence = CA if recommendation class III or no recommendation class I or II) | Proportion of adherent/non-adherent treatment<br><br>A binary measure |
| Rubboli et al. 2001 [21] | ACC/AHA 1999 GL on CA<br><br>CA | Adherence = CA if recommendation class I (useful) or IIa (evidence favours procedure)<br><br>Uncertain = CA if recommendation class IIb (evidence less well established)<br><br>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<br><br>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, ESC = European Society of Cardiology, EACTS = European Association for Cardio-Thoracic Surgery, GL = Guideline, NVL = National disease management guideline, PCI = Percutaneous Coronary Intervention, PTCA = Percutaneous Transluminal Coronary Angioplasty



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## 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 Fig. 2).

[Insert Figure 2: Main steps used to assess guideline adherence]

### *Definition of guideline adherence*

In all of the studies, guideline adherence was defined as the proportion of procedures among patients that 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 (i.e. 'is recommended'),[20,23,26-28,30] while others additionally considered recommendation class IIa (i.e. 'is probably recommended'),[21,24,25] or even recommendation class IIb (i.e. 'might be considered')[19,22,29] 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'.[20,23,27,30] Non-adherent care reflected both procedures offered to patients without a corresponding recommendation and cases where no procedure was performed despite revascularization or diagnostic CA being recommended.

### *Definition of study population*

While eight of the studies only considered patients who received a specific target procedure,[19,21,22,24-26,28,29] four included patients regardless of what treatment they had received in order to examine guideline adherence for revascularization or diagnostic CA.[20,23,27,30]



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

Using clinical data collected from different sources (see Table 1), for each patient it was checked i) which class of recommendation or ii) whether the specific recommendation (class) under evaluation matched the patients' disease criteria (e.g. symptoms, severity of disease). Six of the studies categorized patients into recommendation classes I, II (a,b) and III.[19,21-23,25,29] The remaining studies focused on specific recommendations or recommendation classes (e.g. recommendation class I[30]) and merely categorized patients into two groups: 'procedure indicated' or 'procedure not indicated'.[20,24-28,30] 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 pre-specified allocation rule for cases of an ambiguous assignment (i.e. where a patient was assigned to more than one recommendation class).[27] In cases where guideline criteria had not been explicitly defined, four studies used a priori definitions of these criteria for an explicit assignment (e.g. evidence of ischemia, morbidity risk).[22,23,29,30]

*Quantification of guideline adherence*

Estimating the proportions of patients with adherent or non-adherent care, nine of the studies used a binary approach.[19,20,23-28,30]

Three of the studies quantified the results according to the considered guidelines using a multi-categorical 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).[21,22,29] 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.[21] The



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other two studies used an additional binary categorization into adherent and non-adherent care by accordingly assigning the cases that had initially been classified as uncertain.[22,29]

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# DISCUSSION

To the best of our knowledge, this is the first scoping review to summarize 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, i.e.: i) defining guideline adherence, ii) specifying the study population, iii) assigning recommendations or recommendation classes/grades/strengths, and iv) quantifying guideline adherence. However, differences were identified with regard 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,[19,20] most used secondary data that had been collected retrospectively.[21-30] 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 data base may be non-specific (i.e. information is available on a more aggregate level without providing clinical details) or incomplete (i.e. required information is missing entirely).[37] This limits the informative value of the data base, 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.[15,38] In particular, the interpretation and documentation of patients' test results (e.g. extent/significance of coronary stenoses) and symptoms (e.g. type of chest pain), which are key criteria for the assignment of recommendation classes, varies widely.[19,20,24,25,29,39] Moreover, secondary data



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often fail to provide information on contra-indications or patient preferences that could justify deviations from the guidelines.[22-24] The appropriateness of claims data for assessing guideline adherence might additionally be affected by factors such as the complexity of coding or economic incentives (e.g. coding higher disease severity in order to generate higher payments).[40]

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

A prospective collection of primary data alone or in combination with secondary sources (as reported in two studies[19,20]) may represent the first step towards obtaining a more reliable data base. 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,[20,23,26-28,30] 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[22,29], and by 58% in one study that assessed PCI.[22] The recommendation classes I/strong recommendations[20,22,23,26-28,30] and IIa[21,24,25] are based on high-level evidence, which is associated with a strong or intermediate positive benefit-risk estimate.[7] In contrast, recommendation class IIb as a guideline-adherent scenario[19,22,29] is only associated with a marginal benefit-risk ratio or uncertain outcomes.[7] As such, an assessment of the impact of



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addressing different classes of recommendation on guideline adherence (e.g. 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.[22,23,27,29,30] 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 harmonize cardiovascular terminology, thus enabling improved clinical communication and facilitating research.[41]

### 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%)[26,28] and an ad hoc PCI (17%),[25] while the highest extent of adherence was observed for CABG (98%).[29] Since a high level of evidence has a positive impact on the implementation of guidelines in clinical practice,[8,22] 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 (i.e. consensus of experts or small/retrospective studies and



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registries).[33,42,43] The providers' explanations and the patients' perceptions regarding the benefits and risks of the procedures in question may also contribute to this variation.[44] 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.[44] 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%)[25,26] and most for revascularization in general (between 40% and 94%).[22,24,29] In these studies, the observed variation may be the result of methodological differences (e.g. 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[24,45] (i.e., heart team discussions before PCI and revascularization decisions based on the Syntax Score[24,26,28]) and for recommendations that changed significantly over time[46] (ad hoc PCI[26]). This might indicate difficulties in the implementation of the evolving and more complex recommendations over time.[8] However, the heterogeneity of the included studies did not allow an analysis of a temporal trend.

Further, the variation of results may be influenced by external factors.[8] For example, initiatives to improve the quality and cost-effectiveness of care using decision aids (e.g. AUCs and performance measures) and financial incentives to encourage compliance with guidelines (e.g. pay-for-performance models) are well established in the United States,[7,47] and may have improved awareness of clinical guidelines among providers.[48]

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



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of care.[49] Therefore, to assess the proportion of patients not receiving a procedure with an indication (as reported in two studies[23,30]) would also be informative for developing targeted interventions to promote high quality care.

Some effort will be needed in order to advance research on guideline adherence and improve the credibility of the results. Firstly, prospective databases that comply with guideline criteria should be developed for an objective collection of relevant clinical data. Secondly, the establishment and use of consistent definitions for guideline criteria (e.g. the clinical standard criteria published by the ACC/AHA) should be promoted in care and research. Finally, 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. Firstly, 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.

Secondly, 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.

Thirdly, 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



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methodological aspects among others to enable readers to adequately interpret results on guideline adherence.

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# 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 standardization. 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.

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Supplementary material

The supplementary material associated with this article is available online. File 1: Search strategies; File 2: Potentially relevant studies and exclusion criteria; File 3: Study characteristics, File 4: Methods and results of the included studies.

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Conflicts of interest

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Author contributions

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



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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.

## Data availability

No new data were generated or analysed in support of this research.

## Patient consent for publication

This study does not contain patient personal data.

## Ethics approval

Since this study does not involve human participants, no ethics approval is required.

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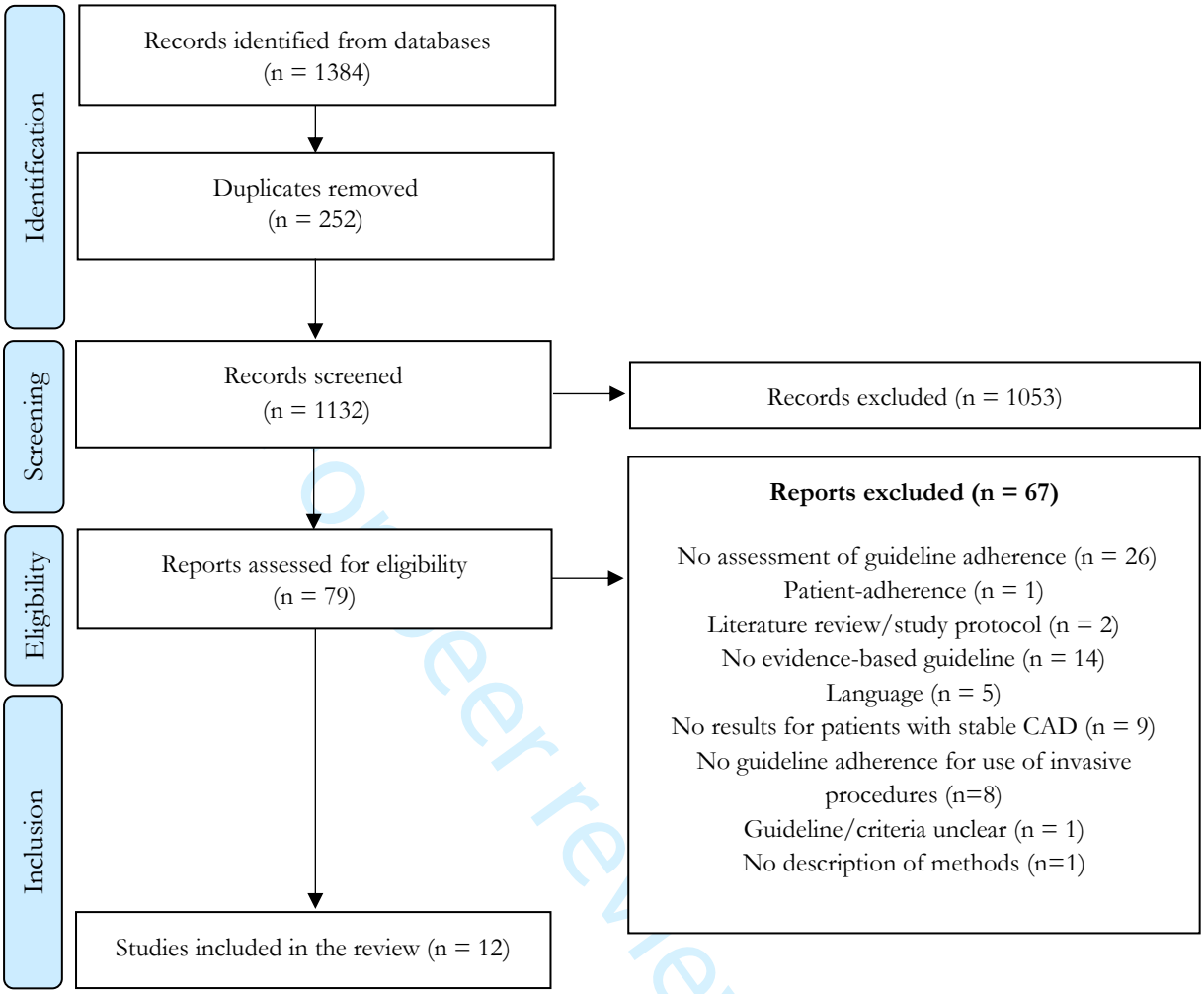


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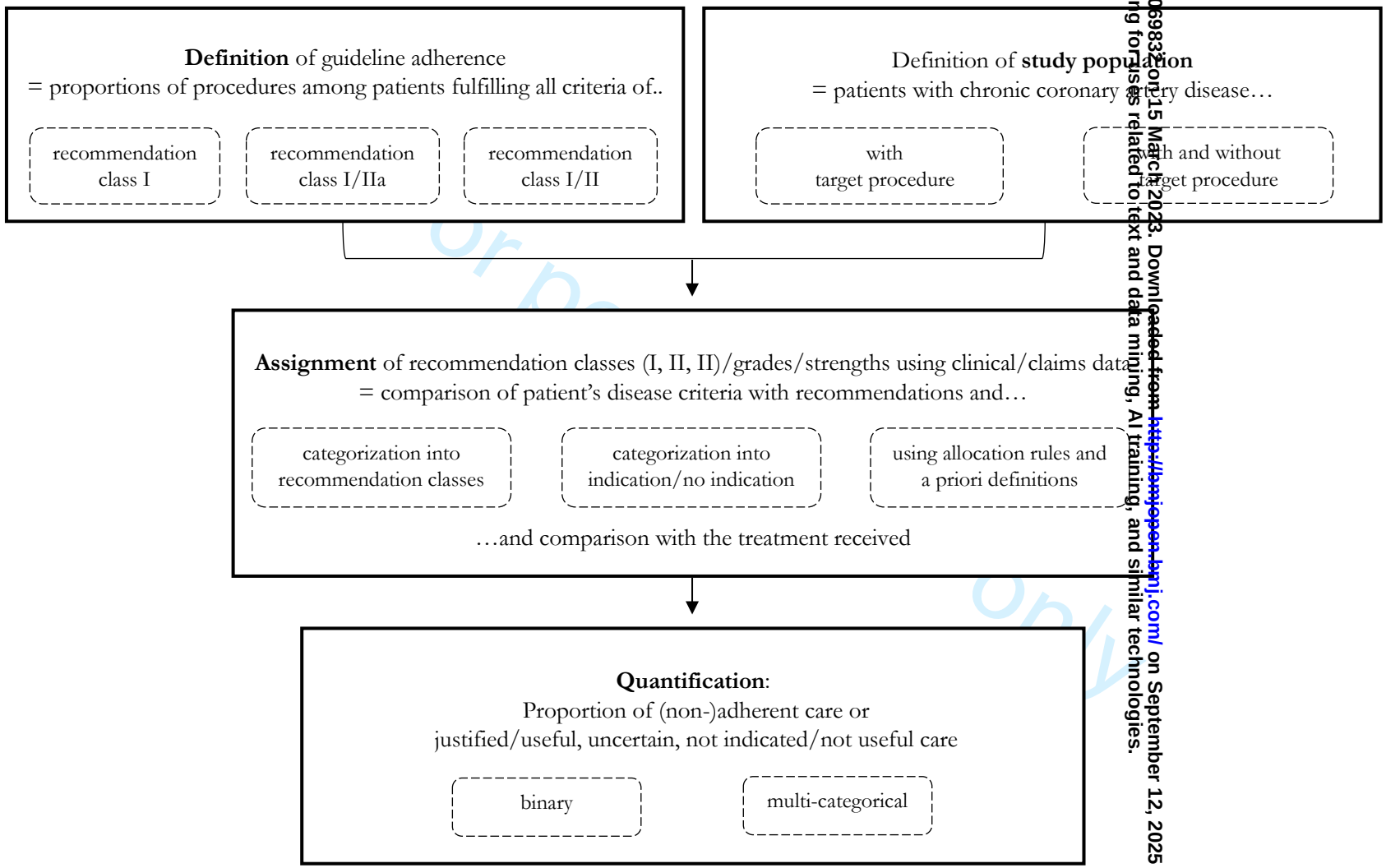


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**Methods for assessing guideline adherence for invasive procedures in the care of chronic coronary artery disease – a scoping review: Supplementary Material**

Supplementary file 1: Electronic Database Searches

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

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

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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 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 |

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| 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 |

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| 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 |

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| 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 |

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| 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

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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 3: Study characteristics

| Study | Procedure | Study design and setting | Study period | Study population |
|---|---|---|---|---|
| Kiselev et al. 2019 [1] | PCI/CABG | Retrospective cross-sectional study<br><br>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<br><br>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<br><br>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<br><br>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<br><br>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<br><br>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 |

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| 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<br><br>ITA, PCI-performing hospitals | 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 | Prospective, single-centre cohort study with historical control-group<br><br>UK, hospital (cardiothoracic unit) | Jan – Jun 2011, Jan – Jun 2010 | 115 patients with stable complex CAD and PCI |
| Leung et al. 2007 [11] | CA | Prospective single-centre cohort study<br><br>AUS, Tertiary referral centre (catheterization laboratory) | 5 months in 2002 | 491 consecutive patients with CA for assessment of chest pain |
| Morgan-Hughes et al. 2021 [12] | CA | Prospective, multicentre cohort study (national audit and service evaluation)<br><br>UK, CTCA-performing Medical centres | 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 | Retrospective, single-centre cross-sectional study<br><br>IT, hospital (catheterization laboratory) | Jan 1999 – Dec 1999 | 266 patients with CA for CAD (stable angina, previous MI) |

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

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| 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<br><br>CABG | American registry<br><br>Data contribution by centres | - Coronary anatomy<br>- Extent of stenosis<br>- Extent of ischemia<br>- Symptom status<br>- Shock<br>- Prior treatment<br>- Suitability for surgery/PCI<br>- Hemodynamic stability<br>- Cardiac history (e.g. STEMI)<br>- Area of viable myocardium<br>- Results of non-invasive testing | Useful procedure = Recommendation class I<br><br>Evidence favours procedure = Recommendation class IIa<br><br>Evidence less well established = Recommendation class IIb<br><br>Procedure not useful = Recommendation class III<br><br>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<br><br>A multi-categorical and a binary measure | 87% useful (class I)<br>11% procedure favoured (class IIa)<br>2% not useful (class III)<br><br>Overall: 98% adherence |
| Witberg et al. 2014 [4] | ESC 2010 GL on myocardial revascularization<br><br>PCI, CABG | Chart review by study personnel<br><br>Calculation of SS (and cSS) by a study physician not blinded to mode of revascularization using a web-based calculator | - Clinical, laboratory, angiographic characteristics<br>- SS/cSS | Adherence = PCI/CABG according to indication<br><br>Indication for PCI = recommendation class IIa<br><br>No indication for PCI/Indication for CABG = recommendation class III for PCI | Proportion of adherent/non-adherent treatment<br><br>A binary measure | PCI:<br>78% adherence<br><br>CABG:<br>49% adherence |

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

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

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| 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<br><br>PCI with heart team discussion | British registry, records on heart team discussion<br><br>Prospective data collection during PCI in registry by care providers<br><br>Review of database of all patients discussed by the heart team by study personnel, minutes recorded at each meeting | - Coronary anatomy<br>- Significance of stenoses<br>- Diagnosis<br>- Management plan<br>- Reasons for deviation from expected practice | Adherence = heart team discussion before revascularization if indication<br><br>Indication = recommendation class I | Proportion of adherent/non-adherent treatment<br><br>A binary measure | 2010:<br>10% adherence<br><br>2011:<br>19% adherence |
| Morgan-Hughes et al. 2021 [10] | NICE CG95 (2016)<br><br>CA | Prospective data collection at participating centres in patient records and picture archiving/communication systems and anonymized collation at audit centre<br><br>Definition of CTCA as diagnostic or not by reporting cardiologist/radiologist using own criteria | - Demographic information<br>- CTCA results<br>- Diagnostic tests<br>- Revascularization | Non-adherence = Overuse of CA<br><br>Surrogate:<br>Overuse of CA = CA without strong recommendation and revascularization | Proportion of adherent/non-adherent (overuse of CA) treatment<br><br>A binary measure | 52% adherence |

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| 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<br><br>CA | N/A<br><br>Prospective data recording by study personnel<br><br>Classification (visual) of chest pain and estimation of the degree of coronary stenosis by experienced study personnel | - Clinical history<br>- Coronary risk factors (e.g. diabetes mellitus, smoking)<br>- Symptoms<br>- Results of electrocardiograms and laboratory tests<br>- Extent of stenosis<br>- Prior treatment | Adherence = CA if recommendation class I or II<br><br>(Non-adherence = CA if recommendation class III or no recommendation class I or II) | Proportion of adherent/non-adherent treatment<br><br>A binary measure | 53% adherence |
| Rubboli et al. 2001 [12] | ACC/AHA 1999 GL for CA<br><br>CA | Chart review by study personnel<br><br>Charts filled out by catheterization cardiologist | - Clinical diagnosis (indication)<br>- Comorbidities<br>- Cardiovascular risk factors<br>- Laboratory test results<br>- Instrumental examination results<br>- Ongoing treatment | Useful procedure = recommendation class I<br><br>Evidence favours procedure = recommendation class IIa<br><br>Evidence less well established = recommendation class IIb<br><br>Non-useful procedure = recommendation class III<br><br>Adherence = CA if recommendation class I (useful) or IIa (evidence favours procedure)<br><br>Uncertain = CA if recommendation class IIb (evidence less well established) | Proportion of useful, evidence favours procedure, evidence less well established and not useful procedures in adherent, uncertain and non-adherent procedures<br><br>A multi-categorical measure | Approx. 71% useful<br>Approx. 8% favoured (class IIa)<br>21% less established (class IIb)<br><br>Overall:<br>79% adherent (class I /IIa)<br>21% uncertain (class IIb)<br>0% non-adherent (class III) |

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| 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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3. O'Connor GT, Olmstead EM, Nugent WC, et al. Appropriateness of Coronary Artery Bypass Graft Surgery Performed in Northern New England. *J Am Coll Cardiol* 2008;51(24):2323-8. doi: 10.1016/j.jacc.2008.01.067

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6. Linder R, Zeidler J, Verheyen F, et al. Guidelines versus reality: is coronary stent application in three-vessel disease standard or the exception? *Eur J Health Econ* 2018 Jul;19(6):821-30. doi: 10.1007/s10198-017-0924-4

7. Marino M, Leonardi S, Crimi G, et al. Lack of implementation of guidelines recommendations for coronary revascularization in stable patients with complex disease is associated with high rates of incomplete revascularization: Analysis from the Apache study. *Heart Vessels* 2020 Jan;35(1):30-7. doi: 10.1007/s00380-019-01459-1

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11. Morgan-Hughes G, Williams MC, Loudon M, et al. Downstream testing after CT coronary angiography: time for a rethink? *Open heart* 2021 Feb;8(1). doi: 10.1136/openhrt-2021-001597

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## Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

| SECTION | ITEM | PRISMA-ScR CHECKLIST ITEM | REPORTED ON PAGE # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a scoping review. | Title page |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives. | Abstract page |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach. | 1-2 |
| Objectives | 4 | Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives. | 2 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number. | 3 |
| Eligibility criteria | 6 | Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale. | 3-4 |
| Information sources* | 7 | Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed. | 3 |
| Search | 8 | Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated. | Supplementary file 1 |
| Selection of sources of evidence† | 9 | State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review. | 3 |
| Data charting process‡ | 10 | Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators. | 3 |
| Data items | 11 | List and define all variables for which data were sought and any assumptions and simplifications made. | 4 |
| Critical appraisal of individual | 12 | If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe | - |

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| SECTION | ITEM | PRISMA-ScR CHECKLIST ITEM | REPORTED ON PAGE # |
|---|---|---|---|
| sources of evidence§ | | the methods used and how this information was used in any data synthesis (if appropriate). | |
| Synthesis of results | 13 | Describe the methods of handling and summarizing the data that were charted. | 4 |
| **RESULTS** | | | |
| Selection of sources of evidence | 14 | Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram. | 6, Supplementary file 2 |
| Characteristics of sources of evidence | 15 | For each source of evidence, present characteristics for which data were charted and provide the citations. | 6, Supplementary file 3 |
| Critical appraisal within sources of evidence | 16 | If done, present data on critical appraisal of included sources of evidence (see item 12). | - |
| Results of individual sources of evidence | 17 | For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives. | 9-10 (Table 1), Supplementary file 4 |
| Synthesis of results | 18 | Summarize and/or present the charting results as they relate to the review questions and objectives. | 7-8, 11-13 |
| **DISCUSSION** | | | |
| Summary of evidence | 19 | Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups. | 14 |
| Limitations | 20 | Discuss the limitations of the scoping review process. | 18-19 |
| Conclusions | 21 | Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps. | 20 |
| **FUNDING** | | | |
| Funding | 22 | Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review. | 21 |

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

*From:* Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

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