



Clinical paper

Feasibility and safety of combined percutaneous coronary intervention and therapeutic hypothermia following cardiac arrest[☆]

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ABSTRACT

Review: Mild therapeutic hypothermia (MTH) has been associated with cardiac dysrhythmias, coagulopathy and infection. After restoration of spontaneous circulation (ROSC), many cardiac arrest patients undergo percutaneous coronary intervention (PCI). The safety and feasibility of combined MTH and PCI remains unclear. This is the first study to evaluate whether PCI increases cardiac risk or compromises functional outcomes in comatose cardiac arrest patients who undergo MTH.

Methods: Ninety patients within a 6-h window following cardiac arrest and ROSC were included. Twenty subjects (23%) who underwent PCI following MTH induction were compared to 70 control patients who underwent MTH without PCI. The primary endpoint was the rate of dysrhythmias; secondary endpoints were time-to-MTH induction, rates of adverse events (dysrhythmia, coagulopathy, hypotension and infection) and mortality.

Results: Patients who underwent PCI plus MTH suffered no statistical increase in adverse events ($P = .054$). No significant difference was found in the rates of dysrhythmias ($P = .27$), infection ($P = .90$), coagulopathy ($P = .90$) or hypotension ($P = .08$). The PCI plus MTH group achieved similar neurological outcomes (modified Rankin Scale (mRS) ≤ 3 ($P = .42$) and survival rates ($P = .40$). PCI did not affect the speed of MTH induction; the target temperature was reached in both groups without a significant time difference ($P = .29$).

Conclusion: Percutaneous coronary intervention seems to be feasible when combined with MTH, and is not associated with increased cardiac or neurological risk.

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1. Introduction

Therapeutic hypothermia is a proven neuroprotective strategy to achieve favourable neurological outcome after cardiac arrest (CA).¹ Two randomized controlled trials provided definitive proof of the efficacy of mild therapeutic hypothermia (MTH) in reduc-

ing mortality and poor neurological outcome.^{2,3} MTH in the range of 32–34 °C for 12–24 h has been recommended by the Advanced Life Support Task Force of the International Liaison Committee on Resuscitation (ILCOR) for unconscious adult patients with return of spontaneous circulation after out-of-hospital CA with ventricular fibrillation (VF) or non-perfusing ventricular tachycardia (VT), and it may be effective in other non-perfusing rhythms as well.⁴

Despite its proven benefit, MTH may be associated with potential adverse events, including cardiac dysrhythmias, coagulopathy and infection.^{2,5} Most dysrhythmias are asymptomatic, the commonest being bradycardia. However, serious and even life threatening atrial and ventricular dysrhythmias can also occur.⁵ As part of post-resuscitation management, many patients undergo percutaneous coronary intervention (PCI), given the beneficial effects of successful prompt revascularization of the coronary vasculature in patients with acute myocardial infarction (MI). However, reperfusing injured myocardium may provoke dysrhythmias as well.⁶

Although recent reports have evaluated the safety and potential benefits of MTH in patients who underwent PCI after ROSC,^{7–9}

Abbreviations: BLS, basic life support; CA, cardiac arrest; DIC, disseminated intravascular coagulation; EMS, emergency medical service; IABP, intra-aortic balloon pump; ILCOR, International Liaison Committee on Resuscitation; IRB, Institutional Review Board; MI, myocardial infarction; mRS, modified Rankin Scale; MTH, mild therapeutic hypothermia; PCI, percutaneous coronary intervention; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

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there is still lack of data to show that performing both concomitantly does not increase cardiac risk, specifically dysrhythmias, and will not negatively impact outcomes. To the best of our knowledge, this is the first study to evaluate whether PCI increases cardiac risk or compromises functional outcomes in comatose cardiac arrest patients undergoing MTH. Elucidating the safety and efficacy of combination catheterization (with or without revascularization) plus MTH is significant, as both therapies have a time-dependent nature to their benefits. Accordingly, we examined patients who underwent cardiac catheterization (with or without PCI) during MTH after cardiac arrest. In order to achieve a better understanding about how this population behaves, different from previous studies,^{2–4,7–9} we analyzed all cardiac arrest patients who underwent MTH, regardless of the initial cardiac rhythm, cause of CA or the presence of haemodynamic instability.

2. Methods

2.1. Study design

This was a single-center study using a retrospective cohort. The data was extracted through a medical record review, and included all patients who underwent MTH following cardiac arrest since 2002, when MTH was introduced into our standard clinical practice. This study was approved by the local Institutional Review Board (IRB). Patients were identified from an IRB-approved registry of patients who underwent MTH as therapy for cardiac arrest, and a waiver of informed consent was provided.

2.2. Recruitment of patients

Ninety-one adult comatose patients who presented within a 6-h window after cardiac arrest and underwent MTH were reviewed. One patient was excluded from the study, due to early cessation of the MTH protocol (the patient suffered an isolated respiratory arrest without haemodynamic collapse, and thus was felt to be inappropriate for MTH). Subjects underwent MTH regardless of initial rhythm or cause of CA, so long as they remained comatose after ROSC. Patients who were in shock on admission (systolic blood pressure <90 mmHg, despite the use of vasoactive medications) were also included.

2.3. Interventions

All 90 patients underwent mild therapeutic hypothermia according to local institutional cooling protocol. The methods used were external, initially with cooling blankets and ice packs, and later with a cooling vest device. Cardiac catheterization may be safely performed with either of these cooling methods, as the vest is radiolucent, allowing adequate access to and visualization of the coronary vasculature. Our protocol stipulates the use of MTH for 24 h to a target temperature of 32–34 °C. During the cooling period, supportive therapy includes monitoring for dysrhythmias or haemodynamic instability, monitoring for electrolyte abnormalities, and surveillance blood cultures drawn at 12 and 24 h after the initiation of cooling to monitor for infection. If any significant dysrhythmias or haemodynamic instability develop, or there is concern for significant infectious complications or bleeding, MTH is discontinued. Only in the setting of significant haemodynamic instability is the patient actively rewarmed; otherwise rewarming is performed in a controlled fashion, typically over at least 8 h.

Twenty patients received PCI during MTH. The decisions for PCI were made according to the 2007 update of the American College of Cardiology/American Heart Association guidelines for the management of patients with ST-elevation myocardial infarction and for PCI.^{10,11} Cardiac catheterization procedures analyzed in the study

were those related specifically to the opening of a diseased coronary vessel with myocardial reperfusion, such as stenting and/or balloon angioplasty. These were all performed during the period from the initiation of cooling to completion of rewarming. Patients who underwent other procedures in the catheterization laboratory but without PCI, such as intra-aortic balloon pump (IABP) placement or coronary angiography without intervention, were not included in the intervention group, as these were not considered to pose significant additional risk for the primary endpoint, cardiac dysrhythmias.

2.4. Data analysis

Data were obtained from a detailed review of the medical records. Adverse events were noted if they occurred during the MTH period and for up to 24 h after the patient had been completely rewarmed. They included dysrhythmias, coagulopathy (bleeding of any severity or disseminated intravascular coagulation (DIC)), hypotension requiring vasopressor therapy, and infectious complications.

The primary endpoint assessed was cardiac dysrhythmias. Cardiac dysrhythmias included both asymptomatic and serious; serious dysrhythmias were defined as those causing haemodynamic instability, requiring anti-arrhythmic therapy or leading to an interruption of MTH. Secondary endpoints were: time-to-MTH induction, defined as the time from the onset of CA to the initiation of MTH, in-hospital mortality, and the rate of adverse events. We considered good neurologic outcome at discharge as a modified Rankin Scale (mRS) score ≤ 3 ,¹² defined as: no residual symptoms (mRS = 0), no significant disability despite symptoms (mRS = 1), slight disability (mRS = 2), or moderate disability (mRS = 3, patient requires some help with routine activities but is still able to walk without assistance).¹²

2.5. Statistical analysis

All statistical analyses were performed using SPSS software (version 17.0, SPSS Inc., Chicago, IL). Age, duration of arrest and time from arrest to induction of MTH were analyzed as continuous variables and reported as mean \pm standard deviation (SD) or as median \pm interquartile range (IQR). All other variables were analyzed as categorical and reported as proportions. Differences between means were assessed by the Student's *t*-test, and medians by the Mann–Whitney *U*-test. Differences between proportions were assessed by the chi-square test or Fisher's exact test when appropriate. In order to assess the safety of PCI in hypothermic patients, univariate analysis was used to test the association between different variables and the occurrence of adverse events during MTH. A multivariable regression analysis was used to adjust for the possible confounding effect of covariates associated with the occurrence of adverse events, dysrhythmias and serious dysrhythmias (age, myocardial infarction, duration of cardiac arrest, shockable rhythm and shock on admission). A forward selection method was used to select significant variables for the final model (0.2 was the threshold for variable entry in the model). The variable 'coronary intervention' was forced to stay in the models. A two-sided *P* value < .05 was considered significant.

3. Results

3.1. Patient characteristics

Of the 90 patients undergoing MTH, only three were in-hospital cardiac arrest. They were due to choking (1 patient) and anaphylaxis (2 patients). They were unsuitable for PCI. Thirty-six subjects (40%) underwent immediate cardiac catheterization, and 20 sub-

Table 1
Patient characteristics.

Characteristic	PCI		P
	Yes (N = 20)	No (N = 70)	
Age–mean (±SD)	66.2 (±9.3)	59.1 (±19.3)	.02
Gender (male) ^a	13 (65%)	50 (71%)	.60
Diabetes	6 (30%)	22 (31%)	.90
Congestive heart failure	4 (20%)	12 (17%)	.80
Cerebrovascular disease	1 (5%)	7 (10%)	.50
Hypertension	13 (65%)	32 (46%)	.10
Coronary artery disease	13 (65%)	19 (27%)	.002
Dyslipidemia	13 (65%)	12 (17%)	<.001
Smoking	6 (30%)	15 (21%)	.40
Drug/alcohol abuse	1 (5%)	15 (21%)	.09
BLS by bystander	10 (50%)	34 (49%)	.90
Shockable rhythm	12 (60%)	30 (43%)	.20
Shock on admission	3 (15%)	19 (27%)	.30
Myocardial infarction (MI)	11 (55%)	13 (19%)	.001
ST-elevation MI	10 (50%)	10 (14%)	.001
Time of cardiac arrest (min)–mean (±SD)	21.2 (±16.8)	25.2 (±16.0)	.34
Cooling for 24 h	14 (70%)	61 (88%)	.09
Withdrawal of care	8 (40%)	46 (65%)	.03
mRS ≤ 3 at the discharge	6 (30%)	15 (22%)	.42

BLS, basic life support; mRS, modified Rankin Scale.

^a Data are presented as means or absolute numbers with frequency in parentheses.

jects (22%) underwent PCI. Those undergoing PCI were compared to the 70 MTH-treated patients who did not.

Incident coronary artery disease, dyslipidemia, and prior MI were more common among subjects who underwent PCI, as was ST-elevation MI (Table 1). The mean age, however, was significantly higher in the MTH without PCI group. Initial non-shockable rhythms (asystole and pulseless electrical activity, PEA) were non-significantly less common in the PCI-treated group (40% vs. 57% $P = .20$).

A determined aetiology of the CA was found in 63/90 patients (70%), and MI was responsible for 38%. As expected, significantly more patients in the PCI group had MI compared with the non-PCI group (55% vs. 19%, $P = .001$). Rates of PCI were significantly lower among those who had CA due to primary respiratory arrest (mostly due to drowning, hanging and choking leading to asphyxia; 0% vs. 21%; $P = .02$). Twenty-seven patients (30%) were considered to have multiple potential causes of CA, including metabolic disturbances, drug abuse, pulmonary embolism, myocarditis, previous MI and anaphylaxis. None of these were significantly different between the two groups.

Twenty-one patients (24%) had a good neurologic outcome at discharge (mRS ≤ 3), 6/20 (30%) in the PCI group and 15/70 (22%) in the isolated MTH group ($P = .42$). Modified Rankin Scale scores of 4 and 5 occurred in 2/20 patients in the PCI group (10%), and in 6/70 patients in the isolated MTH group (8.6%, $P = .85$). Withdrawal of care was performed (due to poor prognosis) in 54 patients (60%), with a significantly higher rate in the isolated MTH group (65% vs. 40%, $P = .03$). Survival to discharge was achieved in 16/43 patients (37%) with VF/VT, and in 9/42 (22%) with PEA/asystole.

3.2. Cardiac catheterization and cooling protocol

Thirty-six patients (40%) underwent an invasive procedure in the cardiac catheterization laboratory, all of which were successful. These included diagnostic coronary angiography (12), IABP placement (20), and PCI (20).

Table 2
Primary endpoint.^a

Dysrhythmia	PCI		OR (95% CI)	P
	Yes (N = 20)	No (N = 70)		
Dysrhythmia (any)	6 (30%)	13 (19%)	1.9 (0.6–5.8)	.27
Serious dysrhythmia	3 (15%)	9 (13%)	1.2 (0.3–5.0)	.80

^a Data are presented as absolute numbers with percentage in parentheses.

3.2.1. Primary endpoint

Dysrhythmias were separately analyzed as all dysrhythmias (which included asymptomatic and serious) versus serious dysrhythmias alone (Table 2). No significant difference was found in dysrhythmia rates, serious or overall. Nineteen patients developed 24 episodes of dysrhythmias, the most common being bradycardia, which occurred 12 times (50%), 3 in the PCI group and 9 in isolated MTH group ($P = .80$). Only 3 of the 12 episodes of bradycardia were considered serious, all in the non-PCI group. Other arrhythmias included atrial fibrillation (in 3 isolated MTH patients), 1 episode of PEA, 1 episode of ectopic atrial rhythm (isolated MTH group), and 1 episode of accelerated idioventricular rhythm (PCI group). Age, duration of cardiac arrest and coronary intervention were the selected variables for the model with dysrhythmias (first model) and serious dysrhythmias (second model) as dependent variables. PCI was not significantly associated with overall dysrhythmias ($P = .80$), or serious dysrhythmias ($P = .70$). In the first model, age and time of cardiac arrest were significantly associated with the occurrence of dysrhythmias ($P = .04$ and $P = .006$). The results of the regression analysis can be seen in Table 3.

3.2.2. Secondary endpoints

Secondary endpoints are shown in Table 4. The median time-to-MTH induction was 5 h (25–75th percentile, 3–5.4 h) with no significant difference between the two groups. Eleven patients in the PCI group (55%) had an adverse event, with a trend toward higher event rates compared to the non-PCI group ($P = .054$). When analyzed individually, no adverse event was statistically different between the groups, although there was a trend toward more hypotension requiring vasopressor therapy in the PCI group (25% vs. 10%, $P = .08$). Infectious complications occurred in 5/90 (6%). Coagulopathy, defined as bleeding of any severity or a diagnosis of DIC, occurred in 5/90 (6%). All of our cases of coagulopathy led to the interruption of MTH for safety concerns. No significant bleeding occurred in the PCI group, but one case of DIC did occur. In the non-PCI group, 1 patient experienced DIC and 3 had a gastrointestinal bleeding, one of which occurred in a patient who had received an IABP.

Univariate analysis revealed that acute MI with PCI was more common in patients who developed adverse events (Table 5). However, after adjustment, neither was significantly associated with any complication (Table 6).

Sixty-one patients (67%) died during hospitalization, but the rates of mortality (mRS = 6) were not statistically different between groups (PCI–MTH 60% vs. isolated MTH 70%, $P = .40$).

Table 3
Multivariate analysis for dysrhythmias.

Dysrhythmia (any)	Dysrhythmia (any)			Serious dysrhythmia		
	OR	95% CI	P	OR	95% CI	P
Variable						
PCI	1.2	0.3–4.2	.80	0.7	0.2–3.4	.70
Age (years)	1.04	1.0–1.1	.04	1.04	1.0–1.1	.07
Time of cardiac arrest (min)	0.9	0.9–1.0	.006	0.9	0.9–1.0	.05

Table 4
Secondary endpoints.

Endpoint	PCI		OR (95% CI)	P
	Yes (N=20)	No (N=70)		
Time to inducing MTH (h) ^a	4.2 (2.2–5.0)	5.0 (3.0–5.5)	–	.29
Adverse event ^b	11 (55%)	22 (31%)	2.6 (1.0–7.3)	.05
Hypotension	5 (25%)	7 (10%)	3.0 (0.8–10.7)	.08
Infection	1 (5%)	4 (5.7%)	0.8 (0.9–8.2)	.90
Coagulopathy	1 (5%)	4 (5.7%)	0.8 (0.9–8.2)	.90
Dysrhythmia ^a (any)	6 (30%)	13 (19%)	1.9 (0.6–5.8)	.27
Serious dysrhythmia	3 (15%)	9 (13%)	1.2 (0.3–5.0)	.80
Mortality	12 (60%)	49 (70%)	0.6 (0.2–1.8)	.40

^a Median with interquartile range.^b Data are presented as absolute numbers with frequency in parentheses.**Table 5**
Univariate analyses of adverse events.

Characteristic	Adverse event		OR (95% CI)	P
	Yes (N=33)	No (N=57)		
Age–mean (±SD)	64.1 (±16.1)	58.8 (±18.6)	–	.24
Gender (male) ^a	21 (64%)	42 (74%)	0.6 (0.2–1.6)	.31
Diabetes	10 (30%)	18 (32%)	0.9 (0.4–2.4)	.90
Congestive heart failure	5 (15%)	11 (19%)	0.7 (0.2–2.4)	.62
Cerebrovascular disease	2 (6%)	6 (10%)	0.5 (0.1–2.9)	.47
Hypertension	18 (54%)	27 (47%)	1.3 (0.6–3.1)	.51
Coronary artery disease	13 (39%)	19 (33%)	1.3 (0.5–3.2)	.56
Dyslipidemia	8 (24%)	17 (30%)	0.7 (0.3–2.0)	.57
Smoking	6 (18%)	15 (26%)	0.6 (0.2–1.8)	.38
Drug/alcohol abuse	6 (18%)	10 (17%)	1.0 (0.3–3.2)	.94
BLS by bystander	13 (39%)	31 (54%)	0.5 (0.2–1.3)	.17
Shockable rhythm	18 (54%)	24 (42%)	1.6 (0.7–3.9)	.25
Shock on admission	7 (21%)	15 (26%)	0.7 (0.3–2.1)	.59
Myocardial infarction (MI)	13 (39%)	11 (19%)	2.7 (1.0–7.1)	.04
ST-elevation MI	10 (30%)	10 (17%)	2.0 (0.7–5.6)	.16
Time of cardiac arrest (min)–mean (±SD)	21.7 (±17.2)	25.9 (±15.4)	–	.17
Time to inducing MTH (h) ^b	4.5 (2.0–5.5)	5.0 (3.5–5.2)	–	.32
PCI	11 (33%)	9 (16%)	2.7 (0.9–7.4)	.05

BLS, basic life support.

^a Data are presented as means or absolute numbers with frequency in parentheses.^b Median with interquartile range.

4. Discussion

This study suggests that cardiac catheterization with PCI may safely be performed in comatose survivors of CA who undergo MTH, specifically without an increased risk of cardiac dysrhythmias.

Coronary angiography and PCI have been associated with improved outcomes after cardiac arrest¹³ particularly when the cause of CA is MI.¹⁴ Consensus guidelines endorse the use of MTH for patients after CA,^{2,3} and similar to PCI for acute MI therapy, earlier application of MTH following ROSC is associated with superior outcomes.¹⁵ Our results suggest that PCI may be safe and feasible during MTH, and outcomes are comparable to those who undergo isolated MTH.

Importantly, both PCI and MTH are associated with the potential for inducing cardiac dysrhythmias.^{6,16–18} A large randomized trial of MTH versus normothermia demonstrated a 36% rate of serious dysrhythmias in patients treated with MTH.² In comparison, we demonstrated a low rate of serious dysrhythmias,^{7,8} and suggest that the rate of cardiac dysrhythmias is not significantly higher

in patients undergoing MTH with concomitant PCI. Indeed, considered as a function of specific dysrhythmia type, asymptomatic bradycardia—a generally benign rhythm—was the most common dysrhythmia seen, and its occurrence is explained by the known effects of hypothermia to decrease depolarization of cardiac pacemaker cells. In addition, dysrhythmias in our subjects were mostly transient, and were not associated with worse neurologic outcomes or mortality rates.

We observed a trend toward higher rates of adverse events in the PCI group, due largely to hypotension. However, multivariate analysis did not show any individual adverse event associated with either treatment group, and overall, PCI was not independently associated with an increased risk of either dysrhythmias or any other adverse outcomes. This suggests that the excess rates of adverse events are largely explainable on the basis of the higher prevalence of baseline risk factors in patients treated with PCI (e.g. advanced age and acute MI) with likely concomitant cardiac dysfunction. Larger cohort studies could be helpful to assess whether this trend could ultimately represent a significant difference between the groups. In contrast, we found that both age and time of CA were independently associated with overall dysrhythmias. However the significantly higher age in the PCI group was not associated with an increased rate of dysrhythmias.

The literature has reported higher rates of coagulopathy and infection in patients treated with MTH.^{2,7,9,19} Some of these studies, when comparing two groups of PCI patients, reported significant

Table 6
Multivariate analysis for adverse events.

Variable	OR	95% CI	P
PCI	2.0	0.7–6.0	.20
Myocardial infarction	2.2	0.8–6.1	.10

increases in infectious complications and the need for transfusion in subjects that underwent MTH.^{7,9} We found no increased risk of either, regardless of whether or not the patient underwent PCI. Although the difference between the two groups did not reach significance, PCI-treated patients were more likely to require vasopressor support. Hypotension may be secondary to the negative inotropic effect of MTH. The trend toward higher rates of hypotension in the PCI group is likely secondary to more myocardial dysfunction due to MI.

There was no significant difference in the mortality rate between the groups; however the overall rate was relatively high in comparison to other studies.^{7–9,20} This is explained by our less-restricted inclusion criteria for cooling cardiac arrest patients, as we included asystolic and PEA patients, historically associated with higher rates of mortality and poor neurological outcome.^{8,21} Asystolic and PEA patients represented 53% of our population. In a study of 4662 out-of-hospital cardiac arrest patients, Engdahl et al.²² showed that just 10% of the patients with asystole as the initial rhythm were admitted alive to the hospital, and only 2% survived to discharge. Oddo et al.²³ did not find any significant improvement in outcomes in patients with non-shockable rhythms undergoing MTH versus normothermia, and only 13% patients were discharged alive. In our cohort, 22% of the subjects with PEA or asystole survived to discharge.

Different from other studies we did not exclude patients who were in shock on admission or with a determined prolonged cardiac arrest.^{2,3,9} Shock on admission was present in 25% of our patients, and this may have contributed to our relatively higher mortality rate, even though the literature suggests that these patients may still benefit from MTH.^{20,22} Moreover, it seems that our patients had a slightly higher mean time of arrest compared with other studies,^{2,7–9} which has been associated with unfavourable neurologic outcomes.⁸ The significantly higher rates of withdrawal of care in the isolated MTH group likely contributed to the trend toward a higher mortality rate. Different from previous studies that evaluated the feasibility of the combined MTH–PCI by the measurement of the door-to-balloon times,^{7–9} our study evaluated the feasibility of the combination, considering that procedures performed in the catheterization lab could potentially cause a delay on the initiation of MTH or could be technically difficult because of the cooling methods. We assessed the time from CA until initiation of MTH and demonstrated that this was not significantly different in the groups. Thus the coronary intervention procedures did not cause any delay in the initiation of MTH, nor did the MTH methods did not impede performance of PCI.

Previous studies of the combination of MTH and PCI analyzed the difference between groups with and without hypothermia, and historical control groups were used for comparison to the hypothermia-treated patients.^{7–9} In order to evaluate the safety of the combined management, with the concern that early PCI is a possible additional risk for cardiac dysrhythmias and other adverse events, we chose to compare groups with and without PCI; all of our patients underwent MTH. Our cohort of patients is larger than previous studies, thereby lending more validity to our results. Moreover, our broader inclusion criteria allowed us to assess the safety of combined therapy in patients with non-shockable rhythms (PEA and asystole) and those with haemodynamic instability. No statistical difference between the PCI-treated and isolated MTH groups for adverse events, neurological outcome or mortality.

4.1. Study limitation

This is a retrospective study. This design has intrinsic limitations; nevertheless we attempted to control for multiple potential confounding factors, including age and comorbidities. The outcome assessment was at the time of discharge, and no further follow

up information was available. Further studies with extended follow up should be performed to evaluate the long-term safety of combined PCI and MTH after cardiac arrest, although it is intuitive that the highest risk of the therapy is in the acute setting. Another limitation is the relatively low rate of adverse events. We found low rates of some previously reported complications, potentially be due to the small number of subjects, mostly in the PCI group. But this is also likely a reflection of improved techniques of MTH and troubleshooting that have developed in the use of MTH for CA patients.

In conclusion, PCI may be feasibly and safely performed with MTH. Although adverse outcomes of patients undergoing PCI in our group were high, there was no clear effect of MTH on major adverse events. Our data suggest that the application of PCI in the setting of MTH does not precipitate additional cardiac adverse events, specifically dysrhythmias, nor does it lead to worse neurological outcomes.

Conflict of interest statement

The authors declare that there are no potential financial or ethical conflicts of interest regarding the content of this submission.

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