EDITORIAL

Medicine, mathematics, and a return to the future

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The history of the relationship between mathematics and biology dates back at least 250 years ago. Descartes was convinced that mathematics was the tool for a unified theory of all the sciences. Therefore, a mathematical explanation for physiological functions was necessary. The oldest and most elementary parts of mathematics – those before the invention of calculus by Newton (1643-1727) and Leibniz (1646-1716) – had and still have practical applications: topography, architectural plans, navigation, accountancy, calculation of interest, etc. However, the introduction of infinitesimal calculus represented a giant step for the scope of mathematics and, interestingly, coincided historically with the emergence of the first science - physics[1]. It is no exaggeration to say that nothing of modern physics or its applications from aircraft to X-ray, automobiles to magnetic resonance, telecommunications to radiotherapy, would have been possible without mathematics.

The link between life sciences and statistics is not new either. The founding fathers of statistics, Karl Pearson (1857-1936) and Ronald Fisher (1890-1962), both mathematics graduates from the University of Cambridge, were at all times motivated by biological applications. The former was primarily interested in the theory of evolution, the latter had eugenic convictions. This relationship with life sciences is reflected in some of the terminology: in statistics we speak of "treatment" or "contagion", even when analyzing a problem of industrial production or conducting a sociological study. A second set of connections between medicine and mathematics is encompassed by the field called mathematical biology, whose nucleus, historically and methodologically, is population dynamics. This is because, in addition to its application to interacting species, it is also used in epidemiological studies, where groups of individuals that are healthy, infected or susceptible to infection play the role of species. This is a well-developed body of doctrine, where the branch of mathematics called "dynamic systems" rules. In these times of crisis and budgetary cuts, we need to optimize all available resources; Taboada et al.[2] show how we can apply modeling techniques of individuals to medicine through simulation. Simulation is one of the most interesting systems when the fundamental object of study is human. Modeling is an observational learning process, in which the behavior of an individual or group (the model) acts as a stimulus to generate similar behaviors, thoughts or attitudes in others observing the performance of the model. Modeling techniques attempt to teach the principles or rules that should guide behavior in particular contexts rather than generating simple imitative responses. The combination of both (simulation and modeling) makes the authors' effort interesting but, in our view, they could attempt to perform the study in more hospitals to obtain more conclusive results. The first step has been taken; the number of quantitative and qualitative variables involved is high, and their interaction provides a basis that health officials should consider. These experiences can be repeated at each center, on days when emergency department (ED) pressure is greatest, or during time bands of greatest pressure on a particular day. This would help prepare for any unexpected massive arrival of ED users, although such arrival is difficult to quantify because it is not constant. The worst performance result found in the study corresponded to the profile of junior doctors. And this coincides with the opinion of ED heads about the presence, sometimes excessive,

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of inexperienced professionals in accident and emergency medicine (EM). In addition, it is well known that inexperience increases burnout syndrome in EM professionals[3,4]. In conclusion, simulation is a very interesting aid to decision-making since it allows one to determine, quickly and easily, what number of professionals and what level of expertise are needed at each moment. It could help reduce waiting time and overcrowding and, therefore, reduce the possibility of ED collapse which is fairly common at certain times of year.

Currently, the two methods of machine learning most widely used in classification tasks are decision trees (DT) and neural networks (NN). In the latter case, the architecture used is multilayer perceptrons (MLP)[5].

However, each method presents various difficulties in real-world applications. For example, DT may show little flexibility to generalize about excessively branched test data. In the case of MLP, it is necessary to define the structure -number of nodes and layers, and even then, there is no guarantee of convergence to an acceptable solution. DT classification is a nonparametric method widely used in complex pattern recognition, especially when the classification task involves various kinds of patterns and a large number of attributes. In this regard, the article by Sanchez Losada et al.[6], essentially based on mathematics, attempts to establish a prediction model to manage the available emergency medical systems (EMS) resources in incidents with multiple victims. They propose two mathematical methods (models). The first is based on artificial NN learning of past major emergencies, so that, as in biological NN, it "learns", i.e. an expert system. The second is based on DT, which are probabilistic systems in which an event develops branching responses and provides an effective method for decision-making. This is because DT clearly poses the problem so that all options are analyzed, and fully analyzes the possible consequences of taking a decision, and provides a scheme for measuring the cost of an outcome and the probability of it occurring, thus helping to make the best decisions on the basis of existing information and best assumptions. We would point out in this editorial that RN and DT are quite complicated methods. They require emergency teams prepared for on-site data collection (data of all kinds: incident, persons involved, place, time of day, weather, etc.) and coordination with other computers around the country. These techniques are mathematically translated into econometric equations: a variable to be predicted on the basis of a number, sometimes very large, of explanatory variables. These may be dichotomous, making calculation difficult, and also requiring much "learning" to provide a more or less quasi-perfect equation. Moreover, when the variable to be predicted is of two types, observed and estimated, and when the estimate is also very different from the observed value, the degree of complication is higher and the result has reduced reliability.

The aggregative tree yields a set of results from which it might be possible to extract more information if the sample size were higher.Turning again to simulation, it is used in applied research where the process is too complex to be studied analytically. Clearly, although the future value of a time series is not predictable with complete accuracy, the result cannot be completely random. There must be some regularity about their behavior over time, which will enable modeling and hence prediction. The traditional method used to study time series is quite simple: it is primarily based on decomposing the series in several parts: trend, regular seasonal variation and other irregular fluctuations. Díaz Herrero et al[7] provide a method which, from a mathematical standpoint, offers the best solution to the problem of volume of demand and care times in the form of a computer program. When studying phenomena that vary with time but are more or less repetitive, there are various methods that allow prediction and lead to appropriate responses. The best known are time series and forecasting, econometric models and those methods listed as ARIMA, MAPE, RMSE and MaxAPE[8]. One has to be an expert at prediction in order to understand and interpret them. The authors have done a good job (although sometimes excessively complex) regarding which model is likely to produce the best prediction. Similar studies should be performed in other centers to strengthen the conclusions reached in this work.

As shown in these three articles[2,6,7], mathematics continues to underlie contributions to medicine and facilitate the management of EDs, EMS and working conditions and thus contributes to better care of patient requiring urgent attention. In life, and also in medicine, we have always wanted to know what the future holds to be able to plan for it, both personally and work-wise. That may be more difficult to achieve in life, but less so in medicine, where thanks to mathematics we are more likely to be able to predict what will happen in the next few days in our EDs and EMS.

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