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Determining optimal threshold for lumen stenosis in coronary CT angiography to select patients for heart catheterization: a single-centre retrospective analysis

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Abstract. *Aim:* Due to high costs and invasiveness (resulting in discomfort/complications) coronary computed tomography angiography (CCTA) has become a clinically useful and relevant examination technique before cardiac catheterization. We aimed to retrospectively compare the utility of incorporating the CCTA data at the East-Slovak Institute of Cardiovascular Diseases into coronary interventions by direct comparison with data obtained following invasive coronary angiography (ICA) focusing on four coronary arteries (LM – left main stem, LDA – left anterior descending artery, CX – circumflex artery and RCA – right coronary artery).

Methods: The study was conducted on 394 patients (153 women and 241 men) within the period 2018-2020 that underwent both CCTA and ICA examinations. Heart coronary arteries were evaluated for the presence or absence of significant stenosis by comparing positive outcomes based on three levels of lumen reduction, i.e. ≥50%, ≥60% and ≥70%.

Results: We recorded overall sensitivity at 95.42%, 92.31% and 80.00% as well as specificity at 30.71%, 49.58% and 75.82%, corresponding to the three significant stenosis thresholds. Accordingly, the overall negative predicting values were recorded at 93.36%, 90.77% and 86.05%.

Conclusion: In summary, CCTA may be found useful in detecting significant coronary stenosis selecting patients for subsequent invasive procedure based on significant stenosis. We conclude that lumen reduction of ≥60% presents a fine balance between negative predicting value and sensitivity/specificity in the environment of our centre. Fig. 4, Tab. 4, Ref. 11, on-line full text (Free, PDF) www.cardiologyletters.sk

Key words: coronary artery disease – coronary stenosis – CT imaging

Non-invasive coronary computed tomography angiography (CCTA) detects significant (≥50%) lumen reduction associated with coronary artery disease (CAD) (1). In particular the excellent sensitivity and high negative predictive value (NPV) of ≥95% highlight the diagnostic technique since its introduction into clinical practice two

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decades ago (2). Of note, clinical limitation of CCTA is related to the presence of extensive coronary calcification, which may lead to false-positive findings: thus current guidelines consider CCTA inappropriate in a high-risk population (3). On the other hand, patients with low and/or moderate pre-test probability of obstructive CAD, may significantly benefit from CCTA. Those patients benefit from high sensitivity with negative predictive value approaching almost 100%. In addition to revealing luminal stenoses CCTA is able to determine the character of non-stenotic coronary atherosclerotic plaques. In particular the introduction of novel technologies such as "dual source CT" (DSCT) and scanners with 256 and 320 detectors provided significant improvment in image quality (better temporal resolution and ability to scan at higher heart rates).

In the present study we retrospectively evaluated the utility of incorporating the CCTA data into coronary interventions. The degree of stenosis is, however, often overestimated which impairs specificity (4). Therefore, we compared the level of stenosis measured from CT images (setting three levels of lumen reduction ≥50%, ≥60% and ≥70%) with that obtained following invasive coronary angiography (ICA) focusing on coronary arteries (LM – left main stem, LDA – left anterior descending artery, CX – circumflex artery and RCA – right coronary artery).

Methods

We retrospectively analyzed 394 patients (**Table 1**) with varying degrees of coronary artery disease that underwent CCTA followed by ICA at the East-Slovak Institute of Cardiovascular Diseases, Inc. in 2018-2021.

CCTA

Our institute has the latest CT Somatom Force device (Siemens Healthineers). This is a 3rd generation dual source CT. The critical features of this CT device for successful performance of CCTA scan are:

- Scan parameters: 2 x 96 x 0.6-mm collimation resulting in a 105-mm z-axis coverage by shuttle mode,
- Rotation time: up to 250 ms,
- Temporal resolution: up to 66 ms,
- Spatial resolution: 0.24 mm,
- Tube voltage: 70-80 kV, automated exposure control (300 mAs/rotation at 80 kV as reference),
- 3.0-mm-thick slices reconstructed with 2.0-mm overlap.
- Maximum speed: 73 cm/s with Turbo Flash.

All subjects were asked to refrain from caffeine-containing drinks for 12 h and nicotine for 3 h prior to the scan. The cardiac rhythm was continuously monitored, and the blood pressure was measured at regular intervals.

Patients were positioned supine, with both arms above the head. The standard contrast injection protocol was a 50-100 mL iopromide (Ultravist, Bayer, 370 mg/mL), followed by 40 mL saline.

All CT scans were examined by two experienced radiologists in a blinded fashion to the clinical history of patients. Coronary stenoses were classified based on the CAD-RADS (Coronary Artery Disease Reporting and Data System) system (5). Coronary lesions were assigned a degree of stenosis by measuring the degree of lumen diameter reduction. Accordingly the lesion degree was expressed as the percentage of the minimum diameter of the lesion to the diameter of a normal segment located proximal or distal from the lesion. Stenosis was measured using the view and the image where the lesion was most severe.

ICA

Cardiac catheterization and contrast enhanced X-ray coronary angiography were performed according to the standard techniques. The angiograms were evaluated by two cardiologists without knowledge of the CCTA findings. Percentage of diameter stenosis was measured in projections showing highest lesion severity. Coronary arteries were either classified as significantly obstructed (diameter reduction ≥70%) or as normal/not significantly obstructed.

Table 1 Patient demographic data with relevant medical history

Population	
No. of patients	394 (F[1]-153 / M[2]-241)
Age	66.10±9.77 (F-69.33±8.45 / M-64.05±10.01)
History	
Myocardial infarction	6.35% (F-4.58% / M-7.47%)
PTCA[3] with stent	33.76% (F-32.06% / M-34.85%)
Cardiovascular risk factors	
DM[4]	30.71% (F-30.07% / M-31.12%)
DLP[5]	74.87% (F-75.16% / M-74.69%)
HT[6]	89.85% (F-91.50% / M-88.80%)
S[7]	32.99% (F-19.61% / M-41.49%)

[1]F – female; [2]M – male; [3]PTCA – percutaneous transluminal coronary angioplasty; [4]DM – diabetes mellitus; [5]DLP – dyslipidemia; [6]HT – hypertension; [7]S – smoker

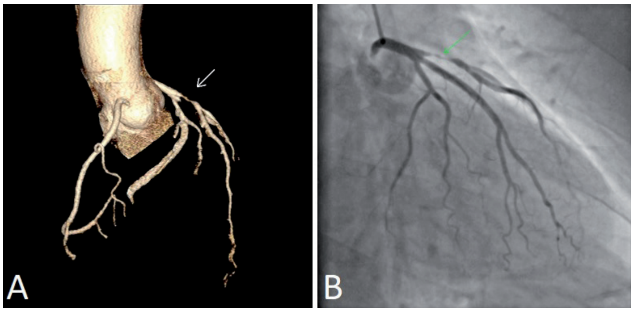


Figure 1 CT image (A) of representative patient with LDA 90% stenosis (arrow) subsequently indicated for PTCA (percutaneous transluminal coronary angioplasty) (B)

Statistical analysis

Statistical analysis was conducted with the MedCalc Version 12.5.00 (MedCalc Software Ltd., Ostend, Belgium) software. Percentages of coronary stenoses were expressed as mean ± SD and compared (between CCTA and ICA) with the unpaired t-test. For correlation analysis, the Spearman's rho coefficient was calculated. Statistical significance was considered to be present once p-values were lower than 0.05. Finally, three levels (≥50%, ≥60% and ≥70%) of significant stenosis were compared to calculate sensitivity, specificity and negative predicting value (NPV) of the CCTA examination. Data were expressed in percentages (%).

Results

A reliable CCTA examination could be performed in all 394 patients. A representative image of the patient examined by CCTA and subsequently indicated for PTCA is shown in **Figure 1**. CT results were compared in a blinded manner with those obtained from ICA. The radiologic examination revealed significant stenosis in 146 (level ≥50%), 144 (level ≥60%) and 120 (level ≥70%) patients. Based on direct comparison 7, 12 and

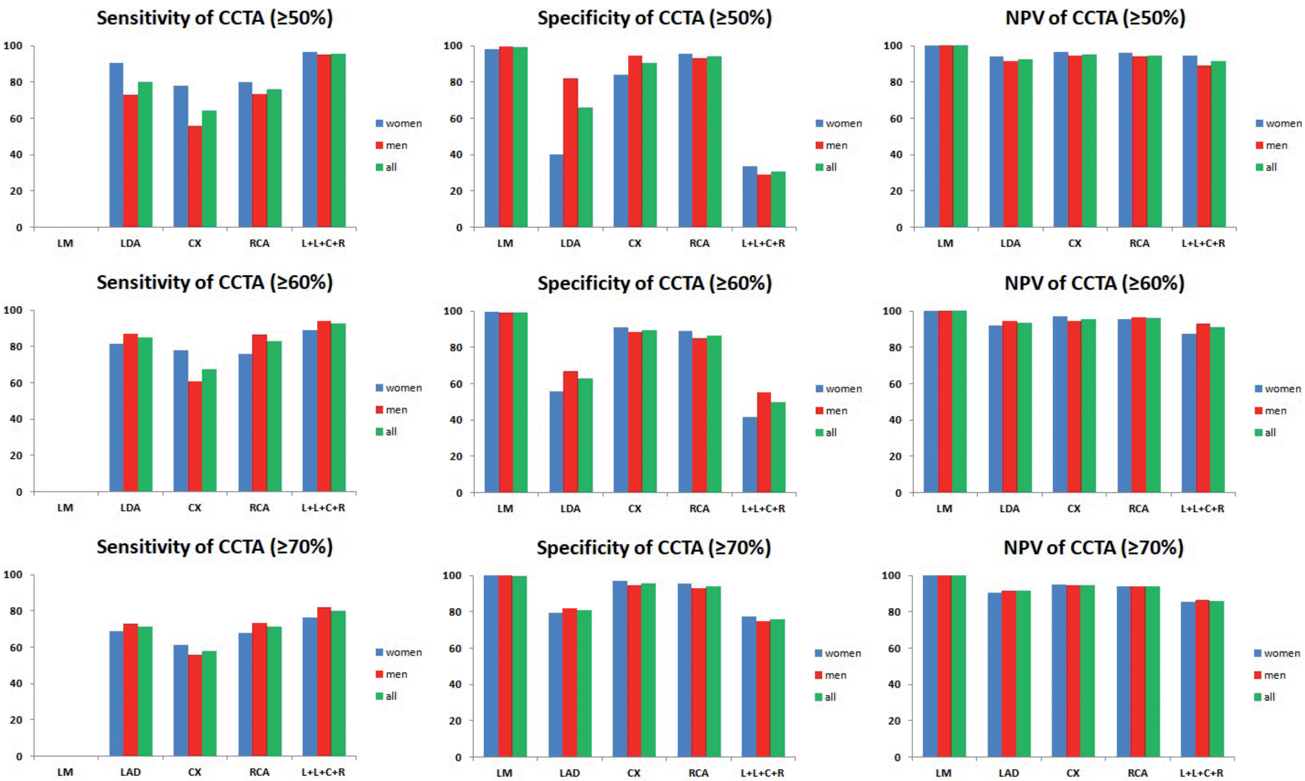
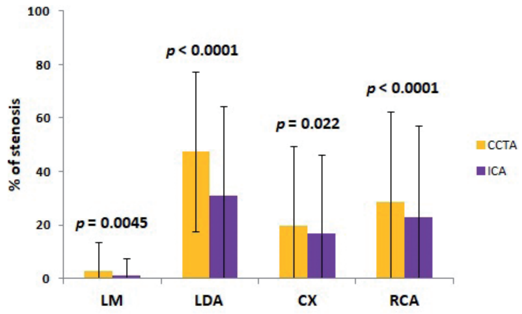


Figure 2 Sensitivity, specificity and negative predicting value (NPV) of coronary computed tomography angiography (CCTA) examination
LM – left main stem, LDA – left anterior descending artery, CX – circumflex artery and RCA – right coronary artery; L+L+C+R – LM+LDA+CX+RCA; data are expressed in percentages



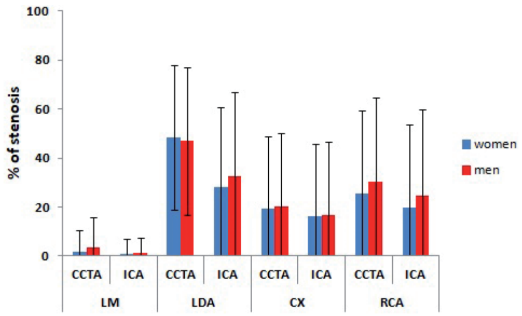


Figure 3 Comparison of the stenosis extent between coronary computed tomography angiography (CCTA) and invasive coronary angiography (ICA) examinations
LM – left main stem, LDA – left anterior descending artery, CX – circumflex artery and RCA – right coronary artery; data are expressed in percentages as mean ± SD

30 patients were assessed as false negative. Accordingly the overall negative predicting values were recorded at 93.36%, 90.77% and 86.06%. Overall sensitivities of CCTA for the detection of significant stenosis were 95.42%, 92.31% and 80.00% and overall specificities were 30.71%, 49.58% and 75.82% corresponding to the three significant stenosis levels ≥50%, ≥60% and ≥70%, respectively. For detailed analysis of patients evaluated at the significant stenosis levels ≥50%, ≥60% and ≥70%, please see **Table 2**, **Table 3** and **Table 4**, respectively. Summary of the analysis is also shown in **Figure 2**.

As the next step, we also directly compared the extents of stenosis examined with CCTA and ICA (**Figure 3**). In detail, the statistical comparison revealed significantly overestimated CCTA values when compared with ICA, while the comparison between women and men found no remarkable differences.

The correlation analysis is shown in **Figure 4**. We found significant positive correlation between CCTA and ICA examinations for each examined coronary arteries except for LM in women.

Discussion

The CCTA examination conducted on the latest SOMATOM Force CT scanner recorded significant co-

Table 2 Sensitivity, specificity and NPV of CCTA in examined patients. The threshold for significant stenosis was set at ≥50%

Sensitivity (%)	LM[3]	LDA[4]	CX[5]	RCA[6]	L+L+C+R[7]
Women	0.00	90.63	77.78	80.00	96.30
Men	0.00	73.08	55.56	73.33	94.95
All	0.00	79.76	64.44	75.71	95.42
Specificity (%)	**LM[3]**	**LDA[4]**	**CX[5]**	**RCA[6]**	**L+L+C+R[7]**
Women	98.04	40.00	83.70	95.31	33.33
Men	99.59	82.01	94.39	92.86	28.87
All	98.98	65.70	90.26	93.83	30.71
NPV[1] (%)	**LM[3]**	**LDA[4]**	**CX[5]**	**RCA[6]**	**L+L+C+R[7]**
Women	100.00	94.12	96.58	96.06	94.29
Men	100.00	91.72	94.39	93.81	89.13
All	100.00	92.27	95.17	94.70	91.36

[1]NPV – negative predicting value; [2]CCTA – coronary computed tomography angiography; [3]LM – left main stem; [4]LDA – left anterior descending artery; [5]CX – circumflex artery; [6]RCA – right coronary artery; [7]L+L+C+R – LM+LDA+CX+RCA

Table 3 Sensitivity, specificity and NPV of CCTA in examined patients. The threshold for significant stenosis was set at ≥60%

Sensitivity (%)	LM[3]	LDA[4]	CX[5]	RCA[6]	L+L+C+R[7]
Women	0.00	81.25	77.78	76.00	89.09
Men	0.00	86.79	60.71	86.67	94.06
All	0.00	84.71	67.39	82.86	92.31
Specificity (%)	**LM[3]**	**LDA[4]**	**CX[5]**	**RCA[6]**	**L+L+C+R[7]**
Women	99.35	55.83	91.11	89.05	41.84
Men	99.17	67.02	88.26	84.69	55.00
All	99.24	62.66	89.37	86.49	49.58
NPV (%)	**LM[3]**	**LDA[4]**	**CX[5]**	**RCA[6]**	**L+L+C+R[7]**
Women	100.00	91.78	96.85	95.31	87.23
Men	100.00	94.74	94.47	96.51	92.77
All	100.00	93.69	95.40	96.00	90.77

[1]NPV – negative predicting value; [2]CCTA – coronary computed tomography angiography; [3]LM – left main stem; [4]LDA – left anterior descending artery; [5]CX – circumflex artery; [6]RCA – right coronary artery; [7]L+L+C+R – LM+LDA+CX+RCA

ronary stenosis with the overall sensitivity and negative predicting value over 90%. All patients could be correctly identified rendering the CCTA technique reliable for identifying patients with no significant coronary obstruction. Moreover, most of patients with significant coronary artery disease were correctly diagnosed, and only 7 and 12 coronary lesion were omitted on the CT scan when the level of significant lesion was set at ≥50% and ≥60%, respectively. In addition, we found positive correlation between CCTA and ICA classification for all studied coronary arteries but LM in women (of note, men and all patients correlated well).

Our results were obtained in patients with a wide spectrum of disease manifestation like atypical chest pain, stable or unstable angina, or non-ST-segment elevation, and who had varying degrees of coronary artery disease, ranging from normal coronary angiograms to obstructive disease of one, two or all three coronary vessels. Of note, we did not include patients with ST-segment elevation (acute myocardial infarction) since these patients should undergo acute PCTA, questioning the relevance of CCTA in this group of patients (6). In our study the sensitivity was somewhat lower compared to previously published data (7) because we tended not to overestimate the severity of a lesion on the CT scan, resulting in a lower number of false-positive outcomes but with still acceptable negative predicting value over 90%.

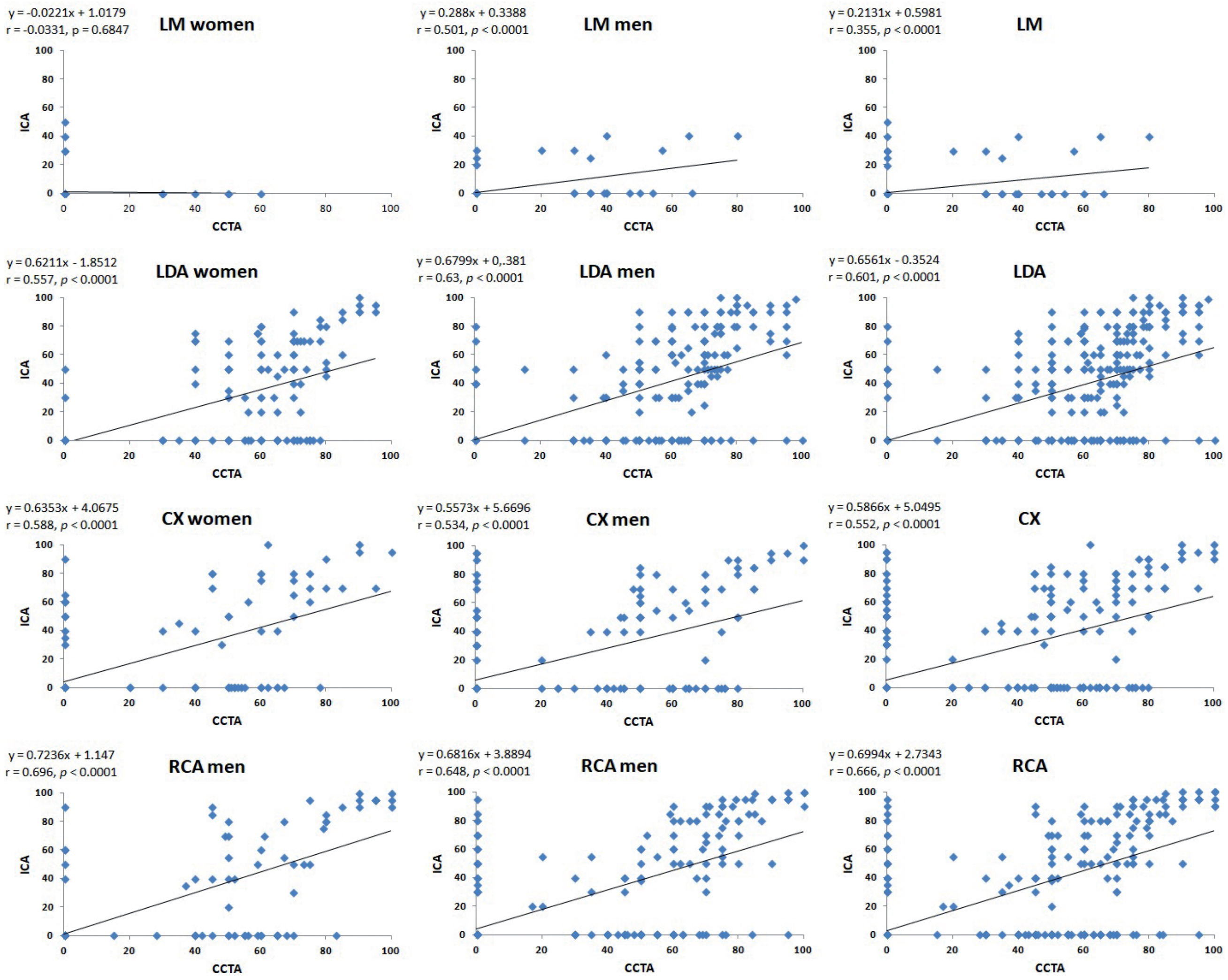


Figure 4 Correlation analysis between coronary computed tomography angiography (CCTA) and invasive coronary angiography (ICA) examinations
LM – left main stem, LDA – left anterior descending artery, CX – circumflex artery and RCA – right coronary artery

Table 4 Sensitivity, specificity and NPV of CCTA in examined patients. The threshold for significant stenosis was set at ≥70%

Sensitivity (%)	LM[3]	LDA[4]	CX[5]	RCA[6]	L+L+C+R[7]
Women	0.00	68.75	61.11	68.00	76.36
Men	0.00	73.08	55.56	73.33	82.11
All	0.00	71.49	57.78	71.43	80.00
Specificity (%)	**LM[3]**	**LDA[4]**	**CX[5]**	**RCA[6]**	**L+L+C+R[7]**
Women	100.00	79.17	97.04	95.31	77.55
Men	99.59	82.01	94.39	92.86	74.66
All	99.75	80.91	95.42	93.83	75.82
NPV	**LM[3]**	**LDA[4]**	**CX[5]**	**RCA[6]**	**L+L+C+R[7]**
Women	100.00	90.48	94.93	93.85	85.39
Men	100.00	91.72	94.39	93.81	86.51
All	100.00	91.24	94.60	93.83	86.05

[1]NPV – negative predicting value; [2]CCTA – coronary computed tomography angiography; [3]LM – left main stem; [4]LDA – left anterior descending artery; [5]CX – circumflex artery; [6]RCA – right coronary artery; [7]L+L+C+R – LM+LDA+CX+RCA

Another important aspect that need to be discussed is the radiation dose of CCTA and ICA. Previously, the radiation dose following CCTA (7.15 ± 3.4 mSv), prevailed over the dose of ICA (5.61 ± 0.55 mSv). However, the mean radiation dose from the new generation CT scanners has been significantly reduced to 2.88 ± 0.85 mSv (8). Further advances in CCTA acquisition resulted also from the development of efficient post-processing techniques with remarkably improved image resolution together with reduced radiation dose enabling a broad use in clinical practice (9). In particular, recent vendor-specific advances have resulted in a dramatic improvement of scanning coverage, spatial, temporal and contrast resolutions (10).

Although our study does not provide entirely novel information, it should be seen as further clinical evidence in a more wider use of CCTA for fast and comfortable patient examination for these with suspected CAD. In particular high negative predicting value and acceptable specificity are able to reduce the pool of patients subjected to ICA. Although our analysis involved almost four hundred patients it is a single-centre study, with several limitations that have to be considered. Firstly, present data are the result of an observational retrospective analysis. We only compared the groups of patients that underwent both CCTA and invasive coronarography at our centre. Based on our retrospective analysis it is also impossible to control other potential interfering factors. Secondly, the coronarography techniques should also be compared in healthy volunteers to exclude/reduce potentially interfering factors which is, however, not possible due to ethical reasons. Nevertheless, present data reflect a realistic single-centre clinical situation where CCTA is daily used to screen patients for CAD.

Conclusions

In summary, CCTA may be found useful to detect significant coronary stenosis selecting patients for subsequent invasive procedure based on significant stenosis. Although, significant lumen reduction subjected to subsequent heart catheterizations is accepted at ≥50%, we found only a slight decrease in the negative predicting value from NPV = 91.36% to NPV = 90.77% between data obtained in ≥50% and ≥60% cohorts, albeit with lower specificity when compared to other centres (11). From this point of view, our centre selects patients with ≥60% lumen reduction for subsequent invasive examination. Therefore, we may conclude that the threshold at ≥60% lumen reduction presents a fine balance between negative predicting value and sensitivity/specificity in the environment of our centre.

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