Criterion validity of a computer-assisted instrument of self-triage (ca-ISET) compared to the validity of regular triage in an ophthalmic emergency department

Eva S.V. Eijk a,b,∗, Marijke Wefers Bettink-Remeijer c, Reinier Timman b, Marion H.B. Heres c, Jan J.V. Busschbach b

a Rotterdam Ophthalmic Institute, Schiedamse Vest 160D, 3011 BH Rotterdam, the Netherlands
b Department of Psychiatry, Section of Medical Psychology & Psychotherapy, Erasmus MC, s-Gravendijkwal 230, 3015CE Rotterdam, the Netherlands
c Rotterdam Eye Hospital, Schiedamse Vest 180, 3011 BH Rotterdam, the Netherlands

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A B S T R A C T

Objectives: The computer-assisted version of a self-triage tool (ca-ISET) for an ophthalmic emergency department (ED) was developed to increase the validity of the triage procedure when trained ED staff is absent.

Methods: We tested whether sensitivity, specificity, Negative Predictive Value (NPV) and Positive Predictive Value (PPV) of the ca-ISET deviated from regular triage. Patients ≥18 years visiting the ED of the Rotterdam Eye Hospital in the Netherlands were invited to participate in this prospective study. This ED focuses on eye-related problems. Patient recruitment was carried out during working hours. The ca-ISET is a touch operated software application and the algorithm of the triage is based in the Manchester triage system. For all participants three triage scores were determined by (1) the participant using the ca-ISET; (2) triage by a regular, trained triage assistant and (3) triage by one physician who was specially trained in ophthalmic triage. The diagnosis of the physician was chosen as the reference standard to define criterion validity. The order of triage administration was alternated per patient. Only cases with triage scores from the two triage systems and the reference standard were included. The outcome variables, four triage colours, were transformed into a binary score: high urgent and low urgent. The difference between the ca-ISET and regular triage in terms of sensitivity, specificity, PPV and NPV was tested by Z-scores.

Results: Of 247 eligible patients, data was elicited from 189 patients (average age 54 years, range 18–89). The sensitivity of the ca-ISET (0.89, CI: 0.75–0.96) did not differ from the sensitivity of the regular triage (0.69, CI: 0.53–0.82, Z = 1.74, p = 0.08). The ca-ISET was less specific (0.78, CI: 0.71–0.84) than the regular triage (0.92, CI: 0.86–0.95, Z = 3.04, p = 0.00). We found no significant difference between the ca-ISET and regular triage for PPV (Z = 0.19, p = 0.85) and NPV (Z = 0.03, p = 0.98).

Conclusions: The sensitivity, PPV and NPV of the ca-ISET does not differ from the sensitivity of the regular triage, while the ca-ISET retained a reasonable level of specificity. Therefore the ca-ISET can be recommended as a tool for ophthalmic emergency departments, and could be used when trained ED staff is absent.

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1. Introduction

Emergency departments (ED’s) are often overcrowded and need triage systems to categorize patients according to the urgency of their complaints [1,2]. In the Rotterdam Eye Hospital in the Netherlands, general triage systems do not apply due to the specialised character of the hospital. In response to a shortage of trained staff outside office hours, the authors of this paper previously developed a pen-and-paper instrument for patient self-triage

* Corresponding author at: Rotterdam Ophthalmic Institute, Schiedamse Vest 160D, 3011 BH Rotterdam, the Netherlands.
E-mail addresses: e.s.vaneijk@gmail.com (E.S.V. Eijk), m.wefers@oogziekenhuis.nl (M. Wefers Bettink-Remeijer), r.timman@erasmusmc.nl (R. Timman), m.heres@oogziekenhuis.nl (M.H.B. Heres), j.vanbusschbach@erasmusmc.nl (J.J.V. Busschbach).

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1386-5056/© 2015 Elsevier Ireland Ltd. All rights reserved.
patients were the reference by published the 5:00 computer-assisted we compare the test order as the maximum research in scoring best and criterion to validate the physician, triage assistants and physician. was presented as a sensitive and specific tool for the ophthalmic ED [3].

To implement the ISET in the ED of the Rotterdam Eye Hospital, a computer-assisted version of the ISET (ca-ISET) was developed [5]. The ca-ISET is a touch operated software application that presents one question at a time about the patient’s ophthalmic complaints. After a maximum of 24 questions the ca-ISET assesses patient priority based on the flow charts of the Manchester Triage System.

Digitalization of procedures in the ED [6–9] or computer-assisted triage [10–12] is not new. The benefits of interviewing patients using a computer have been established before [13]. It has previously been shown to be feasible to use a self-administered computer-assisted history-taking device [14,15] for diagnostic support in emergency departments. However, self-administered computer-assisted triage for the prioritization of patients visiting the ED has not been previously reported.

Sensitivity and specificity of the pen-and-paper ISET were established using the judgments of the regular triage assistants as the reference standard [3]. In order to validate the ca-ISET in the current study, an even better reference standard criterion was chosen, i.e. the triage scoring by the physician. The physician could be seen as almost the best reference level. In that respect one could say that we test ‘the criterion validity’ of the ca-ISET. As we also registered the judgments of the regular triage assistant, were able to test could compare the criterion validity of the regular triage assistant as well.

2. Materials and methods

2.1. Setting

The research took place in the waiting room of the Rotterdam Eye Hospital emergency department, which is exclusively visited by patients with an ophthalmic complaint. The Rotterdam Eye Hospital is the only specialist eye hospital in The Netherlands and the ED is visited by approximately 25,000 unique patients annually.

2.2. Study design

The study was conducted on 14 test days between 9:00 am and 5:00 pm in the study period between 13th December 2011 and 03rd February 2012. The study was not conducted on national holidays such as Christmas and New Year’s Day.

Consecutive patients ≥18 years old visiting the ED with ophthalmic complaints were invited by the researcher, ESVE, to participate in the study. Patients who had visited the ED previously with the same complaints were excluded, as well as unaccompa-nied patients who did not read or speak Dutch well enough to fill in the questionnaire.

Before they formally registered at the ED reception desk, participants were informed about the study by the researcher and they were asked to sign a form giving their consent. In order to obtain the required triage codes to validate the ca-ISET, the participants were allocated alternately to one of the two study routes: (1) first the ca-ISET, then the regular triage, followed by the physician’s triage; or (2) first the regular triage, then the ca-ISET followed by the physician’s triage. For all participants the three scores were determined consecutively with no pause in between. After the physician’s triage, participants proceeded to the ED and waited in the waiting room for their consultation with the ophthalmologist. The order of triage administration was noted. At the end of each test day the triage scores were collected by the researcher from the ca-ISET, the triage assistants and the physician.

Patients were allocated in an alternated sequence as fairly as possible to first the ca-ISET and then the regular administration or the other way around. However, the ED was sometimes confronted with several patients visiting at the same time. When this happened, the researcher lacked time to allocate the participants to one of the two routes and patients would inevitably go directly to the regular triage assistant first.

The participants were unaware of the triage codes received as a result of the interventions or the reference standard. Furthermore, the researcher, triage assistants and physician were unaware of the other triage codes the patient received during the study. When participants were unable to fill in the ca-ISET, their companion was asked to answer the questions on the ca-ISET with the ca-ISET presenting the questions in the third person format.

2.3. Study participants

Patients ≥18 years old visiting the emergency department for the first time with their complaints were invited to participate. All Dutch citizens have a compulsory social health insurance with guaranteed access to the emergency department.

2.4. Procedures

The ca-ISET and the regular triage procedure are described below.

2.4.1. Ca-ISET

The ca-ISET is based on our previously developed pen-and-paper ISET [3] and was developed by iteratively prototyping, testing, analysing and refining. In a pilot study with three test cycles, 16, 53 and 75 patients respectively were invited to use the ca-ISET in the emergency department, with the regular triage as the reference standard. Sensitivity increased from 0.66 (CI: 0.13–0.98) in the first test to 0.80 (CI: 0.51–0.95) in the third test. Specificity increased from 0.69 (0.39–0.90) to 0.78 (0.65–0.88). To improve validity and usability, several adjustments were made in the text and the flow chart of the ca-ISET. A ca-ISET prototype was developed, with minor textual modification of the pen-and-paper version. The algorithm of the ca-ISET is shown in Fig. 1 and as an electronic supplement.

The ca-ISET is a touch operated software application developed by Delft Dimensions, a company specialised in technical and scientific software development and Interaction Design. The application runs on standard Windows-based computer hardware with touch capabilities. The prototype interface background is white with black and dark blue letters to maximise contrast and therefore readability. The questions are presented one by one on a 21” computer screen that is placed on a wheeled trolley in the hallway of the waiting room.

To receive a triage colour code from the ca-ISET, participants fill in the questions presented on the ca-ISET. The questions are answered by touching the screen. When all questions are answered, the participant is asked to register at the ED reception desk or to take a seat with the physician to receive the decision for the reference standard.

The ca-ISET consists of 2–24 questions, depending on the main complaints of the patient. Patients with chemical substance injuries, wounds, foreign bodies, recent ophthalmic surgical intervention or ophthalmologist’s referral were selected and coded by the first five items. The subsequent items focused on the level of sight deterioration of sight, moving spots in the visual field, pain in the eyes, headache and other main eye-related complaints. Ca-ISET automatically records the time the respondent takes to fill in the questions, the participant’s answers and the resulting triage.
Fig. 1. Algorithm presenting the decision making procedure of the ca-ISET. Ca-ISET© is protected by international copyright/copyright registration, with all rights reserved to Rotterdam Ophthalmic Institute. Do not use without permission. For information on, or permission to use Ca-ISET©, please contact: roo@oogziekenhuis.nl.

2.4.2. Regular triage procedure

In the Rotterdam Eye Hospital ED, the regular triage procedure is performed by triage assistants. The procedure is described as follows. When patients enter the emergency department, they present themselves at the ED reception desk. The triage assistant asks the patient about the reason for their visit. The patient reports his or her complaints and answers the triage assistant’s potential additional questions. Based on the patient’s major complaints the triage assistant decides on the urgency colour code, makes a note of the code and the main complaints and registers the patient in the electronic hospital database. The note is attached to the patient records and serves as a guideline for the ophthalmologists to decide which patient should be seen next. The patient is then asked to wait in the waiting room.

Triage assistants working in the Rotterdam Eye Hospital have a minimum education level of secondary vocational education. They are not medically trained nurses, but are specifically trained for ophthalmic triage. All triage assistants have had more than 5 years of experience at the ED reception desk. Their triage decisions are based on the Rotterdam Eye Hospital triage standard, which has been used for almost ten years in the ED of the Rotterdam Eye Hospital. It is based on flowcharts of the Manchester Triage System adapted for the ophthalmic emergency department. Each colour code refers to a maximum predefined allowed waiting time, namely red (0 min), orange (10 min), yellow (30 min) and green (120 min).

2.5. Reference standard

In order to qualify as a reference standard, a physician was trained in ophthalmic triage to provide a triage colour code for the participating patients in the study. Participants were triaged by the physician directly after the two interventions, and before consultation with the ophthalmologist.

In this study we employed one physician with a Msc and MD degree and research experience in the ophthalmic field. He was trained by the ED chief of the in applying the Rotterdam Eye Hospital triage standard as a checklist to interview the participating patients.

In the research setting, the physician sat at a special table in the waiting room of the emergency department. Patients sat down at the table and answered the physician’s questions about their ophthalmic complaints. If the physician was not completely sure of his decision, he was allowed to discuss the complaints with the officiating ophthalmologists.
2.6. Primary outcome variable

The primary outcome was the agreement between the interventions and the reference standard on triage outcome. For all participants three triage scores were determined with (1) the ca-ISET; (2) triage by regular trained triage assistant and (3) triage by one physician who was specially trained in ophthalmic triage. The four triage colour outcomes were transformed into a binary score to test the sensitivity of the ca-ISET; ‘high urgent’ refers to the red, orange and yellow triage score (0–30 min maximum allowed waiting time) and ‘low urgent’ refers to the green triage score (31–120 min allowed waiting time). In the ED of the Rotterdam Eye Hospital, around 80% of the presented patients are low urgent (green colour code).

2.7. Handling of missing information

On quiet days patients could be called in for a consultation with the ophthalmologist before the two interventions and the reference standard provided a triage colour code. In these instances the participants were excluded from analysis.

2.8. Statistical analysis

Criterion validity was expressed in sensitivity and specificity to investigate the capacity of the ca-ISET and regular triage to discriminate between high urgent patients and low urgent patients. To estimate the possibility that a high urgent result of one of the interventions was also a high urgent condition according to the reference standard, we reported the Positive Predictive Value (PPV). To estimate the possibility that low urgent test results of the interventions were low urgent according to the reference standard, we reported the Negative Predictive Value (NPV). In this study, the NPV of the ca-ISET is more critical than the PPV because undertriage could have more direct negative implications for patients than overtriage. Uncertainty was quantified using 95% confidence intervals. Standards for Reporting of Diagnostic Accuracy (STARD) were followed [16,17]. Power was calculated by applying the procedure described by Buderer to these values [18]. We assumed an expected sensitivity of 0.90 and an expected specificity of 0.80. The clinically acceptable 95% confidence interval was set at 10%, and the proportion of the target disorder was 0.20. For the sample size of sensitivity we applied: \( N_2 = Z_2^2 \times \frac{SP(1-SP)}{SP \times (1-SP)} \), and for specificity: \( N_1 = Z_2^2 \times \frac{SN(1-SN)}{SN \times (1-SN)} \) where, SN is the expected sensitivity, SP the expected specificity, W the acceptable confidence interval, \( P \) the proportion of the target disorder and \( Z_{0.2} \) the \( z \)-value associated with the alpha level. For sensitivity this resulted in a minimum sample size of 173, for specificity a sample size of 77. Therefore we calculated that a minimum of 173 participants was needed in this study.

The sensitivity, specificity, PPV and NPV of the ca-ISET related to the reference standard was compared with the sensitivity, specificity, PPV and NPV of the regular triage related to the reference standard. To make this comparison, \( Z \)-scores were calculated by applying the fourfold table procedure described by Fleiss [19].

Logistic regression was performed to investigate whether the order of administration mode for triage influenced the results. The study was approved by the Institutional Review Board of the Rotterdam Eye Hospital (Rotterdam Eye Hospital 2009-03).

3. Results

On the days the researcher was present, 303 consecutive patients visited the ED of the Rotterdam Eye Hospital. 247 were eligible and we elicited data from 189 participants for analysis. A flow diagram with the patient recruitment process and the exclusion of participants is presented in Fig. 2. Patient characteristics are shown in Table 1.

The performance of the ca-ISET and the regular triage procedures, when compared to the physician’s triage, is presented in Fig. 3. Except for specificity, there was no statistical significant difference in criterion validity between the ca-ISET and regular triage.

Overtriage and undertriage are presented in Table 2. In four participants the ca-ISET resulted in a low urgent triage code while the physician decided it was high urgent. In these four cases, the answers to the questions of the ca-ISET did not generate any alarm signals. During the consultation with the ophthalmologist, one patient was diagnosed with a cataract and the other three patients received no diagnosis.

On thirty-three occasions the ca-ISET generated a high urgent triage code while the physician decided it was low urgent. Thirteen participants responded that they had experienced acute visual loss. Six participants indicated that they saw a spot in the eye that remained in the same place in the visual field. Five patients indicated that they had received eye surgery during the last month. Four participants mentioned that they suffered from a chemical substance in the eyes. Three patients said that the ophthalmologist had referred them to the emergency department. Two patients reported extreme pain.

In reporting overtriage and undertriage by the regular triage assistant we shall report the agreement of the ca-ISET with the regular triage, as the reasons for the decisions of the triage assistants were not noted during the study. In 11 cases the triage assistants decided that the participant’s triage code was low urgent while the physician decided it was high urgent. In 10 of these 11 cases, the ca-ISET agreed with the physician to label the complaints as high urgent. In 13 cases regular triage resulted in a high urgent code while the physician decided it was low urgent. In 10 of the 13 cases the ca-ISET agreed with the physician.

The order of triage administration had no influence on study outcome as determined by logistic regression, neither did self-completion or completion by companions have any influence.

4. Discussion

In this study we tested the criterion validity of the ca-ISET and compared it with the validity of the regular triage procedure in the ED of the Rotterdam Eye Hospital. We found that the ca-ISET did not

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient characteristics (n = 189).</th>
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<tbody>
<tr>
<td>Woman, no.</td>
<td>90 (48%)</td>
</tr>
<tr>
<td>Age, Mean (range) in years</td>
<td>54 (18–89)</td>
</tr>
<tr>
<td>Triage administration order</td>
<td></td>
</tr>
<tr>
<td>Ca-ISET: regular triage; physician’s triage</td>
<td>30 (16%)</td>
</tr>
<tr>
<td>Regular triage; ca-ISET; physician’s triage</td>
<td>70</td>
</tr>
<tr>
<td>Time needed to fill in the ca-ISET, Median (range) in seconds</td>
<td>72 (25–220)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Distribution of triage outcome for ca-ISET triage and regular triage both compared to physician’s triage.</th>
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<tbody>
<tr>
<td>Reference standard:physician</td>
<td></td>
</tr>
<tr>
<td>High urgent</td>
<td>Low urgent</td>
</tr>
<tr>
<td>Ca-ISET</td>
<td>32 (17%)</td>
</tr>
<tr>
<td>Low urgent</td>
<td>4 (2%)</td>
</tr>
<tr>
<td>Total</td>
<td>36 (19%)</td>
</tr>
<tr>
<td>Regular triage</td>
<td></td>
</tr>
<tr>
<td>High urgent</td>
<td>25 (13%)</td>
</tr>
<tr>
<td>Low urgent</td>
<td>11 (6%)</td>
</tr>
<tr>
<td>Total</td>
<td>36 (19%)</td>
</tr>
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</table>
differ in sensitivity from regular triage by triage assistants, whilst retaining a reasonable specificity and a high negative predictive value. These results show that the ca-ISET is a valid tool for the triage assistants in an ophthalmic ED setting. The ca-ISET shows a high sensitivity and appears to follow the guidelines for the high urgent patients. The results compared favourably to triage by one physician who was specially trained in ophthalmic triage. In the literature we found that strict adherence to triage guidelines can lead to an optimal use of resources [20].

Some limitations of the study restricted the generalizability of the results mentioned above. One limitation was due to the unpredictable patient flow through the emergency department. When several patients simultaneously visited the department it was not always possible to alternately assign patients to one of the two test arms. The order effect was therefore tested in data that cannot be considered to be randomly assigned.

Another limitation was the use of one physician in the study to provide the criterion on the basis of the Rotterdam Eye Hospital Triage Standard. Multiple physicians would have complicated the logistics of an already complex test location such as an ED and would involve substantial additional costs. However, in future research, it is highly recommended to use the consensus of multiple physicians to provide a criterion, as this would substantially increase the validity of the reference standard.

Another limitation was that we did not weigh undertriage and overtriage according to clinical relevance. An example of undertriage is when a patient with acute visual loss lasting three hours receives a green colour code and has to wait for 2 h. An example of overtriage is when a patient with only a red eye receives a high urgent code and is consequently treated faster than necessary. One could argue that 'undertriage' has more clinical implications or has more severe clinical implications than 'overtriage'. Further research is needed to provide the weights (values) of false alarms and missed diagnoses.

It might be possible that the time of the study period (winter) could have caused a possible bias in the data. However, there is
Fig. 3. Performance of ca-ISET and regular triage when compared to the reference standard: physician's triage: sensitivity (Se), specificity (Sp), Positive predictive Value (PPV) and Negative Predictive Value (NPV) (95% C.I.). Except for specificity, there were no statistical significant difference in criterion validity between the ca-ISET and regular triage.

no evidence that acute pathology was related to season or time of day. The only exception was New Year's Eve, because of accidents with firecrackers. At this time the whole hospital is on full alert and most patients fall under a unified emergency category and are investigated directly by a physician.

Ethnicity of the participants could have played a role in the results of this study. In a former investigation, we had some problems defining ethnicity but it had no direct effect on the test results. Dutch reading and writing skills probably influenced the test results more but were also difficult to measure in an ED test setting. Nevertheless, it could be relevant, especially as the ca-ISET in future will include a facility to switch language. We believe however that the results apply to different ethnicities, as 46% of the population of Rotterdam is defined as immigrants or second generation Immigrants. A next step in the developmental process would be to translate the ca-ISET questionnaire into the languages of the most common minority groups in the Netherlands.

Three patients were excluded from the analysis due to software errors in the ca-ISET. For further research and implementation, these software errors should be solved. Also it should be mentioned that due to the exclusion criteria of this study, the ca-ISET has not yet been validated for ophthalmic patients younger than 18 years old.

The researcher noticed some reluctance in older patients in regard to performing a computer task; nevertheless they did not abort the task. It is expected that older patients in the near future will increasingly adapt to the use of technology in their daily lives [21] such as working with simple computer assisted devices. The ca-ISET has been developed to function as simply and easily as possible but in the meantime, patients still unable to fill in the questionnaire will have their complaints handled by an ED assistant.

5. Conclusion

In this study we found that the Ca-ISET and regular triage by the triage assistants were equally sensitive, while the ca-ISET retained a reasonable level of specificity. Therefore, the ca-ISET can be recommended as a tool for ophthalmic emergency departments to increase the validity of a triage procedure when trained ED staff is absent.

Summary table

What was previously known about the topic:

- Emergency departments are often overcrowded and need triage systems to categorise patients by the urgency of their complaints.
- It is feasible to allow entering their own medical information by using a computer history-taking device in emergency departments in order to support diagnostic decision making.

What this study added to our knowledge:

- Ca-ISET and regular triage by triage assistants were equally sensitive, with a reasonable specificity.
- The ca-ISET proved to be a valid instrument to perform self-triage at the ophthalmic emergency department and might replace trained emergency department staff when absent.

Authors’ contributions

ESV contributed to the conception and design, acquisition of data, analysis and interpretation of data, revised paper for important intellectual content and final approval of the version submitted for publication. MWBR contributed to the conception and design, analysis and interpretation of data, revised paper for important intellectual content and final approval of the version submitted for publication. RT revised the paper for important intellectual content and final approval of the version submitted for publication. MMBH revised the paper for important intellectual content and final approval of the version submitted for publication. JVB contributed to the conception and design, analysis and interpretation of data, revised the paper for important intellectual content and final approval of the version submitted for publication.
Competing interests

None declared.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijmedinf.2015.10.003.

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