Practical application and prognostic value of the expanded Apgar score

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Abstract

Background: There have been numerous investigations proving the influence of the course of action taken immediately upon birth on the incidence of diseases such as periventricular and intraventricular hemorrhage (PVH-IVH), retinopathy of prematurity (ROP), bronchopulmonary dysplasia (BPD) or death in prematurely born children [3-5]. However, the credibility of the score is increasingly being questioned by neonatologists, especially with regard to preterm newborns with extremely low birthweight. Therefore, in order to achieve a more objective and precise description of newborn condition at birth, The American Academy of Pediatrics, Committee on Fetus and Newborn, American College of Obstetricians and Gynecologists and Committee on Obstetric Practice, introduced the expanded Apgar Score Form [11]. The Score, described in 2006, includes also the course of resuscitation apart from the classic Apgar score components. It shows modes and effects of resuscitative interventions at birth. Objective: The aim of the study was to prove that precise information about the proper course of action that is included in the expanded Apgar score might have a prognostic value for the early death incidence in preterm newborns. Study Design: A single-center study based on retrospective analysis of the medical records of 276 children born from < 32 weeks of gestational age pregnancies at the 2nd Department of Obstetrics and Gynecology, who were hospitalized between the years 2009 and 2011 at the Neonatology and Intensive Care Unit, Medical University of Warsaw. Review methods: Artificial intelligence algorithms are commonly used tools in contemporary medical diagnostic and decision systems. The CHAID classification tree was used in this work, enabling us to create a clear knowledge system based on decision rules. Results: When taking into consideration the components of classic and the expanded Apgar scores, the authors obtain a statistically significant split of the second node (1-minute Apgar of 2-3 points) into two daughter nodes, according to the 10-minute oxygen administration rule: FiO₂ < 0.80 and FiO₂ > 0.80: if at 10th minute the oxygen concentration falls below a critical value of 0.80 (inclusive), the authors observe 1 death in 37 neonates (2.7%); otherwise the mortality rate reaches 47% (8 out of 17 preterm babies). Similarly to the classic Apgar score, data regarding gender, gestational maturity and mode of delivery do not alter the configuration of the decision tree. The birthweight matters in the split of the third node. Conclusions: Concentration of oxygen used during resuscitation at birth (a component of the expanded Apgar score) has significantly more prognostic value in the survival of prematurely born children than the Apgar score result alone. The fact that such correlation is observed regardless of gestational age, gender or mode of delivery seems particularly noteworthy.

Key words: death, neonatal, Apgar score

Introduction

The Apgar score has been used for over fifty years to evaluate the overall condition of newborns in the first minutes of neonatal life. The score reflects the influence of intrauterine and labor factors on the infants. Furthermore, it correlates well with their intrauterine well-being. The scale was devised and described by Virginia Apgar in 1952 and further revised in 1958. The aim of this scoring system was to specify the indications for intubation of newborns [1, 2]. Although it was not intended as a prognostic value, attempts have been made to find a correlation between the assessment of the general condition of newborns and their later development. There have been numerous investigations proving the influence of the course of action taken immediately upon birth on the incidence of diseases such as periventricular and intraventricular hemorrhage (PVH-IVH), retinopathy of prematurity (ROP), bronchopulmonary dysplasia (BPD) or death in prematurely born children [3-5]. There have also been reports that low 5-minute Apgar score is linked with abnormal future development of the child [6, 7]. Multiple studies confirmed the usefulness and applicability of the Apgar score in assessing the clinical state of term newborns [8, 9]. However, the credibility

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of the score is increasingly being questioned by neonatologists, especially with regard to preterm newborns with extremely low birthweight. Particularly, the difficulties and challenges of interpreting the Apgar score when assessing extremely premature children are emphasized [10]. Therefore, in order to achieve a more objective and precise description of newborn condition at birth, The American Academy of Pediatrics, Committee on Fetus and Newborn, American College of Obstetricians and Gynecologists and Committee on Obstetric Practice, introduced the Expanded Apgar Score Form [11]. The expanded Apgar score, described in 2006, includes also the course of resuscitation apart from the classic Apgar score components. It shows modes and effects of resuscitative interventions at birth (Fig. 1).

Aim

The aim of the study was to prove that precise information about the proper course of action that is included in the expanded Apgar score might have a prognostic value for the early death incidence in pre-term newborns.

Material

Retrospective, single-center study analyzed the medical records of 276 children born from < 32 weeks of gestational age pregnancies at the 2nd Department of Obstetrics and Gynecology, hospitalized at the Neonatology and Intensive Care Unit, Medical University of Warsaw, between the years 2009 and 2011.

Inclusion criterion: newborns with 1-minute Apgar score of ≤ 7 points that required resuscitation during the first minutes of neonatal life.

Exclusion criteria:
- 1 minute Apgar Score > 7 points,
- presence of serious congenital anomalies,
- no resuscitation attempts due to extreme immaturity or lethal congenital anomalies.

The characteristics of the study group

The study group was composed of 148 male (53.6%) and 128 female (46.4%) newborns. 109 (39.5%) children were born vaginally and 167 (60.5%) were delivered by a Cesarean section. Mean length of pregnancy was 28 gestational weeks.

In the study group the following were analyzed:
- 1- and 5-minute Apgar scores,
- the course of the resuscitation efforts documented according to the expanded Apgar score: mask ventilation, intubation, oxygen concentration, cardiac massage, use of epinephrine,
- deaths.

Methods

Artificial intelligence algorithms are commonly used tools in contemporary medical diagnostic and decision systems. The CHAID classification tree was used in this work, enabling the authors to create a clear knowledge system based on decision rules.

<table>
<thead>
<tr>
<th>SIGN</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 COLOR</td>
<td>Blue or Pale</td>
<td>Acrocyanotic</td>
<td>Completely Pink</td>
<td>1 2 3 5 10 15</td>
</tr>
<tr>
<td>2 HEART RATE</td>
<td>Absent</td>
<td>&lt; 100 minutes</td>
<td>&gt; 100 minute</td>
<td></td>
</tr>
<tr>
<td>3 REFLEX IRITABILITY</td>
<td>No Response</td>
<td>Grimace</td>
<td>Cry or Active Withdrawal</td>
<td></td>
</tr>
<tr>
<td>4 MUSCLE TONE</td>
<td>Limp</td>
<td>Seome Flexion</td>
<td>Active Motion</td>
<td></td>
</tr>
<tr>
<td>5 RESPIRATION</td>
<td>Absent</td>
<td>Weak Cry; Hypoventilation</td>
<td>Good, Crying</td>
<td></td>
</tr>
</tbody>
</table>

RESUSCITATION TOTAL

Comments

Oxygen

PPV/NCPAP

ETT

Chest Compressions

Epinephrine

Fig. 1. The expanded Apgar score 2006 [11]
Advantages of classification trees over other decision algorithms:

- have a simple structure which enables easy interpretation of the studied phenomena,
- allow to assess the importance of the attributes (variables),
- handle missing data easily,
- have high accuracy of classification,
- do not require assumptions with regard to specific distributions of the variables,
- identify and model the nonlinear dependence.

The above-mentioned features are particularly well-suited for our study because the aim of the authors was to find:

- simple and applicable structure to represent knowledge,
- the possibility to analyze different types of variables – nominal, ordinal and continuous – with non-normal distributions,
- high classification accuracy of the obtained knowledge system.

The primary goal of this study was to identify crucial medical factors which influence the mortality of preterm children. One of the main tasks was to assess the mortality risk of prematurely born children on the basis of the identified medical factors and their potential interaction. The categories of the binary variable – death/no death – comprised the decision of the authors.

The algorithm of the CHAID decision tree:

1) Continuous variables are discretized (for example into 10 segments/intervals).

2) The best variable (i.e. the one which divides the set of observations into the most homogeneous groups with regards the decision classes) is identified on the basis of the results of the Chi-square statistical test. In other words, relative to the tree structure, the entire group (root node) is split into the most homogeneous subgroups (daughter nodes) to which the edges of the distribution rules lead.

3) Each daughter node is further split on the basis of the Chi-square test either until nodes with only one category are achieved or until the assumed depth of the tree is reached or when another node split will not significantly influence the proportion structure of the classes. The final nodes are called leaf nodes.

4) ‘Pruning’ is an excellent method of reducing the size of a ready decision tree. The technique removes the rules leading to the leaves that have little influence on improving the predictive accuracy.

The tree edges (top-down fashion, i.e. from the root to the leaf), connected with the nodes, take the form of implied decision rules (the if-then rule): ‘if A’ and ‘if B’ and ... and ‘if Z’, then the class proportion (for example neonatal death) equals X.

This tree algorithm was used for the clinical data collected between 2009-2011, allowing the authors to achieve ‘tree’ decision systems described further in the text. The generated decision rules may be practically implemented.

Results

1. Assessment of the study group newborns according to the Apgar score

In case when the neonatal assessment was based only on the classic Apgar score, the decision tree (Fig. 2) was further subdivided into three subgroups (nodes), according to the 1-minute Apgar scale: 0-1, 2-3 and 4-7 points.

Obviously, the first group (0-1 points) has the highest risk of early death – 9 out of 21 children died (42.9%). In the second (2-3 points) and third (4 points) groups 9 out of 54 (16.7%) and only 1 out of 201 (0.5%) children died, respectively.

Additionally, the authors discovered that added data on gestational weeks, gender and mode of delivery do not alter the configuration. Birthweight data are applicable when identifying death in the 1-minute Apgar score of 4-7 points group (3 node-leaf). In this subgroup, among 12 newborns with birthweight ≤ 640 g the authors identified the child who died.

2. Evaluation of the study group neonates according to the expanded Apgar score

In the other case, when taking into consideration the components of the classic and the expanded Apgar...
scores (Fig. 3), the authors obtained a statistically significant split of the second node (1-minute Apgar of 2-3 points) into two daughter nodes, according to the 10-minute oxygen administration rule: FiO\textsubscript{2} ≤ 0.80 and FiO\textsubscript{2} > 0.80:

- if at 10 minute the oxygen concentration falls below a critical value of 0.80 (inclusive), the authors observe 1 death in 37 neonates (2.7%); otherwise the mortality rate reaches 47% (8 out of 17 preterm babies).

Similarly to the classic Apgar score, the data regarding gender, gestational maturity and mode of delivery do not alter the configuration of the decision tree. The birthweight also matters in the split of the third node.

**Discussion**

The Apgar score is not without limitations. It is essential to remember that the assessment happens within a certain limited time frame and is highly subjective, depending largely on the clinical experience of the person who evaluates the baby. Furthermore, the assessed elements of the Apgar score such as the muscle tone, skin color or response to stimulation, depend not only on the condition of the newborns but also on their maturity (gestational age). Some other authors are of the opinion that a preterm baby, as a rule, may score lower, despite being in a good overall condition [12]. On the other hand, there are numerous factors influencing the score: maternal medication, peripartum trauma, congenital malformations, fetal infection, hypovolemia [13]. Thus, it is not possible to state that low Apgar score is a marker of intrapartum asphyxia. Consequently, the attempts to predict morbidity and mortality of newborns due to asphyxia solely on these grounds remain a source of controversy [10, 14]. Nevertheless, the conviction that there exists a strong correlation between the Apgar score and future development of the infant prevails in everyday medical practice and social awareness of doctors and parents. Resuscitation is yet another aspect that limits the score. Obviously, resuscitated and non-resuscitated children will obtain very different Apgar results [15]. As mentioned before, the so-called expanded Apgar score has been used since 2006 [11] and the Neonatology and Intensive Care Unit of the Warsaw Medical University has been applying it since 2008. It has significantly influenced the accuracy of the documentation on the course of resuscitation in the delivery room and lowered the evaluation subjectivity of the overall condition of the newborns.

The question remains whether the expanded Apgar score has a prognostic value. There have been numerous publications investigating the correlation between the Apgar score result and either mortality or future development or even cerebral palsy. Their reported results vary and are often contradictory [16-19]. It is often emphasized that in order to diagnose or predict the consequences of the intrapartum asphyxia, the following factors must be taken into account: the result of the acid-base balance of the umbilical cord blood, histopathology of the placental insufficiency, clinical symptoms of encephalopathy, brain imaging, EEG, as well as the efficiency of many internal organs [7].

This study investigated only one aspect resulting from asphyxia – early neonatal death. The available literature suggests that, in preterm babies, low Apgar score correlates with increased mortality and may be applicable when predicting their survival [20]. Other reports claim that in children at 23-25 gestational weeks the Apgar score correlates with neonatal death only in the first 24 hours of their life [21]. The results of this study reveal significant differences in mortality rates only when analyzing the Apgar scale for preterm babies with low score. The first cut-off value seems to be the Apgar score of 0-1 points, with 42.9% of the evaluated children dying. The next value is the Apgar score of 2-3 points, with 16.7% mortality rate. However, the group is non-homogeneous in terms of prognosis. The chances for survival significantly decrease if an infant required FiO\textsubscript{2} > 0.8 during resuscitation. In accordance with the widely accepted international norms, at our department a mix
of air and oxygen is used and adjusted to patient saturation [22, 23]. Increased FiO2 signals more damage to the asphyxic tissues, particularly the brain tissue, and consequently, neurological or multi-organ damage and mortality.

In this analysis the authors decided to determine measurable values, the cut-off points to identify the group of children where it might be possible to predict the neonatal outcome. This study is a preliminary report, attempting to determine only the risk of neonatal death on the basis of their condition at birth. The authors were able to demonstrate that the concentration of the oxygen applied during resuscitation is an important criterion. In the studies to come, the authors intend to determine the elements of the expanded Apgar score that might aid us in predicting early complications such as intraventricular hemorrhage (IVH), necrotizing enterocolitis (NEC), patent ductus arteriosus (PDA) retinopathy of prematurity (ROP) or bronchopulmonary dysplasia (BPD) in prematurely born children.

It is commonly believed that low gestational age and birthweight remain the highest risk factors for mortality and the abovementioned complications. Furthermore, all these diseases have a multifactorial pathogenesis but have their roots in cell and tissue oxygenation and blood supply [24, 25]. The final step of this study will be to determine the extent to which the first minutes of neonatal life influence morbidity and, consequently, how to conduct all the necessary medical interventions for the neonate to benefit the most.

Conclusions

The concentration of the oxygen used during resuscitation (a component of the expanded Apgar score) at birth has significantly more prognostic value in the survival of prematurely born children than the Apgar score result alone. The fact that such correlation is observed regardless of gestational age, gender or mode of delivery, seems particularly noteworthy.

References


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