The use of Bayesian Networks Supporting Diagnostic in Emergency

A state of the art

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ABSTRACT

The aim of this study is to evaluate Bayesian Networks (BN) as Clinical Decision Support Systems (CDSS) in medical fields, in general, and in Emergency, specifically. Moreover, we intend to study its usefulness in comparison with the traditional systems applied to diagnosis, prognosis and therapeutics. For this state of the art, we selected articles 234 articles using three online databases, with proper and specific queries – ISI Web of Knowledge, Scopus and Medline. We have two or three reviewers (to solve divergences when necessary) that were responsible for the selection of the articles according to the following inclusion criteria: the included articles must be applied to diagnosis, prognosis or therapeutic related to Bayes' theorem; papers must provide details so that the study can be analyzed; they must be written in English. The articles would be excluded if it was a meta-analysis or a review or if it wasn't applied to humans. The same article could be classified in more than one medical field. After selection, articles were classified according to the medical field and healthcare domain they referred to. Ignoring 32 wrongly included articles, we found 128 articles regarding diagnosis (58%), 41 mentioning prognostic (18%) and 54 about therapeutic (24%). Although we found articles related to 33 different medical areas and the majority of the papers were set in the area of Oncology (24) we followed our aim presented before. We also found 9 articles related to diagnosis in Medical Emergency. We have excluded one of them because the full article was unavailable, leaving us with 8 articles. While analyzing the selected 8 articles, we were able to identify the most relevant information and to put it into a proper database. Then we proceed the study of the selected variables. We concluded that 4 articles were *nonrandomized trials without control group* and with one unique exception, they all considered BN to be a successful CDSS. Although two of the articles did not mention BN to be a successful CDSS, the accuracy of this method ranged from medium to as high as 99%, as in the other papers.

KEYWORDS

Bayesian Network, CDSS, Diagnosis, Emergency

INTRODUCTION

Bayesian networks are models to present knowledge that is anchored in the probability theory of Thomas Bayes (1763). Its mathematical representation is a table of combined probabilities of the problem universe that is translated through a diagram model. In a simple way, they show causal relationships of a system variable. Thus, it is commonly referred to as a causal network and it is represented by a dependency probability chart. Bayesian networks are diagram models that support the reasoning (conclusions) based on uncertainty. They enclose variables (discrete or continuous) and direct connection between them. The model is characterized by a high degree of adaptability that can take account of new information resulting in changes on dependencies and concepts.[1]

In the 80's, to promote abduction and prediction systems in artificial intelligence (Pearl, 2000), Bayesian networks enjoyed strong growth. Since then, they are a standard methodology for building systems based on probabilistic knowledge.

As examples we can mention the work of Omolola Ogunyemi, Phillip Rice, John Clarke, and Michael Matheny who developed a TraumaSCAN based on Bayesian networks to predict the consequences of penetrating trauma to the chest and abdomen; also the work of Dr. P. J. F. Lucas and Dr. M.A.J. van Gerven (2003) that extend Bayesian-network technology to support medical decision in clinical management of cancer patients; or the work of Dr. Peter Lucas (2001) that developed methods for the exploitation of medical temporal data, methods for expert-guided temporal model development, and learning temporal Bayesian models from temporal data (both structure and parameter learning); or even the project of Dr.ir. N. Karssemeijer and Dr. P.J.F. Lucas (2006) that intends to develop new improved classifiers using Bayesian networks based on advanced image analysis and domain knowledge from the breast cancer screening domain to be used in decision support systems for radiologists.

Therefore, Bayesian networks can be used to create a data-base that can help health in diagnosis, prognosis or therapy selection in various domains. That is why they are important to support intelligent health organizational decision making and to promote clinical accountability. Clinical Decision Support Systems (CDSS) are considered to combine medical knowledge base, patient data and an inference engine to generate case specific advice. They are used in clinical routine as expert systems. They include medical knowledge about very specific task as alerts and reminders, diagnostic assistance, therapy critiquing and planning, prescribing decision support, information retrieval, image recognition and interpretation. So they are very useful in

medical emergency because they help to achieve a correct diagnosis thought a list of candidate syndromes in a short period of time.[2]

The objective of this paper is twofold. First, it aims to understand the contribution and income of Bayesian networks in the development of a diagnosis in medical emergency. Second, it also aims to establish a relationship between the use of Bayesian methods and the clinical domain.

OBJECTIVE

The aim of our work is to quantify and qualify the use of Bayesian Networks as a CDSS, to support diagnosis in vary Medical fields with special focus in Emergency Triage and recognize the advantages of this use in daily clinical practice. However, several specific objectives have been defined, such as to explore the use of BN as CDSS in Emergency domain, as well as discussing its usefulness, accuracy and appliance costs. Also, verify the use of BN as CDSS in different medical fields such as Emergency Triage comparing to the old existing systems and identify in which clinical directions - diagnosis, prognosis and therapeutics - BN have been applied as CDSS successfully.

METHODS

The articles were selected after a search of the ISI Web Knowledge, Scopus and Medline databases using the following search draft: 'Bayesian Theorem' AND 'Clinical Decision Support Systems'. The temporal starting point was as far back as possible according to the availability of each database. Duplicated articles found on the different search engines and articles with no abstract were excluded.

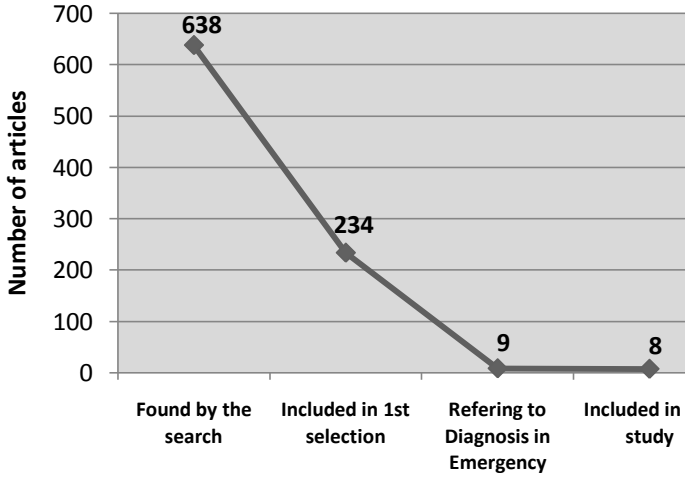
Different groups of two randomly selected readers reviewed each abstract collected by the search, selecting those to be included and excluded. In order to minimize the systematic errors caused by the subjectivity of the analysis, the two reviewers in each group could not discuss their opinion whether to include or exclude the articles. All reviewers used the same inclusion criteria - the articles must be applied to diagnosis, prognosis or therapeutic related to Bayes' theorem; the paper must provide details so that the study can be analyzed; the paper must be written in English - and exclusion criteria - the article would be excluded if it was a meta-analysis or a review or if it wasn't applied to humans. When there was divergent opinion between two readers, a third reviewer would reanalyze the abstract and solve the disagreement.

After this step, there was a second selection. The resulting papers (234) were classified according to the medical field (diagnosis, prognosis, therapy) and healthcare domains (e.g. cardiology, emergency, pediatrics) they belonged. Only those related to diagnosis in Medical Emergency (9) were selected and one of them were excluded because the full article was unavailable.

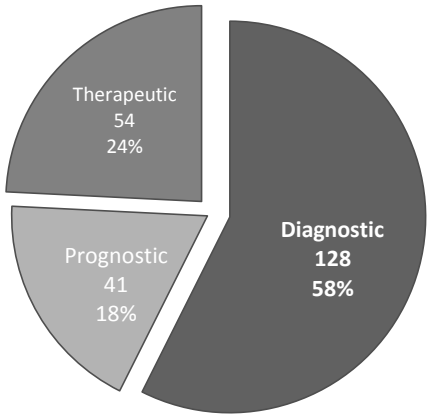
After reading the final articles, data related to relevant variables of each study, such as the

date and country of the study, the characteristics of the methodology (type of study, the size of experimental and control groups, study's duration), type of disease diagnosed and the advantages or disadvantages of the BN application (such as costs, time spent, diagnosis accuracy, limited application…), was collected and summarized in a database in order to discuss the results and take conclusions.

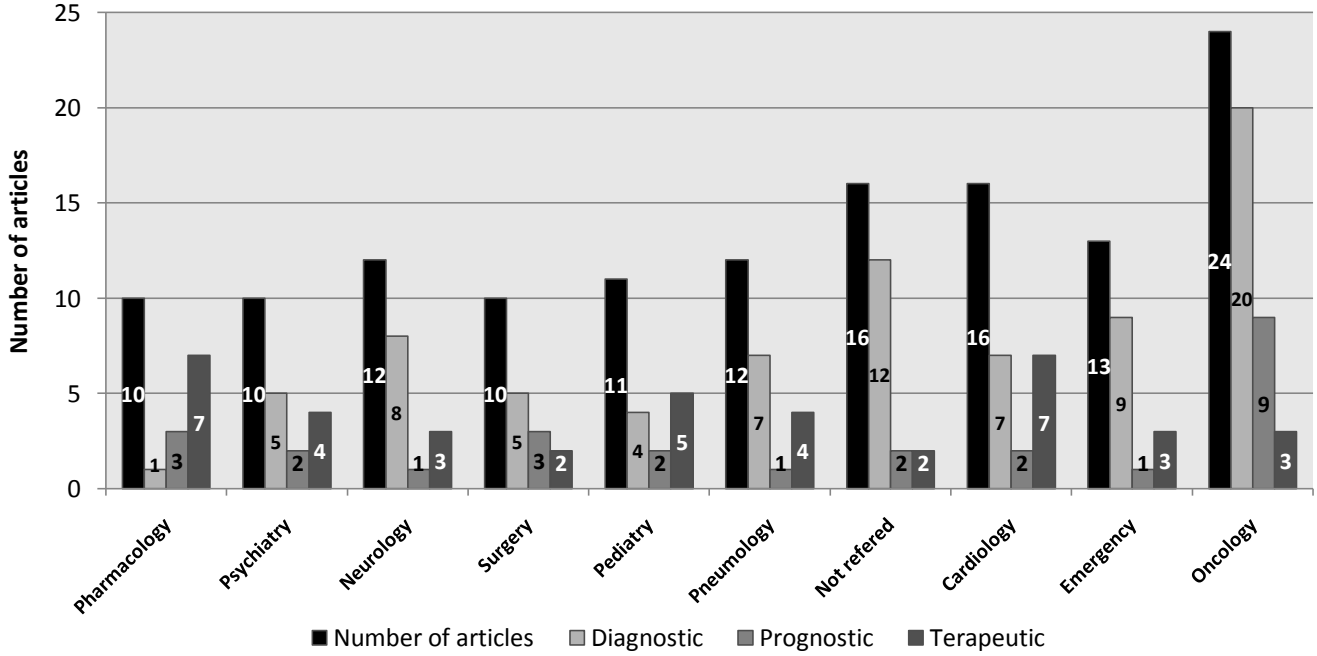
RESULTS



Graphic 1 – ***Quantity of articles along the search.***



Graphic 2 – ***Appliance of BN supporting diagnostic, prognostic and therapeutic.***



Graphic. 2 – ***Distribution of the 234 included articles by the commonest medical areas***. From the 234 articles previously included, there where **another 68 articles (not showed in this graphic) spread among other 24 areas (**50 diagnostic, 15 prognostic, 14 therapeutic) and **32** out of those 234 articles were **excluded** duo to wrong inclusion.

		Pneumonia	Abdominal pain	Acute myocardial infarction*	Acute ischemic heart disease*	Venous Thromboembolism
Number of studies		3	3	1	1	1
Type of design	Case-control	-	2	-	-	-
	Clinical Trial	-	1	-	-	-
	Cohort	-	-	-	-	1
	Nonrandomized trial without control group	3	-	1	1	-
Size of experimental group	Minimum	742	90	178	290	3145
	Maximum	32000	1208	178	290	3145
	Average	12368	641	178	290	3145
	Median	4361	624	178	290	3145
Size of control group	Minimum	-	-	-	-	1423
	Maximum	-	-	-	-	1423
	Average	-	-	-	-	1423
	Median	-	-	-	-	1423
Study duration	Minimum	9 weeks	72 hours	6 months	6 months	90 days
	Maximum	25 months	11 months	6 months	6 months	90 days
	Average	10 months	5 months	6 months	6 months	90 days
	Median	3 months	120 days	6 months	6 months	90 days
Advantages of application	Reduction of costs	Yes (96,102)	Yes (all)	-	-	-
	Reduction of the time spent in Emergency department	Yes (96)	Yes (all)	-	-	-
	Improvement of diagnosis accuracy	Yes (all)	Yes (943,1469)	Yes	Yes (all)	Yes (all)
	Improvement of patient triage in emergency department	None	Yes (1469)	-	-	-
Disadvantages	Limited application of study	Yes (96)	-	-	-	-
	Decrease of diagnosis accuracy	-	-	-	-	-
	Disagreement between healthcare professionals and BN	-	-	-	-	-

Table 1 – Data extracted from the 8 included articles. Firstly, we classified the articles according to the disease which diagnosis was tested – pneumonia, abdominal pain, acute myocardial infarction, acute ischemic heart disease and venous thromboembolism. Secondly, our observations were more specific in order to analyze the variables we aimed to study. Thus, we extracted information about the type of design, size of experimental and control groups used in each study, the duration, advantages and disadvantages of application.

* These two studies were extracted from the same article.

DISCUSSION

After our research we started with a total of 638 articles, number that have been reduced to 234 after the first selection .These articles have been classified by the healthcare domain and the medical field they refered to. Most of the articles (58%) were related to diagnosis, while 18% of the articles were related to prognosis and 24% to therapeutic selection and besides that our results also shows that Oncology(with 24 articles),Cardiology (with 16 articles) and Emergency(with 13 articles) have been the areas where more the use of BN have been tested.

Because the wide range of medical fields that were mentioned in the articles we decided to focus in the studies related to diagnosis in "Emergency", and we finally analyzed 8 articles. Because one of the articles("Clinical experience with a decision support computer program using Bayes' theorem to diagnose chest pain patients*")* was related to two different diseases we decided to analyze them separately like if they were two different studies.

The problems diagnosed in these studies were pneumonia (3 articles), abdominal pain (3 articles), acute myocardial infarction (1 article), acute ischemic heart disease (1 article) and venous thromboembolism.

The studies ranged from clinical trials (1 article, related to abdominal pain) to cohort studies (1 article, related to venous thromboembolism). Two of the articles related to abdominal pain were referent to case control studies. The 5 remainder articles (all studies related to pneumonia, acute ischemic heart disease and acute myocardial infarction) were nonrandomized trial without control group .

The size of experimental/control group had a lot of variation - ranged from 90 to 32.000. The duration was also very variable: from 25 hours to 35 months.

In all the articles the use of Bayesian Networks was considered successful, and some advantages were referred. For example, the reduction of the costs was mentioned in all the articles of abdominal pain and in 2 of the articles of pneumonia. This system improved diagnosis accuracy (in all the areas) and patient triage in emergency department (in one article related to abdominal pain). Nothing was referred against these advantages above mentioned and the only disadvantage.

CONCLUSION

Most of the articles (58%) were related to diagnosis, whilst 18% of the articles were related to prognosis and 24% to therapeutic selection. Most of the studies were made in USA (8 articles) and 2 were made in Norway. The articles were published between 1998 and 2005. The studies ranged from clinical trials (7 articles) to cohort studies (2 articles); one of the studies was not classified. In all the articles the use of Bayesian Networks was considered successful, except one. In the articles where the cost of Bayesian Networks' implementation was referred (2 articles), it was low.

In two of the studies, the accuracy was not referred. In the others it ranged from medium to high, reaching percentages as high as 99%.

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