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Detecting Visually Significant Age-Related Cataract using Retinal Photograph-Based Deep Learning: Development, Validation, and Comparison with Clinical Experts

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Introduction

- Age-related cataract is the leading cause of visual impairment among elderly
- Conventional approach for cataract diagnosis relies mainly on assessment of human crystalline lens using slit lamp biomicroscopy, which is generally not part of community eye screening programs.
- Many significant cases remain undiagnosed or neglected in the communities, due to limited availability or accessibility to cataract screening.

Objective

- To develop and validate a retinal photograph-based deep learning algorithm for automated detection of visually significant cataract (cataract with severe visual loss)

Methodology

- A total of 25,742 retinal photographs from 13,482 individuals across four studies were included.
- The four studies include : The Singapore Malay Eye Study (SIMES, training and internal test set), the Singapore Indian Eye Study (SINDI), the Singapore Chinese Eye Study (SCES) and the Beijing Eye Study (BES)
- **Ground truth:** Visually significant cataract was defined as cataract eyes (eyes with significant nuclear, cortical and posterior subcapsular cataract, according to the Wisconsin cataract grading system and the Age-Related Eye Disease Study system) with best-corrected visual acuity (BCVA) of worse than 20/60.
- The deep learning system comprises of a Residual Neural Network (Resnet)-50 for feature extraction on macular-centered retinal photographs, followed by a XGBoost classifier that generates the probability for presence of visually significant cataract.
- The performance of the algorithm was evaluated with Area under the receiver operating characteristic curve (AUROC), sensitivity and specificity. Classification threshold was selected based on the Youden's index.
- Separately, we further compared the algorithm's performance with two professional graders' (based on retinal photographs only) and four ophthalmologists' evaluation (based on both slit lamp and retinal photographs)

Results

- In the internal test set, AUROC for detection of visually significant cataract was 96.6%.
- For external testing performed across three studies, AUROC ranged between 91.6% and 96.5%.
- The algorithm achieved a sensitivity of 93.3% versus 51.7%-96.6% by ophthalmologists; and algorithm achieved a specificity of 99.0% versus 90.7%-97.9% by ophthalmologists.

Table 1. Performance of Classification Algorithm in Detection of Visually Significant Cataract

Testing sets	AUROC % (95% CI)	Sensitivity % (95% CI)	Specificity % (95% CI)
Internal:			
SIMES (n=72; N=1,692)	96.6 (95.5 – 97.7)	95.7 (90.5 – 100.0)	89.0 (84.7 – 93.5)
External:			
SCES (n=141; N=5,747)	96.5 (96.0 – 97.0)	96.0 (93.1 – 98.9)	88.1 (86.5 – 89.6)
SINDI (n=138; N=5,626)	96.3 (95.6 – 96.9)	94.2 (91.1 – 97.6)	90.3 (89.7 – 91.0)
BES (n=48; N=4,632)	91.6 (90.2– 93.1)	88.8 (79.5 – 97.7)	81.1 (70.5 – 88.2)

n, number of eyes with visually significant cataract; N, total number of eyes

Figure 1. Saliency maps highlighting regions which the algorithm focuses on when predicting visually significant cataract.

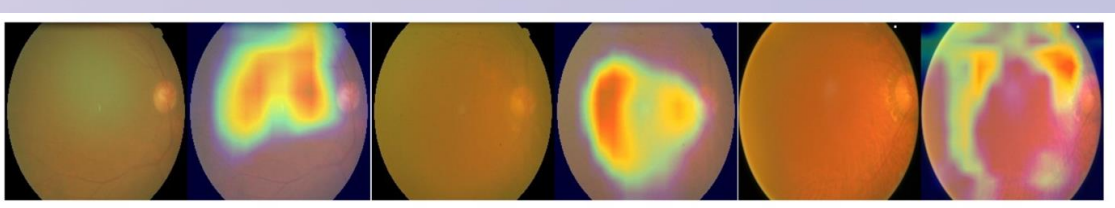
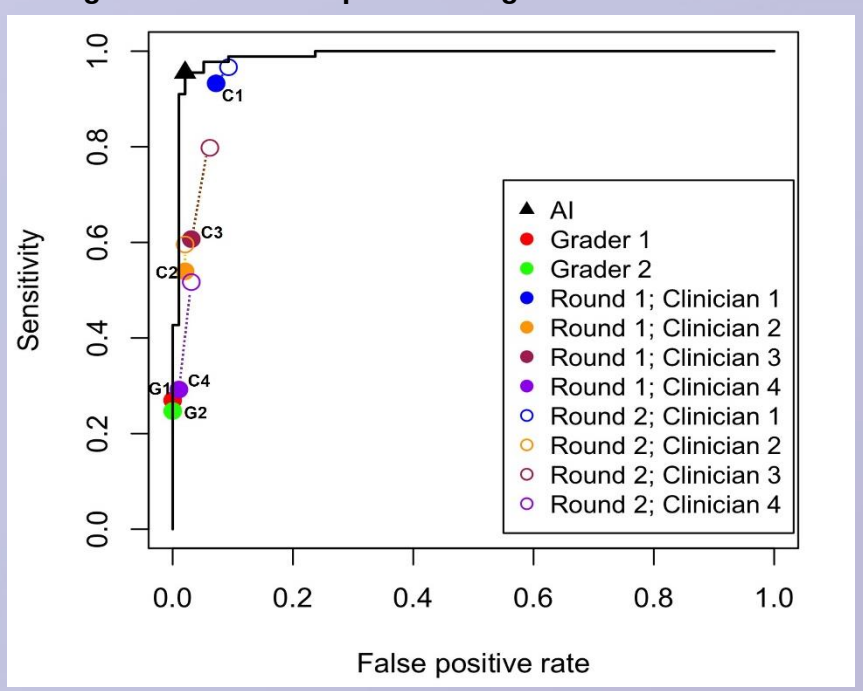


Figure 2. ROC curve showing performance of the algorithm versus two professional graders and four ophthalmologists.



Conclusion

- Our findings show the potential of a retinal photograph-based screening tool for visually significant cataract among elderly, allowing efficient referral to ophthalmologists for possible cataract surgery.
- This new algorithm may potentially help to improve detection of visually significant cataract in elderly communities which lack trained eye care personnel and resources.

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