Dual-Source-CT coronary angiography for predicting success of revascularization in chronic total occlusions

S.D. Reinartz[1], MD, Radiologist;
S. Reith[1], MD, Cardiologist;
R. Koos[1], MD, Professor, Cardiologist;
K.M. Sucigan[1], Technician Working;
C.K. Kuhl[1], MD, Professor, Radiologist;
A.H. Mahnken[2], MD, Professor, Radiologist

[1] University Hospital, RWTH Aachen University,
Pauwelsstrasse 30, 52074 Aachen, Germany;
[2] Department of Diagnostic and Interventional Radiology,
University Hospital, Marburg University,
Biegenstrasse 10, 35032 Marburg, Germany

Возможности компьютерно-томографической коронароангиографии, выполненной на двухэнергетическом компьютерном томографе, в прогнозировании успеха реваскуляризации хронических тотальных окклюзий

S.D. Reinartz[1], MD, Radiologist;
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[1] University Hospital, RWTH Aachen University,
Pauwelsstrasse 30, 52074 Aachen, Germany;
[2] Department of Diagnostic and Interventional Radiology,
University Hospital, Marburg University,
Biegenstrasse 10, 35032 Marburg, Germany

***Objective*.** **25 consecutive patients underwent cardiac CT between November 2009 and September 2012 to evaluate configuration of chronic total occlusion (CTO) of a coronary artery to assess eligibility of percutaneous recanalization.**

***Material and methods*.** **Between 11/2009 and 06/2014 25 consecutive patients underwent DSCT-CA for evaluation of CTO. Technical success and complication rate of revascularization procedures were documented. For image analysis the datasets of 12 parameters were used to calculate CTO-try score. By calibration to the study cohort the AC-CTO-try and simplified CTO-try score were constructed respectively and compared to J-CTO by the area under the ROC-curve.**

***Results*.** **88% of CTOs involved the right coronary artery (RCA) with a mean length of 4.6 ± 2.7 cm. 68% (17/25) were stratified as difficult or very difficult CTO-segments by J-CTO. Based on CTO-try an intervention was recommended in 9/25 patients, while revascularization was attempted in 16/25 (64%) patients with a success rate of 56% (n = 9/16). Negative predictive value for revascularization failure was 75%. By using sCTO-try, discrimination between success and failure of the intervention was measured with an AROC = 0.892.**

***Conclusions*.** **DSCT-CA permits visualization of the occluded vessel segment and provides a tool for assessing the probability**

***Цель* исследования – предсказать успех чрескожной реканализации хронических тотальных окклюзий (ХТО) коронарных артерий (КА) по данным компьютерно-томографической (КТ) коронароангиографии (КАГ), выполненной на двухэнергетическом компьютерном томографе (ДЭКТ) с помощью простой системы подсчета баллов.**

***Материал и методы*.** **Для оценки приемлемости проведения чрескожной реканализации ХТО КА проведен анализ КТ-признаков ХТО у 25 пациентов, которым была выполнена ДЭКТ-КАГ за период с ноября 2009 г. по июнь 2014 г. Технический успех процедуры или ее осложнения были зафиксированы документально. Для подсчета вероятности успеха реваскуляризации ХТО использована шкала оценки, основывающаяся на данных 12 параметров КТ-изображений, полученных при ДЭКТ-КАГ. С помощью бинарной линейной регрессии были рассчитаны так называемая аахенская прогностическая шкала (AC-CTO-try), а также упрощенная прогностическая модель (sCTO-try), которые сравнивались с японской шкалой (J-CTO score) путем подсчета площади под ROC-кривыми.**

***Результаты*.** **В 88% случаев ХТО локализовались в правой КА, средняя протяженность окклюзии составила 4,6 ± 2,7 см. 68% (17/25) были оценены как сложные и очень сложные сегменты по Японской шкале оценки ХТО (J-CTO).**

of revascularization failure based on the CTO-try score. SCTO-try, calibrated to our cohort and expertise, can be used for predicting success of recanalization attempt.

Index terms: coronary arteries; computed tomography angiography; total occlusion.

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For correspondence: Sebastian D. Reinartz; E-mail: Sebastian.D.Reinartz@rwth-aachen.de

Information about authors:

Reinartz S.D., http://orcid.org/0000-0003-1769-4953

Sucigan K.M., http://orcid.org/0000-0002-9771-4637

Mahnken A.H., http://orcid.org/0000-0001-8077-9306

Основываясь на результатах предложенной нами КТ-оценки ХТО, эндоваскулярное вмешательство было рекомендовано 9 пациентам, в то время как реваскуляризация была предпринята в 64% случаев (у 16 из 25 пациентов), при этом доля успеха составила 56% (9/16). Отрицательная предсказательная ценность безуспешности реваскуляризации достигла 75%. Площадь под ROC-кривой при использовании упрощенной прогностической модели (sCTO-try) составила 0,892.

***Заключение.* ДЭКТ-КАГ позволяет визуализировать окклюзированные сегменты КА и предоставляет возможность оценки вероятности безуспешности попытки реваскуляризации КА при ХТО с помощью системы подсчета баллов (CTO-try score). Упрощенная прогностическая модель (sCTO-try), откалиброванная для нашей когорты пациентов, может быть использована для прогнозирования успеха попытки реваскуляризации ХТО КА.**

Ключевые слова: коронарные артерии; компьютерно-томографическая ангиография; тотальная окклюзия.

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Для корреспонденции: Sebastian D. Reinartz; E-mail: Sebastian.D.Reinartz@rwth-aachen.de

Introduction

Chronic total occlusion (CTO) of a coronary artery is a frequent phenomenon with a prevalence ranging between 12% and 20% in patients with ST-elevation myocardial infarction (STEMI) [1]. Approximately 33% of patients undergoing conventional coronary artery angiography (CCA) [2] and about 20% of patients with multivessel coronary artery disease (CAD) [3] suffer from CTO.

CTO is defined having a TIMI (Thrombolysis in myocardial infarction) 0 flow for equal or more than 3 months. According to current consensus statements and guidelines on interventional revascularization [4, 5], two requirements have to be fulfilled prior to any percutaneous or surgical revascularisation procedure.

First duration of occlusion has to be verified as well as ischemia [6] in and/or presence of viable myocardium in the territory of the target vessel is required. Assessment of myocardial viability is of particular importance in patients with impaired left-ventricular (LV) function, as revascularization of the coronary arteries does not improve global or regional LV function in the absence of viable myocardium. However, meta analysis on current available studies identify possible advantages regarding mortality and need of coronary artery bypass graft (CABG) surgery in case of successfully accomplished procedure [7].

Endovascular recanalization of a chronically occluded coronary vessel is technically demanding and expensive procedure with only limited success rate, even if performed in specialized centers. Therefore, it is important to identify patients suitable for endovascular therapy in CTO.

So far, several studies explored parameters for predicting procedural failure by evaluating CTO morphology. In detail, calcification burden is mentioned in most references [8–12], while plaque characteristics is addressed less often [8, 13]. Length of lesion with various cut off values [8, 9, 12, 14, 15], ranging between 1.5 to 2.0 cm is another important parameter. Additionally, some minor parameters of CTO appear in literature like configuration of occluded segments as a blunt stump [12], the existence of side branches proximally or distally [10, 14] and positive vessel remodelling in the area of CTO [8]. Vessel tortuosity in front of and distally to CTO [14] as well as tortuous course of the CTO are parameters, negatively associated with recanalization success. Based on these data, this retrospective study sough to predict procedural success by using the absence of parameters previously identified as predictors of failure in endovascular therapy of CTO.

Materials, Methods and Patients

Patients. 26 consecutive patients underwent cardiac CT between November 2009 and September 2012 to evaluate configuration of CTO of a coronary artery to assess eligibility of percutaneous recanalization. One participant had to be excluded from evaluation, because the definition of CTO was not met (duration of occlusion > 3 month). The remaining 25 Patients, 19 men (76%) and 6 women (24%) had a mean (SD) age of 65.4 ± 10 years (Table 1). As per protocol 0.4 mg glyceryl trinitrate (Nitrolingual®, G. Pohl-Boskamp, Hohenlockstedt, Germany) s.l. was administered 23 patients (92%). 5 (21%) patients required additionally esmolol 30–130 mg i.v. (Brevibloc, Baxter, Deerfield, IL, USA), one patient received metoprolol 5 mg (Beloc i.v.®, AstraZeneca, London, GB).

Table 1

Patients characteristics

Parameters	Entirecohort ($n = 25$)	Male ($n = 19$)	Female ($n = 6$)
Demographics			
age (years)	65.4 ± 10	61.8 ± 8	76.7 ± 5
Examination			
mean heart rate (bpm)	61.3 ± 11	61.1 ± 12	61.8 ± 7
Coronary risk factors			
arterial hypertension	21 (84%)	15 (79%)	6 (100%)
diabetes	7 (28%)	6 (32%)	1 (17%)
hypercholesterolemia	10 (40%)	8 (42%)	2 (33%)
obesity	5 (21%)	3 (16%)	2 (33%)
smoking	13 (54%)	12 (63%)	1 (17%)
family history of CAD	4 (16%)	3 (16%)	1 (17%)
Coronary artery disease			
one vessel	7 (28%)	4 (21%)	3 (50%)
two vessels	9 (36%)	9 (47%)	0 (0%)
three vessels	9 (36%)	6 (32%)	3 (50%)
Cardiac function			
impaired LV-function	10 (40%)	9 (47%)	1 (17%)
symptomatic	19 (76%)	15 (79%)	4 (67%)

The study was approved by the local ethics committee and informed consent was obtained from each patient prior to the examination.

Imaging protocol and dose estimation. 14/25 patients (56%) underwent prospective ECG-triggered dual source CT (DSCT) using adaptive sequence mode. In 11/25 patients (44%) ECG-gating was applied with ECG-dependent tube current modulation, decreasing the nominal tube current-time product to 4% of its nominal value outside the gating window. 21 scans were performed with a first generation DSCT scanner (SOMATOM Definition, Siemens Healthcare Sector, Forchheim, Germany) after institutional replacement of the scanner the remaining 4 ECG-triggered examinations were performed with a second generation DSCT scanner (SOMATOM Definition Flash, Siemens Healthcare Sector, Forchheim, Germany). Because of the scanner replacement, collimation changed from 2×32×0.6 to 2×64×0.6 and gantry rotation time improved from 330 ms to 280 ms, whereas tube current time product and peak tube voltage were kept constant throughout the different scanners.

Effective radiation dose was estimated by multiplying the dose length product (DLP) and the chest's conversion coefficient of 0.014 $mSv \cdot mGy^{-1} \cdot cm^{-1}$[16].

For contrast enhancement iopromide 370 (Ultravist 370, Bayer, Berlin, Germany) was delivered with a biphasic injection protocol, applying 30 ml at 6.0 ml/s in the first phase into an antecubital vein, followed by 70 ml at 5.0 ml/s in the second phase. Thereafter a saline chaser bolus was administered at a flow rate of 5.0 ml/s.

For contrast timing the bolus-tracking technique was applied with the region of interest (ROI) positioned in the ascending aorta. Data acquisition was initiated after 5 sec after a threshold of 140 Hounsfield-Units (HU) was reached in the ROI.

Image Reconstruction. A section thickness of 0.75 mm with a 0.4 mm reconstruction increment was chosen for image reconstruction. The field-of-view (FOV) was set to 180×180 mm^2. Image data was reconstructed applying a filtered back projection technique with a medium to smooth convolution kernel (B26f). In retrospectively ECG gated data the point of least cardiac motion was determined using the Bestphase™ algorithm [18] as well as by using phases of identical chamber filling [19]. For ECG-triggered data the phase of identical chamber filling as identified in a recent ECG recorded up to 72h prior to examination was used as trigger point. Image data was evaluated with a dedicated software tool (Circulation Ver. 11, Siemens) on an external workstation (Leonardo Multimodality Workplace MMWP, Siemens).

Evaluation of CTO. For DSCT-CA two radiologists with eleven and three years experience in cardiac CT assessed in consensus the occluded coronary arteries.

Twelve predictors (Table 2) for failure of recanalization have been extracted from former studies and have been empirically subdivided into major and minor parameters for failure of intervention.

Degree of calcification [8, 9, 12] was weighted as minor parameter in case of little to moderate Calcification burden. Severe calcifications were assumed being major criteria due to literature [8–11]. If calcification appeared in a concentric ring or in a transluminal calcification ⩾ 50% this was denoted as major criteria as well [13]. By observing a calcification cap proximally and distally [20] to CTO, this configuration was weighted as a major criteria.

Regarding minor criteria, remodelling index [8] was calculated by comparing cross sectional vessel diameter proximally to CTO with diameter of CTO itself. Values ⩾ 1.05 were counted positive.

Table 2

Empirically deduced CTO predictors, subdivided in minor and major criteria, with corresponding prevalence and CTO success/failure rate

Criteria	Entirecohort ($n = 25$)	Subgroups		
		Successful recanalization ($n = 9$)	Failed recanalization ($n = 7$)	Not attempted ($n = 9$)
Major criteria				
Concentric calcification	8 (32%)	1 (11%)	1 (14%)	6 (67%)
Severe calcifications	8 (32%)	1 (11%)	1 (14%)	6 (67%)
Bilateral calcification cap	6 (24%)	0 (0%)	0 (0%)	6 (67%)
Minor criteria				
CTO Length > 2 cm	20 (80%)	8 (89%)	3 (43%)	9 (100%)
Side branches distal	15 (60%)	7 (78%)	5 (71%)	3 (33%)
Little to moderate calcification burden	14 (56%)	7 (78%)	4 (57%)	3 (33%)
Bluntstump	13 (52%)	6 (67%)	2 (29%)	5 (56%)
Side branches proximal	12 (48%)	6 (67%)	2 (29%)	4 (44%)
Tortuosity of CTO	6 (24%)	3 (33%)	1 (14%)	2 (22%)
Positive remodeling	5 (20%)	2 (22%)	2 (29%)	1 (11%)
Vessel tortuosity distal	1 (4%)	1 (11%)	0 (0%)	0 (0%)
Vessel tortuosity proximal	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Curved length was measured from ending of antegrade coronary vessel opacification until the beginning of vessel's retrograde filling. Although this parameter was weighted as major predictor for failure in former studies [8, 9, 12, 14] it was assumed being a minor criteria. Reason for this is the mean length of occlusion being much longer than the cut off values in former studies.

Sidebranches [10, 14] proximally or distally to CTO as well as vessel tortuosity [14] proximal to CTO or of CTO segment itself [20], defined as a bending ⩾90°, were classified as minor criteria. Blunt configuration of CTO entry [12] was also classifiedas minor criteria.

Out of these parameters we empirically constructed a model for (not) recommending recanalization attempt, called CTO-try. By rating minor criteria with one point and major criteria with 5 points, CTO-try recommended rejection with values ⩾5. Vice versa, only four minor criteria were allowed for recommending interventional recanalization attempt.

For comparison purposes, J-CTO Score [15] was calculated and analysed, too. This score consists of five dichotomous variables (blunt stump, any calcification, failure of previous recanalization attempt, bending over 45° of CTO segment and length ⩾20 mm). These values were extracted from our data.

Results and complications during interventional procedures were monitored. Major adverse cardiac events (MACE = Death or myocardial infarction) and subsequent measures such as coronary artery bypass (CABG) surgery were also noted.

Follow up was provided by evaluating control CCA after successful CTO recanalization.

Statistical analysis. SPSS 20 (IBM Corporation, NY, USA) was solely used for statistical analyses. Continuous data is expressed as mean ± single standard deviation (SD), categorical variables as counts and percentages. Significant differences in categorical data was analysed using the χ^2-test, while t-test was used for comparing continuous data. Pearson's correlation coefficients were computed for assessing the relation of imaging features on the prediction of failure of recanalization procedures. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of DS-CTCA were computed by fourfold tables to predict success or failure of recanalization. Main-factor analysis was performed for reducing parameters regarding successful recanalization. Binary linear regression was used for calculating Logit L and therefore probability for successful intervention, calibrated to our data. Receiver Operating Characteristic curve analysis was applied for measuring performance of the prediction models. A *P*-value below 0.05 was interpreted as statistically significant.

Results

Cohort analysis and dose estimation. The majority of patients ($n = 18$, 72%) suffered from multivessel CAD, two patients (8%) were previously treated with CABG. One patient (4%) underwent examination while suffering from cardiogenic shock. Female participants ($n = 6$) were significantly older than male patients ($P<0.001$) and had either one or three vessel disease. But, mean heart rate and most of coronary risk factors except arterial hypertension and smoking did not differ between both groups significantly. However, ejection fraction was worse in male patients compared to female patients.

CTO definition was checked in electronic records by doctor's letter, date and results of former examinations (e.g. CCA, MRI etc.) to ensure duration of occlusion ⩾3 month. 8 patients (32%) were reassigned due to failed primary recanalization attempt.

Viability and/ or ischemia were verified by cardiac MRI (84%) and

SPECT (4%) with regard to the territory of CTO vessel. In the remaining cases (12%, $n = 3$), referring physician did not order further evaluation because of either non-interventional treatment or patient's opposition to treatment.

Regarding CT data acquisition technique (triggered vs. gated) no statistically significant difference was revealed for mean heart rate 60 ± 11 bpm vs. 62 ± 11 bpm. In 21 patients (84%) sinus rhythm was present, four patients (16%) suffered from atrial fibrillation.

Effective radiation dose amounted to 6.4 ± 2.1 mSv for ECG-triggering. In case of ECG-gating estimated effective radiation dose was 11.24 ± 5.05 mSv ($P < 0.05$).

CTO assessment by DSCT-CA. All CT scans were completed in the absence of complications and by delivering diagnostic image quality in this symptomatic cohort. A total 25 patients having each at least one CTO segment, were evaluated by DSCT-CA. The majority of CTO involved the right coronary artery (RCA) with 88% ($n = 22$), followed by the left anterior descendent artery (LAD: 12%, $n = 3$) and the left circumflex artery (CX: 4%, $n = 1$). In the latter case the LAD and RCA were also occluded, but the CX was primarily evaluated for revascularization. Therefore, a total of 37 coronary segments were evaluated with a mean length of CTO 4.6 ± 2.7 cm (range 1.3 to 10.6 cm).

22 findings fulfilling major criteria for indicating treatment failure and 86 minor findings were documented during evaluation (table 2). Severe or concentric calcifications (each 32%) were the major predictor most frequently found for treatment failure. Side branches distally to CTO were observed in 60%, and little to moderate calcification in 56% of all cases. A blunt stump and side branches proximally to the CTO were registered in 52% and 48% of patients, respectively. Mean CTO-length was 4.6 cm ± 2.7 in successful attempts and 4.5 cm ± 2.7 in failed or rejected interventions (P = n.s.).

Analysis of percutaneous recanalization attempts during CCA. 16 patients underwent endovascular revascularization, in which 9 vessels were successfully recanalized, generating a success rate of 56%. Regarding the subgroup of 11 patients with multivessel disease, success rate amounted 55%, in patients with single vessel disease it was 60% ($n = 5$). Follow up by CCA was performed in 6 cases with 4 open CTO segments.

Complications occurred in 7 patients ($n = 1$; successful resuscitation) with necessity for extended monitoring ($n = 2$), stent implantation ($n = 2$) or surgery ($n = 2$). Regarding recanalization attempts ($n = 16$), complication rate was 43%: 20% in patients with single vessel ($n = 5$) disease and 45% for patients suffering from multivessel disease ($P < 0.05$). No patient died as consequence of a percutaneous revascularization attempt.

9 patients not undergoing percutaneous treated underwent CABG surgery ($n = 4$), TAVI procedure ($n = 1$), rejected consent ($n = 2$) or conservative therapy was decided ($n = 2$) in sight of clinical circumstances.

Analysis of the Score-systems. A total of 16 (64%) negative recommendations were given by CTO-try, in which 4 (16%) interventions succeeded and 12 (84%) failed or were not attempted.

In 9 cases positive recommendations were given by CTO-try, 5 interventions succeeded whereas 4 procedures failed. Therefore sensitivity for detecting CTO suitability for interventional desobliteration by CTO-try is 55% with specificity of 75%, PPV 55% and NPV 75%, respectively.

Because of the poor capability to predicting success of the planned intervention with an area under the ROC-curve 0.649, a prediction model called AC-CTO-try (AC = Aachen) was calculated by binary linear regression, calibrated to our data. Since the parameter "tortuosity proximal to CTO" was constantly zero, it was excluded from further analysis. By this approach, the area under the ROC-curve was 0.958 (Fig. 1).

For practicability factor analysis was performed, revealing six main factors with Eigenvalues $\geqslant 0.8$. Therefore these parameters (Tortuosity distally to CTO, length > 25 mm, blunt stump, severe calcifications, concentric calcification, non-severe calcifications) were manually chosen from a rotated component matrix, which are highly loaded on these six main factors. This simplified model (sCTO-try) yielded an area under the ROC curve 0.892.

J-CTO score classified 2 (8%) CTOs in the intermediate difficulty group, 6 (24%) patients into the difficult group (J-CTO = 2 points). 17 (68%) patients had three or more points regarding the definition of J-CTO and were therefore stratified into the very difficult group. Performance analysis regarding success of recanalization attempts revealed an area under the ROC-curve of 0.389 for J-CTO in our cohort.

Discussion

Aim of this retrospective study was to predict success or failure of percutaneous recanalization attempts by using an empirically deduced prediction model (CTO-try).

Cohort analysis. In consequence of CTO prevalence with proven viability, only 25 consecutive patients were available for evaluation during a time period of almost three years at our university hospital.

A majority of male patients is observable having more coronary risk factors and impaired ejection fraction. In contrary, the small number of women ($n = 6$) is significantly older. Mean estimated dose in ECG-triggered examinations is comparable to existing studies using tube voltage 120 kVp [22], whereas ECG-gated examinations yield higher doses than documented in literature.

Performance of catheter laboratory. CT coronary angiography

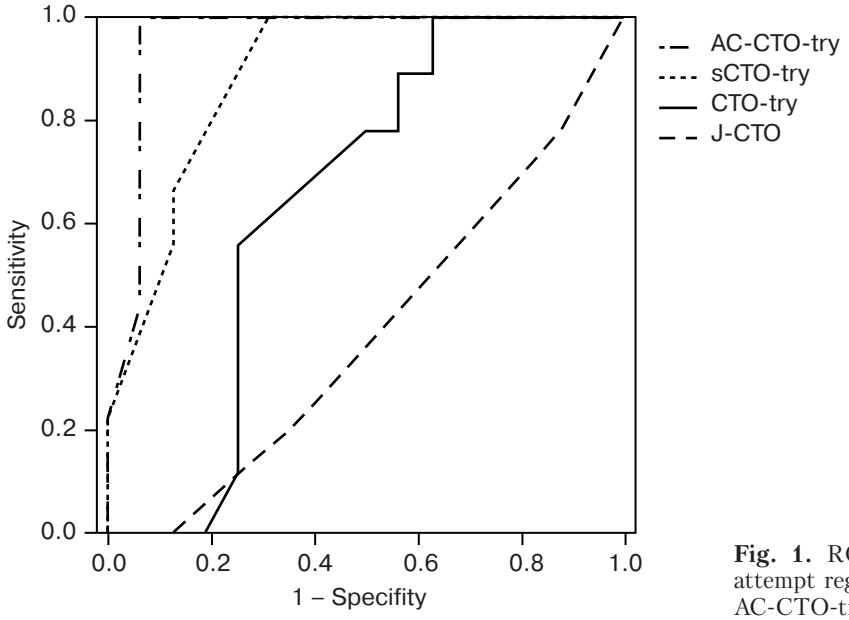

Fig. 1. ROC-curves for successful recanalization attempt regarding CTO-try (0.649), J-CTO (0.389), AC-CTO-try (0.958) and sCTO-try (0.892)

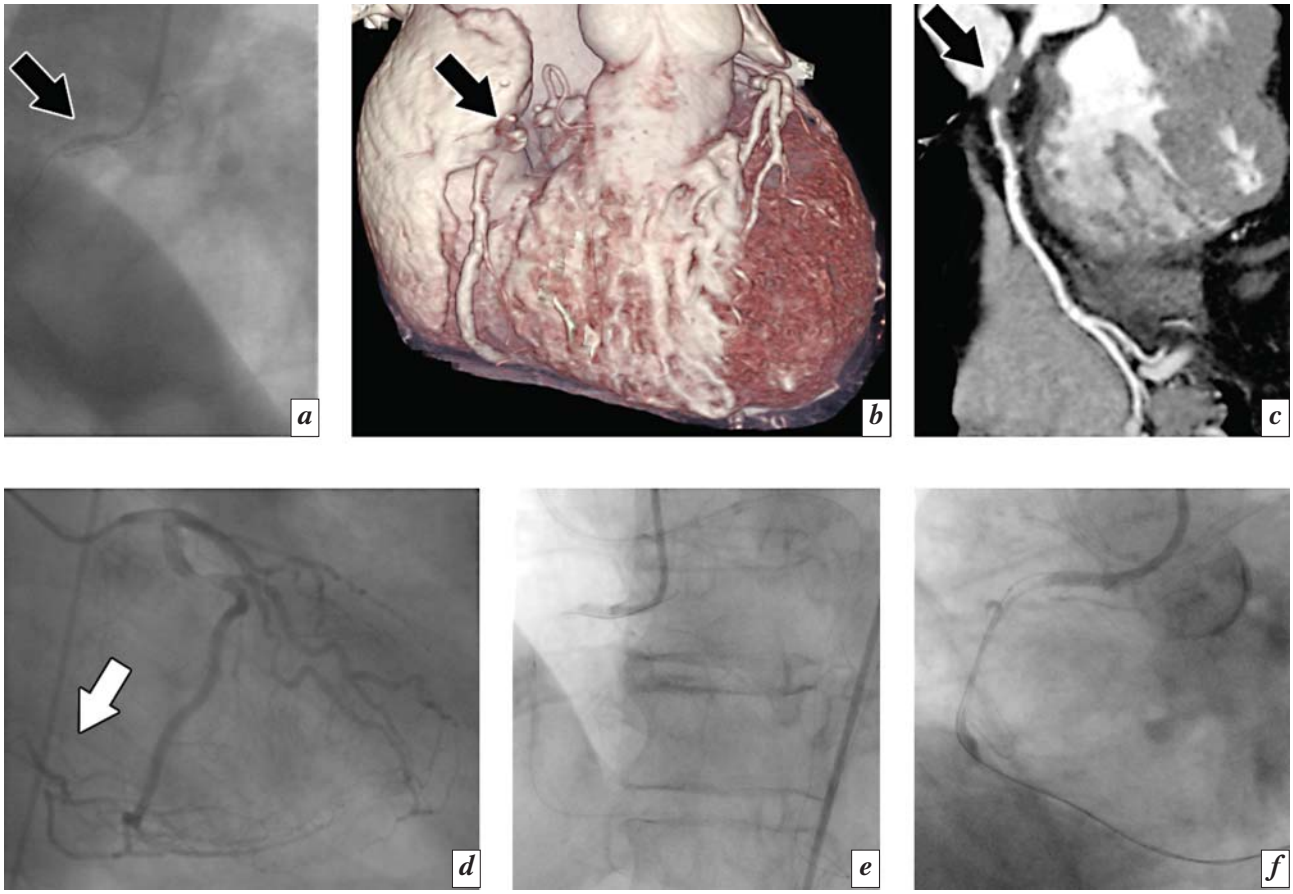

Fig. 2. Example for failure of recanalization: CTO of RCA with a length of 2.0 cm, J-CTO and CTO-try scored 3 points, therefore prediction of success was 49% by CTO-try. In AC-CTO-try probability yielded p = 39%, in sCTO-try p = 37%. Occluded vessel in conventional coronary angiography (*a*), VRT (Volume rendering technique: *b*) and cMPR (*c*: black arrow). During CCA of the LCA collaterals to the occluded RCA (white arrow) became visible (*d*). After failure of antegrade approach, collaterals were used for retrogradely accessing CTO segment. *e* and *f*: incomplete retrograde recanalization which reoccluded during intervention.
Abbreviations: CTO – chronic total occlucion; RCA – right coronary artery; cMPR – curved multiplanar reconstruction; CCA – conventional coronary angiography; LCA – left coronary artery

is proven as a robust tool for assessing coronary arteries in patients with symptomatic CTO, as described previously for symptomatic patients [21]. In line with former results on prevalence, CTO was most frequently observed in the RCA and least common in the CX [6].

Recanalization of a chronically occluded vessel is a technically demanding, time consuming and expensive therapy in interventional cardiology. Success rate in our study is 56%, which is minor compared to current European guideline's recommendations [5], but adequate compared to other catheter laboratories in Germany [23] or the Netherlands [20] and superior when compared to the literature in patients with coronary multivessel disease [24]. Two clinical examples for failure (Fig. 2) and success (Fig. 3) – of recanalization are shown. In Fig. 2 a CTO of RCA with a length of 2.0 cm, is presented in conventional coronary angiography (*a*), VRT (Volume rendering technique: *b*) and cMPR (*c*: black arrow). During CCA of the LCA collaterals to the occluded RCA (*d* – white arrow) became visible. After failure of antegrade approach, collaterals were used for retrogradely accessing CTO segment. Finally CTO reoccluded during this approach an remained incomplete (*e* & *f*). In Fig. 3 CTO of the mid RCA with a length of 4.3 cm is visible in conventional coronary angiography (*a*), VRT (Volume rendering technique: *b*) and cMPR (*c*: black arrow). After antegrade guidewire passing of the CTO segment (*d*), PTA (*e*) and final recanalization result (*f*) of CCA is presented.

Score-Systems. The empirically deduced Score-Model CTO-try yielded a moderate negative predictive value and can therefore be used for refusing recanalization attempts. Furthermore, this score is easily obtainable because calculation is simple.

But positive predictive value is poor with a low discrimination between predicting success or failure of percutaneous revascularisation try (AROC = 0.65). This is inline with the results of the J-CTO score regarding our cohort, which scored even lower with an AROC = 0.389. That means, both scores are not applicable to our cohort for prediction purposes. Therfore we calibrated the CTO-try score to our dataset by using binary logistic regression, constructing the AC-CTO-try score. Following this, discrimination between failure and success is high (AROC 0.96), but calculation complexity increased by using the new weighting coefficients. Consequently, we eliminated unnecessary parameters by performing main-factor analysis. Only parameters with high values on the main factors were admitted to the simpli-

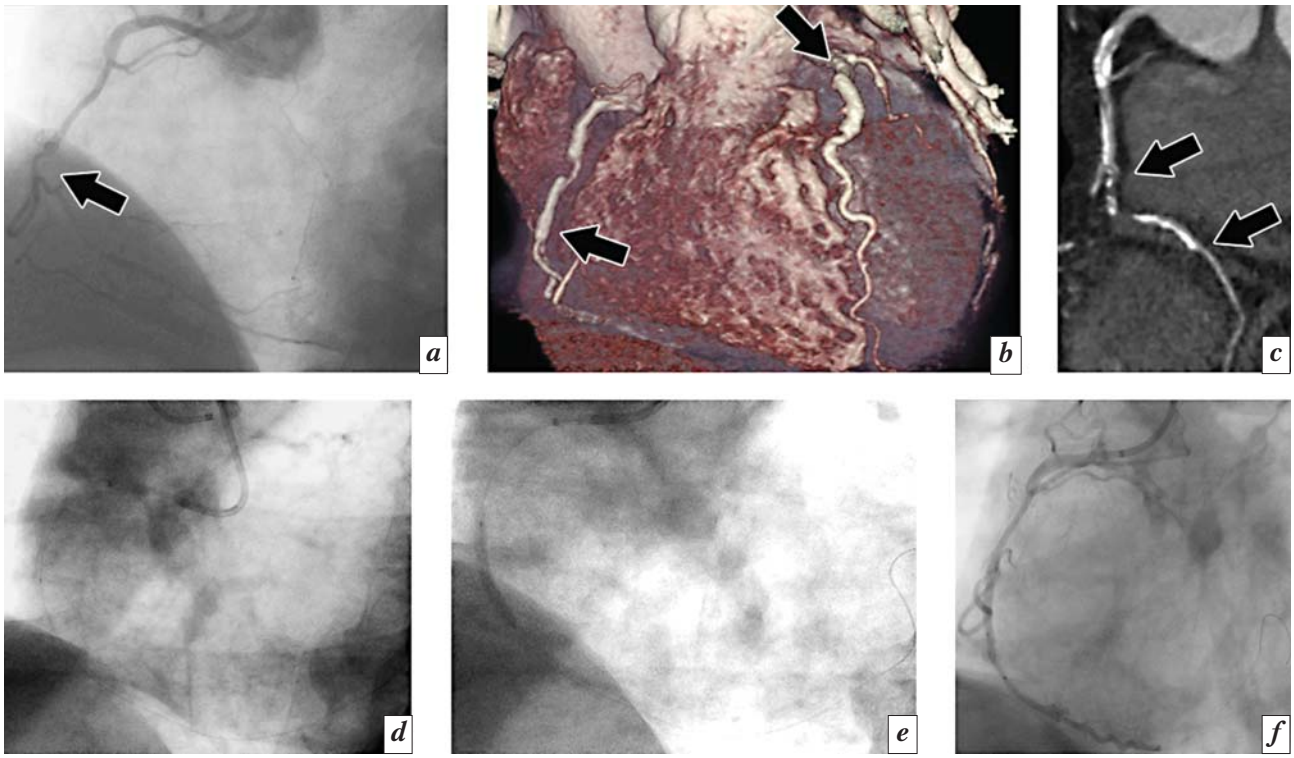

Fig. 3. Example for successful recanalization: CTO of the mid RCA with a length of 4.3 cm, J-CTO score yielded 4 points and CTO-try scored 9 points, therefore prediction of success was 31% by CTO-try. In AC-CTO-try probability yielded p = 100 as well as in sCTO-try. Occluded vessel in conventional coronary angiography (*a*), VRT (*b*) and cMPR (*c*: black arrow). Guidewire has passed CTO segment antegradely (*d*), PCI (*e*) and final result (*f*) of CCA.
Abbreviations: CTO – chronic total occlucion; RCA – right coronary artery; cMPR – curved multiplanar reconstruction; PTA – percutaneous coronary intervention; CCA – conventional coronary angiography

fied CTO-try (sCTO-try). By this concept, a compromise between simplicity and discriminative power (AROC 0.892) was attained. What remains to be done is to validated sCTO-try prospectively.

Limitations. Although, these CTO parameters were thought to indicate non-feasibility of percutaneous revascularization independently to our prediction model other factors might be responsible for treatment failure, e.g. significant stenosis in coronary vessel neighbouring CTO.

Furthermore, the interventionalist's experience and learning curve in CTO revascularization is not part of this analysis, but potentially an explanation, especially since one failure is timed early in this number wise relatively small study.

In this retrospective study design, the interventionalist has not been blinded to the DSCT-CA findings, potentially having caused selection bias.

J-CTO score has been validated for predicting guidewire crossing of CTO segment within 30 minutes, and not specially for assessing success of an intervention. Reasons for this are independence from "operator's skill, experience, judgment, effort and perseverance" [15]. Our study design differed from this, because the clinical endpoint, reopened vessel after procedure, was assumed to be more important than solely achieving an important procedural step in a certain time.

Finally the small number of treated vessels (n=16) and the relatively small cohort with very difficult CTO segments according to J-CTO stratification (68%) hampers evaluation made analysis and interpretation difficult.

Conclusions

CTO-try score is easily obtainable from DSCT-CA and suitable for predicting failure in percutaneous CTO recanalization attempts with moderate accuracy. SCTO-try can be used for predicting success of intervention regarding our cohort and expertise. Yet validation of this calibrated score needs to be performed.

Conflict of interest

The authors declare no conflict of interest.

Ethical Statement

The study was approved by the local ethics committee and informed consent was obtained from each patient prior to the examination.

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