The effects of risk factors on the improvement of neonatal hypothermia using fuzzy transition

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Abstract

Background: Neonatal hypothermia is a major risk factor for mortality after delivery. The present study aims to identify the risk factors associated with transition in hypothermia state with new definition of hypothermia states.

Methods: A total of 479 neonates hospitalized in Neonatal Intensive Care Unit of Valiasr Hospital, Tehran, Iran, in 2005, participated in the study. The rectal temperature of neonates were measured immediately after delivery and every 30 min afterwards, until their temperature became normal.

Results: The mean weight of neonatal was 2580±882.9 grams and the mean of delivery room temperature was 29.2±1.45 °C. Most of the neonates had mild hypothermia. There were significant associations between the weight of neonate, Cardiopulmonary Resuscitation, and Apgar scores and hypothermia state (P<0.05). Also, death of neonates was related to hypothermia state.

Conclusion: Findings of the current study indicated that a major risk factor for hypothermia was low weight of the neonates.

Keywords: Neonatal; Hypothermia; Temperature; Fuzzy transition model


Introduction

Hypothermia in newborns is described as an abnormal thermal condition in which the body temperature of the neonates drops below 36.5°C. Gradual reduction in body temperature leads to unpleasant clinical effects. One of the most important risk factors for morbidity and mortality in newborn infants is hypothermia (1). There Mota Silveira et al. suggested hypothermia as a risk factor of death in newborn (3). are several possible causes of hypothermia in the newborn infant: evaporation (by wet skin or blankets or low humidity in the ambience), radiation (by large areas of skin exposed to cooler surroundings), conduction (contact with cooler bed materials), and convection (by flow of cooler air across baby's skin or mucous membranes) (2).

Therefore, hypothermia and its risk factors are often considered momentous for the
newborn baby. Researchers are interested in studying the risk factors for hypothermia. For instance, Delavar studied neonatal hypothermia and associated risk factors and concluded that spontaneous labor and warm room are associated with reduced risk of hypothermia (4).

According to the findings of several studies, low weight neonates are confronted with various degrees of hypothermia. In addition, environment temperature, low Apgar scores, birth rank, and receiving cardiopulmonary resuscitation (CPR) are risk major factors for hypothermia (5-8).

World Health Organization (WHO) has graded hypothermia into three groups based on core temperature. If the body temperature of a newborn is between 36.0 to 36.5°C, the patient is considered as mild hypothermia, if the temperature is between 32.0 to 35.9°C, the baby is diagnosed with moderate hypothermia, and if temperature is <32.0°C, the baby is considered as having severe hypothermia (9).

Therefore, we used “severe”, “moderate”, “mild” and “normal” as states of hypothermia.

Different studies have employed different criteria to study hypothermia. For instance, they differ in the cut-off points decided for the categories. Kumar et al. reviewed 20 studies for definition of hypothermia and found only 7 studies that applied WHO criteria (10).

According to WHO criteria, the difference between lower bound of mild state and upper bound of moderate state was 0.01°C. In other words, 0.01°C decrease in body temperature changed hypothermia level. In addition, if body temperature is 32.01°C, the baby falls into severe hypothermia and when temperature is 31.99°C, baby falls into moderate hypothermia. However, hypothermia status basically evaluated by verbal reports, linguistic variables, and borderlines of categories of linguistic variables are not accurate (11).

The point of view is that the reported borderline between subcategories of patient status is vague. This is because fuzziness must be considered in modeling systems where human estimation is influential (12). Therefore, it is preferable to apply fuzzy logic for modeling the risk factors of hypothermia in newborns. Although literature on neonatal hypothermia is extensive, previous studies with logistic regression have described odds of risk factors on hypothermia status (hypothermia/normal). Nevertheless, in the current study, we surveyed factors, including environment temperature and weight of infants that affect transition from hypothermic state in neonates, using a flexible scale of hypothermia states and reported the rate of transition between states.

Methods
In the present longitudinal study, statistical population included all newborn infants who had hypothermia and were hospitalized in NICU of Valiasr Hospital in Tehran, Iran in 2005. A total of 479 infants were randomly selected for the first pool. For each newborn infant, the rectal temperature was measured repeatedly after birth and every 30 minutes thereafter until neonates passed hypothermia stages. The neonate's birth weight, gestational age, and Apgar score were considered as risk factors. For reliability, body temperature of newborn infants was measured by two nurses; the Kappa statistics was 100% for these nurses.

The information provided in many areas of medical diagnosis are not completely clear; therefore, making correct diagnosis is difficult in such a condition. In such a situation, fuzzy logic is suggested (11). Fuzzy states of hypothermia are defined according to WHO criteria. Figure 1 shows the membership function of hypothermia.
The followings are membership function of hypothermia stats:

\[
\mu_{\text{Severe}}(x) = \begin{cases} 
1 & 31 < x < 32 \\
32 - x & 31 \leq x < 32 
\end{cases}, \\
\mu_{\text{Moderate}}(x) = \begin{cases} 
1 & 32 \leq x < 34 \\
35 - x & 34 \leq x < 35 
\end{cases}, \\
\mu_{\text{Mild}}(x) = \begin{cases} 
x - 34 & 43 \leq x \leq 35 \\
1 & 35 \leq x < 36.5 \\
\frac{37 - x}{0.5} & 36.5 \leq x < 37 
\end{cases}, \\
\mu_{\text{Normal}}(x) = \begin{cases} 
x - 36.5 & 36.5 \leq x \leq 37 \\
0.5 & x > 37
\end{cases}
\]

We calculated possibility transition matrix for transition between hypothermia states and used fuzzy logistic regression for association between risk factors and odd of transition between hypothermia states. To analyse the information, R3.2 was used.

**Results**

The mean temperature of environment was 29.2±1.45°C. Other characteristics of newborn infants are shown in Table 1.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>&lt;1500 gr</td>
</tr>
<tr>
<td></td>
<td>1500-2500 gr</td>
</tr>
<tr>
<td></td>
<td>≥2500 gr</td>
</tr>
<tr>
<td>Apgar score</td>
<td>&lt;8</td>
</tr>
<tr>
<td></td>
<td>≥8</td>
</tr>
<tr>
<td>Survived</td>
<td>Death</td>
</tr>
<tr>
<td></td>
<td>Alive</td>
</tr>
<tr>
<td>CPR</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

Table 2. Hypothermia stat in the first visit according to WHO guideline

<table>
<thead>
<tr>
<th>Hypothermia stat</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sever</td>
<td>3 (0.6%)</td>
</tr>
<tr>
<td>Moderate</td>
<td>201 (42%)</td>
</tr>
<tr>
<td>Mild</td>
<td>275 (57.4%)</td>
</tr>
</tbody>
</table>
According to WHO guidelines, only 0.6% of neonatal had severe hypothermia and 42% were diagnosed with moderate hypothermia, while 57.4% had mild hypothermia. Also, most of the neonates were reported to have Apgar score greater than 8. Table 3 shows significant association between severity of hypothermia and Apgar score and CPR after birth. Moreover, there was a significant relationship between death and severity of hypothermia. The possibilistic transition matrix was:

\[
\begin{bmatrix}
0.333 & 0 & 0.467 & 0.2 \\
0 & 0.095 & 0.846 & 0.059 \\
0 & 0 & 0.436 & 0.564 \\
0 & 0 & 0 & 1 \\
\end{bmatrix}
\]

Table 4 shows the results of fuzzy logistic regression with fuzzy parameters modeling for surveying the effect of neonatal weight and environment temperatures risk factors on neonatal hypothermia.

Table 4. Estimated parameters and goodness of fit of transitions

<table>
<thead>
<tr>
<th>Transition</th>
<th>Estimated Model</th>
<th>Number of transition</th>
<th>Goodness of fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \pi_{22} )</td>
<td>( \tilde{W}_j = (0,0.06)_T + (0.22,0.06)_T \text{ Weight} + (0,0)_T \text{ ET} )</td>
<td>( \tau )</td>
<td>0</td>
</tr>
<tr>
<td>( \pi_{23} )</td>
<td>( \tilde{W}_j = (0.111)_T + (0.21,0.06)_T \text{ Weight} + (0,0.8)_T \text{ ET} )</td>
<td>( \tau )</td>
<td>0.21</td>
</tr>
<tr>
<td>( \pi_{24} )</td>
<td>( \tilde{W}_j = (0,0)_T + (0.1,0.06)_T \text{ Weight} + (0,0)_T \text{ ET} )</td>
<td>( \tau )</td>
<td>0.52</td>
</tr>
<tr>
<td>( \pi_{33} )</td>
<td>( \tilde{W}_j = (0.184)_T + (0.24,0)_T \text{ Weight} + (0,0)_T \text{ ET} )</td>
<td>( \tau )</td>
<td>0.87</td>
</tr>
<tr>
<td>( \pi_{34} )</td>
<td>( \tilde{W}_j = (0.166)_T + (0.23,0)_T \text{ Weight} + (0,0)_T \text{ ET} )</td>
<td>( \tau )</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Because of low frequency, other models are not estimable.

These results show that the neonatal weight was associated with neonatal hypothermia. In other words, in all the models for all transitions, for each unit increase in weight, the possibility of transition to the next state (recovery) was
0.22 and the environmental temperature had no effect on the recovery.

**Discussion**

Hypothermia in neonates is considered as a major synergetic cause of significant morbidity in developing countries. Increased risk of mortality, bleeding lungs, metabolic acidosis, and hypoglycemia are severe complications of neonatal hypothermia. Studies in the developed countries have shown that hypothermia involves neonates with low weight while it involves all the neonates in developing countries. In the present study, we found the relationship between odds of hypothermia and weight of neonatal. In a similar study, Miller et al. (6) showed significant relationship between hypothermia and weight. Furthermore, Kumar et al. in a review study in developing countries, introduced the birth weight as a risk for hypothermia (10).

Our observation was that most neonatal transited to a better state or remained on the previous state and there were no transitions to the worse state. Those who had CPR or low Apgar score were also found to be at increased risk of hypothermia, a finding which is in line with those reported in Ali et al. (5).

In the present study, we did not find any relationship between environmental temperature and hypothermia, but there are studies that suggested plastic wraps combined with other environmental heat sources cause decrease in hypothermia (13). In addition, Akbarzadeh Baghban et al. found significant relationship between environmental temperature and hypothermia (14).

In addition to these results, we used the fuzzy method to describe hypothermia. Fuzzy regression was considered appropriate because the assumption of statistical models, such as distribution assumptions, adequate sample size, and exact observations were not established (11). In the present study, hypothermia was measured using linguistic terms, fuzzy Chi-square, and fuzzy logistic regression. One of the first fields of interest in fuzzy application is medicine. In the present study, making use of fuzzy definition for hypothermia, we found the relationship between some risk factors (weight, Apgar score, and CPR and hypothermia, which are not under control, but delivery room temperature is under control. Therefore, sufficient care after delivery could help neonatal to pass through the hypothermia stages faster.

**Acknowledgments**

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**Conflicts of Interest**

Authors declare no conflicts of interest.

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