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Aid decision algorithms to estimate the risk in congenital heart surgery

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ABSTRACT

Background and objective: In this paper, we have tested the suitability of using different artificial intelligence-based algorithms for decision support when classifying the risk of congenital heart surgery. In this sense, classification of those surgical risks provides enormous benefits as the a priori estimation of surgical outcomes depending on either the type of disease or the type of repair, and other elements that influence the final result. This preventive estimation may help to avoid future complications, or even death.
Methods: We have evaluated four machine learning algorithms to achieve our objective: multilayer perceptron, self-organizing map, radial basis function networks and decision trees. The architectures implemented have the aim of classifying among three types of surgical risk: low complexity, medium complexity and high complexity.
Results: Accuracy outcomes achieved range between 80% and 99%, being the multilayer perceptron method the one that offered a higher hit ratio.
Conclusions: According to the results, it is feasible to develop a clinical decision support system using the evaluated algorithms. Such system would help cardiology specialists, paediatricians and surgeons to forecast the level of risk related to a congenital heart disease surgery.

1. Introduction

Congenital heart diseases (CHDs) are among the most common congenital anomalies, becoming a major global health problem. The 28% of the most critical congenital anomalies are heart defects, causing high rates of morbidity and mortality in neonates [1,2]. If these anomalies are not discovered and treated appropriately in an early stage, children will have a low quality of life and they can even die in the course of time [3].

A CHD is an abnormality that appears in the intrauterine life which in many cases is only detected during the birth and, in the worst cases, much later. These defects can affect the heart walls, valves, arteries and veins, hindering prenatal diagnosis. Congenital heart defects can change the normal flow of blood through the heart [4,5].

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Table 1 – A worldwide reported birth prevalence of the CHD subtypes (per 1000 live births)[5].

Congenital heart diseases	Value
Ventricular septal defect (VSD)	2.62%
Atrial septal defect (ASD)	1.64%
Persistent ductus arteriosus (PDA)	0.87%
Pulmonary stenosis (PS)	0.50%
Tetralogy of Fallot (TOF)	0.34%
Coarctation of aorta	0.34%
Transposition of great vessels (TGA)	0.31%
Aortic stenosis (AoS)	0.22%

The prevalence of CHDs varies widely among studies worldwide; in Europe, it was reported as 8 per 1000 live births/year [2]. The most commonly reported incidence of congenital heart defects in the United States is between 4 and 10 per 1000 live births [6]. Table 1 shows reported birth prevalence of the eight most common CHD in the world.

Many symptoms and signs can be associated to CHDs, such as cyanosis, heart failure, murmurs, aortic regurgitation, rapid breathing, short of breath and faint (during exercise), among others [4]. CHDs the medical diagnosis is complex because there are a lot of variables to assess. Furthermore, cardiologists require extensive knowledge and many years of practice before carrying out an adequate diagnostic process. In order to achieve an accurate diagnose, which would allow an appropriate intervention, the use of new technologies has been added to medical practice, e.g.: perinatal echography, decision support systems (diagnosis, treatments), etc.

In order to get the best classification rate of the risk in congenital heart surgery we have compared four different methods of classification. The classification of the risk has been based on the Risk Adjustment for Congenital Heart Surgery: RACHS-1, which has been taken as gold standard; this risk measure is based on the categorization of surgical interventions, palliative or corrective, which is used to compare the mortality among hospitals. The diseases are assigned to six risk categories (being six the most complex and one the least complex), according to the expected mortality rate predicted for each disease [7].

Within computer science, the field of artificial intelligence offers algorithms that are currently applied to multiple environments, due to their ability to provide computer programs that perform intelligent tasks as learning, recognition or classification. From the different techniques used in artificial intelligence, those related to classification, such as artificial neural networks (ANN) or decision trees, have been used in medical research showing good performance in clinical diagnostic tasks [8–10].

The objective of our work is to achieve a system for classifying the risk of paediatric cardiac surgery independent of RACHS-1 method by means of different machine learning techniques with pre-surgical and post-surgical input data, allowing clinical experts to have better understanding and prior knowledge of the mortality and the risks associated to a patient undergoing surgery because of a CHDs. This could improve plans of care for each service (intensive care unit, hospitalization, etc.) according to the complexity associated to each patient.

This paper is organized as follows: next we present a survey of works related to the use of classification tools to aid in medical diagnosis; secondly, we explain learning and classification methods used in our research; then, we describe clinical data used, the experiments developed and their results; finally, our conclusions and a final discussion are presented.

2. Background

The used of machine learning in any area of medicine as a tool to support decision making and, in particular, in diagnostic tasks has been increasing in the last years. For instance, in neurology, artificial neural networks are used to determine the accuracy of diagnoses that identify typical postural sway patterns for balance disorders [11]; in urology, a multilayer perceptron has been proposed to help urologists in diagnosis of patients with dysfunctions in the lower urinary tract [12]; predicting mortality in patients with strokes [13] and predicting length of hospital stay [14]. Different types of ANN have been used such as those based on radial basis functions [15]. Artificial intelligence classifiers have also been used in oncology and breast cancer diagnosis [10,16,17]; for pulmonary diseases [18]; in haematology [19] and cardiology [20–23]. Decision trees have been also widely used both to represent and to carry out making decision processes. One example is the decision tree used to build a diagnostic model for appendicitis patients [24]. Decision trees are also used in classification of admitted patients according to their critical condition [25], in decision support for early diagnosis of congestive heart failure [26] or in the assessment of risk factors of coronary heart events [27]. Despite we found a large volume of research related to the use of neural networks and decision trees in the diagnosis of heart diseases in adults, only a few were found for CHD diagnosis. For example, in paediatric diagnosis, Reategui proposed a model by integrating case-based reasoning with neural networks [28]. Chowdhury applied a multilayer perceptron with a backpropagation learning algorithm to predict different categories of neonatal disease diagnosis [29].

Classification algorithms are widely used to extract information from datasets. The criteria used to evaluate the classifiers are principally accuracy, computational complexity, robustness, scalability, integration, comprehensibility and stability [30]. There are various classification algorithms and each of them provides different benefits depending on the task and the types of data set on which they are used. The use of ANN provides features such as adaptability, fault tolerance and good classification even when the data presents noise [31]. These characteristics allow neural networks algorithms to recognize complex patterns and then to generate an output assigning a specific category to a given input developing a classification or clustering process. Decision trees (DT) are considered one of the most popular techniques for classifying and they consists on four steps: (1) building tree, (2) stopping of growing the tree (adjusting the information in our database), (3) pruning for making it simpler and leaving only the most important nodes and (4) selection of the optimal tree [32]. Processing is basically a search similar to that in a binary search tree (although DT may not be binary) [33]. Essentially the goal is to find the optimal decision tree by minimizing the