FULL LENGTH ARTICLE

# Impact of body mass index on acute outcome in percutaneous coronary intervention of chronic total occlusion

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***Background:*** **Percutaneous coronary intervention (PCI) of total chronic total occlusion (CTO) still remains a major challenge in interventional cardiology. There is only insignificant knowledge reported in the literature about the influence of body mass index (BMI) on acute outcome, including success rates and complications in CTO-PCI.**

***Methods:*** **Between 2012 and 2017, we included 508 patients. They underwent PCI for at least one CTO. Antegrade and retrograde CTO techniques were applied. The retrograde approach was used only after failed antegrade intervention. BMI was calculated according to the definitions of the World Health Organization. It was subdivided as normal weight (18.5–24.9 kg/m$^2$), overweight (25–29.9 kg/m$^2$), obese (30–34.9 kg/m$^2$), and very obese ($\geq$35 kg/m$^2$). The Shapiro–Wilk test was used to test for normality of distribution. Continuous variables were tested for differences with Kruskal–Wallis or Mann–Whitney *U* test as appropriate. Categorical variables were tested with Fisher exact test.**

***Results:*** **Out of the 508 patients, 77 (15.2%) had normal weight, 286 (56.3%) were overweight, 106 (20.9%) obese, and 39 (7.7%) very obese. Radiation dose and examination time increased with elevated BMI categories ($p < 0.001$, $p = 0.026$). Success rates were similar in all BMI categories ($p = 0.645$). In-hospital procedural complications were rare and showed no statistically significant difference ($p = 0.185$).**

***Conclusions:*** **Our retrospective study suggests that there exists no significant association between overweight and acute outcome in patients undergoing CTO-PCI. It is safe and feasible to perform.**



*Keywords:* Body mass index, Chronic total occlusion, Outcome, Percutaneous coronary intervention

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## 1. Introduction

Recanalization of chronic total occlusion (CTO) remains a complex and challenging procedure in interventional cardiology. CTO of a coronary artery can be identified in up to 20% among patients with a clinical indication for coronary angiography. Due to new interventional techniques and the use of novel sophisticated materials, success rates of CTO recanalization increased steadily in recent years [1–4]. If there is significant myocardial ischemia combined with clinical symptoms due to ischemia, recanalization is indicated; in suitable cases, left ventricular function can be improved, more invasive therapies like coronary artery bypass graft (CABG) surgery can be avoided at lower complication rates and even the prognosis of the disease can be improved with both a short- and long-term survival benefit [5,6].

Simultaneously, prevalence of obesity increased worldwide over the past decades. In the general population, obesity, particularly severe obesity is closely related to an elevated risk of cardiovascular disease (CVD) with the body mass index (BMI) as a strong predictor of CVD mortality [7–9]. Furthermore, rising rates of obesity are an important cause of increase in medical spending [10].

In this retrospective study, we evaluated the impact of BMI on procedural characteristics, complications, and success rates in a large cohort of CTO patients.

## 2. Materials and methods

We performed a total of 508 CTO percutaneous coronary interventions (PCIs) between 2012 and 2017. The patients underwent PCI for at least one CTO. Indications for inclusion were angina pectoris and/or a positive functional ischemia test by magnetic resonance imaging or stress echocardiography. To prevent thromboembolic complications, heparin was given during the interventions guided by the activated clotting time (>300 s).

All procedures were performed via femoral access using 7-Fr guiding catheters; the Finecross (Terumo, Japan) and the Corsair (Asahi, Japan) were used as microcatheters both for the antegrade and retrograde approach. Dual injections were made routinely in most of the cases to identify contralateral collaterals and define the length of the lesion.

The antegrade approach was used as first step. Coronary wiring started with tapered polymer soft-tip guide wires and ended up with super-stiff guide wires (up to 12-g wires).

In most cases the occluded segment was stented with drug-eluting stents, and postdilatation was performed to optimize stent expansion and apposition. After PCI, a dual antiplatelet therapy consisting of 100 mg of aspirin once daily indefinitely and 75 mg clopidogrel daily for at least 6 months was continued. An Angio-Seal vascular closure device (St. Jude Medical, USA) was used to seal the access site. If required, the maneuvers were guided by intravascular ultrasound to understand the local anatomy and to identify the exact entry point of the CTO. The Japanese-CTO (J-CTO) score, combining several parameters of a CTO including the degree of calcification of the lesion, bending >45 degrees in the CTO segment, blunt proximal cap, length of occluded segment (>20 mm), and a previously failed recanalization attempt, was calculated for all patients.

Procedural success was defined as successful recanalization of the CTO and restoration of thrombolysis in myocardial infarction, flow grade 3. A composite safety endpoint summarizing severe complications, such as in-hospital death, stroke, cardiac tamponade, ST-elevation myocardial infarction (STEMI), and vascular complications, was evaluated for any patient.

BMI was calculated according to the definitions of the World Health Organization. It was subdivided as normal weight (18.5–24.9 $kg/m^2$), overweight (25–29.9 $kg/m^2$), obese (30–34.9 $kg/m^2$), and very obese ($\geq$35 $kg/m^2$) [11].

**Abbreviations**

| | |
|---|---|
| BMI | body mass index |
| CABG | coronary artery bypass graft |
| CAD | coronary artery disease |
| COPD | chronic obstructive pulmonary disease |
| CTO | chronic total occlusion |
| CVD | cardiovascular disease |
| DES | drug eluting stent |
| DM | diabetes mellitus |
| HDL | high density lipoprotein |
| IVUS | intravascular ultrasound |
| J-CTO | japanese Chronic Total Occlusion |
| LAD | left anterior descending |
| LCX | left circumflex |
| LVEF | left ventricular ejection fraction |
| MRI | magnetic resonance imaging |
| PAD | peripheral artery disease |
| PCI | percutaneous coronary intervention |
| RCA | right coronary artery |
| TIMI | thrombolysis in myocardial infarction |
| WHO | World Health Organization |

### 2.1. Statistical analysis

Continuous variables are presented as mean ± standard deviation, or median and minimum–maximum, and categorical variables given as frequencies and percentages.

The Shapiro–Wilk test was used to test for normality of distribution. Continuous variables were tested for differences with the Kruskal–Wallis test or the Mann–Whitney *U* test as appropriate. Categorical variables were tested with Fisher exact test.

## 3. Results

The majority of patients were male (84.6%), and the mean age was 61.9 years (±10.4 years). Men were younger than women (60.9 ± 10.1 years vs. 66.5 ± 10.6 years; $p < 0.001$). The mean BMI was 28.42 kg/m$^2$ (±4.1 kg/m$^2$).

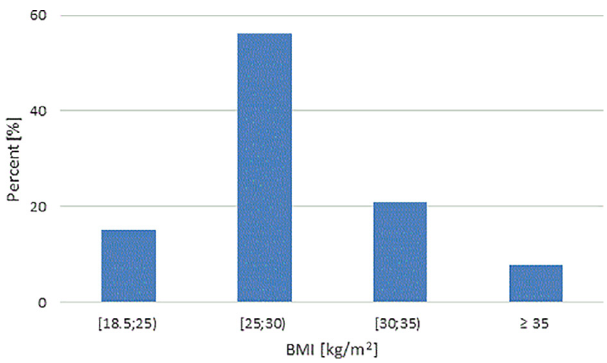


*Figure 1. Prevalence of different body mass index (BMI) categories. Normal weight (18.5–24.9 kg/m$^2$), overweight (25.0–29.9 kg/m$^2$), obese (30.0–34.9 kg/m$^2$), and very obese (≥35 kg/m$^2$).*

Fig. 1 shows the different BMI categories. Out of the 508 patients, 77 (15.2%) had normal weight, 286 (56.3%) were overweight, 106 (20.9%) obese, and 39 (7.7%) very obese.

The descriptive statistics and baseline data are presented in Table 1. The prevalence of most cardiovascular risk factors such as diabetes mellitus (DM), arterial hypertension, and a familial liability for coronary artery disease (CAD) increased parallel to rising BMI categories.

Patients with normal weight displayed a higher high-density lipoprotein (HDL)-cholesterol ($p < 0.001$) and lower triglycerides ($p = 0.006$) than obese patients with a BMI >25. Higher BMI values were more often combined with a left ventricular ejection fraction above 40%. Very obese patients had a lower prevalence of left ventricular dysfunction, a higher incidence of DM but showed a tendency towards a lower prevalence of prior myocardial infarction and CABG.

The prevalence of peripheral arterial disease was lower in overweight patients ($p = 0.094$) who had a higher rate of chronic obstructive pulmonary disease ($p = 0.091$).

Procedural and angiographic characteristics are demonstrated in Table 2. The J-CTO score was similar in all BMI categories ($p = 0.920$). The amount of contrast medium and fluoroscopy time

*Table 1. Baseline characteristics.*

| | BMI 18.5–25) | BMI 25–30 | BMI 30–35 | BMI ≥35 | $p^*$ | $p^{**}$ |
|---|---|---|---|---|---|---|
| Number, *n* | 77 | 286 | 106 | 39 | | |
| Age (yr)*** | 62 (37–85) | 62 (33–86) | 61 (40–82) | 59 (38–79) | 0.327 | 0.234 |
| Male sex | 75.3 (58) | 85.0 (243) | 82.1 (87) | 79.5 (31) | 0.226 | 0.102 |
| Diabetes mellitus | 19.5% (15) | 23.4% (67) | 35.8% (38) | 38.5% (15) | 0.013 | 0.161 |
| COPD | 7.8% (6) | 7.7% (22) | 10.4% (11) | 20.5% (8) | 0.091 | 0.831 |
| Smoking | 51.9% (40) | 45.5% (130) | 48.1% (51) | 48.7 (19) | 0.772 | 0.388 |
| PAD | 20.8% (16) | 10.5% (30) | 9.4% (10) | 10.3% (4) | 0.094 | 0.012 |
| Hypertension | 71.4% (55) | 79.0% (226) | 89.6% (95) | 84.6% (33) | 0.013 | 0.041 |
| Family liability for CAD | 23.4% (18) | 30.8% (88) | 25.5% (27) | 38.5% (15) | 0.273 | 0.276 |
| Cholesterol >200 mg/dL | 23.5% (8) | 18.1% (35) | 21.0% (13) | 23.1% (6) | 0.789 | 0.503 |
| HDL cholesterol >40 mg/dL | 88.2% (30) | 67.4% (130) | 51.6% (32) | 73.1% (19) | 0.002 | <0.001 |
| LDL cholesterol <100 mg/dL | 50.0% (17) | 50.8% (98) | 58.1% (36) | 38.5% (10) | 0.413 | 0.782 |
| Triglycerides <150 mg/dL | 64.7% (22) | 57.0% (110) | 40.3% (25) | 30.8% (8) | 0.007 | 0.006 |
| Prior MI | 35.1% (27) | 33.2% (95) | 37.7% (40) | 23.1% (9) | 0.421 | 0.794 |
| Prior CABG | 10.4% (8) | 9.8% (28) | 8.5% (9) | 5.1% (2) | 0.848 | 0.672 |
| Prior CTO-PCI attempt | 36.4% (28) | 40.9% (117) | 43.4% (46) | 48.7% (19) | 0.603 | 0.380 |
| Prior PCI | 48.1% (37) | 46.9 (134) | 44.3% (47) | 30.8% (12) | 0.276 | 0.620 |
| LVEF ≥40% | 87.0% (67) | 97.9% (280) | 96.2% (102) | 97.4% (38) | 0.002 | <0.001 |

BMI = body mass index; CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; CTO = chronic total occlusion; HDL = high-density cholesterol; LDL = low-density cholesterol; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PCI = percutaneous coronary intervention.

* Comparison between normal weight, overweight, obese, and very obese patients.

** Comparison between normal weight and overweight patients (BMI ≥25 kg/m$^2$).

*** Median (Min–Max).

*Table 2. Procedural and angiographic characteristics.*

| | BMI 18.5–25 | BMI 25–30 | BMI 30–35) | BMI ≥35 | $p^{*}$ | $p^{**}$ |
|---|---|---|---|---|---|---|
| CTO in LAD | 25.0% (19) | 25.3% (72) | 31.1% (33) | 38.5% (15) | 0.645 | 0.886 |
| CTO in LCX | 11.8% (9) | 11.9% (34) | 13.2% (14) | 10.3% (4) | | |
| CTO in RCA | 61.8% (47) | 62.5% (178) | 55.7% (59) | 51.3% (20) | | |
| Coronary | | | | | | |
| 1-vessel disease | 22.1% (17) | 23.1% (66) | 25.5% (27) | 41.0% (16) | 0.090 | 0.080 |
| 2-vessel disease | 29.9% (23) | 42.3% (121) | 42.5% (45) | 28.2% (11) | | |
| 3-vessel disease | 45.5% (35) | 34.3% (98) | 32.1% (34) | 30.8% (12) | | |
| Blunt stump | 41.6% (32) | 37.8% (108) | 34.0% (36) | 23.1% (9) | 0.224 | 0.307 |
| Tortuosity >45° | 46.8% (36) | 57.3% (164) | 52.8% (56) | 61.5% (24) | 0.311 | 0.135 |
| Severe calcification | 67.5% (52) | 70.3% (201) | 67.9% (72) | 66.7% (26) | 0.921 | 0.789 |
| J-CTO score ≥3 | 61.0% (47) | 62.9% (180) | 65.1% (69) | 66.7 % (26) | 0.920 | 0.821 |
| Retrograde approach | 16.9% (13) | 22.4% (64) | 21.7% (23) | 33.3% (13) | 0.264 | 0.238 |
| DES stent | 100% (65) | 98.8% (238) | 97.8% (90) | 96.8% (30) | 0.920 | 0.811 |
| Number of stents ≥3 | 31.2% (24) | 33.2% (93) | 44.7% (46) | 34.2% (13) | 0.174 | 0.936 |
| Amount of contrast medium (mL)*** | 242.0 (100–500) | 250.1 (70–650) | 264.2 (90–800) | 252.6 (70–650) | 0.802 | 0.614 |
| Examination time (min)*** | 92.4 (30–208) | 102.4 (11–240) | 104.3 (35–200) | 105.1 (15–300) | 0.160 | 0.026 |
| Fluoroscopy time (min)*** | 33.2 (4–98) | 36.9 (7–104) | 35.3 (6–81) | 38.8 (8–113) | 0.467 | 0.132 |
| Dose area product (cGycm$^2$)**** | 9.346 (6.549) | 10.789 (8.437) | 12.321 (10.237) | 14.234 (13.235) | <0.001 | <0.001 |
| Length of occlusion (mm)*** | 36.1 (10–100) | 39.2 (10–80) | 38.4 (10–100) | 38.4 (15–80) | 0.540 | 0.160 |
| Stent diameter (mm)*** | 2.9 (2.25–3.5) | 3.0 (2.25–4) | 3.1 (2.5–4) | 3.1 (2.5–3.5) | 0.213 | 0.094 |
| Success | 84.4% (65) | 84.3% (241) | 87.7% (93) | 79.5% (31) | 0.645 | 1 |
| Complications | 7.8% (6) | 4.5% (13) | 7.5% (8) | 0% | 0.185 | 0.276 |

BMI = body mass index; CTO = chronic total occlusion; DES = drug-eluting stent; LAD = left anterior descending; LCX = left circumflex; RCA = right coronary artery, J-CTO = Japanese chronic total occlusion.
* Comparison between normal weight, overweight, obese, and very obese patients.
** Comparison between normal weight and overweight patients (BMI ≥25 kg/m$^2$).
*** Median (Min–Max).
**** Median (±STD).

tended to increase in parallel with rising BMI categories. Radiation dose increased with elevated BMI categories ($p < 0.001$) without any severe acute radiation-induced skin lesion. Patients with normal weight had a shorter examination time than obese patients ($p = 0.026$). The mean stent diameter is larger between normal weight and overweight patients (statistical trend $p = 0.094$). Success rates were similar in all BMI categories ($p = 0.645$; Fig. 2). In-hospital procedural complications were rare and showed no statistically significant difference ($p = 0.185$). They included mostly vascular complications such as a local hematoma at the puncture site and one cardiac tamponade, which could be treated with a pericardiocentesis and without further consequences. One patient had stroke with complete recovery but no other severe complications were recorded, such as periprocedural death or STEMI (Table 3).

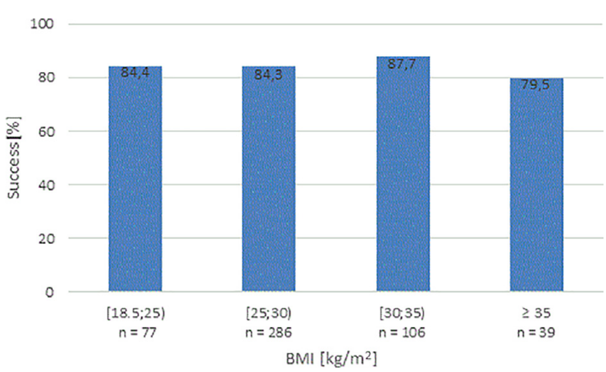


*Figure 2. Success according to body mass index (BMI) categories.*

## 4. Discussion

The impact of overweight on complex cardiovascular procedures such as CTO-PCI is only incidentally evaluated. It is one of the important cardiovascular risk factors, and our data could demonstrate that challenging recanalization procedures can be performed safely in overweight patients.

However, our study emphasizes several important aspects. First, procedural success and in-hospital complications were independent of the BMI categories. This is a remarkable findig. Especially since we know that in western societies with an increasing proportion of overweight and obese patients are more likely to suffer from severe wound infections after CABG [12].

Second, the prevalence of cardiovascular risk factors increased in parallel with rising BMI categories. These results concerning the prevalence of obesity-related comorbidities, such as DM,

*Table 3. In-hospital clinical events.*

| | BMI 18.5–25 | BMI 25–30 | BMI 30–35 | BMI ≥35 |
|---|---|---|---|---|
| In-hospital death | 0 | 0 | 0 | 0 |
| Vascular complications | 4 | 11 | 6 | 0 |
| Cardiac tamponade | 1 | 0 | 0 | 0 |
| Stroke | 0 | 0 | 1 | 0 |
| Myocardial infarction | 0 | 0 | 0 | 0 |

BMI = body mass index.

atrial hypertension, and dyslipidemia, especially HDL-cholesterol and triglyceride, are in agreement with the current literature [13,14].

Third, important procedural characteristics such as examination time and dose area product were different in the BMI categories. In obese patients, the examination time is longer ($p = 0.026$) and the radiation dose is higher ($p < 0.001$). Unfortunately, we could not show a follow-up in our data, but severe skin lesions might be a dangerous consequence. Suzuki et al. proved in a cohort of almost 100 patients that skin injury can occur during PCI, especially for CTO [15,16].

Lundergan et al. proved that increasing BMI is associated with greater preservation of left ventricular function, which is concordant to our data [17]. In addition, Wells et al. reported on the relation between BMI and in-hospital outcome after an acute myocardial infarction, and they did not find any difference between the BMI groups in acute outcome [18].

Stähli et al. showed in a large cohort that overweight was significantly associated with a reduced long-term mortality after CTO-PCI, particularly in men [19]. However, in contrast to our cohort, these patients were older.

Studies concerning the relation between BMI and outcomes in CAD patients are divergent. On one hand, the so called ‘‘obesity paradox’’ refers to the observation that although obesity is a strong risk factor for the development of CVD, mortality rates are low in obese and very obese patients. Possible reasons for the hypothesis are that obese patients may have better and more aggressive medical care and enhanced observation than patients with normal weight or tend to be on more cardioprotective medical therapy and tend to be younger at the time of the acute cardiovascular event, which may confer an age benefit [20]. Won et al. recently showed in a study with 1172 patients that obesity seems to improve long-term survival after CTO-PCI [21]. However, in this study, obesity was defined as a BMI $\geq 25$ kg/m$^2$ and they implanted first-generation drug-eluting stents (DES) in almost 50%. In contrast, some other trials failed to show any relation between BMI and survival after PCI, in line with our data [12]. Diletti et al. presented data from more than 5000 patients and concluded that patients’ BMI had no impact on long-term clinical outcomes after coronary artery interventions [22].

CABG might be an alternative therapy for patients with a CTO. However, some data could show that obesity did not increase operative mortality, but it was associated with reduced late survival in patients undergoing CABG. Furthermore, an analysis of 42 studies revealed that obesity is by far one of the main preoperative risk factors for postoperative deep wound infections [23–25].

While previous data have reported that lean patients and extremely obese patients are at greater risk for adverse outcomes after PCI, we could demonstrate that in-hospital clinical events seem to be independent of BMI [26–28].

### 4.1. Study limitations

Our study is a retrospective analysis, and all data were collected from a single center. The results of this study may have been influenced by selection criteria, operator experience, and varying techniques used by the operators. Furthermore, we have no data about the impact of the long-term follow-up of BMI in CTO patients. Another limitation may be that the matched and unmatched data used in this study were already collected. Thus, the analysis was based on an observation study.

## 5. Conclusions

Our retrospective study suggests that there exists no significant association between patient weight and acute outcome in patients undergoing CTO-PCI.

## Conflict of interest

None.

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