COMBINING MACHINE LEARNING AND MILLIMETER WAVE TECHNOLOGY DEVICES TO BUILD AN ARTIFICIAL INTELLIGENCE WARNING SYSTEM FOR TARGETED TEMPERATURE MANAGEMENT PATIENTS

Chia-Lun Lo, Department of Health- Business Administration, Fooyin University, Jinxue Rd., Daliao Dist., Kaohsiung City 83102, Taiwan (R.O.C.)
Tsung-Lung Yang, Innovation, O.E., Kaohsiung Veterans General Hospital, Dazhong 1st Rd., Zuoying Dist., Kauhsung City, 813414, Taiwan (R.O.C.)

Abstract

Targeted temperature management (TTM) is a clinical technology that has recently been promoted. It maintains the temperature of patients with cardiac arrest (and who have been rescued) at 32°C–34°C to lower the rate of cerebral oxygen metabolism in the patients, stabilizing their medical conditions. because of COVID-19, contactless healthcare and automatic systems have become increasingly critical. This study used millimeter wave technology, a non-invasive technique, to collect patients' physiological data to be fully informed about their physiological statuses. In addition to establishing a model for predicting TTM effectiveness, this study also verified the data collection effectiveness of millimeter wave technology.

Keywords：Targeted temperature management, Millimeter wave technology, Machine learning, In-hospital cardiac arrest.

INTRODUCTION

Sudden cardiac arrest is a global public health issue. Cardiac arrest can be divided into out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) based on the location it occurs. According to relevant medical research statistics, the survival rate of patients with OHCA is merely 1.4%–7.2%; even when emergency treatment is provided in time, mortality rate can still be as high as 30%–50%（Chang & Lin, 2005）. The risk factors of OHCA include being male and aged 60 years or above, being under great financial stress, having diabetes, having a history of cardiovascular diseases or arrhythmias, and being on kidney dialysis（Chen &Wang, 2017）.

According to Bernard (2002), lowering the body temperature of patients with cardiac arrest by 1°C can reduce their cerebral oxygen metabolism rate by 6%–8%. For patients with OHCA who are still in comas after emergency treatment, implementing TTM within a few hours to maintain their body temperatures at 32°C–34°C can continuously improve their prognoses and the probability that they reawaken. Holzer (2010) reported that implementing TTM can increase patients' survival rates from 30%–50% to 50%–70% and improve their neurological functions from 15%–25% to 25%–35%. The American Heart Association (AHA) has added TTM to its guidelines in 2015, advocating that applying TTM for more than 24 h enhances patients' survival rates (Callaway, et. al., 2015).

However, Dumas (2011) contended that TTM cannot effectively restore the consciousness of patients with pulseless electrical activity (PEA) or noncardiogenic cardiac arrest. Scales (2017) compared the differences between patients who received TTM and those who received other supportive care during the first six hours after their cardiac arrest, and found no significant increase in the survival rate of the TTM group and no statistically significant improvements in neurological functions. Zhang (2015) also noted that mild hypothermia did not improve the in-hospital and 6-month mortality results of adult patients with cardiac arrest.

In general, TTM requires relevant equipment to be installed and patients' physiological statuses to be monitored for 24–72 h. Previously, body temperature was measured via an invasive method (i.e., esophageal temperature monitoring), which required the medical staff to monitor every 0.25 unit of temperature change and ensure that a patient does not have fever and subtle changes in physiological signs during the 72 hours after their temperature returned to normal（Arrich J, 2007）. Because contact with patients and the use of invasive equipment can increase the risks of infection, after the outbreak of COVID-19, contactless healthcare and automatic warning control systems have become increasingly crucial.

According to recommendations made by existing studies and American Heart Association guidelines, this study collected the influencing factors of the temperature cooling period, maintained period, and rewarming period on the prognosis of patients receiving TTM to build a model for effective prognosis prediction. Additionally, this study used millimeter wave technology to collect patients' physiological parameters, such as breathing rate, heart rate, breathing status, body temperature, activity pattern, and blood pressure, to develop an artificial intelligence-based physiological analysis and early warning system. The system can alert medical staff of patients' medical conditions (i.e., degrees of improvement or deterioration) in advance, enabling the staff to intervene in a timely manner. Such a noninvasive system eliminates the risks of infection and radiation exposure, and may be used as a tool for evaluating the practicality of remote health care.

LITERATURE REVIEW

Cardiac Arrest is defined as "a sudden loss of heart function that can be restored with appropriate therapy, but in the absence of appropriate treatment, can result in death"; nevertheless, if the time and method of occurrence are unpredictable, the condition is referred to as "Sudden Cardiac Arrest." While men account for approximately 60% of cardiac arrest cases, survival rates are higher in men compared to that of women, with no significant difference in neurological survival rates for discharge from hospital （Brady et al.,2011）; while for out-of-hospital cardiac arrests (OHCAs), patients seen and cared for have a better neurological profile, with a 96% survival rate at one year for those with a better neurological prognosis (CPC=1or2), but a significantly higher mortality rate at one year for CPC=3 or 4 （Corrada et al., 2013）. Infrequently discussed in the literature is the prevalence of in-hospital cardiac arrests (IHCAs), and while the Utstein style guidelines suggest that the older a patient is, the lower his or her likelihood of being discharged alive, while no effect of gender on survival has been demonstrated (Schwenzer et. al, 1993；Cummins, et. al., 1997; Booth C.M., 2004; Mcmanus et. al., 2012).

According to Nielsen (2013), patients with a target temperature setting lower than 34 degrees experienced more favorable prognosis outcomes compared to those who did not receive Targeted Temperature Management (TTM) therapy (Nielsen N et al., 2013). Typically, the important determinant of temperature reduction is the patient's body surface area, with patients of larger dimensions experiencing greater difficulty in achieving therapeutic effects, while patients of lighter weight or older age are more likely to achieve temperature reduction effects (Maier, C.M., etal., 2002; Nielsen N et al., 2011；Lyden P et.al, 2012）.

TTM consists of three phases: (a) Cooling phase: Patients with return of spontaneous circulation (ROSC) following cardiac arrest experience a rapid temperature reduction to 32-34°C within 3 hours, sustained over 24 hours. During this period, patients are prone to hypovolemia, electrolyte imbalance and hyperglycemia. A further extension of six hours in this phase has demonstrated to have a neuroprotective effect. (b) Maintenance phase: With temperature maintained at 33°C for an additional 24 hours; during this period, the patient is prone to shivering, immune deficiency, and pressure sores. (c) Recovery phase: During this period, if patients experience a stable physiological condition, temperature recovery is controlled at 0.2~0.5 degree Celsius per hour, ramping up slowly to the standard 37 degree Celsius. During this phase, patients are prone to electrolyte imbalance and hypoglycemic symptoms. The use of neuromuscular blocking drugs (Cisatracunum) during recovery of normal body temperature restoration necessitates discontinuation, and the patient should be in a sedated state until the temperature reaches 36°C. Upon recovery of body temperature, sedative drugs should be adjusted or administered as appropriate to the patient's condition（Shlee S. S., etal, 2012）. Although the American Heart Association recommends that target temperature management be maintained for at least 24 hours, a study conducted in European hospitals found that extending the temperature to 48 hours did not increase survival over 24 hours, but side effects increased over time, resulting in prolonged ICU stays（Callaway CW, et al, 2015）.

Currently, the use of TTM is associated with a risk of complications, with poor outcome factors including advanced age, chronic renal failure and abnormal left ventricular function (EF<30) (Laish-Farkash A et al., 2007). Several studies have shown a significant positive association between an age <75 years, prompt witnessing and resuscitation of the patient at the time of collapse and a return of spontaneous circulation (ROSC) index <40 minutes and a favorable prognosis (Peberdy MA et. al., 2010; Perman SM et al., 2015). It is recommended in the AHA guidelines that continuous monitoring of brain wave variations is necessary when performing TTM for prevention of seizures with neuromuscular blocking agents, whereas continuous monitoring of brain waves is the only way to detect epilepsy（Polderman KH, Herold, 2009 ）; while monitoring changes in electrolyte potassium and magnesium ions can prevent the risk of arrhythmias. In the case of further hemorrhage during the implementation of target temperature management, rapid rewarming, and rapid hemostasis and transfusion are necessary to reduce subsequent brain damage so as to minimize the complications caused by hypothermia and avoid more severe injuries. Thus, it is essential to monitor the patient's vitals at all times.

A majority of hospitals utilize Rapid Response Teams (RRTs) to prevent and manage patients in the event of an unexpected deterioration of their condition to avoid serious adverse events. In general, RRTs aim to identify and manage patient emergencies before the team is mobilized, so as to reduce nighttime staffing and workload, achieve staff consensus on patient care, reduce stress, reduce medical disputes, and improve quality of care, all of which can lead to improved patient prognosis (Maharaj et.al., 2015; Solomon, etal., 2016). Furthermore, it has been demonstrated that RRT is effective in reducing cardiopulmonary arrest and hospital mortality outside the intensive care unit (Schneider, et.al, 2013; Joonas et. al., 2018). RRT attention can be distinguished into two, the Afferent arm and Efferent arm, in which the Afferent arm highlights its ability to "timely" detect signs of clinical deterioration and "efficiently" mobilize the team to avoid delays; while Early Warning Systems (EWS) are often employed in clinical settings to assess, predict, and select responses to detect and prevent emergencies. As patients undergoing TTM are all patients previously experiencing OHCAs, in order to avoid IHCA during TTM monitoring, immediate notification of patient risk is necessary for immediate emergency intervention. To address the challenges of delayed recording and alerting, wireless monitoring technologies provide continuous data, enabling more timely and less labor-intensive early warning monitoring, while reducing the risk of frequent direct contact resulting in infections, thus can serve as the standard for effective next generation alerting systems.

METHODS

This study comprises of two stages. The first stage consists of the identification of significant factors affecting the prognosis of TTM patients utilizing retrospective data, followed by the collection of CPOE, CIS, NIS, referral forms, and emergency physiological data from ambulances for crosstabulation upon confirmation of TTM cases. Prior to data collection, patient privacy considerations were taken into account and de-identification processes were performed.

According to existing literature, 728 patients with OHCA were identified in the retrospective database of the case hospitals from 2017 to 2020, totaling 148 patients upon excluding for failure to achieve ROSC prior to arrival, automatic discharge and transfer, severe brain injury, and death 48 hours after admission, 141 patients upon excluding for IHCA, and 109 patients following exclusion based on TTM model of patient hospitals. Following a comparison of the 109 patients who underwent TTM with a total of 180 patients sampled for conventional supportive care by gender and age. Basic information of patients, emergency characteristics, time duration of cooling procedures, and emergency outcomes were collected. Age, sex, disease history, patient origin, use of AED, initial heart rhythm, defibrillation exposure, pre-arrival ROSC, CPR time, post-ROSC consciousness index, cooling implementation, co-morbidities, interventions, survival to discharge, and post-discharge consciousness status were identified as independent variables, while survival after TTM and supportive care were used as dependent variables for comparison model construction.

The second stage consists of testing the effectiveness of the wireless physiological alert system developed by the research team based on the impact factors established in the first stage. Forty subjects utilizing TTM in collaborating hospitals were enrolled in the experiment for automatic measurement of physiological signs via a zero-contact wireless motion sensor based on Millimeter Wave Technology developed by Wistron Medical Technology, featuring radar sensing technology that registers pulse and respiratory signals. Radar detection enables continuous monitoring of the patient's heart rate and respiration values and real-time cloud uploading independent of external light sources and circadian environment, eliminates the necessity of contact and wearing of device, thus minimizing disturbance to the user, and obviates privacy concerns owing to device non-video recording properties. For the control group, patient heart rate and respiratory values were continuously monitored and stored in a designated device for follow-up comparison using a general patient monitor with at least 3 Lead ECG modules affixed by the caregiver to the sides of the clavicle and below the rib cage respectively for the acquisition of cardiac and respiratory measurements. A comparison of the results of the two groups was then performed and consistency of the physiological measurements were tested. Lastly, TTM prediction models were constructed by integration of significant factors from the first stage and the physiological information collected from the wireless zero-contact device in the second stage by means of a data mining classification.

RESULTS

Of the 109 TTM cases collected in the first stage, patients ranged from 18 to 92 years of age, with a mean age of 60.8, predominantly males (65.8%), with a history of hypertension (62.2%), diabetes mellitus (38.7%), and coronary artery disease (23.4%). 72.1% of patients experienced OHCA, 26.1% experienced IHCA, 50.5% received AED resuscitation. The majority of initial rhythms were VT/VF (56.8%), 35.1% of the patients experienced pre-arrival ROSC, the majority of patients had endotracheal tubes inserted for all verbal response (68.5%), followed by tracheotomy (28.8%), hypokalemia (48.6%) and infection (17.1%) were the most common complications in performing cooling procedures, and 7.2% were treated with ECMO, with a final survival rate of exactly 51%, with 24.3% having undergone coronary angiography.

In this study, Cox regression analysis as table 1, was further performed to analyze the relationship between duration and temperature of patients undergoing target temperature management and the independent variables established in this study. Results indicated that: 1. The younger the patient, the higher the probability of successful survival with targeted temperature management therapy. 2. Within patients with coronary artery diseases and cardiac arrhythmias, the longer the TTM time period, the higher the chance of survival. 3. Patients without chronic kidney disease have a higher probability of survival given a shorter TTM time period. 4. Patients who have experienced defibrillation have a better TTM efficacy. 5. Patients without de novo cardiac arrhythmia can achieve physiological stability with a shorter duration of TTM. However, if there is a new onset of epilepsy during the TTM process, TTM duration requires extension. The life cycle of the TTM treatment as Figure 1.

For the experiments of the second stage of this study, results were compared between patients monitored with conventional general patient monitors and patients monitored with millimeter wave technology-based wireless zero-contact automatic physiological data collection and transmission systems, with data processing steps as follows: 1. MP20 and radar time were first aligned, 2. data was collected mainly during stable rest, 3. data during activity and respiratory arrest was removed, followed by analysis of the results of MP20 and millimeter wave radar devices. Results of the analysis indicated a mean heart rate of 76.05 bpm, a median of 76.00 bpm, and a standard deviation of 10.61; a mean respiratory rate of 18.60 rpm, a median of 18.00 rpm, and a standard deviation of 4.12. The results of regression analysis demonstrated that the R2 for the MP20 and radar wave comparisons was 0.998 for heart rate and 0.9929 for respiratory rate; the mean absolute error (MAE) of heartbeat value was 1.96 bpm and the MAE of respiration value was 1.32 rpm, which suggested a high positive correlation between the heartbeat and respiration values of the two devices. In addition, according to the results of Bland-Altman analysis, the measurement discrepancies between the two devices were within the 95% limits of agreement (95% LoA), with error range of heartbeat values within +6.48 to -7.07 and an average absolute deviation of -0.3; error range of respiration values within +3.66 to -3.85 and an average absolute deviation of -0.09. According to these results, it can be considered that the measurement of these two devices are consistent and reliable.

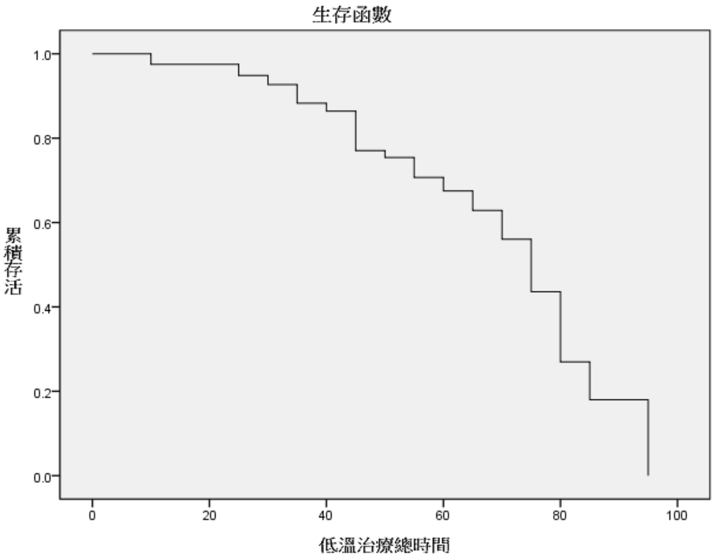

Figure 1 Life cycle of the TTM treatment

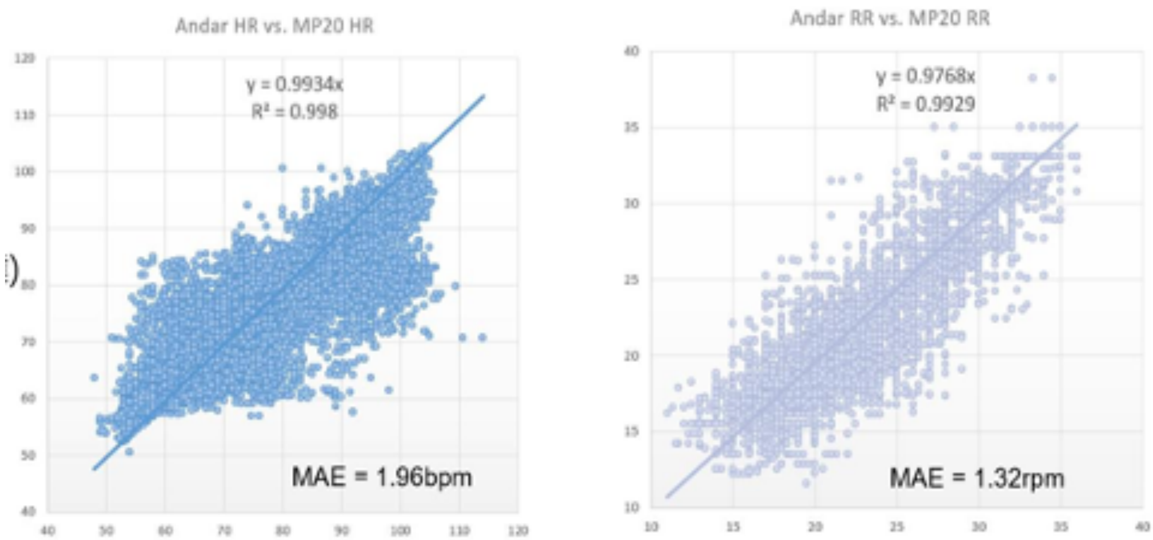

Figure 2 Compare results between MP20 and Millimeter wave technology radar

Table 1 the results of Cox analyses for TTM patients

Variables	B	SE	Wald	df	p	Exp(B)
basic information						
age	-.026	.013	4.017	1	.045	.974
diabetes	.451	.411	1.203	1	.273	1.570
hypertension	.416	.335	1.538	1	.215	1.516
coronary heart disease	.749	.367	4.170	1	.041	2.116
congestive heart failure	-.432	.532	.660	1	.417	.649
irregular heart rhythm	3.750	1.334	7.901	1	.005	42.540
chronic obstructive pulmonary disease or asthma	.933	.679	1.887	1	.170	2.542
chronic kidney disease	-1.727	.410	17.756	1	.000	.178
end-stage renal disease	.412	.504	.668	1	.414	1.510
cirrhosis	.079	.558	.020	1	.887	1.083
stroke	-.947	.611	2.398	1	.121	.388
Hyperlipidemia	.172	.451	.146	1	.703	1.188
tumor	-.227	.388	.343	1	.558	.797
First Aid Features						
Patient source (IHCA, OHCA)	.115	.355	.104	1	.747	1.121
AED	.244	.409	.355	1	.551	1.276
initial heart rhythm	-.299	.765	.153	1	.696	.742
electric shock	-1.070	.457	5.489	1	.019	.343
ROSC before arrival	-.194	.366	.279	1	.597	.824
Comorbidities						
new bleeding	-.921	.597	2.379	1	.123	.398
new onset arrhythmia	-1.299	.466	7.783	1	.005	.273
new serious infection	-.038	.394	.009	1	.923	.963
new-onset epilepsy	.922	.500	3.406	1	.065	2.515
Hypokalemia	-.056	.377	.022	1	.882	.945
Hypoglycemia	.149	.543	.075	1	.783	1.161
related treatment						
ECMO	.504	.508	.985	1	.321	1.655
Coronaryangiography	-.137	.479	.082	1	.775	.872
PCI	.600	.437	1.887	1	.170	1.822

Based on the above experimental results, we then adopted the significant factors established in the first stage and the bestshape VS AI system developed by Wistron Medical Technology in the second stage to collect physiological data from cases in a zero-contact manner. We adopted five well-known classification algorithms (including C4.5, SVM, classical neural network, and random forest) to construct a predictive model, which was validated for regarding validity against a 10-fold cross-validation on a test set and a training set. The results of the experiments were shown as figure 2, which indicated that a random forest-based predictive model was the optimal classification method for further development of classification and early warning systems binding in the healthcare information system in the case hospital.

Table 2 Experiment results of the classifiers for TTM models

Technique	Sensitivity	Specificity	AUC	Accuracy
J48	0.78	0.57	0.73	0.71
RF	0.82	0.75	0.88	0.80
SMO	0.84	0.69	0.76	0.79
LR	0.83	074	0.81	0.81
MLP	0.82	0.67	0.78	0.77

CONCLUSION and SUGGESTION

In this two-stage study, we identified significant factors for the prognostic effectiveness of TTM and demonstrated the feasibility of wireless monitoring technology prior to the construction of a random forest-based early warning system. For caregivers of TTM patients, wireless monitoring technology facilitates the provision of 24-hour continuous monitoring, which allows for more timely early warning monitoring and real-time alerts to be sent to caregivers' handheld devices enabling them to keep track of changes in patients' medical status on-the-go, without the need for additional labor-intensive manual measurements and transcription processes. In terms of pandemic prevention mechanism, wireless monitoring technology provides safer clinical care by minimizing human contact. However, as TTM is implemented on non-common cases among patients and the study is conducted in a single hospital, there are limitations in sample size and data collection, therefore, it is suggested that future studies can expand the target of sample collection to compare hospital level and regional differences. Furthermore, to ensure the accuracy and credibility of the experimental results, brain wave monitoring may be incorporated to further enable more accurate prediction of neurological conditions, whereas the duration of the study should be extended to observe the degree of neurological recovery and the level of post-therapy care. Lastly, a clinical decision-making support system may be integrated to translate examination and consultation-related data into valuable decision-making information, enabling physicians or decision makers to more accurately assess patient co-morbidities and status at each stage utilizing the predictive model.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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REFERENCES

Arrich J. Clinical application of mild therapeutic hypothermia after cardiac arrest. *Critical Care Medicine*, 2007, 35: 1041-1047.

Booth CM, Boone RH, Tomlinson G, et al. Is this patient dead, Vegetative, or severely neurologically impaired? Assessing outcome for comatose survivors of cardiac arrest. Journal of the American Medical Association, 2004, 291:870-9.

Bernard SA, Gray TW, Buist MD, et al Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. New England Journal Medicine, 2002, 346: 557-63.

Brady, W. J., Gurka, K. K., Mehring, B., Peberdy, M. A., and O'Connor, R. E. In-hospital cardiac arrest: impact of monitoring and witnessed event on patient survival and neurologic status at hospital discharge. *Resuscitation Journal*, 2011, 82(7), 845-852.

Callaway CW, Donnino MW, Fink EL, Geocadin, Golan E, Kern KB, et al, Post Cardiac Arrest Care: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*.2015, 132: S465-482.

Chang, M. Y., & Lin, M. Predictors of survival and hospital outcome of prehospital cardiac arrest in southern Taiwan. *Journal of the Formosan Medical Association*, 2005, 104, 639-646.

Chen, D.L.、Wang G.J. Adult Out-of-Hospital Cardiac Arrest: Cause, Mechanism, Management and Prevention. Adaptive Medicine, 2017, 9(3), 125-129.

Corrada, E., Mennuni, M. G., Grieco, N., Sesana, G., Beretta, G., & Presbitero, P.Neurological recovery after out-of-hospital cardiac arrest: hospital admission predictors and one-year survival in an urban cardiac network experience. *Minerva Cardioangiologica, 2013*, *61*(4), 451-460.

Cummins, R. O., Chamberlain, D., Hazinski, M. F., Nadkarni, V., Kloeck, W., Kramer, E., Becker, L., Robertson, C., Koster, R., Zaritsky, A., Bossaert, L., Ornato, J. P., Callanan, V., Allen, M., Steen, P., Connolly, B., Sanders, A., Idris, A., and Cobbe, S.. Recommended guidelines for reviewing, reporting, and conducting research on in-hospital resuscitation: the inhospital 'Utstein style'. *Resuscitation Journal*, 1997, 34(2), 151-183.

Dumas F, Grimaldi D, Zuber B, et al. Is hypothermia after cardiac arrest effective in both shockable and nonshockable patients? insights from a large registry. *Circulation Journal*, 2011, 123, 877-86.

Holzer, M. Targeted temperature management for comatose survivors of cardiac arrest. *New England Journal Medicine,* 2010, 363, 1256-1264.

Joonas T., Heini, H., Sanna, H., In-hospital cardiac arrest after a rapid response team review: A matched case-control study. *Resuscitation, 2018*, 126(1), 98-103.

Laish-Farkash A, Matetzky S, Kassem S, et al.. Therapeutic hypothermia for comatose survivors after cardiac arrest. *Israel Medical Association Journal,* 2007, 9: 252-6

Lyden P, Ernstrom K, Cruz-Flores S, Gomes J, Grotta J, Mullin A, Rapp K, Raman R, Wijman C, Hemmen T. Determinants of effective cooling during endovascular hypothermia. *Neurocritical care*. 2012, 16:413–420.

Maier CM, Sun GH, Cheng D, Yenari MA, Chan PH, Steinberg GK. Effects of mild hypothermia on superoxide anion production, superoxide dismutase expression, and activity following transient focal cerebral ischemia. *Neurobiology of disease.* 2002, 11:28–42.

Maharaj R., Raffaele I., Wendon J. Rapid response systems: a systematic review and meta-analysis. *Critical Care, 2015*, 19(1), 254.

McManus, D. D., Aslam, F., Goyal, P., Goldberg, R. J., Huang, W., and Gore, J. M. Incidence, prognosis, and factors associated with cardiac arrest in patients hospitalized with acute coronary syndromes. t*he Global Registry of Acute Coronary Events Registry. Coronary Artery Disease*, 2012, 23(2), 105-112.

Nielsen N, Friberg H, Gluud C, Herlitz J, Wetterslev J. Hypothermia after cardiac arrest should be further evaluated. A systematic review of randomised trials with meta-analysis and trial sequential analysis. *International Journal of Cardiology*, 2011, 151: 333–41.

Nielsen N, Wetterslev J, Cronberg T, Erlinge D, Gasche Y, Hassager C, et al. Targeted temperature management at 33 degrees C versus 36 degrees C after cardiac arrest. *New England Journal of Medicine*, 2013, 369:2197-2206.

Perman SM, Grossestreuer AV, Wiebe DJ, et al. The utility of therapeutic hypothermia for post-cardiac arrest syndrome patients with an initial non-shockable rhythm. *Circulation Journal,2015*, 132, 2146-51.

Peberdy MA, Callaway CW, Neumar RW et al. 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2010, 122, S768–86.

Polderman KH., Herold I. Therapeutic hypothermia and controlled normothermia in the intensive care unit: practical considerations, side effects, and cooling methods. *Critical Care Med*, 2009, 37(3): 1101–20.

Scales, D.C., Cheskes,S., P.R. Verbeek, R. Pinto, D. Austin, S.C. Brooks, K.N. Dainty, K. Goncharenko, M. Mamdani, K.E. Thorpe, L.J. Morrison, Prehospital cooling to improve successful targeted temperature management after cardiac arrest: A randomized controlled trial. *Resuscitation Journal*, 2017, 121, 187-194.

Schwenzer KJ, Smith WT, Durbin CG Jr. Selective application of cardiopulmonary resuscitation improves survival rates. *Anesthesia & Analgesia* 1993, 76:478–484.

Schneider A.G., Warrilow S., Robbines R., Jones D.A., Bellomo R. An assessment of the triage performance of the efferent arm of the rapid response system. *Resuscitation*, 2013, 84(1), 477-482.

Song, S. S. and P. D. Lyden. Overview of therapeutic hypothermia. *Current Treatment Options in Neurology*, 2012, 14(6): 541-548.

Soloman R.S., Corwin G.S., Barclay D.C., Quddusi S.F., Dannenberg M.D. (2016), Effectiveness of rapid response teams on rates of in-hospital cardiopulmonary arrest and mortality: a systematic review and meta-analysis. *Journal of Hospital Medicine*. 11(6), 435-445.

Zhang, X. W. The effect of mild induced hypothermia on outcomes of patients after cardiac arrest: a systematic review and meta-analysis of randomized controlled trials. *Critical Care 2015,* 19: 1-17.