Improved Prognosis After Using Mild Hypothermia to Treat Cardiorespiratory Arrest Due to a Cardiac Cause: Comparison With a Control Group


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Introduction and objectives. Patients who survive a cardiac arrest have a poor short-term prognosis in terms of mortality and neurological function. The use of mild hypothermia has been investigated in only a few randomized studies, but appears to be effective for treating these patients. The aim of this study was to investigate the effect of this treatment on survival and neurological outcomes.

Methods. We compared mild hypothermia and usual treatment in patients who had experienced a prolonged cardiac arrest due to ventricular fibrillation or tachycardia and who showed signs of neurological damage. Patients were divided into 2 groups: a control group of 28 patients and a group of 41 patients who were treated with hypothermia. Patients were assessed at discharge and at 6 months.

Results. There was no significant difference between the 2 groups in baseline characteristics, including those of the cardiac arrest, or in the time to treatment. At discharge, neurological status was good in 18 patients (43.9%) in the hypothermia group but in only 5 (17.9%) in the control group (risk ratio =2.46; 95% confidence interval, 1.11-3.98; P=.029). At 6 months after discharge, neurological status was found to be good in 19 patients (46.3%) in the treatment group and 6 (21.4%) in the control group (risk ratio =2.16; 95% confidence interval, 1.05-3.36; P=.038). The effect of hypothermia may have been affected by various confounding factors.

Conclusions. Our findings demonstrate that hypothermic treatment after cardiac arrest prolonged by ventricular fibrillation or tachycardia helps improve the prognosis of anoxic encephalopathy.

Key words: Hypothermia. Anoxic encephalopathy. Cardiac arrest. Ventricular fibrillation.

 Mejora del pronóstico tras parada cardiorrespiratoria de causa cardiaca mediante el empleo de hipotermia moderada: comparación con un grupo control

Introducción y objetivos. Los pacientes que sobreviven a una parada cardiaca tienen mal pronóstico vital y neurológico a corto plazo. La hipotermia moderada se ha ensayado en escasos estudios aleatorizados y parece ser eficaz en el tratamiento de estos pacientes. Nuestro objetivo es mostrar el impacto de esta estrategia en la supervivencia y en el estado neurológico.

Métodos. Hemos comparado hipotermia frente a tratamiento habitual en pacientes tras parada cardiaca prolongada por fibrilación o taquicardia ventricular y con signos de daño neurológico, para lo que se establecieron un grupo control de 28 pacientes y otro grupo de 41 pacientes tratados con hipotermia. Los pacientes fueron evaluados al alta y a los 6 meses.

Resultados. No se encontraron diferencias significativas entre los grupos al comparar las características basales, las características de la parada y los tiempos de asistencia. Al alta tenían una buena situación neurológica 18 (43,9%) pacientes del grupo de hipotermia y 5 (17,9%) del grupo control (riesgo relativo [RR] = 2,46; intervalo de confianza [IC] del 95%, 1,11-3,98; p = 0,029). A los 6 meses del alta, se encontraban en buena situación neurológica 19 (46,3%) pacientes del grupo tratado y 6 (21,4%) del grupo control (RR = 2,16; IC del 95%, 1,05-3,36; p = 0,038). El efecto de la hipotermia puede verse afectado por diversos factores de confusión.

Conclusiones. Nuestros resultados ponen de manifiesto que el tratamiento con hipotermia después de parada cardiaca prolongada por FV o TV contribuye a mejorar el pronóstico de la encefalopatía anóxica.

of CPR had to have been successful and a stable rhythm obtained, the patient being admitted to the coronary unit in coma (Glasgow <8) owing to cerebral anoxia (other causes had to have been excluded, especially pharmacological and metabolic coma).

Patients not considered candidates for MH were those with comorbidities in the terminal stage or who from the outset were hemodynamically or electrically unstable (arrhythmic storm) and refractory to treatment leading to death in the 24 h following admission. Patients in cardiogenic shock treated by conventional means (fluid therapy, sympathomimetic amines, emergency coronary intervention, and intra-aortic balloon counterpulsation) were not excluded if stabilization was achieved.

To analyze the influence of MH on prognosis in terms of mortality and neurological function, 2 cohorts of patients were compared, one in which the members received MH, the other in which the members received standard treatment (control). The control group was composed of patients with no contraindication for MH under the conditions outlined above; comparisons between this and the MH treatment group were therefore possible.

Mild Hypothermia Protocol

The MH protocol requires cooling be performed as early as possible after any complementary tests the attending physician should deem necessary. Patients are sedated with midazolam and morphine chloride; myorelaxation is achieved with cisatracurium. Cooling is achieved using an isothermal blanket at 33°C and bags of ice. If the core temperature is not reduced (monitored using a urethral catheter or Swan-Ganz catheter) physiological saline or Ringer’s solution at 4°C is administered. Body temperature is maintained at 33-34°C for 12-24 h. Re-heating is passive, with sedation and relaxation suspended when 36°C is reached. Hypothermia can be suspended if any important clinical deterioration becomes apparent that might hinder the management of the patient.

Data Gathered

Patient baseline characteristics and medical attention times from the moment of arrest until the target temperature was reached were gathered retrospectively from clinical records. The condition of each patient at admission was recorded in terms of the Glasgow score, the APACHE II score, the presence of infarction, whether the patient was in a state of cardiogenic shock, the need for balloon counterpulsation, acute coronary perfusion...
(angioplasty, fibrinolysis, or nothing) and via a cranial CT scan. The main aim of the study was to describe the neurological status of the patients at discharge and after six months using the Glasgow-Pittsburgh cerebral performance categories\textsuperscript{15}: 1 – no sequelae, 2 – slight incapacity, although the patient is independent and no institutionalization is necessary, 3 – severe incapacity, the patient is not independent and needs to be institutionalized, 4 – persistent vegetative state, and 5 – death. As in earlier studies,\textsuperscript{8,9} the first two steps on this scale were considered to represent a good neurological outcome, and the latter three a poor outcome.

### Statistical Analysis

All collected data were subjected to descriptive statistical analysis, via frequency measurements (absolute frequencies and percentages) if the variables were qualitative, and via means and standard deviations or medians and interquartile range if quantitative. The magnitude of the effect of hypothermia was expressed in the form of relative risk (RR) and 95% confidence limits (95% CI). Univariate analysis of the quantitative variables was undertaken using the Student $t$ test when their distribution was normal, and the Mann-Whitney $U$ test when they were not. The qualitative variables were analyzed using the $\chi^2$ or the Fisher exact test when the conditions required for the former test were not met. Interactions could not be evaluated in multivariate analysis owing to the small sample size. Logistic regression was therefore employed to determine whether the association between the intervention and the progress of patients at 6 months post-discharge was influenced by the baseline characteristics of the groups (confounding factors). From the collection of baseline variables shown in Tables 1 and 2, those with the potential to act as confounding factors were selected first in terms of their clinical and biological plausibility, and second in terms of the statistical criterion of Mickey et al,\textsuperscript{16} excluding all those variables that in

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**TABLE 1. Baseline Patient Characteristics and Characteristics of the Arrest**

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>MH Group</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n</td>
<td>28</td>
<td>41</td>
<td>.469</td>
</tr>
<tr>
<td>Men</td>
<td>23 (85.2)</td>
<td>35 (85.4)</td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td>61.7 (12.2)</td>
<td>58.3 (15.8)</td>
<td>.336</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>6 (21.4)</td>
<td>6 (19.5)</td>
<td>.867</td>
</tr>
<tr>
<td>Prior ischemic heart disease</td>
<td>8 (28.6)</td>
<td>10 (24.4)</td>
<td>.721</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>6 (21.4)</td>
<td>6 (8.8)</td>
<td>.296</td>
</tr>
<tr>
<td>History of heart failure</td>
<td>4 (8.8)</td>
<td>4 (8.8)</td>
<td>.296</td>
</tr>
<tr>
<td>Intra-hospital arrest</td>
<td>5 (17.8)</td>
<td>3 (7.3)</td>
<td>.255</td>
</tr>
<tr>
<td>Time elapsed until first assistance, min</td>
<td>1.5 [0-10]</td>
<td>5 [0-10</td>
<td>.860</td>
</tr>
<tr>
<td>Time from arrest until stable rhythm after CPR, min</td>
<td>26.5 [17.8-42]</td>
<td>30 [20-34]</td>
<td>.857</td>
</tr>
<tr>
<td>Time elapsed until arriving at hospital, min</td>
<td>57 [42-62]</td>
<td>54 [45-68]</td>
<td>.547</td>
</tr>
</tbody>
</table>

CPR indicates cardiopulmonary resuscitation; MH, mild hypothermia. Values are expressed as number of individuals (valid percentage), mean (SD) or median (interquartile range).

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**TABLE 2. Condition at Admission**

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>MH Group</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasgow</td>
<td>3 (3.7)</td>
<td>3 (3.7)</td>
<td>.296</td>
</tr>
<tr>
<td>STEMI</td>
<td>4 [53.6]</td>
<td>6 [63.4]</td>
<td>.414</td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>9 (25)</td>
<td>17 (41.5)</td>
<td>.159</td>
</tr>
<tr>
<td>Need for sympathomimetic amines</td>
<td>12 [42.9]</td>
<td>19 [46.3]</td>
<td>.775</td>
</tr>
<tr>
<td>Need for intraortic balloon counterpulsation</td>
<td>6 (21)</td>
<td>11 (27)</td>
<td>.668</td>
</tr>
<tr>
<td>Infarctions treated with primary angioplasty</td>
<td>10 (66.7)</td>
<td>18 [69.2]</td>
<td>1</td>
</tr>
<tr>
<td>Infarctions treated with fibrinolysis</td>
<td>1 (6.7)</td>
<td>4 (15.4)</td>
<td>.636</td>
</tr>
<tr>
<td>STEMI without emergency reperfusion</td>
<td>4 (26.7)</td>
<td>4 (15.4)</td>
<td>.434</td>
</tr>
<tr>
<td>Left ventricular ejection fraction at admission (%)</td>
<td>36 (16)</td>
<td>37 (17)</td>
<td>.911</td>
</tr>
</tbody>
</table>

STEMI indicates ST elevation acute myocardial infarction. Values are expressed as number of individuals (valid percentage), mean (SD) or median (interquartile range).
univariate analysis returned an association with the response reflected by a value of $P > .20$. Given the limitations posed by the sample size, adjustment for the effect of MH on the prognosis at six months post-discharge was performed variable by variable. The results are expressed as RR and 95% CI. The RR was calculated from the odds ratio (OR) provided by logistic regression using the formula $RR = \frac{OR}{\left(1 - P_0\right) + \left(P_0 \times OR\right)}$, where $P_0$ is the incidence of “good neurological outcome” (Glasgow-Pittsburgh cerebral performance category 1-2) in the control group. An RR of $>1$ shows that MH improves the chances of a good neurological outcome at 6 months. The guidelines of the STROBE initiative were used in the presentation of results.

RESULTS

Patient Selection

During the study period, 133 patients with a diagnosis of extra- or intra-hospital CRA were admitted to our unit. Of these, 20 (15%) were excluded who presented with episodes of VF with no need for prolonged CPR, 25 (18.8%) for arrests due to EMD or asystole, 7 (5.3%) for respiratory arrests due to severe pneumonia, 3 (2.2%) for pharmacological coma, 2 (1.5%) for intracranial hemorrhage (1) or sepsis (1), and 1 (0.8%) for unsuccessful CPR within 24 h in a state of refractory cardiogenic shock, and one with advanced lung cancer. Of the final 69 patients included in the study, 41 (59.4%) received MH (all after 2003 except for one in 2002). Of the remaining 28 patients (controls), 21 (75%) were admitted between 2000 and 2003, and 7 (25%) later, overlapping in time with the patients subjected to MH. However, none of the controls showed any contraindications for MH; the treatment received depended on the criterion of the attending physician and his/her familiarity with the MH technique. Figure 1 shows a flow diagram for the selection of the patients.

Characteristics of the CRA and Condition of Patients at Admission

Table 1 shows the baseline characteristics of the patients and the characteristics of the CRA suffered. Table 2 describes the clinical situation of the patients at admission. No significant differences were seen between the baseline characteristics of the patients who underwent MH and those of the control group. Nonetheless, the control group had a larger percentage of patients with ischemic heart disease, who were diabetics, who had suffered a prior infarction and episodes of heart failure, while the MH group had a greater percentage with acute ST elevation myocardial infarction (STEMI), and cardiogenic shock. Since the small sample size limited the detection of any significant differences, all baseline variables were analyzed as potential confounding factors for inclusion in logistic regression analysis.
of hospital stay (median, 11 [4-30] days vs 11 [7-19] days; \( P = .95 \)). However, a trend was apparent, with 7 (25%) of the control patients spending over 30 days in hospital compared to 5 (12.2%) of the MH patients (\( P = .205 \)). The median duration of orotracheal intubation was 7 (3-11) days in the control group compared to 4 (2-7) days in the MH group (\( P = .068 \)). The most common infectious complication was nosocomial pneumonia, which was suffered by 13 (46.4%) of the control patients and 16 (41%) of the MH patients (\( P = .66 \)). Electroencephalograms and evoked N20 neurosensory potentials were performed as deemed required in patients showing initially torpid neurological progress (15 [55.6%] patients in the control group vs 19 [46.3%] in the MH group; \( P = .457 \)). These tests returned a “poor prognosis” or “result compatible with severe anoxic encephalopathy” for 14 (50%) in patients in the control group and 16 (39%) in the MH group (\( P = .366 \)).

**Final Diagnosis**

The final diagnosis was STEMI in 41 (59.4%) patients, non-STEMI (NSTEMI) in 4 (5.8%), chronic ischemic cardiomyopathy in 8 (11.6%), dilated...
cardiomyopathy in 4 (5.8%), long QT syndrome in 2 (2.3%), hypertrophic obstructive cardiomyopathy in 1 (1.4%), and severe hypopotassemia with QT prolongation and polymorphic VT due to proximal tubulopathy in 1 (1.4%). No etiological diagnosis was arrived at in 7 (10.1%) patients, 6 of whom died during their stay in hospital, and one of whom was discharged in a persistent vegetative state.

Survival and Neurological Prognosis

A total of 23 (56.1%) patients in the MH group survived until discharge compared to 11 (39.3%) in the control group (RR=1.43; 95% CI, 0.84-2.44; \( P = .17 \)). At 6 months, 21 (51.2%) patients of the MH group and 9 (32.1%) of the control group remained alive (RR=1.59; 95% CI, 0.86-2.95; \( P = .116 \)). Figure 3 shows the Kaplan-Meier survival curves; no significant differences were seen despite the marked trend in favor of MH treatment (\( P = .219 \)).

At discharge, 18 (43.9%) patients of the MH group and 5 (17.9%) of the control group (RR=2.46; 95% CI, 1.11-3.98; \( P = .029 \)) showed a good neurological status (Glasgow-Pittsburgh categories 1 or 2). Six months after discharge, this was true of 19 (46.3%) patients of the MH group and 0 (0%) of the control group (RR=2.16; 95% CI, 1.05-3.36; \( P = .038 \)), with a significant improvement seen in 1 patient in each group. Information on the progress of all patients was available.

Effect of Hypothermia, Adjusted for Potential Confounding Factors

Adjustment was made for the following potential confounding factors: age, history of diabetes mellitus, prior ischemic heart disease, time until defibrillation, total arrest time, STEMI as the cause of arrest, APACHE II on admission, Glasgow score on admission, and cardiogenic shock. As expected, adjustment for a more serious condition at admission, such as APACHE II or longer total arrest led to MH having a non-significant effect on prognosis. Adjustment for other important factors, such as age or time until defibrillation, led to MH having an effect at the limit of significance (Table 3).

DISCUSSION

At our unit, MH has been used with patients admitted for cardiac arrest due to VF or VT since 2002, and under protocol since 2003. The technique is, however, little used in Spain; indeed, the present study is the largest from Spain to be published to date.

In agreement with previous randomized trials, the results of the present retrospective analysis show that MH may be beneficial in terms of neurological prognosis and survival. The present results also contribute towards confirming the usefulness of MH.
within the context of routine daily practice\textsuperscript{11} in a wide range of less strictly selected patients, including those admitted in cardiogenic shock\textsuperscript{12} and those with CRA having an origin in factors other than ischemic heart disease.\textsuperscript{19} The 39.3\% intra-hospital mortality among the present control patients is comparable to that reported by Bernard et al\textsuperscript{7} (32\%), that indicated for a historic cohort by Belliard et al\textsuperscript{9} (36\%), as well as in other registries.\textsuperscript{2} It should be remembered, however, that this survival following a CRA is only seen in the most favorable context, ie, arrest due to witnessed VF and immediate attention. The prognosis becomes much less favorable when one of these conditions is not met, in fact even with the smallest delays in defibrillation.\textsuperscript{20,21}

Currently, the only therapeutic measures of demonstrated benefit (within a context of full medical attention for critical patients) with respect to survival and neurological progress following a CRA, are MH, defibrillation as early as possible,\textsuperscript{22,23} and primary angioplasty when the CRA is due to an acute myocardial infarction.\textsuperscript{24,25}

The effectiveness of MH with respect to minimizing anoxic damage to the central nervous system has led some authors to question the validity of the variables conventionally used to provide a neurological prognosis after a CRA\textsuperscript{26,27}: certainly, MH is one of the main factors improving prognosis. Given the lack of data on how often this technique is used in Spain, the results of Abella et al\textsuperscript{28} from 2005 are of particular interest: 87\% of doctors interviewed (cardiologists or emergency medicine specialists at a sample of reference centers) had never made use of MH in patients in whom such therapy was indicated. The under-use of this technique is widely recognized and the inclusion of a cooling protocol in clinical practice guidelines has been proposed.\textsuperscript{29}

The effectiveness of MH in the treatment of CRA due to asystole, EMD or non-cardiac causes remains to be determined. Very few case reports exist that indicate clearly favorable results,\textsuperscript{30} and in larger numbers of patients the results have been contradictory.\textsuperscript{11,12} In addition, it still needs to be determined whether reaching the target temperature more quickly provides any benefit. The notion that this might be the case stems from observations mainly made in animal studies.\textsuperscript{31,32} In the large clinical studies mentioned above,\textsuperscript{7-9} large differences with respect to the moment when MH was begun, the time taken to reach the target temperature, and the length of time this is maintained did not seem to have much effect, and certainly did not seem to reduce the effectiveness of the treatment. In the present work, the mean time elapsed between the recovery of a stable rhythm until reaching a core temperature of <34\degree C was notably shorter (median, 405 [360-420] min) than that reported by Belliard et al\textsuperscript{9} (552 [380-665] min).

Different courses of action exist to rectify the potential loss of benefit associated with delay in cooling, including perfusion with 2 L of saline solution at 4\degree C,\textsuperscript{33} or perfusion with Ringer’s lactate serum before arriving at the hospital\textsuperscript{34} or even during CPR.\textsuperscript{35} There are also several ways of inducing MH with closed circuit intravascular devices.\textsuperscript{36} A report involving a large number of patients in which these devices were used has been published,\textsuperscript{37} the results suggesting that a more rapid arrival at the target temperature favors good neurological progress.

In the present work only 3 of the last patients seen were managed using these devices, which facilitate MH. With all probability, their more extended use would increase the use of therapeutic hypothermia in Spain. Finally, diffusion of the technique might be

\begin{table}
\centering
\caption{Relative Risk (Non-Adjusted and Adjusted) of a Good Neurological and Functional Outcome (Pittsburgh Cerebral Performance Category 1-2) Compared to a Poor Outcome (Pittsburgh Cerebral Performance Category 3-5) (MH Group Compared to control Group) at 6 Months Post Discharge}
\begin{tabular}{|l|l|l|}
\hline
Effect of Mild Hypothermia & RR (95\% CI) & \(P\) \\
\hline
Non-adjusted & 2.16 (1.05-3.36) & .038 \\
Adjusted for age & 2.08 (0.98-3.31) & .055 \\
Adjusted for diabetes mellitus & 2.25 (1.07-3.48) & .034 \\
Adjusted for a history of ischemic heart disease & 2.21 (1.02-3.47) & .044 \\
Adjusted for time until defibrillation & 2.37 (0.99-3.72) & .052 \\
Adjusted for total time of CRA & 2.30 (0.83-3.75) & .080 \\
Adjusted for STEMI & 2.27 (1.10-3.47) & .030 \\
Adjusted for Glasgow at admission & 2.55 (1.17-3.79) & .023 \\
Adjusted for APACHE II at admission & 1.99 (0.78-3.43) & .131 \\
Adjusted for cardiogenic shock & 2.25 (1.09-3.45) & .031 \\
\hline
\end{tabular}
\end{table}

95\% CI indicates 95\% confidence interval; CRA, cardiorespiratory arrest; RR, relative risk; STEMI, ST elevation acute myocardial infarction.
expected to have a great influence on the prognosis of patients as well as have an important positive economic impact on health systems, as described in other contexts.\textsuperscript{36}

**Limitations of the Study**

The present work suffers from the intrinsic limitations of all retrospective studies, but with accentuations in 3 areas. First, it was difficult to obtain precise data for the time elapsed until the beginning of CPR, until defibrillation was achieved, or the total time of CPR; none of these were directly measured. Second, there was an overlap from 2003 between patients subjected to MH and those with no contraindication for this technique but who in the end did not undergo such treatment; this gives rise to suspicions of a selection basis. The non-practicing of MH in such candidates depended on the familiarity of the attending medical teams with the technique, although since its implantation in our unit it has been increasingly used as experience has been gained. Thus, of all the candidates for MH in 2002, only 1 patient of 7 (14.4\%) underwent such treatment, in 2003 the figure was 4 out of 8 (59\%), in 2004, 9 out of 10 (90\%), in 2005, 9 out of 9 (100\%), in 2006, 2 out of 3 (66\%), in 2007 10 out of 10 (100\%), and between January and May of 2008, 6 out of 7 (87.5\%). These data reflect the reality of implanting new procedures into conventional clinical practice. Finally, the third limitation is the improvement in the extra-hospital attention for CRA (especially the greater speed of arrival of assistance and the greater availability of defibrillators) that may have occurred over the last 8 years; this may have had a very positive effect with respect to the prognosis of these patients. In conclusion, in this work the non-adjusted effect of MH on prognosis at 6 months is similar to that reported by other authors.\textsuperscript{37,39} Unfortunately, due to the sample size, no adequate adjustment for several potential confounding factors was possible. The adjustments that were possible, however, appear to show that some variables have an important influence (Table 3).

**CONCLUSIONS**

Mild hypothermia is a therapeutic technique that contributes towards an improvement in prognosis with respect to survival and neurological outcome in patients who have suffered a prolonged CRA due to VF or VT. Specific recommendations have been made regarding the use of this technique. Its effectiveness seems to be dependent on several factors, particularly the treatment received for the cause of the arrest (especially if this involves acute myocardial infarction), and the time elapsed before resuscitation procedures begin. It may therefore be a useful therapeutic alternative and perhaps even an essential part of the protocol that should be followed in patients presenting with CRA.\textsuperscript{10}

**REFERENCES**