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Impact of right ventricular side branch occlusion during percutaneous coronary intervention of chronic total occlusions on right ventricular function☆

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ABSTRACT

Objective: To determine the impact of right ventricular side branch (RVB) occlusion, during percutaneous coronary interventions (PCIs) of chronic total occlusions (CTOs) of the right coronary artery (RCA), on right ventricular (RV) function.
Background: Developments in PCI techniques have expanded PCI CTO feasibility. However, the utilization of dissection and reentry techniques and extensive stent implantation increases the risk of coronary side branch occlusion.
Methods: Fifty-four patients (80% male, 63 ± 10 years) evaluated with cardiac magnetic resonance imaging (CMR) prior and three months after successful PCI CTO RCA (median: 99 days, IQR: 92–105 days) were included. Right ventricular end-diastolic volume (RVEDV), end-systolic volume (RVESV), and ejection fraction (RVEF) were quantified on CMR images. Occurrence of RVB occlusion and/or RVB recruitment was assessed using procedural angiograms.
Results: RVB occlusion was observed in 12 patients (22%), while RVB recruitment occurred in seven patients (13%). Overall, RVEF was comparable between baseline and follow-up (53.8 ± 5.8 vs. 53.9 ± 5.8%, p = 0.95). RVB occlusion was not associated with a significant change in RVEDV or RVEF (156.9 ± 36.3 vs. 162.1 ± 35.5 mL, p = 0.30 and 54.2 ± 3.9 vs. 52.7 ± 4.4%, p = 0.19, respectively); however a trend was observed for an increase of RVESV (72.5 ± 20.0 vs. 77.4 ± 20.7 mL, p = 0.05) at follow-up. RVB recruitment did not result in a significant improvement of RVEF (55.4 ± 4.6 vs. 56.1 ± 5.3%, p = 0.75).
Conclusion: RVB occlusion was not associated with a significant decreased RVEF at follow-up, although the results suggested a limited increase of RVESV.

1. Introduction

Chronic total occlusions (CTOs), defined as complete discontinuation of true lumen antegrade coronary blood flow (TIMI flow 0) for a duration of three months or longer, are observed in approximately 20% of patients undergoing invasive coronary angiography. [1–3] Patients with a CTO are less likely to be treated with revascularization as compared with patients with non-occlusive coronary artery disease (CAD). For CTO patients who are referred for revascularization, only one-third is treated with percutaneous coronary intervention (PCI). [3] However, implementation of dissection and re-entry techniques has expanded PCI CTO feasibility and success rates have risen to over 90% in dedicated CTO centers. [4–6] Still, PCI CTO remains a laborious procedure in which iatrogenic injury, due to dissection and re-entry techniques and stent implantation over a relatively long coronary tract, may occur. [7,8] Concomitant myocardial injury is commonly tolerated as tradeoff for procedural success; however periprocedural myocardial infarction is associated with an increased long-term mortality. [9] Particularly right ventricular side branches (RVBs) are regularly subject to iatrogenic occlusion and related right ventricular (RV) myocardial injury, since the majority of CTOs are located in the right coronary artery (RCA) (>50%). [2,10–12] The importance of a well-functioning right ventricle has been demonstrated in previous studies, which reported RV function to be an important prognostic factor in patients with pulmonary hypertension and chronic heart failure. [13–15] Moreover, in the setting of

Abbreviations: ADR, antegrade dissection and re-entry; AWE, antegrade wire escalation; CAD, coronary artery disease; CMR, cardiac magnetic resonance; CC, collateral connection; CTO, chronic total occlusion; IQR, interquartile range; PCI, percutaneous coronary intervention; RDR, retrograde dissection and re-entry; RWE, retrograde wire escalation; RCA, right coronary artery; RV, right ventricular; RVEF, right ventricular ejection fraction; RVEDV, right ventricular end diastolic volume; RVESV, right ventricular end systolic volume; RVB, right ventricular side branch.

☆ Conflict of interest disclosures: none.

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myocardial infarction, a decreased right ventricular ejection fraction (RVEF) is an independent predictor of mortality. [16] To date, no studies have investigated the incidence and impact of RVB occlusion on RV function in the current PCI CTO era. The aim of the present study was to investigate the effect of PCI CTO RCA and associated RVB occlusion on RV volumes and function, as assessed by cardiac magnetic resonance imaging (CMR) before and three months after successful PCI CTO RCA.

2. Methods

2.1. Study design and participants

All patients with a CTO considered for percutaneous revascularization at the VU University Medical Center are analyzed in a dedicated screening and treatment program and a prospective database of all patients is maintained. All consecutive patients between January 2013 and April 2016 with a CTO of the RCA that were analyzed with CMR prior and three months after successful PCI CTO RCA, were included in the study. As part of a clinical dedicated CTO program, follow-up CMR after successful PCI CTO was performed routinely and independently from symptoms. All patients provided written informed consent and the study was approved by the institutional ethics committee.

2.2. Angiographic CTO characteristics

Two experienced CTO operators (PK and AN) assessed all dual arterial invasive coronary angiograms to determine angiographic CTO- and RCA side branch characteristics. A CTO was defined as an occlusion on invasive coronary angiography with no true lumen antegrade flow (TIMI Flow 0). [1] Angiographic CTO morphology was evaluated in accordance with the J-CTO score. [17] Collateral connection score was scored as; no visible connection (CC0), thread-like connection (CC1), or small branch like connection (CC2), and the extent of collateral flow was graded according to the Rentrop and Cohen classification. [18,19] An RVB was defined as a side branch of the RCA supplying the RV territory on invasive coronary angiography originating from proximal, mid, or distal RCA. All side branches from the right posterolateral or right posterior descending artery were not considered as RVB. Diameter and TIMI flow of all RVBs were assessed on the first and last angiographic images of the procedure. An RVB with a diameter ≥ 1 mm and antegrade filling pattern ≥ TIMI flow grade II was deemed clinically significant. [8] In case of post-procedural RVB occlusion (Fig. 1), the etiology (i.e. dissection/stent implant) for side branch occlusion was documented. Development of a pre-procedural occluded or non-significant RVB (<1 mm) into an RVB with a diameter (≥ 1 mm) and TIMI flow ≥ II after PCI, was defined as RVB recruitment (Fig. 1). Coronary recanalization was performed either by antegrade wire escalation (AWE), antegrade dissection and re-entry (ADR), retrograde wire escalation (RWE), or retrograde dissection and re-entry (RDR). Procedural success was defined as <30% diameter stenosis and TIMI flow grade III.

2.3. CMR protocol and image analysis

CMR was performed on a 1.5-T scanner (Avanto, Siemens, Erlangen, Germany) before and approximately 12 weeks after PCI CTO RCA. Functional imaging was performed using an ECG-gated, balanced steady-state free precession sequence in four-, three-, and two-chamber long-axis and short-axis orientations during mild expiration (typical parameters: TR/TE 3.2/1.5 ms, flip angle ~75°, voxel size 1.4 × 1.4 × 5.0 mm, temporal resolution 35–50 ms).

Cardiac magnetic resonance analysis was performed using dedicated software (qMass v7.6, Medis, Leiden, the Netherlands). CMR images were assessed by two experienced observers (PD and SB) who were blinded to the time point of CMR examinations (baseline versus follow-up) and clinical data. Right ventricle endocardial borders were manually delineated on end diastolic and end systolic cine short-axis images (Fig. 2). [20,21] Right ventricular end diastolic volume (RVEDV), right ventricular end systolic volume (RVESV), and RVEF were automatically calculated according to endocardial borders. [20,22].

2.4. Statistical analyses

Continuous variables are presented as mean values ± standard deviation (SD), whereas categorical variables are expressed as actual numbers with percentages. Continuous variables of paired data were compared with the paired sample t-test or Wilcoxon test, depending on the distribution pattern, whereas differences between multiple groups were compared with the One-Way ANOVA test for normally distributed data and with the Kruskal Wallis test if there was a non-normal distribution. A level of $p < 0.05$ was considered significant. Statistical analyses were performed using SPSS software (IBM SPSS Statistics 22.0, Chicago, IL).

3. Results

3.1. Patient population

Seventy-nine patients who underwent CMR imaging prior to successful PCI CTO RCA between January 2013 and April 2016 were retrospectively identified. Of these, 55 consecutive patients with CMR imaging after successful percutaneous treatment of a CTO RCA were included for analysis, whilst 24 patients had refused a follow-up CMR. There were no adverse cardiac events registered during follow up. One patient was excluded for analysis due to insufficient CMR quality to be able to assess RV function accurately. Fifty-four patients (63 ± 10 years) included in the present study underwent CMR imaging 39 days (interquartile range (IQR): 22–62 days) prior and three months after PCI CTO (median days; 99, IQR: 92–105). Patient characteristics are presented in Table 1. CTO characteristics and collateral function are shown in Table 2. J-CTO scores were equally distributed among the 54 CTO lesions with 10% being scored as easy (0), 37% as intermediate (1), 28% as difficult (2), and 25% as very difficult (≥ 3). The majority of patients showed well-functioning collaterals with a CC score of 2 (88%) and a Rentrop grade 3 (88%) on invasive coronary angiography.

3.2. The presence of RVBs and procedural characteristics

The presence of significant RVBs prior to intervention ranged from zero to three (median: 1, IQR: 1–2) per patient (Table 3). Successful procedural strategies and strategy distribution among different J-CTO scores are presented in Fig. 3. Twenty-eight (52%) CTOs were successfully treated with an antegrade approach (AWE; 41%, ADR; 11%), in 26 (48%) patients a retrograde approach (RWE; 9%, RDR; 39%) resulted in successful recanalization of the CTO. Dissection and re-entry techniques were utilized in 25 (46%) procedures. The retrograde dissection and re-entry procedure was the preferred interventional technique among high J-CTO scores; lesions with low J-CTO scores were predominantly successfully crossed using AWE (Fig. 3). In the majority of the treated patients, PCI CTO did not result in RVB occlusion or recruitment (n = 37, 68%). Procedural RVB occlusion was observed in 12 patients (22%); in none of these patients more than one clinically significant RVB was lost (Table 3). Right ventricular branch occlusion occurred primarily during a retrograde technique (n = 7, 58%), and was caused by coronary dissection or stent implantation (n = 7, 58% and n = 5, 42%, respectively). Recruitment of eight RVBs was observed after successful PCI CTO among seven (13%) patients (Table 3). Procedural RVB occlusion and concurrent RVB recruitment occurred in two patients (4%). Recruitment of an RVB was solely observed after successful true-to-true wiring (AWE; 86%, RWE; 14%).

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