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CLINICAL STUDY

The accuracy of the Edinburgh Red Eye Diagnostic Algorithm

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Abstract

Purpose **To assess the diagnostic accuracy of the Edinburgh Red Eye Algorithm.**
Methods **This was a prospective study. A questionnaire was designed and made available to clinicians referring patients to the acute ophthalmology service within Edinburgh. The questionnaire involved them using the algorithm to reach a diagnosis in patients presenting with red eye(s). Patients were then referred to the emergency eye clinic and the questionnaire faxed to the clinic or sent with the patients. Patients were then examined by an experienced ophthalmologist (not blinded) to reach a 'gold standard' diagnosis. The concordance between the 'algorithm assisted' diagnosis and the 'gold standard' was then assessed.**
Results **All patients presenting with red eye(s) were eligible for inclusion. Forty-one questionnaires were completed, two were excluded. The algorithm assisted diagnosis was correct 72% (28/39) of the time. It correctly diagnosed: acute angle closure glaucoma in 100% of cases (4/4); iritis in 82% (9/11); stromal keratitis in 63% (5/8); epithelial keratitis in 70% (7/10); and infective conjunctivitis in 50% (3/6).**
Discussion **The diagnostic accuracy of The Edinburgh Red Eye Diagnostic Algorithm is 72, rising to 76% when only the most serious red eye(s) causes are included. The diagnostic accuracy of nonophthalmologists when assessing patients presenting with red eye(s) is greater when the algorithm is used. We hope that the use of this algorithm will prevent delayed presentations of certain serious eye conditions and reduce the morbidity from delayed treatment.**

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Introduction

Medicine is still typically taught in related but self-contained diagnostic 'packages', hence most books and articles have within the red eye(s) section, descriptions of; iritis, keratitis and so on, which contain orderly details of the symptoms and signs pertaining to each individual disease.[1–5] This approach encourages the novice when faced with a patient with red eye(s) to consider each individual diagnosis in turn until the most suitable match is found. This process is exactly the reverse of how an experienced clinician approaches the same patient; analysing the symptoms and signs, using a combination of pattern recognition and deductive reasoning to reliably and quickly come to a diagnosis or differential diagnoses. Algorithms are simply the user-friendly version of these diagnostic and/or treatment thought processes. They are always a compromise between having enough detail to encompass the most commonly encountered diagnostic/treatment possibilities while remaining simple enough to use. They highlight those key points in the history and examination that allow the inexperienced observer to quickly come to the most likely diagnosis. They still rely upon the clinician being able to clarify the history and elicit the clinical signs which act as signposts on the way to diagnostic nirvana.

Red eye(s) are a common presenting complaint in patients attending A+E, optometrists, and GPs and has been reported to account for 0.9–1.5% of GP consultations.[6,7] Making the correct diagnosis can be overwhelming to nonexperts given the diversity of possible diagnoses, ranging from self-resolving bacterial conjunctivitis to sight threatening acute angle closure glaucoma.

Unfortunately, most UK doctors including GPs and A+E doctors have had between 2 and 12 days ophthalmology attachment[8] during their undergraduate training, leaving them inexperienced and wary of dealing with acute eye problems. Nurse Practitioners are taking on more responsibility and independently managing patients particularly in A+E without having much formal eye training. In addition, opticians are starting to take on extended roles of treating minor eye emergencies in the community, particularly in Scotland.[9]

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Algorithms are being used in other areas of health care; diagnosing pulmonary embolus[10] and diagnosing different types of tachycardia.[11] Diagnostic algorithms have been suggested to reduce time, effort and bias,[12] and cost of care and errors. It has been shown that in situations where algorithms have been introduced, experienced health care workers continue to demonstrate autonomy.[13]

There are a number of red eye diagnostic algorithms,[14–19] each having their strengths and weaknesses. Some algorithms lead to a conclusion of ‘emergency eye referral’ rather than a specific diagnosis,[14] thus minimising their educational value. Some do not indicate the urgency of the ophthalmology referral required,[17] or group more than one unrelated diagnoses together at the diagnosis end of the branch.[16–19] Some omit the serious sight threatening diagnoses[16] or require technical skills beyond the ability of most nonophthalmologists for example, measuring intraocular pressure.[18] The main downfall of these red eye algorithms is that none of them have had their accuracy validated.

Objectives

The aim of this prospective study was to assess the diagnostic accuracy of the Edinburgh Red Eye Algorithm, published in ‘Ophthalmology Pocket Tutor’,[20] which was created by Dr Mark Wright, Consultant Ophthalmologist and Lead for Undergraduate Ophthalmology Education at Edinburgh University.

Materials and methods

An Edinburgh Red Eye Diagnostic Algorithm Questionnaire was designed to evaluate the accuracy of the algorithmic assisted diagnosis (Figure 1) in South East Scotland. This study was approved by the local audit department. Questionnaires were distributed to;

- The two local Accident and Emergency departments through posters on their eye cubicle walls.
- GPs by uploading it to the ophthalmology page on the website that they consult for advice regarding referrals to hospital refhelp (NHS Lothian. Refhelp. Available at: http://www.refhelp.scot.nhs.uk/dmdocuments/Ophthalmology/Red%20Eye%20algorithm.pdf).
- Opticians in Lothian and Midlothian by uploading to the Princess Alexandra Eye Pavilion, Edinburgh Website and emailing them to notify them of this.

All referral groups; A+E doctors, general A+E nurse practitioners, GPs and Opticians were invited to contribute to the study. This involved them using the red eye algorithm to reach a diagnosis in consecutive patients presenting with red eye(s). They were also asked to give their own diagnosis if they disagreed with the diagnosis suggested by the algorithm. The patient was referred in the usual way to the eye emergency clinic at the Princess Alexandra Eye Pavilion, Edinburgh. The questionnaire was either faxed to the Emergency Eye Clinic or given to the patient in an envelope to bring with them to their appointment. An experienced ophthalmologist, defined as ST 3 or above/associate specialist then examined the patient in the Emergency Eye Clinic to arrive at a ‘gold standard’ diagnosis. The ophthalmologist had access to the questionnaire when the patient was seen and were, therefore, not blinded. The degree of concordance between the ‘algorithm assisted’ diagnosis and the ‘gold standard’ was then assessed. Unfortunately, it was not possible to gather control data on diagnoses made before implementation of the algorithm as one of the authors (MW) had been teaching the local target clinicians (GPs, optometrists and A+E doctors) for around 10 years using the red eye algorithm. Laminated copies of the algorithm were already placed in the local general casualty eye exam cubicle and on both the NHS Lothian GP and the NES Scotland optometry websites.

Results

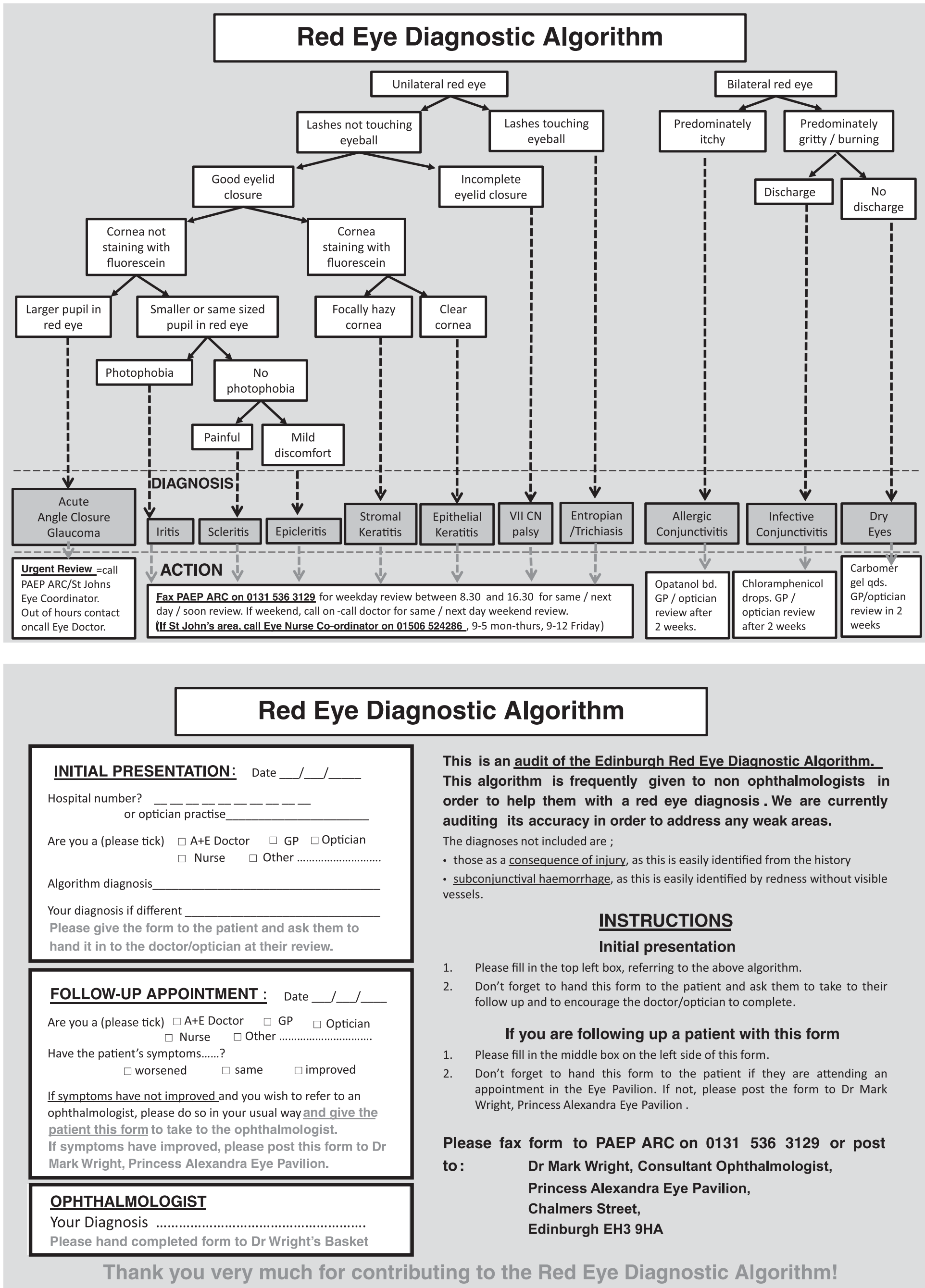
Forty-one completed forms were returned during the recruitment period of October 2013 to February 2014. Two were excluded from the analysis; 1 form had a diagnosis of Herpes Zoster Ophthalmicus by the ophthalmologist but not the specific cause of the red eye and 1 patient’s red eye had resolved by the time they were assessed by the ophthalmologist leaving 39 forms for analysis.

Profile of referrer

The breakdown of referrer by type was; GP 35%, general A+E nurse practitioners 23%, Optician 18%, A+E Doctor 5%. and not documented in 19%.

Diagnostic accuracy

Overall, the algorithm assisted diagnosis was correct 72% (28/39) of the time. The ‘gold standard’ ophthalmologists only made five of the possible eleven diagnoses contained within the algorithm: acute angle closure glaucoma, iritis, stromal keratitis, epithelial keratitis, and infective conjunctivitis. The algorithm correctly diagnosed: acute angle closure glaucoma in 100% of cases (4/4); iritis in 82% (9/11); stromal keratitis in 63% (5/8); epithelial keratitis in 70% (7/10); and infective conjunctivitis in 50% (3/6) (Figure 2). Sensitivity and specificity of the



Red Eye Diagnostic Algorithm

INITIAL PRESENTATION: Date ___/___/_____

Hospital number? __ __ __ __ __ __ __ __ __ __
or optician practise______________________

Are you a (please tick) ☐ A+E Doctor ☐ GP ☐ Optician
☐ Nurse ☐ Other ....

Algorithm diagnosis___________________________________

Your diagnosis if different ____________________________

Please give the form to the patient and ask them to hand it in to the doctor/optician at their review.

FOLLOW-UP APPOINTMENT : Date ___/___/____

Are you a (please tick) ☐ A+E Doctor ☐ GP ☐ Optician
☐ Nurse ☐ Other ....

Have the patient's symptoms……?
☐ worsened ☐ same ☐ improved

If symptoms have not improved and you wish to refer to an ophthalmologist, please do so in your usual way and give the patient this form to take to the ophthalmologist.
If symptoms have improved, please post this form to Dr Mark Wright, Princess Alexandra Eye Pavilion.

OPHTHALMOLOGIST
Your Diagnosis ....
Please hand completed form to Dr Wright's Basket

This is an audit of the Edinburgh Red Eye Diagnostic Algorithm. This algorithm is frequently given to non ophthalmologists in order to help them with a red eye diagnosis. We are currently auditing its accuracy in order to address any weak areas.

The diagnoses not included are ;
- those as a consequence of injury, as this is easily identified from the history
- subconjunctival haemorrhage, as this is easily identified by redness without visible vessels.

INSTRUCTIONS

Initial presentation

1. Please fill in the top left box, referring to the above algorithm.
2. Don't forget to hand this form to the patient and ask them to take to their follow up and to encourage the doctor/optician to complete.

If you are following up a patient with this form

1. Please fill in the middle box on the left side of this form.
2. Don't forget to hand this form to the patient if they are attending an appointment in the Eye Pavilion. If not, please post the form to Dr Mark Wright, Princess Alexandra Eye Pavilion .

Please fax form to PAEP ARC on 0131 536 3129 or post to: Dr Mark Wright, Consultant Ophthalmologist,
Princess Alexandra Eye Pavilion,
Chalmers Street,
Edinburgh EH3 9HA

Thank you very much for contributing to the Red Eye Diagnostic Algorithm!

Figure 1 Front and back of the Edinburgh Red Eye Diagnostic Algorithm audit form.

algorithm for the different diagnoses can be seen in Figure 3.

Analysis of the incorrect algorithm-assisted diagnoses

There are two possible sources of diagnostic error; defects in the algorithm itself and failure of the clinician to elicit the presenting symptom or sign. The algorithm-assisted diagnosis was wrong in two patients with iritis, these patients being labelled as having epithelial keratitis and scleritis. It seems likely that the patient incorrectly diagnosed as having an epithelial keratitis will have had no fluorescein staining that is, the cause of the incorrect diagnosis was clinician related rather than algorithm related. By inference, the patient with iritis who was incorrectly diagnosed as having scleritis must not have had photophobia which would be atypical. The algorithm failed to correctly identify three cases of corneal stromal keratitis, these patients being labelled as having iritis, scleritis, and infective conjunctivitis. Two of these cases were therefore incorrect as a result of the clinician not picking up the fluorescein staining, and one was incorrect owing to the patient having bilateral red eyes. Similarly, the algorithm failed to correctly identify three cases of corneal epithelial keratitis with these patients being labelled as having episcleritis and iritis (two cases). It can be inferred that the referrer failed to correctly identify the presence of corneal staining in all three of these cases. Last, the algorithm failed to correctly identify three cases of infective conjunctivitis with these patients being labelled as having episcleritis, scleritis, and dry eyes. Here the source of error was the algorithm as two patients had unilateral red eyes and one (dry eyes) did not have any discharge noticed. Infective conjunctivitis can be unilateral, classically associated with a blockage of the ipsilateral nasolacrimal duct in a young child. We have deliberately designed the algorithm to discourage the diagnosis of unilateral infective conjunctivitis as this

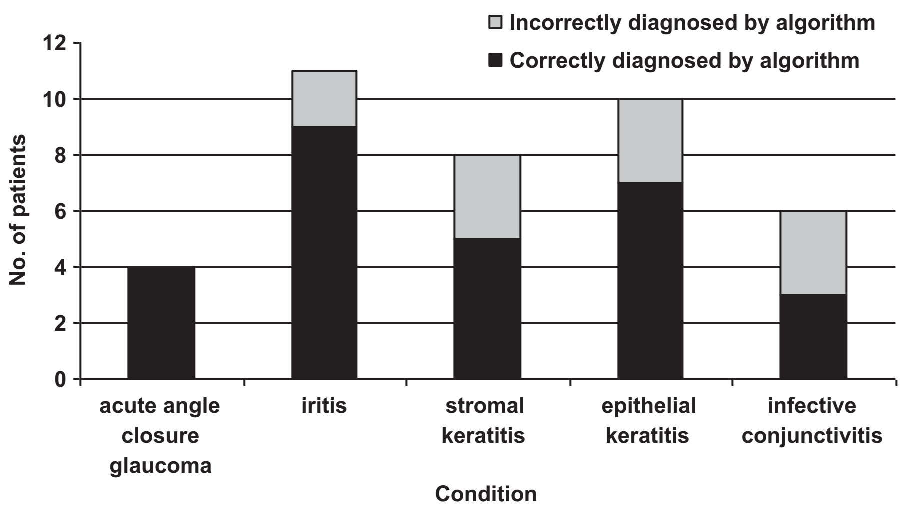


Figure 2 Graph to show the number of patients with each eye condition (determined from the ophthalmologists' diagnoses) and the accuracy of the Edinburgh Red Eye Diagnostic Algorithm in correctly diagnosing these patients.

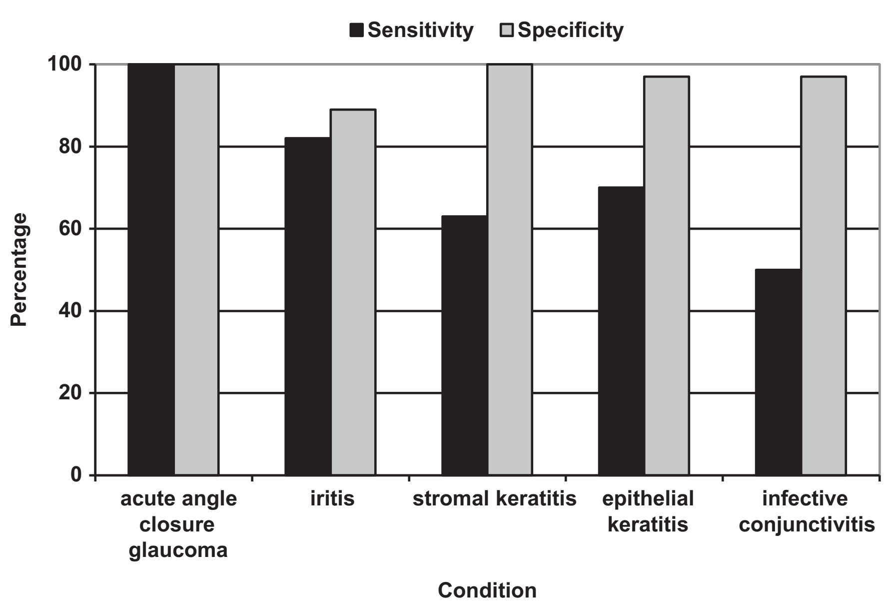


Figure 3 Graph to show the sensitivity and specificity of the algorithm for each diagnosis.

diagnosis is all too often made despite the signs pointing to a more serious underlying cause for example, acute angle closure glaucoma.

Discussion

A retrospective study on patients treated by ophthalmologists for acute angle closure glaucoma showed that only 21% of those referred by GPs and 64% of those referred from a casualty officer had the correct referral diagnosis.[21] The ideal algorithm should allow the user to demonstrate very high sensitivity with respect to the most serious conditions; acute angle closure glaucoma, iritis and keratitis, and also to have reasonable levels of specificity for the more minor conditions. Our results demonstrate the algorithm has satisfied these criteria for both acute angle closure glaucoma and iritis, but not for epithelial and stromal keratitis.

All six corneal misdiagnoses resulted from the examiner's failure to detect corneal staining/opacification and similarly the misdiagnosis of iritis as epithelial keratitis reflects a failure to confirm the absence of corneal staining. Although these diagnostic errors are examiner and not algorithm related, corneal signs can be very subtle. We would therefore suggest that the sensitivity of the algorithm to identify both types of keratitis would be significantly improved if we were to state that when examining the cornea, illuminated magnification should be used for example, the direct ophthalmoscope on a +10 setting. A study comparing the diagnosis of red eye patients when using a direct ophthalmoscope showed 77% exact agreement with diagnosis to that when using a slit lamp, with 85% of patients having the same management plan recommended.[22]

The diagnostic hallmark of iritis is the detection of cell and flare in the anterior chamber. Clearly, this requires the presence of a slit lamp that many referring clinicians do not have access to and/or the expertise in using. Historical diagnostic accuracy data for the diagnosis of iritis by GPs reports a sensitivity of 44% and specificity of 99.8%.[23] In comparison, the Edinburgh Red Eye Algorithm shows almost double the sensitivity 82% in correctly diagnosing iritis with only a small reduction in specificity.

The vast majority of patients with infective conjunctivitis will present with bilateral ocular involvement and will be treated in primary care. Two of the three misdiagnoses of Infective conjunctivitis were made in patients who had unilateral red eyes. This could perhaps be because the patients were caught early in the disease before it spread to the fellow eye or because the disease was significantly asymmetrical.

It is useful for the algorithm to differentiate between epithelial and stromal keratitis for the purpose of determining whether referral to the ophthalmology department is required. The majority of epithelial keratits cases are corneal abrasions which can be independently managed by A+E clinicians or prescribing optometrists, safely reducing the volume of patients traveling long distances to the tertiary referral eye hospital casualty. In contrast, stromal keratitis that includes corneal ulcers, and marginal keratitis all need referral to the eye casualty for management and monitoring.

There are a number of limitations of this study, the main one being the sample size. No patients were encountered with six of the possible diagnostic outcomes. In the bilateral red eyes section allergic conjunctivitis and dry eyes were not reported. This is not surprising as the majority of these patients are usually competently and confidently treated in a primary care setting and would be difficult to recruit. In the unilateral red eye section, the eyelid-related problems of entropion/trichiasis and VII cranial nerve palsy were not reported. Although these diagnoses are usually self evident, the algorithm reminds clinicians to first examine the lids as part of the assessment of a patient presenting with a red eye.

In addition, the experienced ophthalmologists were not blinded to the examining clinician's algorithm diagnosis. This potentially could have minimally influenced their thought process before evaluating the patient. However, it is unlikely to have influenced them to such a degree as to document an incorrect diagnosis, and we identified a potentially much greater risk of loss of the red eye algorithm questionnaire between the patient having been assessed by the referrer and being seen in the eye clinic. Ideally there would be an investigator collecting the algorithm forms from the patients and the experienced ophthalmologists separately. However, this would require a full-time investigator in our eye casualty department, a resource unfortunately not available to us.

Conclusion

This is the first time the diagnostic accuracy of any red eye (s) algorithm has been assessed. The overall diagnostic accuracy of The Edinburgh Red Eye Diagnostic Algorithm is 72%. This rises to 76% when only the most serious red eye(s) causes; acute angle closure glaucoma (100%), iritis (82%), and keratitis (stromal 63% and epithelial 70%) are analysed. We would hope that if the need for good illumination and magnification to clarify corneal pathology is highlighted on the algorithm, the diagnostic accuracy for all types of keratitis would significantly improve. Where data is available,[21–23] the diagnostic accuracy of nonophthalmologists when assessing patients presenting with red eye(s) is significantly greater when the Edinburgh Red Eye Diagnostic Algorithm is used.

This algorithm is useful for A+E clinicians, optometrists, and GPs to identify red eye conditions, commence treatment where appropriate, and refer with the necessary urgency to the ophthalmology department. In particular, the sensitivity and specificity of diagnosing acute angle closure glaucoma were both 100%. We hope that the use of this algorithm will prevent delayed presentations of acute angle closure glaucoma and reduce the morbidity from delayed treatment.

Summary

What was known before

- Red eye(s) are a common presenting complaint in patients attending A+E, optometrists, and GPs and making the correct diagnosis can be overwhelming given the diversity of possible diagnoses Algorithms are being used in other areas of health care and have been suggested to reduce time, effort, bias, cost of care, and errors. There are a number of red eye diagnostic algorithms each having their strengths and weaknesses. The main downfall of these red eye algorithms is that none of them have had their accuracy validated.

What this study adds

- The overall diagnostic accuracy of The Edinburgh Red Eye Diagnostic Algorithm is 72 and rises to 76% when only the most serious red eye(s) causes are analysed. Where data is available, the diagnostic accuracy of nonophthalmologists when assessing patients presenting with red eye(s) is significantly greater when the Edinburgh Red Eye Diagnostic Algorithm is used. This algorithm is useful for nonexperts to identify red eye conditions, commence treatment where appropriate and refer with the necessary urgency to the Ophthalmology department. The sensitivity and specificity of diagnosing acute angle closure glaucoma with the algorithm were both 100%. We hope that the use of this algorithm will prevent delayed presentations of acute angle closure glaucoma and reduce the morbidity from delayed treatment.

Conflict of interest

MW has received minimal royalities from the sales of 'Ophthalmology Pocket Tutor' where the algorithm has been published. HT and LB declare no conflict of interest.

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