Endovascular Therapeutic Hypothermia Adjunctive To Percutaneous Coronary Intervention in Acute Myocardial Infarction: Realistic Simulation as a Game Changer

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Abstract

Background: Endovascular therapeutic hypothermia (ETH) reduces the damage by ischemia/reperfusion cell syndrome in cardiac arrest and has been studied as an adjuvant therapy to percutaneous coronary intervention (PCI) in ST-elevation myocardial infarction (STEMI). New available advanced technology allows cooling much faster, but there is paucity of resources for training to avoid delays in door-to-balloon time (DTB) due to ETH and subsequently coronary reperfusion, which would derail the procedure. The aim of the study was to describe the process for the development of a simulation, training & educational protocol for the multidisciplinary team to perform optimized ETH as an adjunctive therapy for STEMI.

Methods and Results: We developed an optimized simulation protocol using modern mannequins in different realistic scenarios for the treatment of patients undergoing ETH adjunctive to PCI for STEMI starting from the emergency room, through the CathLab, and to the intensive care unit (ICU) using the Proteus® Endovascular System. The primary endpoint was door-to-balloon (DTB) time. We successfully trained 361 multidisciplinary professionals in realistic simulation using modern mannequins and sham situations in divisions of the hospital where real patients would be treated. The focus of simulation and training was logistical optimization and educational debriefing with strategies to reduce waste of time in patient's transportation from different departments, and avoiding excessive rewarming during transfer.

Conclusions: Realistic simulation, intensive training and educational debriefing for the multidisciplinary team propitiated feasible endovascular therapeutic hypothermia as an adjuvant therapy to primary PCI in STEMI. ClinicalTrials.gov: NCT02664194.

Introduction

Endovascular therapeutic hypothermia (ETH) is performed to reduce ischemia/reperfusion cell syndrome damage in cardiac arrests,¹ however its role in ST-segment elevation myocardial infarction (STEMI) patients still remains controversial.^{2–10} Experimental studies showed that mild hypothermia, if rapidly induced before the reperfusion of acute coronary occlusion, can reduce infarct size (IS).^{11,12} So a fast cooling prior to reperfusion may be effective adjunct to primary percutaneous coronary intervention (PCI) in STEMI patients to reduce IS and to improve cardiac outcomes.^{13,14}

The development of powerful endovascular cooling systems, which are able to cool down the patient to low temperatures in a few minutes,¹⁵ brought light for rapid cooling of the patient and its performance in the STEMI scenario. However, there is still concern regarding a possible delay in the door-to-balloon time (DTB) associated with the implementation of the ETH protocol. Therefore, with the more powerful ETH systems,¹⁶ the role of cooling as an adjuvant therapy to endovascular cooling in STEMI remains unclear, but delays in ETH certainly would impair the adequate treatment of the patients.

The aim of the study was the development of a simulation, training & educational protocol for the multidisciplinary team to perform optimized ETH as an adjunctive therapy for STEMI without delays in DTB which would derail the procedure.

Methods

Simulation, Training and Debriefing

Aim: Provide a training program for STEMI Cool trial sites that simulates the procedural flow as described in the trial protocol. This realistic simulation program was created to familiarize site personnel with the procedures required in the protocol and also manage potential complications as listed in the trial protocol that might be related to cooling, while motivating site performance in avoiding delays in the DTB and procedural times consistent for all patients regardless of randomization. All the aspects and a comprehensive description of all the aspects of the simulation intervention are depicted in Table 1.¹⁷

Realistic simulation performance criteria

Performance criteria has been established to limit the difference between study arms regarding DTB time to be inferior to 10 minutes. The objective was to quickly perform and complete all procedural steps up to the point where the guide wire is advanced across the lesion. The timing data from the simulation of a patient randomized to the cooling arm was compared to the current average DTB time of the institution, in order to confirm if the difference between study arms regarding DTB time is inferior 10 minutes. Ideally the cases should be performed with a final DTB < 90 minutes. The workflow overview is shown in Fig. 1.

Keys to success

A successful realistic simulation program requires the following:

- Assigning roles and responsibilities upfront for each team member;
- Execution of assigned tasks in a timely manner;
- Execution of relevant protocol steps in parallel to reduce total procedural time.

Metrics were assessed regarding each team's performance and reviewed during the debriefing at the end of each simulation.

Training requirements

The realistic simulation training took place in the Emergency Department, Cath Lab, Intensive Care Unit or Simulated Lab (hereby named Sim Lab) during the Site Initiation Visit (SIV), according to the hospital's allowance.

Timeframe requirements

1) Expectations and intro: 20 minutes. Prior to the simulation, this was a short recap of the expectations and purpose of the simulation. The study protocol and device training had already taken place earlier in the SIV.

2) Realistic simulation run: 60 minutes. The start point was the patient arrival to the ED. The finish point was the action of the guidewire crossing the lesion during the PCI procedure.

3) Debriefing: 60 minutes. The debriefing should take place immediately after the simulation was completed.

Patient scenario

Patient scenarios for use in the simulations were sham mannequins in STEMI situations, from stable to complex cases. For consistency, all the cases were pre-specified, and the initial simulation training conducted at the SIV.

Logistical optimization

Another focus of simulation and training was the logistical optimization with strategies to reduce waste of time in the patient's transportation from different departments, and avoiding excessive rewarming of the patient during the moving. After several simulations transporting mannequins throughout real sections of the hospital, an appropriate logistic was defined and implemented.

Results

From July 2015 to January 2016, we successfully developed an optimized simulation protocol using modern mannequins in different realistic scenarios for the treatment of patients undergoing ETH adjunctive to PCI for STEMI starting from the emergency room, through the CathLab, and to the intensive care unit (ICU) using the Proteus® Endovascular System. The comprehensive aspects of the Simulation Intervention are detailed in Table 1, and the workflow overview is shown in Fig. 1.

We successfully trained 361 multidisciplinary professionals in realistic simulation using modern mannequins and sham situations in divisions of the hospital where real patients would be treated. The focus of simulation and training was logistical optimization and educational debriefing with strategies to reduce waste of time in patient's transportation from different departments, and avoiding excessive rewarming of the patient during the moving, as seen in Fig. 2.

Discussion

In the critical STEMI scenario, where every minute counts to spare viable myocardium cells, it would be hard imagining to perform further time-consuming procedures without impacting in the over-delay for coronary reperfusion.¹⁻¹⁰ With that said, ETH have never been applied before due to the inherent delay of this procedure, which used to take many hours to cool down the body, therefore it has been incompatible

with this emergency scenario. The new available advanced technology allowed cooling much faster, with target temperatures as low as 32°C being reached in less than 20 minutes. Nevertheless, there was still the problem that even those 20 minutes would impact negatively the coronary reperfusion time, and the revealed solution came from the interaction between conjoined procedures and logistical optimization. This complex equation could only be solved with the application of a high disciplined triad: simulation, training & education.

Realistic simulation has been an important component of health professionals' training.¹⁸⁻²¹ The caveats of dealing with health in emergent situations do not allow unanticipated mistakes, which would have life-threatening consequences. Advanced cardiac life support (ACLS) courses has long been using realistic simulation as an important tool for teaching and learning, with successful results.²²⁻²⁷ We utilized our great experience with this kind of training to come up with realistic scenarios and intensive training before starting the real-world procedures. We started training the multidisciplinary team 2 months prior to the patients' inclusion. Only after our timing targets were reached, we initiated the in-vivo protocol. And at the end of the day, this was the key to the success: recognizing the potential pitfalls and troubles that could emerge during the ETH, solving it, and then by continuous and recurrent training, we were able to overcome a problematic situation and to come up with an optimized protocol.

Simulation, training and debriefing are the triple foundation of the protocol.¹⁸⁻²⁴ The first step of the protocol was the realistic simulation. The creation of simulated scenarios using mannequins and pre-determined intercurrents during the development of the case brought knowledge and confidence to the multi-professional team. The second step was intensive training, continuous and recurrent, so that there would be no mistakes during the case. The third step was the educational debriefing. After every simulated or real case, the details of the attendance were widely discussed and shared among the multidisciplinary team. Suggestions and corrections were taken into account so that the protocol could be updated and improved over time. Of note, the protocol has a dynamic profile, so it can be reinvented and improved whenever the situation requires it.¹⁸⁻²⁴

Current improved technology of the new endovascular Zoll™ Proteus Cooling System™ (more powerful than the previous devices) also contributed to the development of a feasible protocol in a timely manner. It is implanted through a simple femoral vein puncture with the introduction of the cooling catheter, which takes few minutes to be performed. On the other hand, it requires 2 different interventionists working at the same time on the patient if the intention is to perform cooling and angiography at the same time, so a dedicated physician is necessary for all cooling procedures.

It is also important to highlight the focusing on logistical optimization for moving the patient among the different departments of the hospital, i.e., from the ER to the Cath Lab, and then to the Coronary Unit. This logistical planning is important not only to avoid any further delays in the DTB, but also to avoid precocious rewarming of the patient during the transportation. Previous trials already have shown the extremely harmful effects of unstable temperature control during temperature target management, so it is utmost to guarantee a stable maintenance of the core temperature.

Even though randomized clinical trials including COOL MI²⁸, ICE-IT²⁹, CHILL MI³⁰ and VELOCITY³¹ failed to show a significant reduction in infarct size, endovascular cooling appears to be safe and well tolerated. Despite neutral overall results, subsequent unpublished *post hoc* subgroup analysis of COOL MI³¹ and ICE-IT,³² and combined analysis of RAPID MI-ICE³² and CHILL MI³⁰ showed significant reduction in infarct size in a subgroup of early presenters with anterior STEMI who were cooled below 35°C prior to reperfusion.³³ Thereby, benefits of therapeutic hypothermia might be achieved by using a rapid cooling to decrease core temperature below 35°C prior to the opening of acute coronary occlusion to justify the ETH as an adjunctive therapy in STEMI.³³

Limitations

Our results, however, should be interpreted in the light of several limitations. The protocol was single-center and therefore easier to get all professionals trained. Secondly, we did not evaluate the learning curve for the professionals, once some of them already had been exposed to ETH procedures. Third, there was no physician exclusively responsible for the cooling procedure, it was performed concomitant to the interventional procedure, which might imply in delays in the DTB. Last, the inherent limitations of mannequin simulators must be taken into account, such as the impossibility of subjective feedback or bleeding events.³⁴

Conclusions

Realistic simulation, intensive training and educational debriefing for the multidisciplinary team propitiated feasible endovascular therapeutic hypothermia as an adjuvant therapy to primary PCI in STEMI.

Declarations

Ethics approval and consent to participate

The COOL-MI InCor Trial was approved by both local (CAPESQ – number 0242/11) and national (CONEP – approval number 16568) ethical committees. The trial was performed in accordance to the international regulations: 21 CFR Part 812 Investigational Device Exemptions, EN540 Clinical Investigation of Medical Devices For Human Subjects, 21 CFR Part 56 Institutional Review Boards, 21 CFR Part 50 Protection of Human Subjects of United States of America. All the patients were obligated to sign a consent term to be included in the trial.

Consent for publication

All the authors had approved and had given consent for the publication of this manuscript.

Availability of data and materials

All data, including published and un-published material will be available upon request.

Competing interests

Dr. Dae is a consultant for ZOLL Circulation Inc. None of the other authors have conflicts of interest related to this article.

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Authors' contributions

I contributed substantially in collecting data, as well as data interpretation, analysis, writing and reviewing the manuscript. Dr. Giannetti, Dr. Polastri, Dr. Frossard Lima, Dr. San Martin, Dr. Rochitte, Dr. Hajjar, Dr. Gallego Lima, Dr. Nicolau, Dr. Oliveira Jr, Dr. Dallan, Dr. Dae, Dr. Ribeiro da Silva and Dr. Kalil Filho contributed substantially in the analysis and interpretation of data. Dr Lemos Neto and Dr. Timerman are the co-senior authors of this manuscript and had access to all the data, contributed in data interpretation, and reviewing the manuscript for important intellectual content.

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Tables

Table 1
Comprehensive aspects of the Simulation Intervention

Elements	Subelements	Description
Participant orientation	Orientation to the simulator	<p>Expectations and intro: 20 minutes. Prior to the simulation, this was a short recap of the expectations and purpose of the simulation, as well as the study protocol. All the professionals must have been trained in Advanced Life Care Support (ACLS) in the Simulation Center prior to the TH simulation.</p> <p>Realistic simulation run: 60 minutes. The start point was the patient arrival to the ED. The finish point was the action of the guidewire crossing the lesion during the PCI procedure.</p> <p>Debriefing: 60 minutes. The debriefing should take place immediately after the simulation was completed.</p>
	Orientation to the environment	<p>The participants were oriented to the environment according to the proposed HT procedure. There was a real body-size mannequin that was used both to do the TH procedure and to be transferred from one unit to the other according to the timeline of the simulation. The professionals being trained were trained in different sections of the hospital. Therefore, they started at the Emergency Department (ED), then went to the cath lab and finished at the intensive care unit (ICU). 15 minutes for orientation, 30 minutes for each section (ED, cath lab, ICU) and 15 minutes for conclusion, for a total of 2 hours training. The content for the training was specific for each of the scenarios.</p>
Simulator type	Simulator make and model	<p>The training was performed using the original Proteus Cooling System (Zoll Circulation Inc) with sham temperature targets.</p>
	Simulator functionality	<p>The simulator was the real Proteus device with connections to a software that mimicked the temperature of the patient for each time point. It was possible to determine specific temperatures according to the scenario. The limitations were the same inherent to any simulator, i.e., no human being was involved as part of the simulator, only mannequins, so there was no feedback regarding bleedings or subjective feelings. Arrhythmias were simulated using monitors and defibrillators.</p>
Simulation environment	Location	<p>The simulation was conducted in situ clinical environment. Therefore, they started at the Emergency department, then went to the cath lab and finished at the intensive care unit (ICU).</p>
	Equipment	<p>It was used one of the 3 original Proteus Cooling Systems™ (Zoll Circulation Inc™) available at the hospital, each of them located at the ED, cath lab and ICU. Also, there were real defibrillators available in each of the units.</p>

Elements	Subelements	Description
	External stimuli	There were external stimuli such as background noise in all the units. We secured that the simulation training did not interfere in real clinical practice in each of the units, once the simulations were performed in the real units of the hospital.
Simulation event/ scenario	Event description	All the scenarios were previously programmed and scripted, and they would change according to the training's reactions. All scenarios were STEMI patients with meet inclusion and exclusion criteria's that would have had been included in the trial and therefore required TH. They all followed the consistent pathway and progression of the TH across the different units were they were performed.
	Learning objectives	<ul style="list-style-type: none"> - Assigning roles and responsibilities upfront for each team member; - Execution of assigned tasks in a timely manner; - Execution of relevant protocol steps in parallel to reduce total procedural time.
	Group vs. individual practice	The simulation was conducted in groups, once the TH is a multidisciplinary procedure.
	Use of adjuncts	No other adjuncts were used.
	Facilitator/ operator characteristics	All the facilitators were from the multidisciplinary team involved directly and responsible for the therapeutic hypothermia procedure. They were all high-skill experienced health care professionals.
	Pilot testing	A total of 5 pilot testing's with 2-hour duration were conducted one month prior to the full training of the team, so that pitfalls could be corrected and optimizations could be implemented.
	Actors/ standardized/ simulated patients	All the simulations were performed in mannequins. There were no actors involved. All the scenarios were conducted by experienced clinicians with experience in simulator education.
Instructional design	Duration	The total duration of each simulation was 140 minutes.
	Timing	The simulation should be performed prior to the initiation of the clinical trial. All the professionals involved in the TH procedure should be trained.
	Frequency/ repetitions	There was only one formal training / simulation per professional, but there would be the possibility of re-training if the clinical team considered necessary to repeat the process for quality enhancement.
	Clinical variation	A unique template script was used for the training once all the situations involved the same scenario: a STEMI patient that should undergo therapeutic hypothermia concomitant to the percutaneous coronary intervention

Elements	Subelements	Description
	Standards/assessment	As a multi-disciplinary team, all the professionals were assessed at the end of the debriefing to understand if they had assimilated the concepts and if they were able to apply it in the clinical practice, but there was no formal testing at the end of the simulation.
	Adaptability of intervention	All the simulations were performed in groups, but with individual learning focus on the role of each multidisciplinary professional in the TH procedure.
	Range of difficulty	Therapeutic hypothermia is a very complex procedure, therefore all the scenarios were focused on a critical situation involving STEMI and primary PCI concomitant to the TH.
	Nonsimulation interventions and adjuncts	As for the nonsimulation interventions, a debriefing should take place immediately after the simulation was completed, and was performed in small group discussions.
	Integration	The intervention was integrated into curriculum as part of the armamentarium for all the multidisciplinary team in our facility, as a new skill for all the different professionals.
Feedback and/ or debriefing	Source	The feedback was performed using the simulator itself, the computer through a didactic approach from the facilitator.
	Duration	The total duration of each simulation was 140 minutes.
	Facilitator presence	At least one high-skilled experienced facilitator was present in all the simulations.
	Facilitator characteristics	All the facilitators were from the multidisciplinary team involved directly and responsible for the therapeutic hypothermia procedure. They were all high-skill experienced health care professionals.
	Content	The simulation focused on teamwork and development of clinical skills in all the aspects of therapeutic hypothermia.
	Structure/method	The debriefing was performed using the simulator itself, the computer through a didactic approach from the facilitator. The whole simulation was revised, all the possible diversions were corrected and all the clarifications and questions were solved.
	Timing	The feedback was conducted both concurrent to the simulation event, with guidance and orientation when necessary, as well as an extensive debriefing at the end of the simulation.
	Video	Video could be recorded during the simulation to help in the education feedback when necessary, especially during the final debriefing when appropriate, but it was not compulsory to record all the simulation events.

Elements	Subelements	Description
	Scripting	A unique template script was used for the training once all the situations involved the same scenario: a STEMI patient that should undergo therapeutic hypothermia concomitant to the percutaneous coronary intervention.

Figures

Figure 1

Realistic simulation workflow overview. The green bar is the time needed for screening and enrollment tasks required to conduct any trial in the STEMI population (enrollment steps). The yellow bar (PCI preparation) represents the routine steps for performing percutaneous coronary intervention (PCI) for the STEMI population. Both Green and Yellow steps were required in both the control and cooling groups. The blue bar (cooling steps) represents the additional steps that are required in the cooling group. Since some but not all of the cooling steps are conducted in parallel to others, the difference in DTB time between the control and cooling groups is expected to be inferior than 10 minutes.

Figure 2

Pictures of the multidisciplinary team being trained in the Simulation Laboratory (Sim Lab) and real procedure in the catheterization laboratory (Cath Lab). Panel A: Realistic simulation. Panel B: Educational debriefing. Panel C: Real procedure in the Cath Lab; Panel D: ZOLL® Proteus™ Intravascular Temperature Management System™ device in detail.

Image not available with this version

Figure 3

Temperature over time in hypothermia and control groups from baseline to rewarming.

Image not available with this version

Figure 4

Example of a cooling curve using endovascular hypothermia.

Image not available with this version

Figure 5

Comparison of door-to-balloon times between the hypothermia group and the control group in the As-Treated (ATT) analysis. Of note, the 5.1 minutes difference was not statistically significant.