ORIGINAL ARTICLE

A new artificial intelligence tool for assessing symptoms in patients seeking emergency department care: the Mediktor application

Elvira Moreno Barriga[1], Irene Pueyo Ferrer[2], Miquel Sánchez Sánchez[2],
Montserrat Martín Baranera[3], Josep Masip Utset[1]

Objectives. To analyze agreement between diagnoses issued by the Mediktor application and those of an attending physician, and to evaluate the usefulness of this application in patients who seek emergency care.

Methods. Prospective observational study in a tertiary care university hospital emergency department. Patients with medical problems and surgical conditions (surgery and injuries) who did not require immediate emergency care responded to the Mediktor questions on a portable computer tablet. The software analyzed the answers and provided a list of 10 possible preliminary diagnoses in order of likelihood. The patient and the attending physician were blinded to the list to so that the usual care process would not be altered. The level of agreement between the physician's diagnosis and the Mediktor diagnosis was analyzed.

Results. A total of 1015 patients were included; 622 cases were considered valid for study. Cases were excluded if the patients did not meet the inclusion criteria, they did not have a discharge diagnosis, they had a final diagnosis expressed as a symptom or their final diagnosis was not included in the Mediktor database. The physician's diagnosis (the gold standard) coincided with one of the 10 MEDIKTOR diagnoses in 91.3% of the cases, with one of the first 3 diagnoses in 75.4%, and with the first diagnosis in 42.9%. Sensitivity was over 92% and specificity over 91% in the majority of common diagnostic groups; the κ statistic ranged from 0.24 to 0.98.

Conclusions. The Mediktor application is a reliable diagnostic aid for the most prevalent problems treated in a hospital emergency department. The general public finds it easy to use.

Keywords: Emergency department. Agreement. Surgery. Injuries. Symptoms. Physician diagnosis.

Experiencia de Mediktor®: un nuevo evaluador de síntomas basado en inteligencia artificial para pacientes atendidos en el servicio de urgencias

Objetivo. Analizar la concordancia entre los diagnósticos emitidos por Mediktor® con el realizado por el médico responsable, así como valorar la utilidad de este dispositivo en pacientes que acuden a un servicio de urgencias (SU).

Método. Estudio observacional prospectivo realizado en el SU de un hospital terciario universitario. A los pacientes con patologías médicas y quirúrgicas (cirugía y traumatología) que no precisaban asistencia médica inmediata se les entregó una tableta digital para responder al interrogatorio de Mediktor®. Según las respuestas, el *software* adjudicaba un listado de 10 prediagnósticos ordenados por probabilidad, que se ocultaban al paciente y al médico responsable, para no modificar el proceso habitual. Posteriormente se analizó el grado de coincidencia entre el diagnóstico médico y los diagnósticos ofrecidos por Mediktor®.

Resultados. 1.015 pacientes fueron incluidos, de los que 622 se consideraron casos válidos para el estudio. Se excluyeron los pacientes que no cumplían los criterios de inclusión, sin diagnóstico al alta, con diagnóstico final expresado como síntoma y aquellos con diagnósticos no incluidos en Mediktor®. Las coincidencias entre el diagnóstico médico (patrón oro) y los diez diagnósticos de Mediktor® fueron de un 91,3%, en los tres primeros diagnósticos de un 75,4% y en el primer diagnóstico de un 42,9%. Según los grupos de diagnósticos más frecuentes, se objetivó una sensibilidad > 92% y una especificidad > 91% en la mayoría de ellos, con un índice kappa que osciló entre el 0,24 y el 0,98.

Conclusiones. Mediktor® es una herramienta fiable para ayudar al diagnóstico de las enfermedades más prevalentes de un SU y fácil de utilizar por el público en general.

Palabras clave: Servicio de Urgencias. Concordancia. Cirugía. Traumatología. Síntoma. Diagnóstico médico.

Introduction

The proliferation of the internet and the easy accessibility of medical information have led to the fact that the search in the network of medical terms has become a common practice in the general population[1]. If this information is not well contrasted it can lead to erroneous interpretations[2] and, therefore, pose a risk to the user's health. In the line of improving existing disinformation, sophisticated computer programs called

Authors affiliation:
[1]Servicio de Medicina Intensiva del Consorci Sanitari Integral, Barcelona, Spain.
[2]Área de Urgencias, Hospital Clínic, Barcelona, Spain.
[3]Departamento de Epidemiología e Investigación del Consorci Sanitari Integral, Barcelona, Spain.

Contribution of authors:
All authors have confirmed their authorship in the author's responsibilities documents publication agreement and assignment of rights to EMERGENCIAS.

Corresponding author:
Elvira Moreno Barriga
C/ Ricart, 16, 2º, 1º
08004 Barcelona, Spain.

E-mail:
elviramorenobarriga@hotmail.com

symptom evaluators (symptomcheckers)[3-5] have proliferated, using computerized algorithms, interrogating the user about their symptoms, to finally offer a list of possible diagnoses, indicating with what urgency they should request medical help and to whom they should go to. The true impact of the use of these symptom evaluators will depend to a large extent on their degree of precision and the clinical and economic benefit they offer[6,7].

In this line, MEDIKTOR CORP (M.C) - TECKEL SOLUTION is a company whose objective is to develop and market IT solutions based on artificial intelligence focused on the medical field. It has developed a symptom evaluator called Mediktor®, designed to facilitate and speed up the medical diagnostic process using artificial intelligence algorithms. Unlike other evaluators of symptoms that exist in the market[3-5], and because the diagnostic accuracy can be affected by the interaction between the user and the software, M.C. develops and applies Mediktor® natural language interpretation algorithms, without requiring knowledge of technical terms by the user.

For the improvement in the diagnostic process, the studies that had been carried out on some of the different symptom evaluators that existed in the market were made by measuring their accuracy through "virtual patient vignettes". In this way, they obtained an average of 58% agreement between diagnoses, taking into account the first 20 diagnoses granted[8].

Therefore, the objective of this study was to analyse, in a series of real patients, which is the agreement between the diagnoses issued by Mediktor® after completing the guided questioning (performs a differential diagnosis with ten possible diagnoses from greater probability to lower) with the diagnosis issued by the responsible physician (gold standard) for the same patient in the same episode and, in this way, assess its usefulness in patients who go to the emergency department (ED).

Method

Prospective observational study conducted in the ED of the Hospital Clínic de Barcelona (HCB). It is a third-level (high complexity) 800-bed hospital, located in the centre of the city (550,000 inhabitants). At present, some 95,000 general emergencies are attended annually, except for the specialties of obstetrics and gynaecology, paediatrics and ophthalmology, which are carried out in other centers. Since February 2009, the triage of patients in the ED is carried out by nursing staff, using the assignment of the level of emergency according to the Andorran Triage Model (ATM)[9]. The study was conducted over a period of 4 months, from October 1, 2016 to January 31, 2017.

The patients selected were those to whom the triage assigned levels of MAT III, IV and V (which did not require immediate attention) according to the order of arrival and in different shifts to ensure obtaining a re-

presentative sample. The inclusion criteria were: age > 18 years, adequate level of consciousness and ability to understand the Spanish language in order to answer the questions of the program. We excluded patients who did not meet the inclusion criteria, those who refused to participate in the study, those who did not have a diagnosis at discharge ("USERS"), those in whom the final diagnosis was expressed as a symptom or sign ("UNSPECIFIC "= Diagnoses not admitted in ICD-10) and cases with diagnoses not included in the Mediktor® dictionary at the time of the study ("NOT CONTEMPLATED").

A nurse assigned to the HCB and assigned to the study (EE) interviewed patients in the emergency, surgery and traumatology wards, after having been triaged (levels III-V) and distributed following the usual procedure. While patients waited in the waiting room they were introduced and explained what the study consisted of in an understandable language (without technicalities), ensuring that the study would not change the time, diagnostic tests or treatment that could apply for their ailment. After confirming the inclusion criteria and discarding the exclusion criteria, a prudent time of reflection was established, after which written informed consent was requested for inclusion in the study and a copy of it was delivered. To the patients who agreed to participate in the study, the program assigned them a randomized code of 5 numbers to be able to identify them. Each of the codes was generated by the computer, with the user's data completely anonymous since they did not include initials, date of birth, or national identity document number. The EE registered this code in a file protected with the MR number (Medical records) of the patient. This process ensured the random coding and the anonymity of the participant. After the code was assigned, the EE checked the vital signs of the patient (blood pressure, heart rate, temperature and pulse oximetry) by filling in the corresponding sections in Mediktor®. Subsequently, he gave them the digital tablet to introduce the reason for consultation by which they had come to the ED and answered themselves to the questions that the program was asking them (between 7 and 20), thus performing the evaluation individually (self-administered). The average number of questions that the evaluator made among all the patients included in the study was 17 questions and the average time calculated for each session was 2 minutes and 25 seconds.

Some of the questions were answered when selected, others had a multi-response format (text, image or the combination of both), and the vast majority were answered by choosing between five possible answers: YES, NO, PROBABLY YES, PROBABLY NOT, or I DON'T KNOW. At the end of the interrogation, the software appreciated their participation and wished them a speedy recovery without showing the list of diagnoses, which were recorded in a hidden way on the digital tablet. In this way, it was avoided to influence the doctor in charge, or to generate conflicts if there had been diagnostic differences between the doctor and Medik-

tor®. At the end of the questionnaire, patients were invited to answer four questions about the usefulness of Mediktor®. The questions were: 1) Did you understand most of the questions well? 2) Did the application seem easy to use? 3) Do you think that new technologies can help improve the health system? 4) Would you like to be able to get medical guidance from home? All of them responded with NO/YES/DK/NA.

The study protocol was approved by the Clinical Research Ethics Committee of the Hospital Clínic de Barcelona.

Statistical analysis, data processing and concordance analysis were performed in a deferred manner, reviewing the MR of the patient and the diagnoses registered by the program, introducing them in a database. Diagnostic fields of similarity were established that allowed the grouping of diagnoses expressed with different terminology.

Since there was no history in the literature, a pilot study was conducted with 358 patients to estimate the sample size. After the statistical analysis and taking into account the percentage of associated losses, a minimum of 588 cases was considered necessary. The data was analysed with the statistical program SPSS v20 (IBM®, North Castle, New York, USA), with which several calculations were made:

- The proportion of coincidences between Mediktor® and the responsible physician as the number of coincidences over the total of valid cases. The coincidences in the first diagnosis, in the first three diagnoses and in the first ten diagnoses provided by Mediktor® were taken into account. For each of the three proportions, 95% confidence intervals (CI) were calculated using the exact Clopper-Pearson method.

- Taking into account the most frequent diagnoses in the ED and considering the medical diagnosis at discharge as a reference standard, sensitivity (Se) was calculated (probability that Mediktor® included the clinical diagnosis considered when the disease was present among the first ten diagnoses), specificity (Sp) (probability that the result of Mediktor® was negative when the disease was not present), positive predictive value (PPV) (probability that the disease was present when Mediktor® included it among its top ten diagnoses) and negative predictive value (NPV) (probability that the disease was not present when Mediktor® offered a negative result for that disease), expressing each of them as percentages. The 95% CIs for sensitivity and specificity were calculated using the exact formula of Clopper-Pearson. For the CI at 95% of the predictive values, the standard logit method of Mercaldo et al.[10] was applied. The reliability assessment methodology was performed by calculating the kappa index with its specific CI for each diagnostic category.

Results

During the study period, 1,015 patients were selected according to the inclusion criteria, and a total of 622 patients were considered definitively as valid cases for the analysis. 393 patients were excluded from the study, among those who were not diagnosed at discharge ("USER", 61 cases), those under 18 years ("UNDER 18", 21 cases), those that the final diagnosis was expressed as a symptom ("UNSPECIFIED" = diagnoses not admitted in ICD-10, 151 cases) and patients with diagnoses not included at that time in the Mediktor® dictionary ("NOT CONTEMPLATED", 160 cases).

The variability of the sample is represented according to sex (women: 56.0% and men: 44.0%), to the age ranges expressed in years (18-24: 26.7%, 25-49: 52,9%, 50-75: 18.3% and greater than 75: 2.1%), as well as the work shifts in which the total number of cases was collected (from 8-14 hours: 53.7 % and from 14-20 hours: 46.3%).

The most prevalent diagnoses within the ED, having as a reference standard the medical diagnosis upon discharge from the emergency department, were defined as those groups of pathologies in which there were more than 4 cases collected in our series. It can be observed in each of them the degree of agreement of the evaluator in the ten diagnoses granted by Mediktor®, in the first three diagnoses and in the first diagnosis (Table 1).

The coincidences, analysing the global of included patients (622), between the diagnosis of the doctor and the ten diagnoses of Mediktor® were in 568 cases, 91% (95% CI: 88% to 93%); in the first three diagnoses in 469, 75% (95% CI: 71% to 78%); and in the first diagnosis in 267 patients, 43% (95% CI: 39% to 46%) (Table 2).

The results in terms of Se, Sp, NPV and PPV are presented for the twelve most frequent diagnoses (Table 3), with an Se > 92% in 9 of the 12 groups analysed and an Sp > 91% in 10 of them. Likewise, the kappa index calculated for the same diagnostic groups ranged between 0.24 and 0.98, obtaining the lowest value for the urinary tract group and the highest value for the group of upper respiratory tract infection (Table 4).

The degree of utility of the evaluator was assessed with the 4 questions that Mediktor® asked at the end of the questionnaire. These and the results thereto are shown in Table 5. For more than 98% of respondents Mediktor® is an easy-to-use program.

Discussion

In order to find a new tool to help clinical diagnosis we decided to carry out this study on Mediktor®, since, in addition to being a symptom evaluator that used artificial intelligence algorithms, it allowed us to perform the medical questionnaire without understanding problems on the part of the users when using a natural language.

After making a comparison between the diagnoses obtained (doctor and evaluator), it was found that Mediktor® had a diagnostic agreement of 91.3% when analysing the results on the list of 10 possible

Table 1. Most prevalent diagnoses in the emergency department and coincidences between the medical diagnosis and Mediktor®

Diagnosis in the emergency Department	Coincidences between the diagnosis between physician and Mediktor®		
	As first diagnosis (%)	In the first three diagnosis (%)	In the first ten diagnosis (%)
Respiratory infection of upper tracts *	76.2	93.7	97.5
Affectation of the urinary tract	70.6	87.2	100
Lumbosciatalgia	82.2	93.3	100
Otitis	73.3	96.6	100
Contusion	76	88	100
Sprain*	79.2	87.5	91.7
Non-specific abdominal pain	4.5	45.4	100
Headache	88.9	88.88	100
Tendinitis*	81.25	81.25	81.2
Acute gastroenteritis	80	100	100
Vertigo*	84.6	84.6	84.6
Cervicalgia	53.8	61.5	100
Other diagnoses**			

*Less than 100% agreement is achieved by adding the cases of the three columns.
**Includes more than 200 different diagnoses where less than 4 patients were included/pathology: anal fissure, constipation, nail fold, herpes zoster, acute diverticulitis, haemorrhoids, plantar fasciitis, mechanical costal pain, traveller's diarrhoea, respiratory infection of low ways, allergic reaction, etc.

pathologies identified as diagnoses by Mediktor® (ordered by probability), of 75.4% counting the first 3 possible diagnoses and of 42.9% with the first diagnosis, with a moderate degree of agreement in the majority of patients analysed, with a kappa index that ranged between 0.24 and the 0.98. In turn, the high sensitivity (> 92%) and specificity (> 91%) of the evaluator could be verified for the majority of patients analysed.

On the other hand, during the realization of the study the patients were confident with the system and did not have difficulties when answering the different questions that the evaluator was making them. Thus, more than 98% of respondents considered Mediktor® to be an easy-to-use program.

The medical diagnosis of the diseases that our patients suffer continues to pose difficult challenges,

Table 2. Coincidences between the medical diagnosis and Mediktor® in the total number of patients (622)

	Success Mediktor® (%)	CI 95%	
		Lower limit	Upper limit
As first diagnosis	267 (42.9)	39.0	46.9
In the first three diagnosis	469 (75.4)	71.8	78.7
In the first ten diagnosis	568 (91.3)	88.8	93.4

and although there are few studies on diagnostic accuracy, it is known that the percentage of error in the medical diagnosis (including the performance of complementary tests) is between 10 and 15%[11]. Arriving at a correct diagnosis is a complicated process that can be influenced in a positive way by the ease of memory to recover representative patterns of diseases[12-14]. Although, this capacity is limited, since they cannot handle more than seven possibilities at once and this is subject to the possibility of biases in clinical reasoning. And also, and in a negative way, due to errors linked to the cognitive process of reasoning and, also, to human factors such as fatigue, work overload and scarce organization of assistance time, among others[15,16]. So far, no strategy, cognitive[17] or systemic[18], has helped to improve the diagnostic accuracy and, therefore, to decrease the diagnostic error.

Therefore, we consider that the results of our study provide relevant data that lead us to consider that Mediktor® is a diagnostic tool that can be complementary to normal clinical practice, and that its implementation in hospital EDs could accelerate the process diagnosis with an improvement in efficiency.

In addition, and after the analysis of the results, future strategies are proposed with regards to the evaluator, since Mediktor® could become a complement to conventional triage, such as advanced nursing triage[19]. In this way, it could be a tool to help advance the request for diagnostic tests or administer treatments and, therefore, shorten the stay in the ED[18]. In turn, it could be considered if Mediktor® could become a new triage system, for which it would be convenient to demons-

Table 3. Most frequent diagnoses in the emergency department: sensitivity, specificity, positive predictive value and negative predictive value achieved by Mediktor®

	Sensitivity (CI 95) %	Specificity (CI 95) %	PPV (CI 95) %	NPV (IC 95) %
Upper respiratory tract infection	97.5 (91.3-99.7)	100.0 (99.3-100.0)	100	99.6 (98.6-99.9)
Impact of the urinary tract	92.6 (82.1-97.9)	68.5 (64.5-72.3)	21.8 (19.5-24.4)	99.00 (97.4-99.6)
Lumbosciatalgia	94.9 (82.7-99.4)	93.5 (91.2-95.3)	49.3 (41.5-57.2)	99.6 (98.6-99.9)
Otitis	93.7 (79.2-99.2)	93.7 (91.5-95.5)	44.8 (36.9-52.9)	99.6 (98.6-99.9)
Non-specific abdominal pain	88.0 (68.8-97.4)	98.0 (96.5-98.9)	64.7 (50.7-76.6)	99.5 (98.5-99.8)
Sprain	100.0 (84.6-100.0)	98.3 (96.9-99.2)	68.7 (54.3-80.3)	100
Contusion	100.0 (86.3-100.0)	93.1 (90.8-95.0)	37.9 (31.2-45.0)	100
Tendinitis	81.2 (54.3-95.9)	93.4 (91.1-95.2)	24.5 (18.2-32.2)	99.5 (98.5-99.8)
Headache	100.0 (80.5-100.0)	91.9 (89.4-93.9)	25.8 (20.9-31.2)	100
Acute gastroenteritis	94.1 (71.3-99.8)	89.3 (86-5-91.6)	19.7 (15.9-24.2)	99.8 (98.8-99.9)
Cervicalgia	100.0 (71.5-100.0)	95.2 (93.2-96.8)	27.5 (21.0-35.1)	100
Vertigo	84.6 (54.5-98.1)	98.7 (97.4-99.4)	57.9 (39.9-73.9)	99.7 (98.8-99.9)

PPV: positive predictive value; NPV: negative predictive value; CI: Confidence interval.

Table 4. Most frequent diagnoses in the emergency department: concordance (kappa index) in the diagnosis between Mediktor® and the emergency doctor

Most frequent diagnoses	Kappa Index	CI 95 (%)
Upper respiratory tract infection	0.986	0.965-1.000
Impact of the urinary tract	0.248	0.185-0.310
Lumbociatalgia	0.618	0.511-0.724
Otitis	0.577	0.459-0.694
Non-specific abdominal pain	0.733	0.604-0.862
Sprain	0.807	0.690-0.923
Contusion	0.522	0.397-0.646
Tendinitis	0.351	0.207-0.496
Headache	0.383	0.252-0.513
Acute gastroenteritis	0.295	0.180-0.409
Cervicalgia	0.415	0.247-0.584
Vertigo	0.680	0.492-0.867

CI: Confidence interval.

trate agreement with the level of emergency compared to the result of systems validated at present. Other artificial intelligence algorithms referenced have tried unsuccessfully[8].

Our study presents a series of limitations. The first and important one is that it has been carried out in a single centre. In addition, the included patients only belonged to groups III-V of the ATM (triage system) and, therefore, that did not require immediate attention due to their severity. On the other hand, the percentage of patients older than 75 years was very low, without being able to draw conclusions in this age group. In summary, it can be said that only Mediktor® has been evaluated in the profile of young low risk patients, in which the results can be interpreted. On the other hand, a large group of patients were excluded because they were classified as "non-specific" due to lack of diagnosis included in ICD-10 at discharge (14%) or "not contemplated" for not having the diagnosis defined in Mediktor® (15%), which at the time of the study contemplated 560 pathological diagnoses. In any case, no study to date had analysed the concordance between medical diagnoses and evaluators of symptoms with real patients.

In conclusion, we can say that our findings suggest that Mediktor® has a high coincidence with medical diagnosis, being a sensitive and specific evaluator, which makes it a useful tool to help diagnose the most prevalent diseases of an ED and easy to be used by patients in general. As a future line of work, a study based on analysing the agreement of the level of urgency granted by Mediktor® versus the result of triage systems already validated at present could be proposed.

Conflicting interests

Financing

Ethical Responsibilities

The study was approved by the Ethics and Clinical Research Committee of the Hospital Clínic of Barcelona.

Informed consent was obtained from participants.

All authors have confirmed the maintenance of confidentiality and respect for patients' rights in the author's responsibilities document, publication agreement and assignment of rights to EMERGENCIAS.

Article not commissioned by the Editorial Committee and with external peer review

References

1 Barnett ML, Linder JA. Antibiotic prescribing to adults with sore throat in the United States, 1997-2010. JAMA Intern Med. 2014;174:138-40.
2 Black P. The dangers of using Google as a diagnostic aid. Br J Nurs. 2009;18:1157.
3 North F, Ward WJ, Varkey P, Tulledge-Scheitel SM. Should you search the Internet for information about your acute symptom? Telemed J E Health. 2012;18:213-8.
4 Luger TM, Houston TK, Suls J. Older adult experience of online diagnosis: results from a scenario-based think-aloud protocol. J Med Internet Res. 2014;16:e16.
5 North F, Varkey P, Laing B, Cha SS, Tulledge-Scheitel S. Are e-health web users looking for different symptom information than callers to triage centers? Telemed J E Health. 2011;17:19-24.
6 Fox S, Duggan M. Health Online 2013. Internet and American life project. Pew Research Center and California Health Care Foundation. (Consultado 7 Agosto 2017). Disponible en: http://www.pewinternet.org/files/old-media/Files/Reports/PIP_HealthOnline.pdf
7 Saczynski J, Yarzebski J, Lessard D, Spencer FA, Gurwitz JH, Gore JM, et al. Trends in pre-hospital delay in patients with acute myocardial infarction (from the Worcester Heart Attack Study). Am J Cardiol. 2008;102:1589-94.
8 Semigran HL ,Linder JA, Gidengil C, Mehrotra A. Evaluation of symptom checkers for self diagnosis and triage: audit study. BMJ. 2015;351:3480.
9 Jiménez JG. Clasificación de pacientes en los servicios de urgencias y emergencias: hacia un modelo de triaje estructurado de urgencias y emergencias. Emergencias. 2003;15:165-74.
10 Mercaldo ND, Lau KF, Zhou XH. Confidence intervals for predictive values with an emphasisto case-control studies. Stat Med. 2007;26:2170-83.
11 Graber ML. The incidence of diagnostic error in Medicine. BMJ Qual Saf. 2013;22(Supl 2):ii21-ii27.

Table 5. Degree of acceptance and usefulness of Mediktor® perceived by patients

Questions	Answer			
	Yes (%)	No (%)	DK/NA (%)	Total (%)
1) Have you understood most of the questions correctly?	98.8	0.7	0.4	100
2) Has the application found it easy to use?	98.2	1.1	0.7	100
3) Do you think that new technologies can help improve the health system?	95.3	3.9	0.9	100
4) Would you like to be able to get medical guidance from your home?	85.3%	13.8	0.9	100

DK/NA: does not know or does not answer the question.

12 Alonso Carrión L, Castells Bescós E, Alba Conejo E, Ruiz Cantero A. El razonamiento clínico como fuente de error. Med Clin (Barc). 2002;118:587-9.

13 Alonso Carrión L, Bermúdez F, Abarca M, García Almeida JM. ¿Diagnosticar mejor? Savia nueva para un árbol viejo. Med Clin (Barc). 2011;137:561-4.

14 Charlin B, Boshuizen HP, Custers EJ, Feltovich PJ. Scripts and clinical reasoning. Med Educ. 2007;41:1178-84.

15 Scott I. Errors in clinical reasoning: causes and remedial strategies. BMJ. 2009;339:22-5.

16 Croskerry P. The importance of cognitive errors in diagnosis and strategies to minimize them. Acad Med. 2003;78:775-80.

17 Graber ML, Kissam S, Payne VL, Meyer AND, Sorensen A, Lenfestey N. Cognitive interventions to reduce diagnostic error: a narrative review. BMJ Qual Saf. 2012;21:535-57.

18 Singh H, Graber ML, Kissam SM, Sorensen AV, Lenfestey NF, Tant EM, et al. System-related interventions to reduce diagnostic errors: a narrative review. BMJ Qual Saf. 2012;21:160-70.

19 Carballo Cardona C. Triaje avanzado: es la hora de dar un paso adelante. Emergencias. 2015;27:332-5.