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Original Article

Improving Success Rates of Percutaneous Coronary Intervention for Chronic Total Occlusion at a Rural Hospital in East Taiwan☆

Kuang-Te Wang [1], Chun-Yen Chen [2, 3 *], Yun-Tzy Chen [1], Jui-Peng Tsai [1, 2], Wen-Hsiung Lin [1], Hsiao-Yang Cheng [1], Hung-I Yeh [2, 3], Charles Jia-Yin Hou [2, 4, 5]

[1] *Division of Cardiology, Department of Internal Medicine, Mackay Memorial Hospital, Taitung,* [2] *Division of Cardiology, Department of Internal Medicine, Mackay Memorial Hospital, Taipei,* [3] *Faculty of Medicine, Mackay Medical College,* [4] *Faculty of Nursing, Mackay Medicine, Nursing, and Management of College,* [5] *Faculty of Medicine, Taipei Medical University, Taipei, Taiwan*

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SUMMARY

Background: We aimed to report the results of percutaneous coronary intervention for chronic total occlusion (CTO) in a remote hospital of southeast Taiwan that does not have on-site coronary artery bypass graft support and has insufficient medical resources.
Methods: From 2006 to 2009, we identified 96 patients who underwent percutaneous coronary intervention and whose coronary angiogram showed CTO lesions. On-site cardiovascular surgeons were unavailable from 2006 to 2009.
Results: The success rate (test for trend, $p = 0.02$) and numbers of guidewires used (test for trend, $p = 0.59$) significantly increased from 2006 to 2009, and the procedural time reduced significantly (test for trend, $p = 0.001$). The volume of contrast media injected decreased, although this result was not statistically significant ($p = 0.70$).
Conclusion: Our experience in managing CTO lesions substantially improved and the procedural time reduced over 4 years, even when constrained by a relative shortage of medical resources.

1. Introduction

Chronic total occlusion (CTO), which is a challenging clinical condition treated using percutaneous coronary intervention (PCI)[1], has been associated with a high incidence of adverse cardiovascular events[2,3], a low procedural success rate[4,5], and a high restenosis rate[6,7], as documented in previous studies of PCI. Recent clinical trials have proved that successful interventions in such lesions are associated with prolonged survival[2,3] and improved left ventricular (LV) function[8,9], leading to myocardial electrical stability and increased tolerance for future coronary events.

Restenosis rates associated with PCI have decreased remarkably since the introduction of drug-eluting stents[10–12]. Recently, PCI techniques for CTO have changed significantly[13,14] with the introduction of parallel wiring and a retrograde approach. Many previously used PCI techniques for CTO improved the success rate but simultaneously prolonged potential radiation and procedural time.

Taitung County, situated in southeast Taiwan, is characterized by mountains and hills, which proves challenging for major transportation and housing construction. Lower economic productivity, low population density, and an aging population have led to insufficient or poorly accessible medical resources in this county. This study analyzes the results of treatment of CTO in a catheterization room at the Mackay Memorial Hospital (Taitung branch), the largest hospital in Taitung. Medical resources and equipment were restricted by health insurance policies; therefore, we desired an optimal, simple, and cost-effective strategy for treating CTO lesions.

2. Materials and methods

2.1. Participants

This study was conducted in accordance with the guidelines of the Declaration of Helsinki and has received approval from the Ethics Committee of Mackay Memorial Hospital (Taitung branch).

☆ Conflicts of interest: All contributing authors declare no conflicts of interest.

* Correspondence to: Dr. Chun-Yen Chen, Cardiovascular Division, Department of Internal Medicine, Mackay Memorial Hospital, 92, Section 2, Chung San North Road, Taipei 10449, Taiwan.
E-mail address: mwplasma@ms9.hinet.net (C.-Y. Chen).

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Of the 3037 consecutive patients referred for coronary catheterization from 2006 to 2009, 1798 patients underwent elective PCI. From 2006 to 2009, we identified 96 patients who underwent PCI and whose coronary angiogram showed CTO lesions. During this period, on-site cardiovascular surgeons were unavailable at the hospital. The indications for referral included ischemia documented either by resting electrocardiogram or stress testing, or typical stable class II or III angina according to the Canadian Cardiovascular Society. The demographic profile, medical history, coronary angiogram findings, number of guidewires used, PCI procedural time, and contrast volume used in PCI were obtained from the hospital registry. Patients were considered to have hypertension (HTN) if they had a history of HTN or a systolic blood pressure (BP) $\geq$140 mmHg or a diastolic BP of $\geq$90 mmHg. Patients were considered to have diabetes mellitus (DM) if they had a history or a fasting blood glucose level $\geq$126 mg/dL. Moreover, patients were considered to have uremia if they were on maintenance hemodialysis. Complications included perforation of the coronary artery, severe dissection (type C), no reflow after PCI, cardiac tamponade, or shock during the PCI procedure performed with or without an intra-aortic balloon pump or a coronary artery bypass graft.

Stenotic coronary artery disease was defined as the presence of at least 50% stenosis of any of the major coronary arteries (left anterior descending, left circumflex, or right coronary artery) or their major branches (diagonal, obtuse marginal, posterior descending, or posterior left ventricular)[15]. For the number of significant stenotic vessels, the occurrence of stenotic segments in one of the major arteries or one of the major branches were estimated, as visualized by two experienced cardiologists (K.T.W. and H.Y.C.). A major branch was defined as one in which the diameter was $\geq$2.5 mm. A CTO was defined as an occlusion on angiography with no antegrade filling of the distal vessel other than that via the collaterals. The duration of the occlusion had to be >90 days, which was estimated from the onset of clinical events such as myocardial infarction (MI), sudden onset or worsening of the chest symptoms, or proven by angiography. Coronary angiography was performed using Philip Integris BH 5000 equipped with the CAAS II cardiovascular angiography analysis system (Pie Medical Imaging, Maastricht, the Netherlands). The success rate of the treatment for CTO lesion was defined as a final stenosis diameter of <50% on quantitative coronary angiography. We treated all CTO lesions with the antegrade approach and bare metal stent implantation.

2.2. Statistical analysis

Results are expressed as mean ± standard deviation or as percentages. Analysis of variance or Student's t test was used for continuous variables and the χ^2 test was used for categorical data to compare differences between groups. A p value <0.05 was considered statistically significant. Multivariate logistic regression model was performed to examine the independent factors associated with success CTO-PCI such as age ($\geq$70 years vs. <70 years), sex (men vs. women), HTN (yes vs. no), DM (yes vs. no), uremia (yes vs. no), smoking status (yes vs. no), and statin (yes vs. no). All statistical analyses were performed with SAS software version 9.0 (SAS Institute, Cary, NC, USA).

3. Results

3.1. Patients, lesions, and procedural characteristics

Overall, 96 patients (age, 69.6 ± 12.2 years; male, 72.9%) with CTO lesions underwent PCI from 2006 to 2009. Approximately 20–30 patients per year received treatment for CTO at our hospital, with a mean success rate of 73% (70 out of 96 patients). These patients received a sequential change of devices used from 2006 to2009. There were no significant differences in age, sex, prevalence of HTN and DM, smoking status, history of uremia, previous MI, approach site of PCI, and numbers of stenotic vessels from 2006 to 2009. The percentage of patients using angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, beta blockers, or calcium-channel blockers was not different from 2006 to 2009, but the percentage of statin use increased from 2006 to 2009 (Table 1). A high percentage of patients who underwent PCI in 2006 had previously undergone PCI and had total occlusion of the left descending artery compared to those who underwent PCI in the following 3 years. There were no significant differences in age, sex, prevalence of HTN and DM, smoking status, history of uremia, previous MI and PCI, approach site of PCI, or the numbers of stenotic vessels between the successful and nonsuccessful groups. The percentage of patients using angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, beta blockers, or calcium-channel blockers was not different between the successful and nonsuccessful groups (Table 2). The procedural complication rate was 3 (15.7%) in 2006, 3 (9.4%) in 2007, 0 (0%) in 2008, and 0 (0%) in 2009 ($p = 0.09$). To further clarify the factors associated with the success of CTO-PCI, the logistic regression model was performed (Table 3). All patients with successful CTO-PCI were likely to be aged >70 years [adjusted odds ratio (AOR), 1.49; 95% confidence interval (CI), 0.54–4.14]; other factors were DM (AOR, 1.24; 95% CI, 0.44–3.47), HTN (AOR, 1.17; 95% CI, 0.37–3.72), uremia (AOR, 3.57×10^8; 95% CI, 0), and statin use (AOR, 1.46, 95% CI: 0.53–4.02), but these factors did not reach statistic significance.

3.2. Contrast volume, guidewire use, procedural time, and success rate

The success rate (test for trend, $p = 0.02$) and numbers of guidewires used (test for trend, $p = 0.59$) increased significantly from 2006 to 2009, and the procedural time reduced significantly (test for trend, $p = 0.001$). The contrast volume injected decreased from 2006 to 2009, although the difference was not statistically significant (test for trend, $p = 0.70$) (Figs. 1 and 2). The mortality rate in the successful and nonsuccessful groups was 6.7% and 4.8% ($p = 0.58$), respectively, at 1 year follow-up. In the successful group, three patients died because of noncardiac death and two patients because of cardiac death. In the nonsuccessful group, one patient died owing to cardiac death. Of the total, 47 patients (62.7%) in the successful group received 1-year angiographic follow-up and 25 (53.2%) of 47 patients in the successful group underwent target vessel revascularization.

4. Discussion

Our study results found an increased success rate for CTO lesions, decreased procedural time, and increased numbers of guidewires in a consecutive series of patients from 2006 to 2009 in a remote hospital. In our study, the success rate increased from 60% in 2006 to 94.7% in 2009, and PCI-CTO became much safer from 2006 to 2009. The reasons for the increased success rate and decreased procedural time might be related to operator volume, operator experience, technique innovations, and well-trained staff.

The safety and effectiveness of more complex strategies are related to operator volume and ascension of a learning curve[16,17]. It is also important that a catheterization laboratory should have resources to perform these complex procedures. Specifically, a well-disciplined support staff is necessary to ensure familiarity with infrequently used devices and to assist in the recognition and management of complex lesions. Since the advent of better

Table 1
Demographic data of patients with chronic total occlusion who underwent percutaneous coronary intervention between 2006 and 2009.

	Year group				
	2006 ($n = 19$)	2007 ($n = 32$)	2008 ($n = 26$)	2009 ($n = 19$)	p
Age (y)	71.5 ± 9.5	65.3 ± 12.5	70.6 ± 12.9	73.4 ± 11.9	0.09
Sex (male)	15 (78.9)	23 (71.9)	18 (69.2)	14 (73.7)	0.91
HTN (yes)	16 (84.2)	20 (62.5)	22 (84.6)	14 (73.7)	0.19
DM (yes)	9 (47.4)	14 (43.8)	17 (65.4)	11 (57.9)	0.37
Smoking status (yes)	6 (31.6)	19 (59.4)	8 (30.8)	11 (57.9)	0.06
Uremia (yes)	1 (5.3)	4 (12.5)	0 (0)	3 (15.8)	0.19
Previous MI (yes)	5 (26.3)	5 (15.6)	3 (11.5)	1 (5.3)	0.30
Previous PCI (yes)	7 (36.8)	11 (34.4)	3 (11.5)	1 (5.3)	0.02
Medication					
ACEI or ARB (yes)	14 (73.7)	22 (68.8)	19 (73.1)	10 (52.6)	0.45
Beta blocker (yes)	12 (63.2)	13 (40.6)	17 (65.4)	14 (73.7)	0.08
Statin (yes)	6 (31.6)	9 (28.1)	18 (69.2)	14 (73.7)	0.001
CCB (yes)	3 (15.8)	10 (31.3)	12 (46.2)	16 (31.6)	0.20
No. of stenotic CAD					0.91
Single	1 (5.3)	3 (9.4)	4 (15.4)	2 (10.5)	
Double	4 (21.1)	4 (12.5)	5 (19.2)	3 (15.8)	
Triple	14 (73.7)	25 (78.1)	17 (65.4)	14 (73.7)	
CTO lesion location					
LAD	11 (57.9)	10 (31.3)	6 (23.1)	3 (15.8)	0.03
LCX	1 (15.8)	10 (31.3)	4 (15.4)	6 (31.6)	0.35
RCA	7 (36.8)	16 (50.0)	16 (61.5)	10 (52.6)	0.44
Approach					0.37
Radial artery	16 (82.4)	23 (71.9)	17 (65.4)	10 (55.6)	
Brachial artery	0 (0)	1 (3.1)	3 (11.5)	1 (5.6)	
Femoral artery	3 (15.8)	8 (25.0)	6 (23.1)	7 (38.9)	
Contralateral simultaneous injection	1 (5.3)	0 (0)	2 (7.7)	2 (10.5)	0.37

Data are presented as n (%) or mean ± SD.
ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin receptor blocker; CAD = coronary artery disease; CCB = calcium channel blocker; CTO = chronic total occlusion; DM = diabetes mellitus; HTN = hypertension; LAD = left anterior descending; LCX = left circumflex; MI = myocardial infarction; PCI = percutaneous coronary intervention; RCA = right coronary artery.

guidewires, interventional cardiologists can successfully recanalize CTO lesions[18].

Procedural success may be achieved on the operators' persistence. For all the procedures at our institute, we decided to minimize procedural time. Therefore, there was no significant difference in procedural times between the successful and nonsuccessful groups.

Table 2
Demographic data among successful and nonsuccessful CTO-PCI groups.

	Successful group ($n = 75$)	Nonsuccessful group ($n = 21$)	p
Age (y)	70.0 ± 12.5	68.8 ± 12.4	0.89
Sex (male)	52 (69.3)	18 (85.7)	0.14
HTN (yes)	57 (76.0)	15 (71.4)	0.67
DM (yes)	42 (56.0)	9 (42.9)	0.29
Smoking status (yes)	33 (44.0)	11 (52.4)	0.99
Uremia (yes)	8 (10.7)	0 (0)	0.12
Previous MI (yes)	11 (14.7)	3 (14.3)	0.97
Previous PCI (yes)	18 (24.0)	4 (19.0)	0.63
Procedural time	104.5 ± 39.7	96.9 ± 401	0.45
Medication			
ACEI or ARB (yes)	51 (68.0)	14 (66.7)	0.91
Beta blocker (yes)	45 (60.0)	11 (52.4)	0.53
Statin (yes)	38 (50.7)	9 (42.9)	0.53
CCB (yes)	23 (30.7)	8 (38.1)	0.52
No. of stenotic CAD			0.58
Single	8 (10.7)	2 (9.5)	
Double	14 (18.7)	2 (9.5)	
Triple	53 (70.7)	17 (81.0)	
CTO lesion location			
LAD	25 (33.3)	5 (23.8)	0.41
LCX	17 (22.7)	6 (28.6)	0.58
RCA	39 (52.0)	10 (47.6)	0.72
Mortality at 1-year follow-up	5 (6.7)	1 (4.8)	0.58

Data are presented as n (%) or mean ± SD.
Abbreviations as in Table 1.

4.1. Historical reviews of CTO success rate

In a single-center, 25-year study from the Mayo Clinic, the procedural success rate for CTO-PCI in the pre-stent era between 1979 and 1989 was only 51%.[5] After the introduction of stents, the CTO-PCI success rate increased to 70–72% in the bare-metal stent era and reached approximately 70% in the drug-eluting stent era. The CTO New techniQUE for Standard procedure (CONQUEST) registry was conducted by the CTO "specialized" operators at six Japanese centers, and the success rate was 86.2%[13]. The J-CTO registry (a multicenter CTO registry in Japan) reported that a success rate of 86.6% and reduced contrast volume compared with those obtained in the CONQUEST study[19]. Contemporary experiences in the United States and Europe have shown technical success rates of approximately 90% and 83.4%, respectively, using the retrograde approach.[16,17] Although the success rate for CTO lesions from our study was initially lower, it reached approximately 94.7% over 3 years. Our success rate finally reached 80–90% and was comparable to the results of the abovementioned studies.

Table 3
Contributions of variables to success in chronic coronary total occlusion– percutaneous coronary intervention.

Variables	Odds ratio (95% CI)	p
Age (≥70 y vs. <70 y)	1.49 (0.54–4.14)	0.45
Sex (men vs. women)	2.07 (0.48–8.88)	0.33
HTN (yes vs. no)	1.17 (0.37–3.72)	0.79
DM (yes vs. no)	1.24 (0.44–3.47)	0.68
Smoking (yes vs. no)	1.05 (0.35–3.13)	0.93
Uremia (yes vs. no)	3.57×10^8 (0–)	1.00
Statin (yes vs. no)	1.46 (0.53–4.02)	0.47

Abbreviations as in Table 1.
CI = confidence interval.

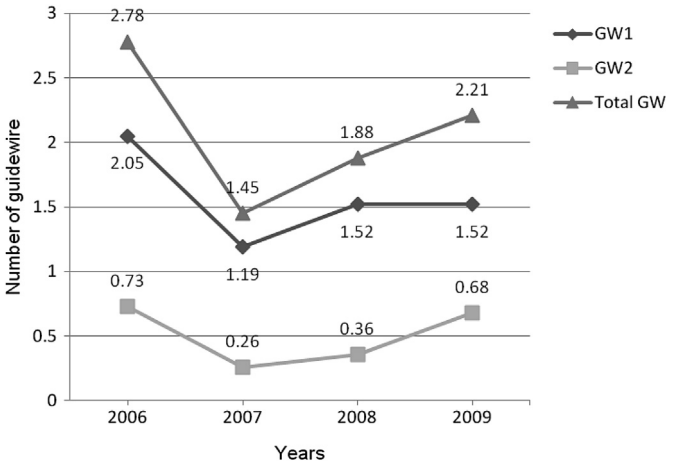

Fig. 1. The number of guidewires used for chronic total occlusion from 2006 to 2009. Guidewire (GW)1 including Runthrough (Terumo), Rinato (Asahi), Fielder FC (Asahi), Whisper (Guidant), Runthrough NS intermediate (Terumo) and CROSS-IT XT (Abbott vascular). GW2 including Miracle 3-5g (Asahi), Conquest pro 9 (Asahi), Conquest pro 12 (Asahi) and Conquest pro 20 (Asahi). Total GW number = GW1 number+GW2 number. Test for trends in GW1, GW2, and total GW: $p = 0.42$, $p = 0.77$, and $p = 0.59$, respectively.

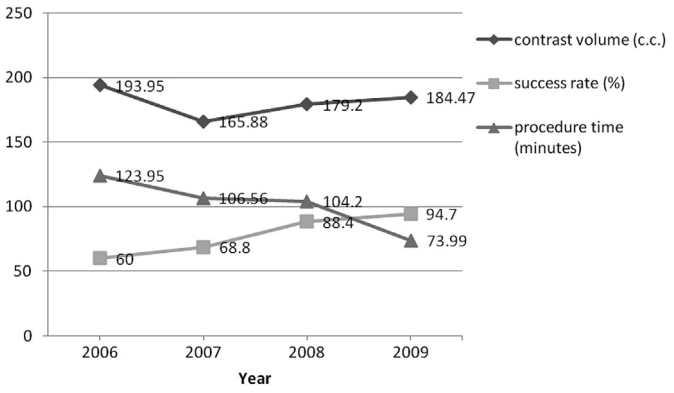

Fig. 2. Contrast volume, procedural time, and success rate from 2006 to 2009. Test for trends in the contrast volume, procedure time, and success rate: $p = 0.70$, $p = 0.001$, and $p = 0.02$, respectively.

In our study, the right coronary artery (51.0%) was the most common location of the CTO, whereas this percentage was 44.3% in the J-CTO registry[19] and 41.7% in a meta-analysis of 65 studies[20]. The prevalence of HTN in our study was higher than that noted in the J-CTO registry[19] or the Mayo Clinic study[5]. The prevalence of DM in our study was higher than that in the CONQUEST registry[13]. The percentage of triple-vessel disease was higher in our study (72.9%) than that in the CONQUEST registry, J-CTO registry, or the Mayo Clinic study (17.3%, 22.7%, or 30.8%, respectively)[5,13,19]. In a meta-analysis of 13 observational studies, multivessel disease, location of CTO, cardiovascular factors such as age, sex, and renal dysfunction, and DM were not associated with CTO-PCI success[20]. Our study also had similar results.

4.2. Current status of PCI-CTO

The potential disadvantages of PCI-CTO are long procedural time, long fluoroscopic time, and a high contrast volume. In our study, we reduced the procedural time and the contrast volume. Decreased procedural time could avoid skin injury due to radiation. Suzuki et al[21] have shown that limiting the total fluoroscopic time or dose-area product or changing the beam angulation is important for controlling the skin dose during prolonged procedures. Contrast-induced nephropathy was one of the serious adverse effects in complex PCI. We attempted to adjust the contrast volume based on preoperative renal function and minimize the volume used in this study. However, it is necessary that continuous efforts be made to further decrease the procedural time and contrast volume.

4.3. Follow-up and clinical implications

In the successful group of our study, two patients (2.6%) died because of cardiac death 1 year after PCI. However, in a previous meta-analysis, 77 deaths were reported after PCI, with mortality rates ranging from 0% to 3.6%[22]. In addition, 53.2% of angiographic follow-up patients underwent target vessel revascularization, which is 23.95% of bare metal stent-treated patients and 11.71% of drug-eluting stent-treated patients in the meta-analysis study[23]. Several observational studies have shown a survival benefit when CTO is successfully treated compared to that when the vessel is not opened[4,5,24]. Other studies have shown an improvement in regional and global left ventricular function after treatment, with a decrease in end-systolic volume and an increase in ejection fraction[8,9]. Therefore, recanalization of coronary CTO may be associated with favorable long-term outcomes and better cardiac function. In our study, the rate of procedural complications decreased, whereas the rate of procedural success increased from 2006 to 2009. Therefore, CTO for PCI carries a low risk for procedural complications and results in high success rates.

There were several limitations in this study. First, this study is an observational study, and the study design did not involve randomization. Some unobserved characteristics may be sources of residual confounders. The nonrandomized nature of this study did not allow prediction of the precise success rate of PCI-CTO. Further research is needed to clarify these potential effects. Second, the number of operators at this remote hospital was limited during the duration of the study. Our experience might be applied to other hospitals without on-site surgical support. Third, the small sample size limited the power of the statistical analyses in this study. Fourth, we cannot analyze predictors related to success rate and revascularization rate in our dataset. However, all CTO-PCI procedures were performed or supervised by K.T.W.. The introduction of new PCI techniques for CTO that combine different strategies such as the use of contralateral injections or dissection/reentry techniques coupled with dedicated, high-volume CTO PCI operators may play a role in improving success rates.

5. Conclusion

The success rate of PCI for CTO can be increased using contemporary strategies and techniques by experienced cardiologists with a safety profile compared to that of standard risk-adjusted PCI. Our experience in managing CTO lesions in Taitung County showed substantial improvements over the years, as well as a shortened procedural time even when constrained by a relative shortage of medical resources. Information regarding the cost-effectiveness of such a challenging intervention may need to be clarified in the future.

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