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Relation between Body Mass Index and Clinical Outcome after Percutaneous Coronary Intervention of Chronic Total Occlusion

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ABSTRACT

Background: Obesity is a significant risk factor for coronary artery disease (CAD), which continues to be a primary cause of death. About 20% of individuals undergoing coronary angiography have chronic complete occlusion (CTO), and although PCI is the recommended course of treatment, the results in obese people are still not fully understood.

Aim of the study: to evaluate the relationship between clinical outcomes following PCI for chronic complete blockage and BMI.

Patients and Methods: A cross-sectional retrospective cohort study included 40 adults who received PCI for angiographically confirmed chronic total occlusion in two Egyptian tertiary centers and examined the association of BMI with post-procedure outcomes. The patients were followed up for 3 months with procedural success, MACE, and symptom relief as endpoint measurements. **Results**: Out of 40 PCI patients, baseline, angiographic, and procedural factors within BMI groups were largely similar, with differences significant only in prior PCI (p=0.040) and baseline ECG abnormality (p=0.016). Adverse effects were rare, with no difference in procedural success among BMI groups. Lesion complexity, as indicated by higher J-CTO scores, was the main factor for longer wire crossing time and greater contrast usage, and not BMI.

Conclusion: BMI did not differentially affect procedural success, complications, or post-discharge outcomes with CTO-PCI, even though higher J-CTO scores and chest pain were more frequent in overweight/obese patients, implying potential correlation with lesion complexity or symptom burden. This is in line with the "obesity paradox" where overweight patients have comparable or better outcomes than normal-weight patients.

Keywords: Body Mass Index, Chronic Total Occlusion, Clinical Outcomes, Obesity Paradox, Percutaneous Coronary Intervention.

INTRODUCTION

Over the past few decades, the global prevalence of obesity has increased sharply, with current data showing that nearly 50% of adults meet the criteria for overweight or obesity based on body mass index (BMI). The World Health Organization (WHO) reports that Egypt holds the 18th position worldwide in obesity prevalence[1].

Excess body weight is strongly associated with a higher occurrence of cardiovascular risk factors—including diabetes mellitus, arterial hypertension, as well as lipid disorders and contributes significantly to the likelihood of major cardiovascular events in the general population. It is recognized as a key contributor to the development of coronary artery disease (CAD)[2].

Coronary artery disease remains one of the foremost causes of illness and death globally. Its primary underlying mechanism is the formation of atherosclerotic plaques, which gradually narrow the vessel lumen and can destabilize, precipitating acute coronary syndromes. Chronic total occlusion (CTO) refers to a complete blockage of a coronary artery resulting from atherosclerosis, characterized by thrombolysis in myocardial infarction (TIMI) grade 0 flow in the affected segment, and persisting for at least three months[3].

CTOs typically contain a combination of atherosclerotic plaque and thrombotic material, which may be uniform or composed of multiple layers formed through repeated thrombotic events over time. They are not uncommon, being identified in approximately one-fifth of patients undergoing coronary angiography[4].

Percutaneous coronary intervention (PCI) has emerged as the mainstay for reopening CTOs. Nonetheless, CTO PCI continues to be one of the most technically demanding areas in interventional cardiology, particularly in patients with overweight or obesity. Given the rising global burden of obesity and ongoing advancements in procedural techniques, accurate pre-procedural risk evaluation for such patients is becoming increasingly relevant. Despite this, research on the influence of BMI on outcomes following CTO PCI remains scarce[5].

The present study aims to investigate the relationship between BMI and post-procedural clinical outcomes in patients undergoing PCI for chronic total occlusion.

PATIENTS AND METHODS

Examining the association between BMI and clinical outcomes after PCI for CTO was the goal of this cross-sectional, retrospective cohort study. Two tertiary high-volume cardiovascular facilities the National Heart Institute in Cairo, Egypt, and the Cardiology Department of Menoufia University Hospital in Shebin El-Kom, Egypt were the sites of the inquiry. The timeframe of data

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collecting was September 2023–October 2024.Both the Cardiology Department Review Board and the Institutional Ethics Committee of Menoufia University's Faculty of Medicine accepted the study's protocol, which adhered to the national research ethics norms and the Declaration of Helsinki's tenets with IRP approval (N:11/2024CARD12).

Patients were retrospectively selected from medical records and catheterization laboratory data at each of the participating institutions. 40 adult patients who had undergone PCI for angiographically proven CTO lesions were enrolled, based on predefined exclusion and inclusion criteria. Patients had clinical follow-up of at least three months following the intervention to allow for proper outcome evaluation.

Patients were considered for enrollment if they were age 18 years or older at the time of PCI and had documented chronic total occlusion in one or more major coronary arteries. CTO was defined as TIMI grade 0 antegrade flow and occlusion duration ≥3 months, based on prior angiographic studies, symptom onset time (e.g., stable angina), history of myocardial infarction, or acute effort intolerance or exertional dyspnea of >12 weeks' duration. Eligible patients had undergone elective PCI with CTO-targeted revascularization.

Patients with a history of previous coronary artery bypass grafting (CABG) or other cardiac surgeries, acute coronary syndrome (ACS) like STEMI or non-STEMI, left ventricular ejection fraction (LVEF) <40%, or advanced systemic comorbidities like end-stage renal disease on dialysis, CKD stage ≥4, decompensated liver cirrhosis (Child-Pugh B or C), active or remitted malignancy, or survival of any condition <one year were excluded. Exclusion also included patients with incomplete medical records or lost to follow-up within 3 months of procedure.

All PCI was performed following written informed consent from the patients or their guardians. Patient anonymity was ensured for this retrospective review through the use of de-identified datasets, and access to data was restricted to study investigators. The study posed no additional risk to the participant and was deemed exempt from additional requirements for consent by the ethics board.

Demographics and clinical characteristics were age, sex, anthropometric measurements (weight, height, and BMI), smoking status, comorbidities (hypertension, type 2 diabetes mellitus, dyslipidemia, history of cerebrovascular events, and peripheral arterial disease), and discharge medications. BMI was calculated as weight in kg divided by height in meters squared and graded according to WHO criteria: underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), obese class I (30.0–34.9 kg/m²), and obese class II and III (≥35.0 kg/m²). Careful physical examination was noted, including blood pressure, heart rate, respiratory rate, temperature, and cardiac auscultation findings such as murmurs, gallops, and other heart sounds. With baseline laboratory workup included complete blood count (CBC), coagulation profile, renal function tests, liver enzymes, lipid profile, and levels of fasting blood glucose (FBG) and HbA1c.

Cardiovascular and Diagnostic Evaluation

All patients were provided with a 12-lead ECG to interpret ischemic ST-T wave abnormalities, Q-waves, rhythm disturbance, and conduction defects. Routine transthoracic echocardiography (TTE) was performed pre-procedure to evaluate left ventricular ejection fraction, regional wall motion abnormality, valvular function, and diastolic dysfunction.

All CTO-PCIs were performed in a specialist cardiac catheterization laboratory under real-time fluoroscopic guidance and in strict accordance with current ESC and ACC guidelines. Vascular access was obtained from the femoral or radial artery, with the femoral approach used for more complex CTO lesions. Guiding catheters (7-Fr) were also used as a routine, and double injection coronary angiography was performed in all cases for optimal visualization.

Lesion crossing maneuvers were selected based on angiographic appearance and included antegrade wire escalation, antegrade dissection and re-entry, or retrograde maneuvers. Intravascular imaging (IVUS or OCT) adjuncts and supportive devices such as microcatheters were employed as necessary. Predilatation with drug-eluting stent (DES) implantation followed by post-dilatation for maximal stent expansion was achieved. Procedure success was recorded as <10% residual stenosis, TIMI grade 3 flow, and lack of significant procedural complications.

Patients underwent dual antiplatelet therapy (P2Y12 inhibitor plus aspirin) for a minimum of 6–12 months, as well as other medications as clinically appropriate. Monitoring post-procedure involved vital signs, access site inspection, ECG, and echocardiogram if needed.

Regarding outcomes Procedural success was defined as successful crossing and recanalization of CTO, residual stenosis <30%, TIMI grade 3 flow, and absence of in-lab complications. Clinical outcomes were assessed during admission and at 3 months regarding major adverse cardiovascular events (MACE), symptoms improvement, and hospital readmission.

Follow-Up Protocol All patients were followed up on an outpatient basis at 1, 2, and 3 months post-discharge with assessment of symptoms, physical examination, ECG, echocardiography as required, and monitoring of drug therapy and lifestyle modification.

Ethical Approval

Prior to the commencement of the study, each participant completed a written consent that was authorized by Faculty of Medicine Menoufia university's Local Ethical Research Committee. Additionally, the Institutional Review Board approval was obtained. The study was conducted in accordance with ethical standards, including the Declaration of Helsinki and its amendments [under code no. 11/2024CARD12].

Statistical analysis

Data were analyzed in SPSS v25. Normality was checked with the Shapiro–Wilk test. Parametric data were summarized as mean ± SD and compared with one-way ANOVA; non-parametric data as median (IQR) and compared with Kruskal–Wallis. Categorical data were shown as counts (%) and compared using Fisher's exact test. Spearman's correlation was used for non-normal data. Significance threshold was $p < 0.05$.

RESULTS

Baseline characteristics were largely comparable across BMI groups and there were no significant differences in most clinical or demographic factors, with the exceptions of higher rates of a history of PCI in BMI Group 3 (p=0.040) and significant heterogeneity in baseline ECG abnormalities (p=0.016), **Table 1.**

Table 1: Baseline Clinical Characteristics of the Study Population

Variable	BMI Group 1 (n=2)	BMI Group 2 (n=15)	BMI Group 3 (n=22)	BMI Group 4 (n=1)	**p-value**
Age (mean ± SD)	70.5 ± 0.71	56.0 ± 6.57	52.86 ± 10.58	51.0 ± 0.0	.076
Sex (M/F, n, %)	2	14	18	1	0.595
Diabetes (n, %)	2	8	8	0	0.207
Hypertension (n, %)	1	6	14	0	0.516
Current smoker (n, %)	0	6	8	0	0.785
Family history of CAD	0	1	3	0	0.735
Previous MI (n, %)	0	1	3	0	0.735
Previous CABG (n, %)	1	5	6	0	0.917
Previous PCI (n, %)	1	3	13	0	0.040*
Previous stroke/TIA (n,%)	0	0	0	0	NA
Renal dysfunction (n, %)	0	0	0	0	NA
Baseline LV EF % (mean ± SD)	48.0 ± 18.38	56.67 ± 10.71	54.36 ± 9.86	49.0 ± 0.0	.652
Baseline ECG abnormalities (n, %)					0.016*
NSR	0	11	13	1	
ST depression anterior	0	0	4	0	
Inverted T wave lateral	0	0	1	0	
Inverted T wave anterior	0	1	0	0	
ST depression, T inversion in anterior leads	1	0	0	0	
Q waves in inferior leads	0	0	1	0	
ST depression in all leads	0	3	0	0	
Inverted T wave in inferior leads	0	0	2	0	
ST depression in leads I, aVL, V5, V6	1	0	0	0	
Q waves in anterior leads	0	0	1	0	

One-way ANOVA, Fisher's Exact Test, * statistically significant, **SD:** Standard deviation.

There were no significant differences between groups by BMI for target vessel distribution, lesion complexity parameters, or procedural strategy. Median J-CTO scores and rates of lesions with unfavorable anatomical features were comparable, and procedural measures like contrast utilization and time to wire crossing were not significantly different. **Table 2**

Table 2: Angiographic and Procedural Characteristics by BMI Group

Variable	BMI Group 1	BMI Group 2	BMI Group 3	BMI Group 4	p-value
Target Vessel (LAD/LCX/RCA, n, %)					
LAD	1 (50.0%)	7 (46.7%)	9 (40.9%)	0 (0.0%)	0.927
LCX	0 (0.0%)	2 (13.3%)	2 (9.1%)	0 (0.0%)	1.000
RCA	1 (50.0%)	6 (40.0%)	11 (50.0%)	1 (100.0%)	0.804
Segment - Osteal	0 (0.0%)	2 (13.3%)	2 (9.1%)	0 (0.0%)	0.502
J CTO Score median (Max-Min)	0.50 (0.00–1.00)	2.00 (0.00–3.00)	1.00 (0.00–3.00)	2	0.348
Blunt stump (n, %)	0 (0.0%)	3 (20.0%)	8 (36.4%)	0 (0.0%)	0.579
Heavy calcium (n, %)	0 (0.0%)	6 (40.0%)	4 (18.2%)	0 (0.0%)	0.436
Bending angle > 45° (n, %)	0	0	0	0	—
Lesion length > 20mm (n, %)	1 (50.0%)	9 (60.0%)	12 (54.5%)	1 (100.0%)	1.000
Retrograde approach used (n, %)	2 (100.0%)	6 (40.0%)	12 (54.5%)	1 (100.0%)	0.346
Second attempt (n, %)	0 (0.0%)	7 (46.7%)	6 (27.3%)	1 (100.0%)	0.237
Number of stents median (Max-Min)	2.50 (2.00–3.00)	2.00 (0.00–3.00)	2.00 (0.00–3.00)	0.00	0.260
Number of wires used median (Max-Min)	4.00 (3.00–5.00)	3.00 (1.00–7.00	3.00 (2.00–7.00)	5.0	0.520
Time to wire crossing median (Max-Min)	27.5 (25.0–30.0)	40.0 (15.0–60.0)	37.5 (15.0–180.0)	60	0.432
Amount of contrast median (Max-Min)	475 (450–500)	450 (300–650)	500 (300–600)	600	.614

Kruskal-Wallis test**,** Fisher's Exact Test, * statistically significant.

In-hospital outcomes did not statistically significantly vary by BMI groups, and there was a low complication rate in general. There was a single in-hospital mortality and a single cardiac tamponade, both in BMI Group 3. Post-discharge complications like chest pain and dyspnea were higher in higher BMI groups but were not statistically significant. **Table 3**

Table 3: Comparison of In-Hospital and Post-Discharge Clinical Outcomes Across BMI Groups

Outcome	Overall (n=)	BMI Group 1	BMI Group 2	BMI Group 3	BMI Group 4	p-value
In-Hospital Clinical Outcomes						
In-hospital death	1 (2.5%)	0 (0%)	0 (0%)	1 (4.5%)	0 (0%)	0.840
Vascular complications	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Cardiac tamponade	1 (2.5%)	0 (0%)	0 (0%)	1 (4.5%)	0 (0%)	0.840
Stroke	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Myocardial infarction	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Follow-Up Clinical Outcomes After Discharge						
Myocardial infarction	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Hospital admission	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Chest pain	11 (27.5%)	0 (0%)	3 (20%)	7 (31.8%)	1 (100%)	0.259
Dyspnea	6 (15%)	0 (0%)	2 (13.3%)	4 (18.2%)	0 (0%)	0.865
Contrast-Induced Nephropathy (CIN)	1 (2.5%)	0 (0%)	0 (0%)	1 (4.5%)	0 (0%)	0.840

Fisher's Exact Test.

Procedural success rate was excellent in all groups of BMI but BMI Group 4 (0%). No statistically significant relationship was found between BMI and procedural success, time to wire crossing, or contrast volume used. **Table 4**

Table 4: Association between BMI and Procedural Success Parameters

Variable	BMI Group 1	BMI Group 2	BMI Group 3	BMI Group 4	p-value
Procedural success rate	2/2 = 100%	13/15 = 86.7%	18/22 = 81.8%	0/1 = 0%	0.300
Time to wire crossing median (Max-Min)	27.5 (25.0–30.0)	40.0 (15.0–60.0)	37.5 (15.0–180.0)	60	0.432
Amount of contrast used (ml) median (Max-Min)	475 (450–500)	450 (300–650)	500 (300–600)	600	.614

Kruskal-Wallis test**,** Fisher's Exact Test, * statistically significant, SD: Standard deviation.

The distribution of J-CTO score categories did not significantly differ by BMI groups (p=0.587). Most were of intermediate-to-difficult category and hardly any were of "easy" or "very difficult" in any of the BMI groups. **Table 5**

Table 5: Distribution of J-CTO Score Categories Across BMI Groups in PCI Patient

J-CTO Score Category	BMI Group 1	BMI Group 2	BMI Group 3	BMI Group 4	Total	P-value
Easy (0)	1 (12.5%)	2 (13.3%)	5 (22.7%)	0 (0.0%)	8	.587
Intermediate (1)	1 (12.5%)	3 (20.0%)	7 (31.8%)	0 (0.0%)	11	
Difficult (2)	0 (0.0%)	9 (60.0%)	7 (31.8%)	1 (100.0%)	17	
Very Difficult (≥3)	0 (0.0%)	1 (6.7%)	3 (13.6%)	0 (0.0%)	4	
Total	2	15	22	1	40	

Fisher's Exact Test.

J-CTO score was positively correlated with time to wire crossing (r=0.770, p<0.001) and positively correlated with contrast volume used (r=0.401, p=0.010). None existed for BMI, LV EF, or number of stents used. **Table 6**

Table 6: Correlation of J CTO Score with Clinical and Procedural Variables

Variable	Correlation (r)	p-value
BMI	0.015	0.929
LV EF %	0.061	0.708
Time to wire crossing	0.770	<0.001
Amount of contrast	0.401	0.010
Number of stents	-0.226	0.161

DISCUSSION

Obesity prevalence increased markedly in recent decades, with close to half of the adult population currently being overweight or obese based on body mass index (BMI). Egypt ranks 18 globally in terms of the prevalence of obesity, as recorded by the World Health Organization (WHO). Obesity is causally linked to increased rates of diabetes, hypertension, and dyslipidemia, which heighten the risk of cardiovascular occurrences and serve as a major risk factor for coronary artery disease (CAD) [6].

CAD remains the most common cause of morbidity and mortality worldwide, with the leading culprit being atherosclerotic plaques that progress to acute coronary syndromes. Chronic total occlusion (CTO) can be defined as complete vessel occlusion with thrombolysis in myocardial infarction (TIMI) grade 0 flow for a duration of at least three months [7]. CTOs, whether atherosclerotic or thrombotic, occur in around 20% of those who come in for coronary angiography [8]. The standard treatment of CTOs is percutaneous coronary intervention (PCI), although technically demanding, especially in obese patients. Given the rising rate of obesity, it is important to know its influence on the outcomes of CTO PCI, although to date, data are still scarce [9,10].

This cross-sectional retrospective cohort study assessed the relationship between BMI and clinical outcomes after CTO PCI at both Menoufia University Hospital and the National Heart Institute. Adult patients with CTO ≥3 months documented by angiography were included, with the exclusion of those with a history of cardiac surgery, acute MI, severe comorbidities, or malignancy. The patients were classified into four BMI groups: Group 1 (normal, n=2), Group 2 (overweight, n=15), Group 3 (obese, n=22), Group 4 (morbidly obese, n=1). Clinical history, BMI assessment, ECG, echocardiography, and laboratory tests were applied as the assessments.

Demographics and baseline comorbidities were comparable for the most part by BMI groups, except for previous PCI (p=0.040) and ECG findings (p=0.016), particularly in Groups 2 and 3. Group 1 and Group 4 had very few numbers. **Patterson *et al.* [11]**, **Stähli *et al*. [12]**, **and Guelker *et al.* [8]** also observed that comorbidity burdens (especially hypertension and diabetes) were

elevated in the obese but with no baseline handicaps of significant quality. **Mehta *et al.* [15] and Biswas *et al.*** [14] also identified increased comorbidity but no poorer baseline clinical status, and **Hannan *et al.* [16]** concluded that BMI was not an independent predictor of adverse baseline characteristics.

Angiographic and procedural characteristics did not differ significantly by BMI groups. J-CTO lesion complexity, as per J-CTO score definition, was similar, albeit somewhat higher in Groups 2 and 4. Use of retrograde approach, stent/wire use, crossing time, and contrast use were all similar. These findings are consistent with those of **Patterson *et al.* [11]**, **Stähli *et al*. [12]**, **Guelker *et al*.** [8], **Hannan *et al.* [16]**, **Biswas *et al.* [14]**, **and Schumacher *et al*. [13]**, all of whom reported no significant effect of BMI on procedural approach or outcome.

In-hospital complications were rare: one death and one tamponade (both in Group 3) with no inter-group difference (p=0.840). Severe complications (stroke, MI, vascular injury) were not observed. **Patterson *et al.* [11]**, **Stähli *et al*. [12]**, *and* **Guelker *et al*. [8]** also found low complication rates independent of BMI. **Mehta *et al.* [15] *and* Biswas *et al*. [14]** also observed no rise in in-hospital complications in obese PCI patients, with some evidence suggesting a protective role ("obesity paradox").

Unplanned hospitalization or MI was negative on follow-up. Chest pain occurred more often in Group 3 (31.8%) and in the one patient in Group 4 (100%) but without statistical difference (p=0.259). Dyspnea and contrast-induced nephropathy were infrequent. **Patterson *et al.* [11]** also noted similar or greater symptomatic improvement in obese/overweight patients, while **Stähli *et al.* [12]** reported reduced long-term mortality in overweight women, a demonstration of the "obesity paradox." **Schumacher *et al*.** [13] noted increased ischemic burden after CTO PCI regardless of BMI. **Biswas *et al*. [14]** cautioned that severe obesity may have long-term risk of mortality in a U-shaped pattern.

Procedure success did not differ appreciably (p=0.300), but limited statistical power was imposed by small sample sizes in Groups 1 and 4. Procedural parameters such as contrast volume and wire crossing time were comparable across BMI groups. **Patterson *et al.* [11], Hannan *et al.* [16]**, **Guelker *et al.* [8]**, **Stähli *et al*. [12]**, and the British Cardiovascular Intervention Society (2017) likewise reported that BMI was unrelated to technical success.

There was no correlation between BMI-lesion complexity (p=0.587). "Difficult" lesions (J-CTO score 2) were seen more often in Groups 2 and 3, with "very difficult" lesions (score ≥3) being dominant in Group 3 but without the BMI trend. This follows **Guelker *et al*. [8]** and **Patterson *et al.* [11]**, who similarly found lesion complexity to be BMI independent.

Correlation analysis revealed that J-CTO score correlated significantly with wire crossing time (r=0.770, p<0.001) and moderately with contrast volume (r=0.401, p=0.010) and crossing time (r=0.490, p=0.001). Wire crossing time was negatively correlating with stent number (r=-0.358, p=0.023), which means longer times were due to crossing complexity and not stenting complexity. **Guelker *et al*. [8]** found no correlation between BMI and contrast use or fluoroscopy time, and **Stähli *et al.* [12]** noted a slightly longer procedure time in obese patients without compromising on success. **Patterson *et al.* [11]** confirmed BMI did not affect success but noted functional gain post-procedure.

The "obesity paradox" improved survival or outcome in overweight/mildly obese patients is established by **Mehta et al. [15]**, **Biswas et al. [14],** and the British Cardiovascular Intervention Society (2017), who presented improved or similar outcomes compared with normal weight, except for the extremes of BMI. Severe obesity can also be associated with technical challenges, including vascular access difficulty, imaging limitations, and radiation exposure, which remain to be studied thoroughly.

The present study has several limitations that should be acknowledged. The small sample size, particularly in the normal BMI and morbid obesity groups, limits the statistical power and reduces the generalizability of the findings. Additionally, the retrospective single-center design may introduce selection bias and constrain the external validity of the results. The short-term follow-up period could have missed delayed complications or late restenosis events, potentially underestimating long-term risks.

CONCLUSION

While BMI did not significantly influence procedural success, complication rates, or post-discharge outcomes, some trends were observed. Notably, higher J-CTO scores and chest pain incidence were more common among overweight and obese groups, suggesting a possible link between adiposity and lesion complexity or symptom burden. However, the overall safety and efficacy of CTO-PCI were maintained across BMI categories, even patients who were overweight or obese had good outcomes. These findings align with the “obesity paradox,” where overweight patients may not experience proportionally worse outcomes and, in some cases, may fare comparably or better than their normal-weight counterparts**.**

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