

Oral glucose tolerance test and HbA_{1c} for diagnosis of diabetes in patients undergoing coronary angiography the Silent Diabetes Study

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Abstract

Aims/hypothesis The primary aim of this study was to compare the results of HbA_{1c} measurements with those of an OGTT for early diagnosis of ‘silent diabetes’ in patients with coronary artery disease (CAD) undergoing angiography without prediagnosed diabetes. A secondary aim was to investigate the correlation between the extent of CAD and the glycaemic status of the patient.

Methods Data from 1,015 patients admitted for acute ($n=149$) or elective ($n=866$) coronary angiography were analysed. Patients with known diabetes were excluded from the study. Using the OGTT results, patients were classified as having normal glucose tolerance (NGT), impaired fasting glucose (IFG), impaired glucose tolerance (IGT) or diabetes. Accord-

ing to the results of the HbA_{1c} measurements, patients were classified into three groups: normal (HbA_{1c} <5.7% [<39 mmol/mol]), borderline (HbA_{1c} 5.7–6.4% [39 – 47 mmol/mol]) and diabetes (HbA_{1c} \geq 6.5% [≥ 48 mmol/mol]). **Results** Based on the OGTT, 513 patients (51%) were classified with NGT, 10 (1%) with IFG, 349 (34%) with IGT and 149 (14%) were diagnosed with diabetes. According to HbA_{1c} measurements, 588 patients (58%) were classified as normal, 385 (38%) as borderline and 42 (4%) were diagnosed with diabetes. The proportion of patients with IGT and diabetes increased with the extent of CAD (IGT $\rho=0.14$, $p<0.001$, diabetes $\rho=0.09$, $p=0.01$). No differences in HbA_{1c} were seen among the groups with different extents of CAD ($p=0.652$).

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Conclusions/interpretation An OGTT should be performed routinely for diagnosis of diabetes in patients with CAD undergoing coronary angiography, since HbA_{1c} measurement alone appears to miss a substantial proportion of patients with silent diabetes. A limitation of the study is that the OGTT was not performed before the angiography.

Keywords Coronary angiography · Coronary artery disease · Diabetes · HbA_{1c} · Oral glucose tolerance testing

Abbreviations

CAD	Coronary artery disease
FPG	Fasting plasma glucose
IFG	Impaired fasting glucose
IGR	Impaired glucose regulation
IGT	Impaired glucose tolerance
NGT	Normal glucose tolerance
ROC	Receiver operating characteristic

Introduction

In recent years, a number of studies have reported on the high prevalence of undiagnosed diabetes and impaired glucose regulation (IGR) in patients with cardiovascular disease (up to 33% and 40%, respectively) [1–7]. The importance of detecting ‘silent diabetes’ in these individuals is highlighted by the adverse prognostic implications for this population [5]. It is well known that diabetes is associated with a worse prognosis for cardiovascular patients compared with normoglycaemic patients [8], ranking alongside hypertension, smoking and dyslipidaemia in terms of risk of poor outcome [9]. More specifically, in patients with coronary artery disease (CAD), the Euro Heart Survey reported that the 1 year mortality rate of patients with newly diagnosed diabetes was 5.5%, compared with 7.7% for patients with previously diagnosed diabetes and 2.2% for patients with normal glucose tolerance (NGT) [10].

The results of the Euro Heart Survey were based on the performance of an OGTT and demonstrated that IGR and diabetes are commonly undiagnosed in patients with CAD. Abnormal glucose regulation (IGR and diabetes) was detected in the majority (53%) of patients [4, 11]. Of these, 36% of the patients with acute admissions presented with IGR (impaired fasting glucose [IFG] and/or impaired glucose tolerance [IGT]) and 22% with newly diagnosed diabetes. In the group of patients admitted for elective surgery, the corresponding proportions were 37% and 14% [5]. Similar findings have been reported from the China Heart Survey, in which the OGTT was used to assess the glucometabolic status of CAD patients without a diagnosis

of diabetes [6]. Overall, IGT was present in 37% of patients and diabetes was detected in 27% [6].

In 2008, an International Expert Committee was appointed by the ADA, the EASD and the International Diabetes Federation to review methods of diagnosing diabetes [12]. The committee modified previous recommendations and suggested that measurement of long-term glycaemic exposure, as determined by HbA_{1c} levels, would provide a better diagnostic tool for diabetes than single measures of glucose concentration such as fasting plasma glucose (FPG) and OGTT. The cut-off value of HbA_{1c} $\geq 6.5\%$ (≥ 48 mmol/mol) for diagnosis of diabetes was selected on the basis of the large volume of data indicating a marked increase in the prevalence of moderate retinopathy associated with this HbA_{1c} level [12]. In selecting HbA_{1c} measurement over the traditional measures of FPG and OGTT, the committee highlighted that HbA_{1c} is a more convenient test, with less biological variability and greater stability compared with measures of glucose levels, which are known to fluctuate [12].

The primary aim of our study was to investigate whether the new recommendation for diabetes diagnosis using the HbA_{1c} cut-off $\geq 6.5\%$ (≥ 48 mmol/mol) was suitable for detecting the presence of silent diabetes in patients with known or suspected CAD undergoing coronary angiography, by comparing results with those from the OGTT. The secondary aim was to investigate whether the prevalence of abnormal glucose regulation correlates with the severity of CAD, since up-to-date data on this question are lacking.

Methods

Study population One thousand and fifteen patients consecutively admitted for coronary catheterisation (acute $n=149$; elective $n=866$) to the Praxisklinik Herz und Gefaesse, Dresden, Germany, from June 2007 until June 2009, were included in the study. Inclusion criteria were age ≥ 45 years and suspected CAD. Patients with known diabetes mellitus or a history of taking glucose-lowering agents were excluded from the study. In patients with known diabetes, diagnosis of diabetes had been based on the WHO criteria [13]. Patients with pancreatic, hepatic or kidney disease were also not eligible for the study. Additional exclusion criteria were the presence of endocrine diseases, such as pheochromocytoma, hypercortisolism, thyroid disease, Addison’s disease or Cushing’s disease, glucagonoma or treatment with a steroid medication. All patients provided written informed consent and the study was performed in accordance with the Declaration of Helsinki. Ethical approval was obtained from the local ethics committee (Saechsische Landesaeztekammer, Registration Number EK-BR-36/06-1).

OGTT All patients underwent an OGTT on the day after the coronary angiography. After an overnight fast of at least 10 h, a standard OGTT (75 g glucose in 250 ml water) was performed between 08:00 hours and 10:00 hours, according to WHO recommendations [13]. The diagnosis of diabetes according to the OGTT results was based on the WHO Consulting Group Criteria [13]: venous FPG ≥ 126 mg/dl (7 mmol/l) and/or 2 h post-load plasma glucose after an OGTT ≥ 200 mg/dl (11.1 mmol/l) [13]. IGT was defined as FPG < 126 mg/dl (7.0 mmol/l) and 2 h post-load plasma glucose ≥ 140 mg/dl (7.8 mmol/l) and < 200 mg/dl (11.1 mmol/l) by WHO criteria [13]. IFG was defined using ADA criteria [14] as FPG ≥ 100 mg/dl (5.6 mmol/l) and < 126 mg/dl (7 mmol/l). NGT was defined as FPG < 100 mg/dl (5.6 mmol/l) and 2 h post-load plasma glucose < 140 mg/dl (7.8 mmol/l) by WHO criteria [13].

Laboratory study HbA_{1c} was measured by DCCT-aligned cation-exchange chromatography (PDQ Plus; Trinity Biotech, Ireland) [15]. Diagnosis of diabetes according to HbA_{1c} was made according to the recommendations of the International Expert Committee report on the role of the A1c assay in the diagnosis of diabetes [12], in which a level of HbA_{1c} $\geq 6.5\%$ (≥ 48 mmol/mol) was selected for diagnosis of diabetes [12]. Subsequently, patients were stratified into three groups: HbA_{1c} $< 5.7\%$ (< 39 mmol/mol) (normal), HbA_{1c} 5.7–6.4% (39–47 mmol/mol) (borderline) and HbA_{1c} $\geq 6.5\%$ (≥ 48 mmol/mol) (diabetes).

Plasma glucose was measured by the standard glucose oxidase method using a Super GL ambulance analyser (Dr Müller Geraetebau, Freital, Germany).

Plasma glucose, HbA_{1c}, lipid levels, creatinine kinase, electrolytes, blood count and C-reactive protein were analysed in the central laboratory of the Municipal Hospital, Dresden-Neustadt.

Coronary angiography Coronary angiography was performed by the Judkins method or modified Sones technique with direct puncture of either the brachial or radial artery, at the catheterisation laboratory of the Praxisklinik Herz und Gefaesse, Dresden. CAD was defined according to the results of the coronary angiography as shown in Table 1. Coronary angiography findings were classified by independent visual assessment by two experienced interventional cardiologists and, at the 50% diameter stenosis threshold, by computer-based quantitative coronary angiography as: no angiographic evidence of obstructive CAD, minor CAD with lesions of $< 50\%$ diameter narrowing, single-vessel disease, double-vessel disease or triple-vessel disease [16].

Statistical analysis Continuous variables are reported as mean \pm SD and median. Categorical data are given as numbers (percentage). Percentages relate to all patients

Table 1 Definition of extent of CAD in patients undergoing coronary angiography

Extent of disease	Damage observed on coronary angiogram
No CAD	Normal lumen diameter of any coronary artery
Minor CAD	$< 50\%$ stenosis of any coronary artery
Single-vessel disease	$\geq 50\%$ stenosis of any coronary artery
Double-vessel disease	$\geq 50\%$ stenosis of two different main coronary arteries
Triple-vessel disease	$\geq 50\%$ stenosis of three different main coronary arteries

enrolled if not stated otherwise. Group comparisons were performed using the Kruskal–Wallis test for continuous variables in more than two groups using SPSS program, version 10.0.1 (SPSS, Chicago, IL, USA). The Mann–Whitney *U* test was used for post hoc comparisons with a Bonferroni α -correction. Sensitivity, specificity and Youden's Index were the measurements used to rate the performance of the HbA_{1c} tests [17]. Youden's Index is calculated as follows: sensitivity + specificity – 1. The index ranges from –1 to 1, where the closer the value is to 1, the better the performance of the test. If the index is below 0 the test is not reasonable. The AUC for the receiver operating characteristic (ROC) curve was assessed as a measurement of the accuracy of the test. The discrimination thresholds were varied according to the classification of CAD. The sensitivity and specificity for a binary classifier system (extent of CAD vs HbA_{1c}) was plotted. In the ROC curve, the area ranges from 0 to 1, where 1 indicates the best performance of testing and 0.5 indicates random results.

Results

Data from 1,015 patients (69% male, 31% female) undergoing coronary angiography were analysed. Of these, 149 patients were acutely admitted for a coronary angiography, and in 866 patients an elective coronary angiography was performed. Clinical characteristics of the total patient group are summarised in Table 2.

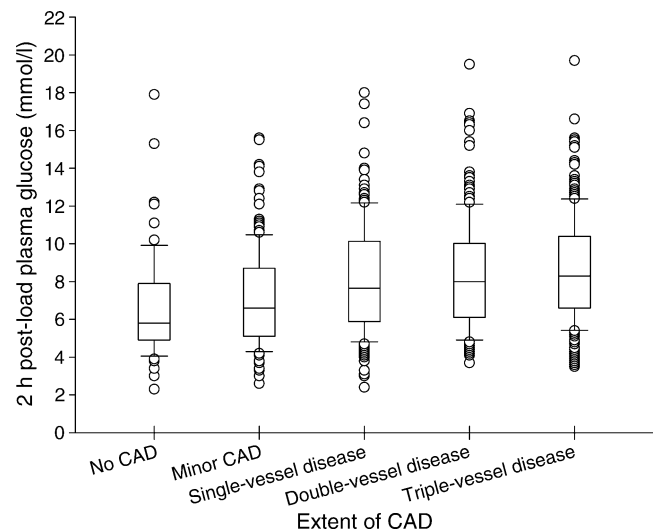
OGTT Overall, 513 patients (51%) were classified as being normoglycaemic based on the results of the OGTT [13]. IFG was detected in 10 patients (1%) and IGT in 349 patients (34%). A diagnosis of diabetes was made in 143 patients (14%). As shown in Table 3, as the severity of CAD increased, there was a decrease in the number of patients classified with NGT ($\rho = 0.18$; $p < 0.001$). Correspondingly, the proportion of patients with IGT and diabetes increased with the extent of CAD (IGT group $\rho = 0.14$, $p <$

Table 2 Clinical characteristics of entire patient population

<i>N</i>	1,015
Age (years)	68.2±9.0 (69)
Female, <i>n</i> (%)	319 (31.4)
Smoker, <i>n</i> (%)	491 (48.4)
BMI (kg/m ²)	27.4±3.9 (27.0)
Diastolic BP (mmHg)	78.6±9.1 (80.0)
Systolic BP (mmHg)	140.9±17.7 (140.0)
Blood glucose	
Fasting OGTT (mmol/l)	4.4±0.8 (4.3)
2 h OGTT (mmol/l)	8.0±2.8 (7.6)
HbA _{1c}	
%	5.6±0.6 (5.6)
mmol/mol	37.7±6.6 (37.7)
Haemoglobin	
mmol/l	8.8±0.8 (8.9)
g/l	142±13 (143)
Leucocytes (×10 ⁹ /l)	6.9±1.8 (6.7)
Thrombocytes (×10 ⁹ /l)	229.0±63.5 (225.0)
Total cholesterol (mmol/l)	5.4±1.3 (5.4)
HDL-cholesterol (mmol/l)	1.3±0.4 (1.2)
LDL-cholesterol (mmol/l)	3.0±1.0 (2.9)
Triacylglycerol (mmol/l)	1.6±0.8 (1.4)
Lipoprotein(a) (μmol/l)	0.3±0.3 (0.1)
Creatinine (μmol/l)	90.1±37.4 (87.0)
Estimated GFR (ml/min)	76.5±19.0 (76.0)
C-reactive protein (nmol/l)	53.3±109 (22.9)
NT-pro-BNP (pg/ml)	505.3±692.9 (231.0)

Data are presented as mean ± SD (median) unless otherwise indicated
NT-pro-BNP, N-terminal fragment of brain natriuretic peptide

0.001, diabetes group $\rho=0.09$; $p=0.01$) (Table 3). It is of note that, of the group of patients with IGT, 25% were detected to have double-vessel disease and 37% presented with triple-vessel disease. The null hypothesis that mean glucose values are equal across the five categories of CAD can be rejected following the Kruskal–Wallis test ($p<0.0001$, Fig. 1). Post hoc pairwise comparisons show differences in mean 2 h post-load plasma glucose between the No CAD group and the

**Fig. 1** Boxplot of 2 h post-load plasma glucose and categories of CAD ($p<0.0001$). Circles represent outliers

groups with single-, double- and triple-vessel disease (p values <0.0001 , respectively). Differences were also seen between the minor CAD group and the groups with single-, double- and triple-vessel disease (p values <0.0001 , respectively). No significant differences were observed between the No CAD and minor CAD groups ($p=0.149$), as well as between the single- and double- ($p=0.536$), the double- and triple- ($p=0.079$), and the single- and triple-vessel groups ($p=0.093$).

In the entire group, the prevalence of newly detected abnormal glucose regulation (IGR) was 49%. Diabetes was detected in 143 patients (14%). Twenty-seven patients (18%) who underwent acute coronary angiography and 116 patients (13%) who underwent elective coronary angiography presented with newly detected diabetes as assessed by an OGTT.

HbA_{1c} In the overall group, 588 patients (58%) had a normal HbA_{1c} level of $<5.7\%$ (<39 mmol/mol), 385 (38%) presented with a borderline HbA_{1c} of $5.7\text{--}6.4\%$ ($39\text{--}47$ mmol/mol), and diabetes (HbA_{1c} $\geq 6.5\%$ [≥ 48 mmol/mol]) was diagnosed in 42 patients (4%). There was no significant correlation between the extent of CAD and glycaemic status of the patients in these three groups

Table 3 Glucometabolic classification according to WHO [13] and ADA [34] criteria and relationship with extent of CAD

Variable	NGT, <i>n</i> (%)	IFG, <i>n</i> (%)	IGT, <i>n</i> (%)	Diabetes, <i>n</i> (%)
Total (<i>n</i> =1,015)	513 (50.5)	10 (1.0)	349 (34.4)	143 (14.1)
No CAD (<i>n</i> =63)	46 (73.0)	1 (1.6)	11 (17.5)	5 (7.9)
Minor CAD (<i>n</i> =183)	116 (63.4)	5 (2.7)	49 (26.8)	13 (7.1)
Single-vessel disease (<i>n</i> =222)	113 (50.9)	1 (0.5)	71 (32.0)	37 (16.7)
Double-vessel disease (<i>n</i> =225)	102 (45.3)	2 (0.9)	87 (38.7)	34 (15.1)
Triple-vessel disease (<i>n</i> =322)	136 (42.2)	1 (0.3)	131 (40.7)	54 (16.8)
ρ	-0.18	-0.67	0.14	0.09
p value (for correlation)	<0.001	0.03	<0.001	0.01

(Table 4). Furthermore, in the two subgroups with acute or elective coronary angiograms, there was no significant correlation between HbA_{1c} and the presence or progression of CAD. An absence of a correlation between the extent of CAD and HbA_{1c} has been observed using additional analyses: for each category of CAD, a ROC curve was plotted and the AUC was measured. Figure 2 demonstrates four calculated ROC curves together with the corresponding AUC. The AUCs range from 0.479 to 0.531 indicating the absence of a relationship. From these results, the need for additional analysis of cut-off points was not seen. The mean HbA_{1c} within each category of CAD was also comparable (Fig. 3). The Kruskal–Wallis test demonstrated no significant differences in mean HbA_{1c} among the groups ($p=0.652$; Fig. 3).

Comparison of OGTT and HbA_{1c} Twenty-three patients (16%) diagnosed with diabetes by OGTT were also diagnosed by the HbA_{1c} measurement. Table 5 gives a breakdown of the rate of detection of diabetes by HbA_{1c} according to the category of vessel disease. Nineteen patients (45%) with an HbA_{1c} $\geq 6.5\%$ (≥ 48 mmol/mol) did not present with diabetes based on an OGTT. With an overall Youden's Index of 0.14, ranging from 0.09 to 0.35 in the severity of CAD, the HbA_{1c} measurement shows a poor performance. This lack of performance is the result of the low sensitivity of HbA_{1c} (15–20%). The specificity of HbA_{1c} was very good, with a range from 95% to 99.5%.

Fasting glucose and the 2 h post-load glucose values demonstrate a low linear relationship with HbA_{1c} ($\rho=0.37$; $p<0.0001$ and $\rho=0.323$; $p<0.0001$).

Discussion

The International Expert Committee, appointed by the ADA, EASD and the International Diabetes Federation has suggested that, because HbA_{1c} measurement captures chronic

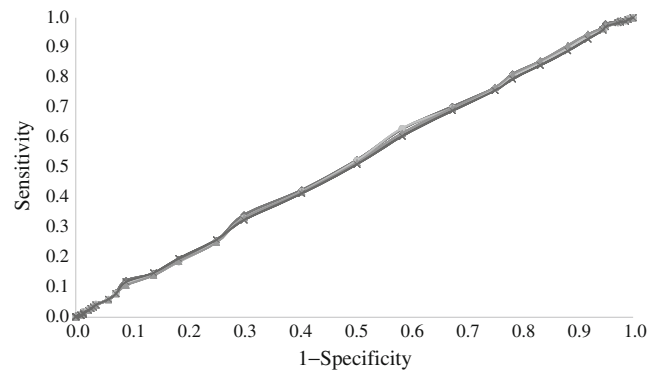


Fig. 2 ROC curve of HbA_{1c} and extent of CAD. Area under the ROC curve: minor CAD 0.531, single-vessel disease 0.479, double-vessel disease 0.498, triple-vessel disease 0.502. Crosses, CAD; triangles, single-vessel disease; circles, double-vessel disease; squares, triple-vessel disease

glucose exposure, it should provide better information about the presence of diabetes than a single measure of glucose; in addition, it is an easier test to perform [12].

Our study, therefore, was designed to compare the outcome of HbA_{1c} measurement with OGTT results in a patient population with CAD that is known to be at high risk for silent diabetes. Our results demonstrate that the OGTT identifies considerably more patients with abnormal glucose regulation undergoing coronary angiography than does the HbA_{1c} measurement using a cut-off point of $\geq 6.5\%$ (≥ 48 mmol/mol).

This differential diagnosis persisted through each category of cardiovascular morbidity. Overall, 143 (14%) of 1,015 patients were found to have previously undiagnosed diabetes when applying the OGTT, 349 (34%) were classified with IGT and 10 (1%) with IFG, representing a total of 49% with abnormal glucose regulation. As in the Euro Heart Survey, more patients were diagnosed with diabetes in the acute admission group (18%) than in the elective admission group (13%). In contrast, using the HbA_{1c}, only 42 of the patients (4%) were diagnosed with diabetes, leaving a considerable number of patients undiagnosed.

Table 4 Glucometabolic classification according to HbA_{1c} and relationship with extent of CAD

Variable	HbA _{1c} <5.7% (<39 mmol/mol), n (%)	HbA _{1c} 5.7–6.4% (39–47 mmol/mol), n (%)	HbA _{1c} $\geq 6.5\%$ (≥ 48 mmol/l), n (%)
Total (n=1,015)	588 (57.9)	385 (37.9)	42 (4.1)
No CAD (n=63)	41 (65.1)	18 (28.6)	4 (6.3)
Minor CAD (n=183)	100 (54.6)	75 (41.0)	8 (4.4)
Single-vessel disease (n=222)	132 (59.5)	82 (36.9)	8 (3.6)
Double-vessel disease (n=225)	130 (57.8)	87 (38.7)	8 (3.6)
Triple-vessel disease (n=322)	185 (57.5)	123 (38.2)	14 (4.3)
ρ	-0.01	0.02	-0.01
p value (for correlation)	NS	NS	NS

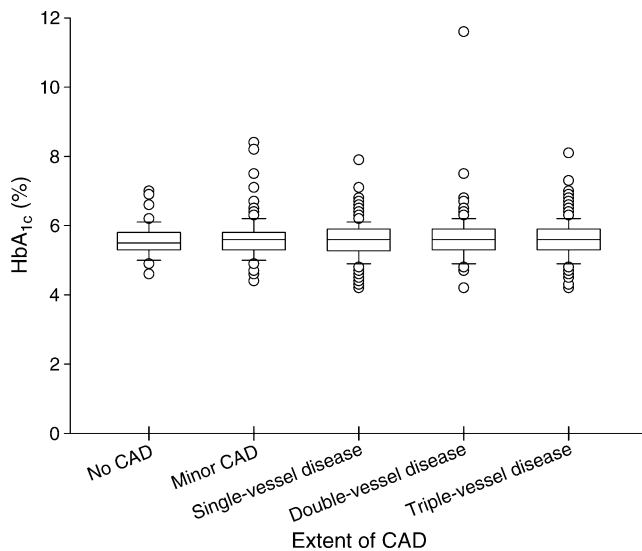


Fig. 3 Boxplot of HbA_{1c} and extent of CAD ($p=0.652$). Circles represent outliers. To convert values for HbA_{1c} in % to mmol/mol, subtract 2.15 and multiply by 10.929

The results of our study are in accordance with the Euro Heart Survey, in which 10% of patients with CAD but without previously known diabetes fulfilled the WHO criteria for diabetes [11]. Studies using the OGTT to identify cases of diabetes in patients with coronary heart disease have reported similar results. In a recent cross-sectional study of 530 patients with suspected or overt coronary heart disease but without previous diagnosis of diabetes, 16% were newly diagnosed with diabetes [7].

Studies investigating the effectiveness of HbA_{1c} measurement as a screening tool for diabetes have reported varying sensitivities and specificities of the HbA_{1c}, depending on the cut-off points and populations investigated [18–21] and the methods used. A study based in six countries with different ethnic groups found a wide variation (17–78%) in the proportion of patients with HbA_{1c} levels $\geq 6.5\%$ (≥ 48 mmol/mol) in participants diagnosed with diabetes by the OGTT [22]. In another study on HbA_{1c} screening in routine clinical practice in Australia [23], two-thirds of all patients with an HbA_{1c} level of 6.1–6.9% (43–52 mmol/

mol) were found to have an abnormal glucose status as identified with an OGTT. The authors concluded that ‘individuals with an A1c of 6.1–6.9% [43–52 mmol/mol] may require an OGTT to confirm their glycemic status’.

Thus the lower rate of detection of diabetes using the HbA_{1c} test in our study coupled with the adverse impact of diabetes and IGR on the prognosis of CAD and myocardial infarction [5, 24–27] suggests that an OGTT, rather than an HbA_{1c} measurement, should be performed to identify those patients with overt or suspected CAD who are at an increased risk because of their metabolic status. This is supported by the observation that the categories of CAD did not all have the same mean 2 h post-load glucose values. The significant difference in mean glucose between the No CAD group and the single-, double- and triple-vessel disease groups may underline this conclusion. It is also noteworthy that fasting and 2 h post-load glucose values were not highly correlated with HbA_{1c} levels.

Our study also showed a significant correlation between the prevalence of abnormal glucose regulation as detected by the OGTT and the extent of CAD. For example, a significant decrease in the number of patients who were categorised with NGT, as the severity of CAD progressed, was observed. The non-significance of the Kruskal–Wallis and AUC test results suggest that HbA_{1c} levels were not different across the five categories of CAD. HbA_{1c} levels $< 5.7\%$ excluded the diagnosis of diabetes with high specificity.

In addition, the OGTT diagnosed diabetes in 17% of patients with triple-vessel disease, compared with 4% using HbA_{1c}, and 40% of patients with triple-vessel disease were diagnosed with IGT using the OGTT. In contrast, there was no significant correlation between patients categorised with borderline hyperglycaemia as detected by HbA_{1c} measurement and the extent of CAD. This is an important finding since differences in glycaemic status, as detected by OGTT, with regard to the extent of vessel disease had not been reported previously. It also shows that the OGTT has an advantage over HbA_{1c} testing as a clinically relevant and important screening tool for abnormalities of glucose metabolism in patients with CAD, in particular given the high risk of development of diabetes in patients with IGT as

Table 5 Rates of detection of diabetes by HbA_{1c} in OGTT-diagnosed patients stratified according to the extent of vessel disease (CAD)

Extent of CAD	Patients diagnosed with diabetes according to OGTT ($n=143$)	Patients diagnosed according to HbA _{1c} $\geq 6.5\%$ ($n=23$)		
		Sensitivity	Specificity	Youden's Index
Overall	143	0.160	0.98	0.14
No CAD	5	0.400	0.95	0.35
Minor CAD	13	0.154	0.97	0.12
Single-vessel disease	37	0.108	0.98	0.09
Double-vessel disease	34	0.206	0.995	0.2
Triple-vessel disease	54	0.148	0.98	0.13

well as the risk for cardiovascular disease associated with this state [28].

In our study, there was no significant increase in the number of patients with IFG as the extent of vessel disease increased. This is in agreement with results from the Diabetes Epidemiology Collaborative analysis Of Diagnostic criteria in Europe (DECODE) study, where IGT was identified as a better predictor of adverse outcomes than IFG alone in patients with cardiovascular disease [29, 30].

It is important to identify patients with IGT and CAD as early as possible in order to prevent or delay the onset of diabetes, for example by lifestyle and pharmacological interventions [31, 32]. In addition, it has been shown that intensifying therapy in patients with manifest diabetes and acute myocardial infarction may reduce mortality [33, 34] and this may also be true for patients with IGT. In this respect, interdisciplinary approaches, such as the guidelines from the EASD and the European Society of Cardiology [35], which recommend using an OGTT for screening for diabetes and IGT in all patients with established cardiovascular disease, appear appropriate in order to identify all patients who would benefit from intervention.

A strength of the present study is that it assesses a real-world clinical cohort undergoing coronary angiography with a broad cross-section of patients, meaning that these results are relevant to current clinical practice. However, a weakness of the study is the heterogeneity of the overall cohort, since the study did not assess patients with a specific single category of vessel disease. In addition, there were relatively small numbers of such patients in some of the subgroups. It will be important to gather details of what follow-up procedures have been initiated in those patients in the group newly diagnosed with diabetes, for example with respect to education programmes and pharmacological treatments, and further investigation of these could form part of a follow-up study. A limitation of the study is that the OGTT was not performed before the angiography. It remains to be speculated whether this might have had an impact on the outcome of the study. Further studies should be carried out in which the OGTT is performed before the angiography. Future studies should also compare OGTT results before and after performing angiography.

Mean haemoglobin and GFR levels were in the normal range and an influence on HbA_{1c} seems unlikely in the majority of patients. The study was designed as a single-centre analysis and multi-centre investigations need to be performed in the future.

The SYNTAX score for scoring the extent of CAD, which was published in 2009 and 2010, was not used because of the earlier design of the study [36, 37].

In conclusion, our results highlight the importance of conducting an OGTT to assess the glycaemic status of patients with CAD undergoing coronary angiography, since

HbA_{1c} testing alone missed a substantial proportion of cases of silent diabetes. In addition, our study found a significant correlation between the extent of vessel disease and the glycaemic status of the patient, as determined by the OGTT. Differences in mean HbA_{1c} in the different categories of CAD could not be shown by statistical analyses. These results indicate that an OGTT should be performed as a routine screening procedure in all patients without previously diagnosed diabetes who are admitted for acute or elective coronary angiography.

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