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CARDIAC

Patient satisfaction with coronary CT angiography, myocardial CT perfusion, myocardial perfusion MRI, SPECT myocardial perfusion imaging and conventional coronary angiography

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Abstract
Objectives To evaluate patient acceptance of noninvasive imaging tests for detection of coronary artery disease (CAD), including single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI), stress perfusion magnetic resonance imaging (MRI), coronary CT angiography (CTA) in combination with CT myocardial stress perfusion (CTP), and conventional coronary angiography (CCA).
Methods Intraindividual comparison of perception of 48 patients from the CORE320 multicentre multinational study who underwent rest and stress SPECT-MPI with a technetium-based tracer, combined CTA and CTP (both with contrast agent, CTP with adenosine), MRI, and CCA. The analysis was performed by using a validated questionnaire.
Results Patients had significantly more concern prior to CCA than before CTA/CTP ($p<0.001$). CTA/CTP was also rated as more comfortable than SPECT-MPI ($p=0.001$). Overall satisfaction with CT was superior to that of MRI ($p=0.007$). More patients preferred CT (46 %; $p<0.001$) as a future diagnostic test. Regarding combined CTA/CTP, CTP was characterised by higher pain levels and an increased frequency of angina pectoris during the examination ($p<0.001$). Subgroup analysis showed a higher degree of pain during SPECT-MPI with adenosine stress compared to physical exercise ($p=0.016$).
Conclusions All noninvasive cardiac imaging tests are well accepted by patients, with CT being the preferred examination.
Key Points
- *A variety of cardiac imaging tests is available without known patient preference*
- *CTA/CTP shows a lower degree of concern than conventional coronary angiography*
- *CTA/CTP shows higher overall satisfaction compared to stress perfusion magnetic resonance imaging*
- *CTA/CTP is rated as more comfortable than SPECT-MPI*
- *CTA/CTP is the preferred cardiac imaging test*

Keywords Coronary artery disease · Multidetector computed tomography · Single-photon emission computed tomography · Stress perfusion magnetic resonance imaging · Patient satisfaction

Abbreviations

bpm	Beats per minute
CAD	Coronary artery disease
CCA	Conventional coronary angiography
MRI	Stress perfusion magnetic resonance imaging
CTA	Coronary computed tomography angiography
CTP	Computed tomography myocardial stress perfusion
FFR	Fractional flow reserve
IV	Intravenous

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PCI	Percutaneous coronary intervention
SPECT-MPI	Single-photon emission computed tomography myocardial perfusion imaging
VAS	Visual analog scale

Introduction

Coronary computed tomography angiography (CTA) noninvasively detects significant coronary stenoses with high sensitivity in patients with a low to intermediate pretest likelihood of coronary artery disease (CAD) [1–3] compared to conventional coronary angiography (CCA) as the reference standard.

The clinical outcome of patients with CAD is mainly determined by the presence of myocardial ischemia, which is often determined by nuclear imaging tests [4]. While there is a positive correlation between the degree of stenosis and reduced myocardial perfusion [5], CCA as an anatomic test does not allow reliable identification of myocardial ischemia [6, 7]. Myocardial ischemia and viability can be detected by both single-photon emission CT myocardial perfusion imaging (SPECT-MPI) and stress perfusion magnetic resonance imaging (MRI) [8, 9]. Compared to SPECT-MPI, CT myocardial stress perfusion (CTP) with adenosine administration shows good correlation in detecting perfusion abnormalities [10–13] and may, on this account, increase the diagnostic accuracy of CTA alone as an additional predictor of the functional relevance of a stenosis diagnosed by CTA [13–17]. Therefore, these four imaging tests, CTA/CTP, SPECT-MPI, MRI, and CCA are complementary.

Besides the diagnostic accuracy of a clinical test, patient acceptance is an important requirement before a test can be implemented in clinical routine. In general, patient-centred care may improve communication, compliance, and finally, clinical outcome of patients [18]. Several studies analysed the acceptance of noninvasive diagnostic imaging tests [19–22]. However, only a few studies addressed cardiac imaging, and those studies found greater patient preference for CT than for CCA for imaging of the coronary arteries [19, 23]. CCA was characterised by higher pain levels [19] and a higher incidence of adverse effects [23] compared to CTA. Studies analysing patient acceptance of CTA compared to coronary MR angiography and CCA [19] found CTA to be experienced as more comfortable in comparison to CCA and coronary MR angiography, while both MR angiography and CTA had lower pain levels than CCA. However, stress MR perfusion imaging and SPECT-MPI were not analysed in these previous studies and no study addressed patient satisfaction with CTP.

The objective of this study was, therefore, to compare intraindividually patient acceptance of four noninvasive imaging-based tests for detection of CAD: CTA/CTP, SPECT-MPI, stress perfusion MRI, and CCA.

Methods

Study design

This is a single-centre ancillary study of a multicentre trial [24–26]. Briefly, the multicentre study included patients who underwent combined CT, including CTA and CTP with administration of adenosine, rest and stress SPECT-MPI with a technetium-based tracer, and CCA for the analysis of the diagnostic accuracy in detecting significant coronary stenoses and myocardial perfusion deficits. In addition to these three tests, the patients in this substudy also underwent cardiac MRI with adenosine stress provocation. Physicians provided oral and written information on each test beforehand, and they informed the patients also about the research nature of the protocol. The examinations were performed within a maximum of 60 days, and CTA/CTP was always performed as the second to last examination before CCA. For the analysis of patient acceptance, the patients were administered a validated questionnaire 24 h after CCA. The study protocol was approved by the local ethics committees; all patients gave written informed consent for the analysis of patient acceptance, and also for the global research including the four tests. The steering committee of the multicentre study approved the analysis plan and manuscript of this ancillary study.

Study population and CT examination

In this single-centre substudy we approached 49 consecutive patients with known or suspected CAD and a clinical indication for CCA for participation in this patient preference study. If the heart rate was higher than 60 beats per minute (bpm), 75 mg of metoprolol (body mass index <30 kg/m^2) or 150 mg of metoprolol (body mass index ≥30 kg/m^2) was administered orally. An IV injection of metoprolol was additionally given in patients with a persistent heart rate above 60 bpm (2.5 – 5.0 mg every 5 min; maximum dose of 15 mg). Rest CTA was performed before CTP using 320-slice CT (Aquilion One, Toshiba Medical Systems, Tokyo, Japan). Nitroglycerin was administered sublingually if systolic blood pressure was >110 mmHg. The total dose of contrast agent (Isovue 370, Bracco Diagnostics, Monroe Township, NJ, USA) was 50 – 70 ml, dependent on the patient's body weight [24]. The IV infusion of adenosine (Adenosin Life Medical, Carinopharm, Elze, Germany, 140 μg/kg/min) for subsequent CTP was performed 20 min after nitroglycerin administration. Four minutes after the beginning of the adenosine administration, the scanner settings were adjusted following the protocol and current heart rate [24], and the scan with contrast agent

administration was initiated at 4:30 min. During adenosine administration, a physician monitored the patient.

SPECT myocardial perfusion imaging

SPECT-MPI was performed as a 1-day protocol or 2-day protocol (Table 1) by using Tc-99 m tracer with a mean dose of 377±202 MBq (rest acquisition) and 285±21 MBq (stress acquisition). Stress was induced pharmacologically in nine patients (60±17 mg adenosine; 0.14 mg/kg body weight/min) and by physical exercise (treadmill) in 40 patients (127 ±35 W; one patient underwent both pharmacological and physical stress). Images were acquired with a gamma camera (GE Sophy or Siemens Symbia R 10). The mean duration of the stress provocation was 469±152 s.

Table 1 Characteristics of the 48 patients who were included in the study and answered the questionnaire completely

Feature		
Age		64.0±19.1 years
Sex	female	17 (35 %)
	male	31 (65 %)
Abdominal circumference		99.5±10.8 cm
Height		172.2±8.3 cm
Weight		81.6±13.1 kg
BMI		27.5±3.8 kg/m^2
Smoker		8 (17 %)
Diabetes mellitus II		11 (23 %)
Hyperlipidaemia		26 (54 %)
Arterial hypertension		35 (73 %)
Myocardial infarction *[1]		8 (17 %)
Interval between SPECT-MPI and CTA/CTP		21.1±13.2 days
Interval between CTA/CTP and CCA		7.9±7.5 days
Interval between CTA/CTP and MRI		0.6±3.0 days
SPECT-Myocardial Perfusion Imaging		
1-day protocol		10 (21 %)
2-day protocol		38 (79 %)
Dose of Tc-99 m tracer	rest	377.4±210.9 MBq
	stress	284.7±20.6 MBq
Pharmacological stress		9 (19 %)
Physical stress		40 (83 %)
Conventional Coronary Angiography		
With FFR		8 (17 %)
Without FFR		40 (83 %)
With PCI		15 (31 %)
Without PCI		33 (69 %)
Approach	femoral artery	44 (92 %)
	radial artery	4 (8 %)

Values are given as arithmetic mean±standard deviation or number of patients (%) *[1] Myocardial infarction dated back more than 48 h Our Patient collective had a male-to-female ratio of 2:1 with a mean age of 64 years. The mean BMI was preobese, and nearly 20 % of the patients had a prior myocardial infarction

Magnetic resonance myocardial perfusion imaging

Each patient underwent MRI at 1.5 Tesla (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany) using a 32-channel dedicated surface breast coil. The patients laid supine and wore ear protection during the procedure. Patients with known claustrophobia did not undergo MRI. If necessary, the patients got blankets for their thermal comfort. Cine steady-state free precession sequences were acquired in the three long and short axes of the heart through the left ventricle. For myocardial stress perfusion, adenosine was administered (140 μg/kg/min over 4:30 min). Myocardial rest perfusion followed afterwards. After contrast agent injection (Magnevist; 0.1 mmol Gd/kg) for both the stress and rest phase, phase-sensitive inversion recovery sequences in the short and long heart axes were acquired for delayed enhancement imaging without additional contrast agent administration.

Conventional coronary angiography

In each case, CCA was performed after CTA/CTP. A transfemoral approach was used in 44 patients (92 %; radial artery approach in four patients; Table 1) by using 223±64 μg nitroglycerin (Lidoject, Hexal AG, Holzkirchen, Germany). Additional measurement of fractional flow reserve (FFR) during CCA with adenosine injection was performed in eight patients (17 %). A mean amount of contrast agent of 138±75 ml, including interventional procedures if necessary, was administered for CCA (Xenetix 350, Villepinte, France). If a vascular closure device (AngioSeal, St. Jude Medical, MN, USA; Starclose und Perclose, Abbott Laboratories, IL, USA) was used, the patients had to lie flat for 4 – 6 h. After manual compression, the bed rest time was 12 h. The pressure tourniquet was removed 2 h after placement of the closure device and 6 h after manual compression.

The questionnaire

The patients were handed the validated acceptance questionnaire (Appendix) 24 h after CCA. The questionnaire asked about patients' subjective perceptions during the four examinations: CTA/CTP, SPECT-MPI, stress perfusion MRI, and CCA. By using an ordinal 5-point scale including the options "very good", "good", "moderate", "poor", and "very poor", the patients evaluated preparation and information, comfort, and overall satisfaction. To assess the degree of concern, the

degree of helplessness, and problems with the stress medication adenosine, the patients could choose from a 5-point scale including "no", "little", "moderate", "intense", and "very intense". Additionally, the patients stated their willingness to undergo the tests again by using an ordinal scale including "no", "yes", and "don't know". The degree of pain was evaluated on a 100-mm unmarked visual analog scale (VAS). For CTA/CTP, the patients were asked to mark in different colours the amount of pain caused by CTA and CTP. Additionally, the patients could choose one of the four examinations as their preferred clinical test for future diagnostic examinations. Using free texts, the patients gave their subjective reasons for their degree of concern as well as advantages and disadvantages of each examination. For the comparison of CTA and CTP, the patients could state the degree of concern and their willingness to undergo the tests again as described above. Additionally, the occurrence of angina pectoris or dyspnoea during CTA and CTP was assessed with an ordinal scale including "yes" and "no".

Statistical analysis

The values are given as mean±standard deviation. First of all, an overall test was done, including the four examinations, SPECT-MPI, CTA/CTP, MRI, and CCA. For the analysis of the degree of pain, the analysis of variance (ANOVA) test for repeated measures was used for the examinations as multiple dependent variables. The Friedman test was used as an overall test for the ordinal and nominal variables preparation and information, comfort, overall satisfaction, degree of concern, degree of helplessness, problems with adenosine, and willingness to undergo the tests again. Only if the overall analyses showed a p-value ≤ 0.05, which was considered statistically significant, the following single tests were performed for each variable. The t-test for dependent variables was used for analysis of the degree of pain. For nominal and ordinal variables, the signs test was used. Preference was evaluated using the chi-square test. A p-value ≤ 0.008 was defined statistically significant after Bonferroni correction because of multiple testing for the following comparisons: SPECT-CT, SPECT-MRI, SPECT-CCA, CT-MRI, CT-CCA, and MRI-CCA. As an additional parameter for overall satisfaction, assessment of the variables preparation and information, concern, comfort, and degree of helplessness was summed. The possible sum ranged from 4 to 20 points, with a lower number of points indicating better assessment. Statistical analysis was performed according to the analysis of ordinal and nominal variables. The subgroup analyses were performed with the chi-square test, the t-test for independent variables, and the Mann-Whitney U test for preference, degree of pain, and ordinal and nominal variables, respectively. Statistical significance was defined for a p-value ≤ 0.05. The statistical analysis was performed using SPSS version 21.

Results

Patient population

Forty-nine patients underwent all four diagnostic tests. The questionnaire was completed by 48 patients (98 % response rate). The one patient who did not answer the questionnaire presented with atypical angina pectoris and had no history of prior myocardial infarction. He underwent no intervention during CCA. The included patients had a mean age of 64 years (64±19.1 years) with a female-to-male ratio of 1:2 (Table 1). Eight patients had a prior myocardial infarction (17 %). CTA/CTP was performed on average 0.6±3.0 days before MRI, and CCA was conducted 7.9±7.5 days after CTA/CTP. PCI during the CCA was indicated in 15 patients, whereas 33 patients received no intervention during the CCA.

Patient acceptance

Preparation and information were rated as good or very good for both SPECT-MPI and CT by 47 patients (98 %), and for both MRI and CCA by 46 patients (96 %). There was no significant difference between the four tests (Table 2). More than half of the patients stated no or little concern before the diagnostic tests. Concern was lower for CTA/CTP as compared to CCA ($p<0.001$). The comparison between CTA/CTP and MRI showed no significant difference. Regarding CT, the degree of concern was higher for CTP compared to CTA ($p<0.001$). Reasons were the possible complications of adenosine during CTP and fear of the results of CTA. More than 90 % of the patients rated the comfort for each clinical examination as very good or good. CTA/CTP was rated as more comfortable than SPECT-MPI ($p=0.001$). Forty-seven patients (98 %), 45 patients (94 %), 40 patients (83 %), and 41 patients (85 %) felt no or little helplessness during SPECT-MPI, CT, MRI, and CCA, respectively. The comparison of the degree of helplessness during the four examinations revealed no significant difference (Table 2). The sum of these four variables showed a significant advantage of CTA/CTP over SPECT-MPI ($p=0.001$), MRI ($p=0.005$), and CCA ($p\leq 0.001$), which is consistent with the trends suggested by the results when each question is analysed separately.

Pain and adverse events

Forty-five patients (94 %) had pain during at least one diagnostic test (Fig. 1). The comparison of the pain between SPECT-MPI, CTA/CTP, MRI, and CCA showed no significant difference ($p=0.182$). For combined CTA/CTP, CTP was characterised by higher pain levels than CTA ($p<0.001$). CTP caused angina pectoris more frequently (n=14) compared to CTA (n=1; $p<0.001$). There was no significant difference of the dyspnoea and combined dyspnoea with angina pectoris

Table 2 Patient acceptance (n=48 patients)

Feature	CTA/CTP	SPECT	MRI	CCA	*p* Friedman	*p* CT-SPECT	*p* CT-MRI	*p* CT-CCA
Preparation and Information	1.3±0.5	1.5±0.5	1.5±0.6	1.6±0.7	0.058			
Degree of Concern	1.7±1.0	2.0±1.0	2.0±1.0	2.5±1.3	0.000	0.019	0.093	0.000
Comfort	1.4±0.5	1.7±0.5	1.7±0.6	1.5±0.5	0.001	0.001	0.012	0.227
Degree of Helplessness	1.5±0.7	1.4±0.5	1.8±0.9	1.6±0.8	0.067			
Sum	5.9±1.9	6.7±1.9	6.9±2.1	7.3±2.4	0.000	0.001	0.005	0.000
Overall Satisfaction	1.5±0.6	1.7±0.6	1.7±0.5	1.5±0.7	0.008	0.049	0.007	0.774

Values are given as arithmetic mean±standard deviation. Patient acceptance for combined coronary CT angiography (CTA) and CT myocardial stress perfusion (CTP), single-photon emission computed tomography myocardial perfusion imaging (SPECT), stress perfusion magnetic resonance imaging (MRI), and conventional coronary angiography (CCA). All features were rated from 1 to 5 points. In addition to overall satisfaction, the sum of preparation and information, degree of concern, comfort, and degree of helplessness was compared (4 – 20 points, 4 points were the best possible assessment). First, an overall analysis was performed using the Friedman test (*p* Friedman). If the *p*-value was ≤0.05, the signs test was used for the single comparisons with a significance level of $p \leq 0.008$ (*see* the Methods section for further details). The degree of concern before CCA was higher than that before CTA/CTP. Comfort during CTA/CTP was higher than during SPECT-MPI. The sum showed an advantage of CTA/CTP over SPECT-MPI, MRI, and CCA. Overall satisfaction with CT was superior to that with MRI. The remaining single tests showed no significance ($p > 0.01$) and are not included in the table

between the CTA and the CTP ($p=0.317$ and $p=0.125$). The problems with adenosine, as reflected by the occurrence of angina pectoris or dyspnoea during SPECT-MPI, CT, MRI, and CCA, were without significant difference ($p=0.118$).

Overall satisfaction and preference

The overall satisfaction with SPECT-MPI, CT, MRI, and CCA was rated as very good or good by 44 (92 %), 46 (96 %), 46 (96 %), and 47 patients (98 %), respectively (Table 2). Overall satisfaction with CTA/CTP was superior to MRI ($p=0.007$). More patients preferred CT ($p<0.001$; Fig. 2) to SPECT-MPI, MRI, and CCA. Respectively, 81 %, 85 %, 67 %, and 67 % of the patients were willing to undergo SPECT-MPI, CT, MRI and CCA again. Comparison between the four tests showed no significant difference. The willingness to undergo CTA again for future diagnostic evaluation was higher than that for CTP (98 % versus 77 %; $p<0.001$).

Open-ended questions

For SPECT-MPI and CTA/CTP, patients named more advantages than disadvantages (Table 3). The most frequent advantage of SPECT-MPI was the noninvasiveness, followed by the short duration of the clinical test, and the absence of hospitalisation. In the patients' view, the limited diagnostic accuracy was the most common disadvantage of SPECT-MPI, followed by the long duration of the diagnostic test. The most frequently listed advantages for CTA/CTP were the noninvasiveness and the diagnostic accuracy of the test. The most frequently mentioned

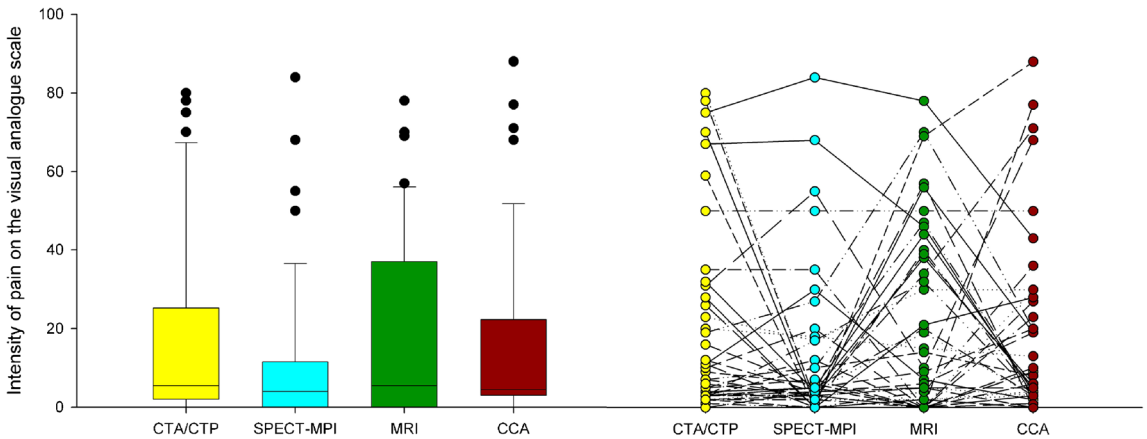

Fig. 1 **a** Boxplot of pain intensity during combined coronary computed tomography angiography and CT myocardial stress perfusion (CTA/CTP), single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI), stress perfusion magnetic resonance imaging (MRI), and conventional coronary angiography (CCA). The repeated measures ANOVA test was used for overall analysis with the different diagnostic tests as multiple dependent variables. The degree of pain showed no significant difference between the four diagnostic tests ($p=0.182$). **b** Intraindividual comparison of the 45 patients who felt pain during at least one examination

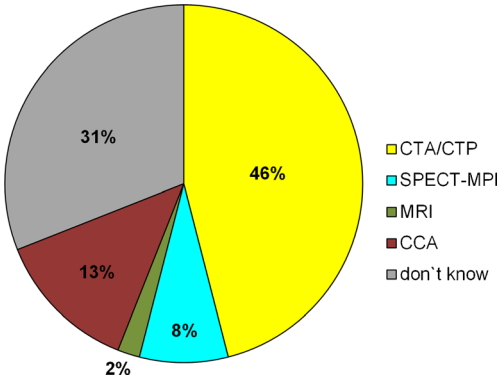

Fig. 2 Patient preference for each diagnostic test. All patients were asked to state which of the four tests they would prefer for future cardiac diagnostic imaging: single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI), stress perfusion magnetic resonance imaging (MRI), combined coronary computed tomography angiography and CT myocardial stress perfusion (CTA/CTP), or conventional coronary angiography (CCA). Nearly half of the patients preferred CT to all three other tests ($p<0.001$ by using chi-square test)

disadvantages were the limited diagnostic accuracy and administration of adenosine. For MRI and CCA, our patients listed more disadvantages than advantages. The additional diagnostic benefit and the noninvasiveness were frequently stated advantages of the MRI. The disadvantages of MRI experienced by our patients were the discomfort caused by slight claustrophobia due to the confined space of the bore and the long duration of the clinical examination. Diagnostic accuracy was the most frequently given advantage of CCA, followed by the short duration. Invasiveness was the most often given disadvantage, followed by the long laying time.

Subgroup analysis

In our patient population, there were 17 women (35 %) and 31 men (65 %). Gender had no significant influence on preference in our patient collective ($p=0.502$). Pain was higher for women during SPECT-MPI and CT than for men ($p=0.026$ and 0.010; Table 4). The occurrence of angina pectoris showed no correlation with problems with adenosine, pain, or helplessness during SPECT-MPI, CT, MRI, and CCA (Table 4). The pain during CCA was slightly higher in patients with percutaneous coronary intervention (PCI) compared to the patients without an intervention, but without a significant

Table 3 Advantages and disadvantages given by the patients for each examination

	CTA/CTP		SPECT-MPI		MRI		CCA	
Advantages	noninvasive	6	noninvasive	4	diagnostic accuracy	5	diagnostic gold standard	10
	diagnostic accuracy	5	no hospitalisation	3	noninvasive	4	short duration	4
	no hospitalisation	3	fast examination	3	fast examination	3	possibility of a therapy	3
	fast examination	3	comfortable	2	no X-rays	2		
	no pain	3	no pain	2	no pain	1		
	comfortable	2	diagnostic value	1				
		22; given by 16 patients		15; given by 11 patients		15; given by 11 patients		17; given by 17 patients
Disadvantages	diagnostic accuracy	2	lower diagnostic accuracy	5	claustrophobia	9	invasive	10
	administration of adenosine	2	long duration	3	long duration	7	long laying time	6
	not comfortable	1	administration of adenosine	1	no therapeutic intervention	1	haematoma	4
	contrast agent	1					pain	3
							hospitalisation	3
							uncomfortable	2
							pressure bandage	1
							contrast agent	1
		6; given by 5 patients		9; given by 7 patients		17; given by 15 patients		30; given by 17 patients

Each patient could give more than one advantage or disadvantage for the clinical examinations: combined coronary computed tomography angiography (CTA) and CT myocardial stress perfusion (CTP), single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI), stress perfusion magnetic resonance imaging (MRI), and conventional coronary angiography (CCA). Values are given as number of indications given by patients. The largest number of advantages was given for CTA/CTP, and the largest number of disadvantages for CCA

Table 4 Subgroup analysis of acceptance of the different diagnostic tests: single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI), stress perfusion magnetic resonance imaging (MRI), combined coronary computed tomography angiography (CTA) and CT myocardial stress perfusion (CTP), and conventional coronary angiography (CCA)

Feature	Male (n=31)	Female (n=17)	*p*
CTA/CTP pain	10.9±18.6	28.9±27.7	0.010
SPECT-MPI pain	6.7±11.1	19.0±26.0	0.026
MRI pain	13.8±17.7	26.4±28.9	0.067
CCA pain	13.3±21.1	20.3±24.0	0.298
	with angina pectoris (n=10)	without angina pectoris (n=38)	
SPECT-MPI problems with adenosine	1.8±0.6	2.2±1.2	0.523
CTA/CTP problems with adenosine	1.7±0.8	2.3±1.0	0.126
MRI problems with adenosine	2.2±1.0	2.3±1.1	0.851
SPECT-MPI pain	4.1±6.1	12.9±20.3	0.187
CTA/CTP pain	17.5±27.9	17.2±22.8	0.975
MRI pain	12.8±23.3	19.7±22.8	0.398
CCA pain	17.7±26.6	15.2±21.2	0.758
SPECT-MPI helplessness	1.3±0.5	1.4±0.6	0.540
CTA/CTP helplessness	1.2±0.6	1.5±0.7	0.169
MRI helplessness	1.4±0.7	1.8±0.9	0.146
CCA helplessness	1.4±0.7	1.7±0.8	0.285
	with PCI (n=15)	without PCI (n=33)	
CCA comfort	1.5±0.6	1.6±0.5	0.387
CCA helplessness	1.7±1.0	1.6±0.7	0.854
CCA pain	24.0±27.6	12.0±18.5	0.082
	known CAD (n=16)	no known CAD (n=32)	
CCA pain	15.1±18.9	16.1±23.9	0.881
CCA comfort	1.6±0.6	1.5±0.5	0.990
CCA preparation	1.4±0.5	1.7±0.8	0.334
CCA overall satisfaction	1.5±0.5	1.6±0.8	0.920
	with FFR (n=8)	without FFR (n=40)	
CCA pain	8.0±10.4	17.3±23.6	0.284
CCA willingness to repeat	1.5±0.9	1.5±0.8	0.787
CCA comfort	1.5±0.5	1.6±0.6	0.881
CCA overall satisfaction	1.5±0.5	1.6±0.7	0.968
	SPECT-MPI adenosine stress (n=8)	physical stress (n=39) *	
SPECT-MPI degree of pain	25.5±28.6	8.4±14.8	0.016

Values are given as arithmetic mean±SD. Subgroup analysis was performed for the groups male versus female (n=31 versus n=17), with and without angina pectoris (n=10 versus n=38), with percutaneous coronary intervention (PCI) versus without PCI (n=15 versus n=33), known coronary artery disease (CAD) versus no known CAD (n=16 versus n=32), with fractional flow reserve (FFR) versus without FFR (n=8 versus n=40), SPECT-MPI with adenosine stress versus physical stress provocation (n=8 versus n=39; * one patient with both adenosine and physical stress provocation is not included in the analysis). Pain was evaluated on a 100-mm unmarked visual analog scale. Preparation and information, comfort, the degree of helplessness, the problems related to stress medication and overall satisfaction were rated from 1 to 5 (*see* the Methods section for further details). The willingness to repeat the examinations was rated as 1="yes", 2="no", or 3="don't know". CTA/CTP and SPECT-MPI were associated with higher degrees of pain for women compared to men. The degree of pain during SPECT-MPI with adenosine stress was higher compared to the use of physical stress

difference. A prior diagnosis of CAD showed no statistical correlation with pain, comfort, preparation, or overall satisfaction for CCA. The pain, the willingness to undergo the examination again, the comfort, and overall satisfaction with CCA were not significantly different between the patients with and without FFR (Table 4). The method of stress provocation during SPECT-MPI showed no relevant influence on comfort, helplessness, and overall satisfaction during SPECT-MPI (p=0.478, p=0.667, p=0.901), whereas the degree of pain during SPECT-MPI was higher with adenosine stress compared to the use of physical stress (p=0.016).

Discussion

Most patients in our study preferred CTA/CTP for future cardiac diagnostic examinations. CT showed a lower degree of concern than CCA and higher overall satisfaction compared to MRI and CTA/CTP was rated as more comfortable than SPECT-MPI. The sum of the variables concern, preparation, comfort, and helplessness showed an advantage of CTA/CTP over SPECT-MPI, MRI, and CCA. Regarding combined CTA/CTP, CTP was characterised by a higher degree of concern and a higher pain score on the VAS than CTA alone.

Interestingly, in our analysis, approximately half of the patients preferred combined CTA/CTP, while only 2 % preferred stress perfusion MRI for future evaluation of the coronary arteries. In contrast, pain, degree of concern, degree of helplessness, and comfort showed no significant differences between CTA/CTP and MRI. Reasons for this discrepancy were identified in the free text analysis; the discomfort and claustrophobia induced by the narrow MR gantry as well as the long duration of the examination were the most common disadvantages of MRI. This is in line with the higher overall satisfaction and sum of preparation, concern, comfort, and helplessness we found for CT in comparison to MRI in our patient collective and may explain the higher preference for CT. Interestingly, CT was also rated as slightly more comfortable than MRI, but without significant difference. Despite the high acceptance of combined CTA/CTP, the patients had a higher degree of pain and more frequently suffered angina pectoris during CTP compared to CTA. Additionally, patients were more concerned about CTP than about CTA. The main cause of concern was adenosine administration during CTP.

Comparison with prior studies

While the noninvasive imaging-based tests for detection of CAD have high diagnostic accuracy and may predict outcomes in patients with CAD, only a few studies compared patient acceptance. In cardiovascular imaging, patient-centred care including patient safety and patient involvement in decision making gains in importance [27]. An intraindividual comparison of 122 patients in the context of a study of Sandgaard et al. [23] showed a higher preference for coronary CT angiography against CCA and a lower presence of adverse effects during CT compared to CCA. A study of Schönenberger et al. compared patient satisfaction with CTA, MR angiography, and CCA. In this study CTA was evaluated as more comfortable than MR angiography and CCA, and the patients preferred CTA as a future method for imaging the coronary arteries. Both CTA and MR angiography were less painful than CCA. While in our study CT was also the preferred clinical examination, there was no significant difference between pain and comfort experienced during CTA/CTP, perfusion MRI, and CCA in our patient collective. A relevant reason for this discrepancy is that no adenosine was used during coronary CT and MR angiography in the study of Schönenberger et al. Mumma et al. showed a lower willingness to undergo CCA for women than for men [20]. In our patient collective, gender had no relevant influence on the acceptance of CCA or preference, although women experienced more severe pain during SPECT-MPI and CTA/CTP than men. In contrast to the study of Mumma et al., our patients underwent CTP and SPECT-MPI with adenosine administration or with physical stress, which could be a reason for the higher pain levels reported by women during the noninvasive tests compared to men. In general, adenosine has a high safety profile and is well tolerated by patients [28].

Limitations

An important limitation is the small number of only 48 patients analysed in our study. Nevertheless, we performed an intraindividual comparison of all four cardiac imaging tests in all 48 patients. For such an analysis, lower patient numbers are sufficient for statistical analysis than in cohort studies where only some of the patients underwent one test and other patients a different test. Patient acceptance may be influenced by the temporal sequence of the tests or by the moment when the test was handed. However, the CCA as a diagnostic test and also as a therapy option is usually performed after a noninvasive test. Thus, the CCA can not only be seen as an independent option. Moreover, the questionnaire could consider which combined examination with CCA would be chosen for the patient. All patients underwent CTP and stress perfusion MRI with adenosine administration, whereas only one fifth of the patients had combined CCA with FFR using adenosine and SPECT-MPI with pharmacologic stress (80 % of the patients had physical stress during SPECT-MPI). While our subgroup analysis showed no influence of the FFR on pain, comfort, overall satisfaction, and willingness to undergo CCA again, FFR could have influenced the acceptance of CCA. In addition, approximately one third of the patients had a PCI during the CCA. The necessity of a PCI might have influenced the patient acceptance. So, patients with PCI mentioned slightly higher pain levels during the CCA as compared to the patients without PCI. Different physicians explained the clinical examinations and obtained informed consent from the patients, which might also have influenced patients' ratings of information and evaluation as well as the degree of concern but reflects clinical routine.

Conclusion

This study shows a higher preference for noninvasive cardiac imaging-based tests compared to CCA, among which CT was the preferred diagnostic test in our patient collective. CT was

experienced to be more comfortable than SPECT-MPI. Additionally, CTA/CTP showed an overall satisfaction superior to that of MRI and a lower degree of concern compared to CCA.

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The study subjects or cohorts have not been previously reported in regards to patient acceptance. The CORE-320 main study publication in regards to diagnostic accuracy has been published recently be Rochitte et al. (Eur Heart J 2014) and this is a single-centre substudy on the intraindividual patient perception of four cardiac imaging tests. Methodology: prospective, non-randomised controlled trial / intraindividual comparison, performed at one institution.

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