Classification tree for identifying ineffective breathing pattern in children with acute respiratory infection

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ABSTRACT

The objective of the study was to verify defining characteristics with greater predictive power to aid in the classification of ineffective breathing pattern using classification trees in children with acute respiratory infections. A cross-sectional study was carried out in two pediatric hospitals with 249 children with acute respiratory infection. For data collection, a specific instrument developed for the study was used. Three induction algorithms were used to generate the trees: Chi-square Automatic Interaction Detection, Classification and Regression Trees, and Quick, Unbiased, Efficient Statistical Tree. Three trees were constructed to aid in the identification of ineffective breathing pattern. The classification trees generated present probabilities conditional to the occurrence of the diagnosis associated with dyspnea and changes in respiratory depth. Ineffective breathing pattern was present in 65.5% of the sample. Thus, the probability of occurrence of this diagnosis in children with acute respiratory infection was 100% with the presence of dyspnea and changes in respiratory depth.

Descriptors: Decision Trees; Child Health; Pediatric Nursing.

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INTRODUCTION

Diagnostic decision making is one of the essential elements in determining quality care and good clinical outcomes. However, several conditions may hinder or confuse a precise diagnostic inference, such as the lack of familiarity of nurses with nursing diagnoses, the subjectivity of clinical indicators and diagnostic inference, the use of common signs and symptoms, and the overlap of diagnoses [1]. Moreover, in many situations, the nurse needs to quickly decide whether a clinical condition represents the patient's true status, based on a small number of clinical indicators, generating an environment of uncertainty.

Classification trees (CT) are tools that aim to predict an outcome from predictor variables [2]. These trees are graphical elements used to calculate the probabilities of an individual presenting a nursing diagnosis, considering the presence/absence of a small set of clinical indicators. These graphical elements allow an overview of multiple combinations of clinical statuses with a measure of probability for each status. This enables a rapid and efficient diagnostic decision, facilitating the clinical reasoning process, and allows early decision making in regard to the required therapy, in order to produce good nursing results [3].

When using classification trees, diagnostic decision making is treated as a process of reducing uncertainty based on conditional probabilities, obtained from available clinical information at a given time [3]. This process is particularly useful in situations that require diagnostic screening and which represent impairment of a vital function. At this point, children with acute respiratory infection (ARI) may present changes in the ventilatory process that are recorded quickly and require ventilatory support. Thus, the development of a classification tree for the rapid identification of an ineffective breathing pattern (IBP) diagnosis can be a useful tool for nurses.

Ineffective breathing pattern is a nursing diagnosis, included in NANDA-I in 1980, and is currently defined as "inspiration and/or expiration that does not provide adequate ventilation". This diagnosis has as defining characteristics: changes in respiratory depth; assumption of three-point position; nasal flaring; bradypnea; decreased vital capacity; increased anteroposterior diameter; dyspnea; altered thoracic excursion; prolonged expiratory phase; orthopnea; decreased expiratory pressure; decreased inspiratory pressure; breathing with pursed lips; tachypnea; use of accessory muscles to breathe; and decreased minute ventilation [4].

Respiratory tract infections are common problems in children and are the main reason for seeking hospital care [5-6]. They represent a major cause of morbidity and mortality in children under five years of age worldwide [7].

Within the topic of respiratory nursing diagnoses in the infant population, it was observed that the objective of many previous studies was to present the profile of the diagnoses. Studies developed with children with ARI and IBP were frequently found [8-9]. Although these studies clarified many questions, the process of inference and decision making in clinical practice had not yet been contemplated.

Based on the foregoing, the objective of this study was to identify the defining characteristics with greater predictive power, using Classification Trees to aid in the correct classification of ineffective breathing pattern in children with acute respiratory infection.

METHODOLOGY

This is a quantitative, descriptive, cross-sectional study developed with 249 children with respiratory compromise, hospitalized in two pediatric hospitals in the Northeast region of Brazil. The sample was selected

consecutively. To participate in the study, participants had to have a medical diagnosis of acute respiratory infection and been at least five years of age at the time of participation. The sample size was determined considering the number of defining characteristics, with 15 children for each defining characteristic (total of 16). Therefore, the sample size was estimated at 240 children with ARI.

Six nurses previously trained in an eight-hour workshop performed data collection. This was developed with the aim of standardizing the data collection procedure, composed of the following topics: preliminary methods inherent to the respiratory evaluation, general and pediatric semiology and discussion about IBP diagnosis. The data collection instrument was developed based on the relevant literature on pulmonary evaluation and submitted to two professors with experience in semiology and nursing diagnoses.

The instrument provided a survey of variables related to the identification of children and respiratory evaluation, including the defining characteristics of the study diagnosis mentioned above. It should be emphasized that four characteristics could not be evaluated in this study due to the age of the participants and the impossibility of performing pulmonary function tests to measure these indicators: decreased vital capacity, decreased expiratory pressure, decreased inspiratory pressure, and decreased minute ventilation.

Spreadsheets containing information of each child were organized based on the presence or absence of the defining characteristics of IBP and analyzed by diagnostic nurses to determine the presence or absence of the aforementioned diagnosis. The occurrence or non-occurrence of the diagnosis was determined by the absolute agreement among the diagnosticians. To participate in this stage, the nurses met the following criteria: authored a publication of research on diagnoses, interventions or nursing outcomes, and currently teaching or in a clinical practice. They were also trained and given a test for the assessment of attributes and qualification of the inferences made.

Three Classification Tree induction algorithms were chosen to generate the trees: Chi-square Automatic Interaction Detection (CHAID), Classification and Regression Trees (CART) and Quick, Unbiased, Efficient Statistical Tree (QUEST). For tree induction, the IBP diagnosis was adopted as the dependent variable and the defining characteristics were adopted as independent variables that would compose the secondary nodes and branches of the tree.

To generate the CT with the CHAID algorithm, the following was used: level of significance for the division of nodes and merging of categories of 0.05, likelihood ratio as method to obtain Chi-Square value, maximum number of 100 interactions and minimum change of the expected frequencies of the boxes of 0.05 for model estimation. Significance values for the methods, division, and fusion parameters were corrected via the Bonferroni method.

The CT generated with the CART growth method used the GINI measure as a parameter to reduce the necessary impurities in the division of nodes. This is based on the square of the probabilities of belonging of the cases in each category of the dependent variable. A value of 0.001 was established as the minimum reduction value of the impurities in the node splitting. For the QUEST algorithm, a level of significance of 0.05 was established for the division of nodes. QUEST is a fast method and avoids the biases observed in other methods, thus favoring predictors with many categories.

Growth limits were determined regardless of the adopted generation method. These limits varied according to the generation method itself, the level of measurement of a dependent variable or the combination of both. A maximum number of three levels was adopted for the CHAID algorithm and five levels for CART and QUEST. A minimum of 50 cases was determined for the root node and 20 for the derived nodes. These parameters were used to generate all possible relations between the variables.

The pruning criterion of the tree was used to avoid an over-adjustment of the model with the use of CART and QUEST algorithms. Thus, the tree was trimmed to obtain a smaller sub tree based on the specification of the maximum risk difference, which is expressed in typical errors. The risk value determined in the present study was zero.

In this study, the quality of the tree structure was evaluated using cross validation. This divides the sample into a preset number of subsamples (maximum of 25 subsamples). Therefore, several trees are generated, always excluding a subgroup of general data. For each tree, the risk of classification error is calculated by applying the tree to the subsample that was deleted before it was generated. The final result is a single tree with a risk estimate calculated by the average risk of all trees. Consequently, the trees generated in the study can be used in a generalized manner.

To perform these analyses the data were processed in IBM's SPSS software version 19.0 for Windows, adopting a significance level of 0.05.

The study met the ethical criteria for research with human beings, and was approved by the Research Ethics Committee under protocol number 309/10. The parents' consent was sought through the signing of an informed consent form, which was also signed by the diagnostic nurses who participated in the study.
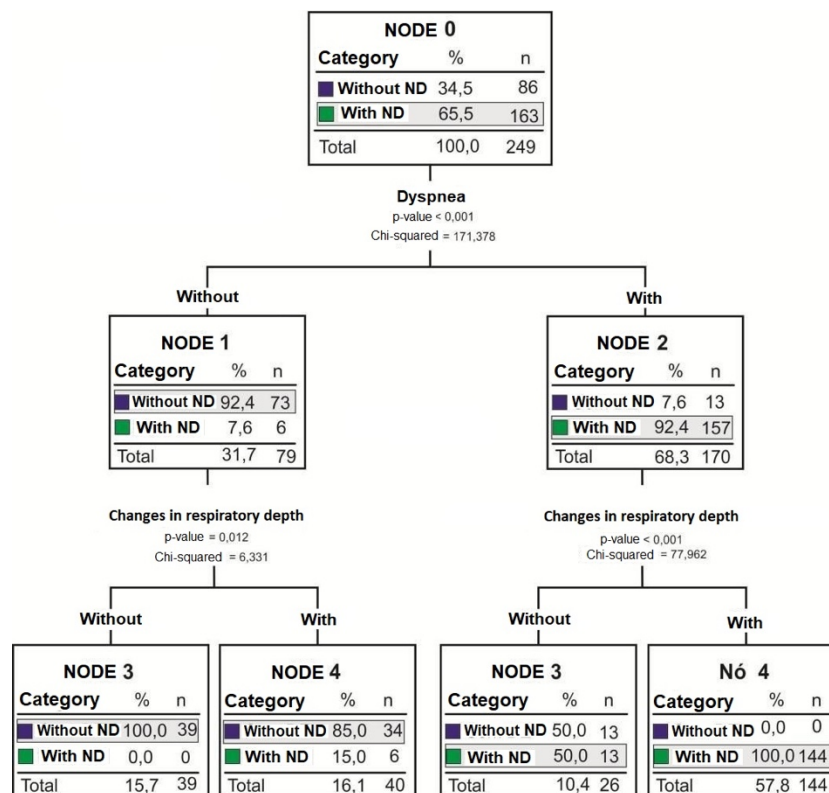
RESULTS

The nursing diagnosis of IBP was identified in 65.5% of the 249 children with ARI.

Three CTs were constructed for the IBP nursing diagnosis. These present probabilities conditional to the occurrence associated with the defining characteristics of the diagnosis. In this manner, it was possible to estimate the prediction probability of each set of data for IBP.

The CHAID growth method was used to generate the first tree. It has seven nodes, four of which are terminal nodes. The relationships between the variables were expressed in two depth levels and two characteristics were considered relevant for the construction of this tree: dyspnea and changes in respiratory depth (Figure 1).

Figure 1: Classification tree generated with the defining characteristics of the nursing diagnosis ineffective breathing pattern, using the CHAID growth method.

NODE 0

Category	%	n
■ Without ND	34,5	86
■ With ND	65,5	163
Total	100,0	249

Dyspnea
p-value < 0,001
Chi-squared = 171,378

Without — With

NODE 1

Category	%	n
■ Without ND	92,4	73
■ With ND	7,6	6
Total	31,7	79

NODE 2

Category	%	n
■ Without ND	7,6	13
■ With ND	92,4	157
Total	68,3	170

Changes in respiratory depth
p-value = 0,012
Chi-squared = 6,331

Without — With

Changes in respiratory depth
p-value < 0,001
Chi-squared = 77,962

Without — With

NODE 3

Category	%	n
■ Without ND	100,0	39
■ With ND	0,0	0
Total	15,7	39

NODE 4

Category	%	n
■ Without ND	85,0	34
■ With ND	15,0	6
Total	16,1	40

NODE 3

Category	%	n
■ Without ND	50,0	13
■ With ND	50,0	13
Total	10,4	26

Nó 4

Category	%	n
■ Without ND	0,0	0
■ With ND	100,0	144
Total	57,8	144

The defining characteristic most strongly associated with IBP was dyspnea. Children who exhibited this characteristic had a probability of IBP occurrence of 92.4%. For children who exhibited dyspnea and changes in respiratory depth together, the probability of occurrence of IBP was 100%.

Children without the characteristic dyspnea, data from the left side of the referring tree, presented a low probability of IBP manifestation (7.6%). When dyspnea was absent but the children exhibited changes in respiratory depth, the probability of developing IBP was 15%. The absence of the two defining characteristics cited presented no probability of IBP occurrence. This CT generated by the CHAID algorithm showed a predictive power of 92.4%.

In the second tree generated for IBP, the CART growth method was applied. It has five nodes, three of which are terminal. In a similar way to the tree generated by the CHAID method, the tree presents the relationships between the characteristics in two levels of depth, using as the characteristics dyspnea and changes in respiratory depth as most relevant for IBP (Figure 2).

The prediction of the tree by the CART growth method was also 92.4%. Dyspnea was the most strongly associated feature, with a probability of 92.4% occurrence of an IBP diagnosis. The presence of dyspnea and changes in respiratory depth also presented a maximum value for IBP manifestation (100%). From the left side of the tree, it was observed that children who did present dyspnea had a low probability of having IBP (7.6%).

The CT generated with the QUEST growth method is similar to the other two induced for IBP. The tree has five nodes in total, three of which are terminal nodes, as well as two levels of depth. The defining characteristics used to construct the tree are the same as those used in previous trees: dyspnea and changes in respiratory depth (Figure 3).

Figure 2: Classification tree generated with the defining characteristics of the nursing diagnosis ineffective breathing pattern, using the CART growth method.
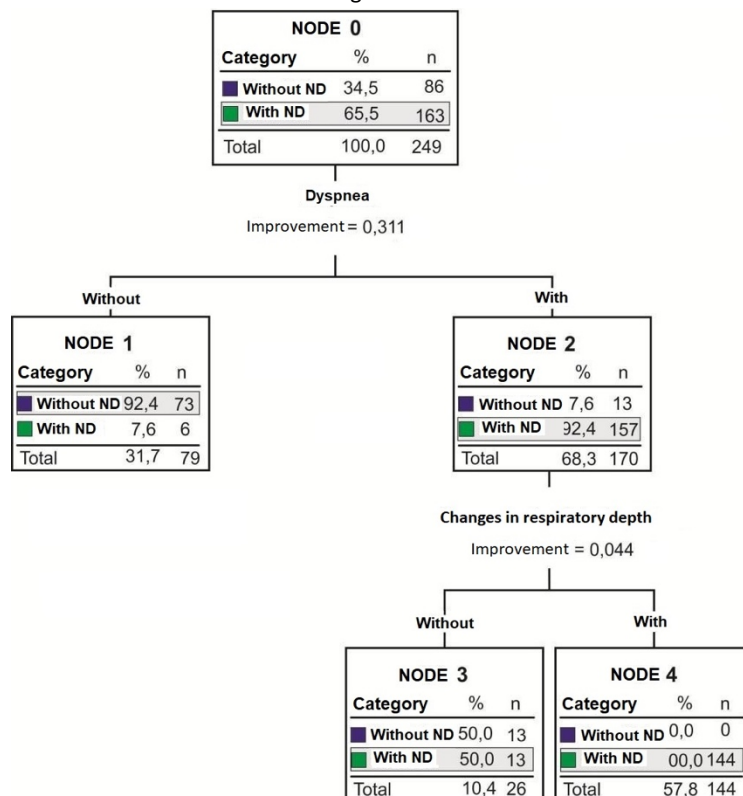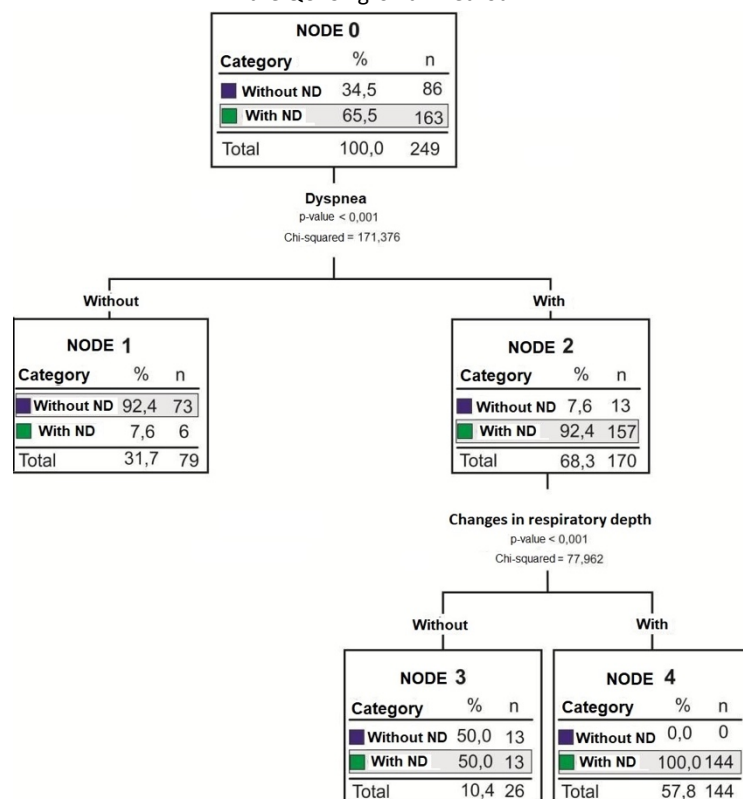

Figure 3: Classification tree generated with the defining characteristics of the nursing diagnosis ineffective breathing pattern, using the QUEST growth method.

The identified values were the same: dyspnea was more strongly associated, with a 92.4% probability of diagnostic occurrence. With regard to the presence of dyspnea and changes in respiratory depth, the deductible

rule showed a 100% probability for the occurrence of IBP. The global prediction power of the tree by the QUEST method, calculated using the cross validation method, was 92.4%.

DISCUSSION

Children who develop IBP have inspiration and/or expiration that do not provide adequate ventilation [4]. This inadequate ventilation can arise with the presence of diseases such as ARI, commonly observed in the infant population [10]. Therefore, given the respiratory impairment, it is important for nurses to better understand the diagnosis and know how it behaves in a specific population.

Most of the children evaluated in this study presented an ineffective breathing pattern. This diagnosis is also identified in other studies with children in different clinical situations [11-13]. In this context, it can be seen that the manifestation and high prevalence of IBP can arise due to the clinical manifestations resulting from respiratory infections presented by the specific population. This statement is corroborated in previous research on respiratory nursing diagnoses in children with ARI [9,14].

The three CTs generated to aid in the inference of IBP also maintained a standardized structure; they presented dyspnea and changes in respiratory depth in their structure. In all the generated trees, the probability of occurrence of the IBP nursing diagnosis was 100% with the presence of dyspnea and changes in respiratory depth. The three trees exhibited the same global prediction power. They correctly predicted IBP in 92.4% of the cases. The CT obtained by the CHAID growth method showed an additional branching in comparison to the other trees. The rule expressed by the absence of characteristics dyspnea and changes in respiratory depth showed no probability of occurrence of IBP.

In this sense, the defining characteristics presented above are representative of IBP. According to the multivariate analysis of the data, the classification trees present probabilities conditional to the occurrence of IBP associated with dyspnea and changes in respiratory depth. These correspond to a process of compensation of the human body to aid in the breathing pattern [15]. Dyspnea, however, refers to a condition that causes discomfort or difficulty breathing, suggesting complications or failure of the defense mechanisms [15-16].

Changes in respiratory depth were the most prevalent clinical indicator in the research population, and it is manifested by changes in respiratory rate, respiratory frequency and/or use of accessory muscles. When assessing the presence of nursing diagnoses in children with respiratory signs and symptoms, changes in respiratory depth showed a statistically significant association with IBP and was present in 73.3% of the population [8]. Similarly, other investigators [9] verified that this indicator exhibited good sensitivity values, indicating that in its presence, the diagnosis will most likely be present. It is worth noting other signs of IBP. For example, the indicator dyspnea, when manifested, is associated with changes in respiratory depth.

Dyspnea was the second most frequent defining characteristic of IBP in the studied population, and given the association of this indicator with respiratory effort [10], breathing becomes difficult, uncomfortable, and tiring [17]. This situation is presented by 170 (68.3%) participants. Similarly, in other studies, when evaluating respiratory nursing diagnoses in children, dyspnea was present in 75% (102) and 99% (203) of the population [18-19].

When investigating this indicator, it can be noted that dyspnea is strongly associated with the presence of IBPs, data corroborated by previous studies, in which the clinical indicator presented a statistically significant

association with the diagnosis [17] and was associated with an increase of 15 or 36 times the chance of presenting IBP [14,20]. In addition, dyspnea presented significant sensitivity values for diagnosis [9,20-21].

Thus, the correct identification of the set of indicators that represent an outcome is crucial for nurses to provide adequate and quality care. However, in clinical practice it is not always easy for the nurse to identify this set of human responses, given the peculiarities of each patient. Therefore, the use of technological tools, such as CTs, help in the process of accurate diagnostic inference.

CONCLUSION

The children evaluated with ARI presented a high prevalence of ineffective breathing pattern. The three trees developed based on the CHAID, CART, and QUEST methods aided in the inference of the diagnosis of IBP. Thus, one can identify the occurrence of this diagnosis in 100% of cases when dyspnea and changes in respiratory depth were present.

The scarcity of studies with similar methodological designs to the ones used in this study, mainly in the area of nursing, limited the comparison of the results. However, we emphasize that the generated trees are innovative and effective technological tools to calculate the probabilities of a child presenting IBP through a set of indicators. This methodology provides the nurse with a broad view on the clinical variations of the children and stimulates the process of diagnostic reasoning. Therefore, new studies should be conducted to apply the trees generated in clinical practices to the specific population and other population groups.

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