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ORIGINAL RESEARCH

Assessment of Emergency Department Intraocular Pressure and Visual Acuity Assessment as a Screening Exam

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Purpose: To evaluate the utility of Emergency Department (ED) assessment of intraocular pressure (IOP) and visual acuity (VA) measurements as a screening tool for abnormal IOP and VA on ophthalmology exams.

Patients and Methods: This retrospective cross-sectional study reviewed eye-related ED visits between February 1, 2022, and January 31, 2023, at Harborview and University of Washington Medical Centers (Seattle, WA) with same-day ophthalmology consultation. Electronic medical records were reviewed for right eye and left eye IOP and VA obtained by ED and ophthalmology services. The ED exam as a screening tool for abnormal IOP (>25 mmHg) and visual acuity (<20/40) on ophthalmology exam in either eye was evaluated using receiver operating curves (ROC). A calculator user interface was created to report sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) with a range of user inputs for both the thresholds applied to ED measurements and the targets for detection for Ophthalmology IOP and VA.

Results: Of 1463 visits, IOP and VA were recorded in at least 1 eye by the ED in 627 (42.8%) and 821 (56.1%) patients, respectively. The area under the curve (AUC) for the receiver operating curves for ED screening was 0.846 for detecting an abnormal IOP and 0.863 for detecting an abnormal VA. The sensitivity of a value >25 mmHg on ED IOP testing was 0.78 (95% CI 0.69–0.87), and the specificity was 0.84 (95% CI 0.80–0.87). The sensitivity of a VA value logMAR >0.3 (worse than 20/40) on ED testing was 0.88 (95% CI 0.85–0.91), and the specificity was 0.59 (95% CI 0.54–0.65).

Conclusion: ED acquired measurements of IOP and VA are useful to screen for abnormalities in IOP and VA on the ophthalmology exam. However, IOP and VA are infrequently obtained by the ED prior to ophthalmic consultation.

Keywords: ophthalmic consults, vision screening, IOP screening, emergency ophthalmic care, ophthalmic triage

Introduction

Eye-related complaints comprise approximately 1.5% of all Emergency Department (ED) visits in the United States,[1] totaling around 2.4 million eye-related ED visits annually.[2] Nearly half of all eye-related ED visits are due to non-emergency or low severity ophthalmic conditions,[3–5] and Emergency Medicine (EM) physicians must appropriately triage, treat, and refer those requiring urgent intervention. Abnormalities in the ocular vital signs of intraocular pressure (IOP) and visual acuity (VA) are key factors in identifying severe ophthalmic disease.[6] While the measurement of systemic vital signs is automated, IOP testing and VA testing still constitute clinical assessments requiring training and experience for precision and accuracy.[7,8] Most EM physicians have limited training in ocular examination techniques, with around two-thirds of EM resident physicians receiving less than 10 hours[9] and only around half of EM physicians feeling comfortable with the eye exam,[10] potentially putting EM physicians at a disadvantage for appropriate ophthalmic triage. Currently, there are limited data appraising the quality and function of IOP and VA measurements obtained in the

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ED[11–13] and interpretation of ED IOP and VA assessments can be difficult. This study assesses the utility of measurements of IOP and VA obtained in the ED as a screening tool for abnormal IOP and VA measured on ophthalmic consultation.

Materials and Methods

The Institutional Review Board (IRB) of the University of Washington School of Medicine approved this study before the study began and the IRB determined that patient consent was not required due to retrospective nature of the study. All research was performed in accordance with the principles stated in the Declaration of Helsinki and patient data remained confidential. We performed a cross-sectional study of all patients with an eye or vision-related complaint between February 1, 2022, and January 31, 2023, at the Harborview Medical Center and University of Washington Medical Center Emergency Departments (Seattle, WA), for which an ophthalmology consult was requested.

Electronic medical records were manually reviewed to extract the right eye and left eye data for IOP obtained in the ED (ED-IOP), IOP obtained by ophthalmology (O-IOP), VA obtained in the ED (ED-VA) and VA obtained by ophthalmology (O-VA) during the same-day consultation within 24 hours. For the purposes of assessing predictive value of ED testing for identifying true abnormalities of VA or IOP, the O-VA and O-IOP are considered to be the reference measurements due to the ophthalmology consultants' training, experience, access to additional ophthalmological material resources (eg, exam lane, slit lamp), and prior studies validating relatively good inter-rater reliability of these measures in the eye clinic setting.[14,15]

Both the ED and ophthalmology services obtained IOP using Tonopen Avia® electronic handheld tonometers (Reichert Inc., Depew, NY). The same tonometer was not used between ED and ophthalmology services, but all devices were maintained and calibrated by the hospitals' clinical engineering departments. All Snellen VA measurements were converted to logarithm of the minimum angle of resolution (logMAR) for statistical analysis. The method of VA acquisition was not recorded by the ED. When the ophthalmology service obtained more than one VA, the method of acquisition used to compare to the ED-VA was prioritized as follows: 1) distance VA with correction, 2) distance VA without correction, 3) near VA with correction, and 4) near VA without correction. The rate of ED-acquisition of IOP and VA was calculated. Differences in age, sex, O-IOP, O-VA, chief complaint, transfer status, and need for interpreter between those with and without ED-acquired measures were assessed using Fisher Exact tests for categorical variables and Mann Whitney tests for continuous variables.

For those with both ED and ophthalmology acquired measures, agreement was assessed using intraclass correlation and 95% limits of agreement, and screening accuracy was calculated. For the primary analysis, decreased VA was defined as an O-VA worse than 20/40 (logMAR > 0.3) in either eye, and elevated IOP was defined as an O-IOP of greater than 25 mmHg in either eye. A receiver operating curve (ROC) was created using the O-IOP and O-VA as the gold standard, and an area under the curve (AUC) was reported for the predictive value of the ED-IOP and VA (Matlab R2023a, Statistics and Machine Learning Toolbox, The MathWorks Inc., Natick, MA). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for detecting elevated O-IOP and decreased O-VA were calculated for different ED-VA and ED-IOP thresholds. A positive IOP screen by the ED was defined as a ED-IOP value greater than the given threshold in either eye and a positive VA screen by the ED was defined as an ED-VA of logMar greater than the given threshold in either eye. Using the results obtained when ED thresholds were set to the same numerical values as the targeted levels of O-IOP and O-VA, differences between true and false positives and between true and false negatives with regard to patient characteristics were assessed using Fisher Exact tests for categorical variables and Mann Whitney tests for continuous variables (Prism, GraphPad Software, Boston, MA). A calculator user interface was created in Microsoft Excel (Microsoft, Redmond, WA) to report sensitivity, specificity, PPV, and NPV with a range of user inputs for both the thresholds applied to ED measurements and the targets for detection with regard to Ophthalmology IOP and VA.

Results

One thousand, four hundred and sixty-three patient charts were reviewed. Table 1 summarizes the demographics of patients included in the study. Table 2 presents the summary of IOP and VA measurements by ED and ophthalmology.

Table 1 Baseline Demographics and Descriptive Statistics for the Patients Included in the Analysis. All Values are Percentages or Mean ± Standard Deviation (SD) (N = 1463)

Sex, N (%)	
Male	810 (55.4%)
Female	652 (44.6%)
Nonbinary	1 (0.1%)
Age, Mean (SD)	50.9 (17.5)
Race and Ethnicity, self-reported N (%)	
White (Non-Hispanic or Latino/a or Latinx)	804 (55.0%)
Hispanic or Latino/a or Latinx	250 (17.1%)
Black or African American	181 (12.4%)
Asian	150 (10.3%)
American Indian or Native Alaskan	26 (1.8%)
Native Hawaiian or Pacific Islander	22 (1.5%)
Unknown or Declined to Answer	25 (1.5%)
Two or More listed Races	45 (3.1%)

Table 2 Rate of ED Acquisition of IOP and VA for Patients with Ophthalmology Measured IOP and VA

	ED Acquired IOP	**ED Did Not Acquire IOP**	**P-value**	**ED Acquired VA**	**ED Did Not Acquire VA**	**P-value**
Total, N (%)	627 (45.0%)	768 (55.0%)		821 (58.5%)	583 (41.5%)	
Age, Mean ± SD	51.5 (16.3)	50.7 ± 18.4	0.25	50.4 ± 17.2	51.7 ± 17.8	0.28
Male sex, N (%)	348 (45.3%)	420 (54.7%)	0.79	466 (60.1%)	310 (39.9%)	0.17
Maximum IOP by ophthalmology, Mean ± SD	18.8 ± 9.3	17.0 ± 6.9	0.007	18.3 ± 8.5	17.5 (7.9)	0.07
LogMAR VA (higher of 2 eyes), Median (IQR)	0.40 (0.14–2.4)	0.60 (0.10–1.9)	<0.001	0.40 (0.18–2.4)	0.80 (0.10–2.1)	<0.001
Chief Complaint, N (%)			0.01			<0.001
Eye Pain, Irritation, or Redness	230 (42.7%)	309 (57.3%)		271 (50.2%)	269 (49.8%)	
Vision Loss or Blurry Vision	280 (47.2%)	313 (52.8%)		381 (63.4%)	220 (36.6%)	
Flashes/Floaters	82 (51.9%)	76 (48.1%)		122 (76.7%)	37 (23.3%)	
Other	35 (33.3%)	70 (66.7%)		47 (45.2%)	57 (54.8%)	
Transfer status, N (%)			<0.001			<0.001
Not Transferred	463 (50.1%)	462 (49.9%)		594 (63.9%)	336 (36.1)	
Transferred	164 (34.9%)	306 (65.1%)		227 (47.9%)	247 (52.1%)	
Interpreter Needed, N (%)			<0.001			0.94
Yes	125 (58.4%)	89 (41.6%)		126 (58.1%)	91 (41.9%)	
No	502 (42.5%)	679 (57.5%)		695 (58.6%)	492 (41.4%)	

IOP and VA were recorded in at least 1 eye by both the ED and ophthalmology in 627 (42.8%) and 821 (56.1%) patients, respectively. The ED acquired IOP in 45.0% of 1395 patients with O-IOP measurements and VA in 58.5% of 1404 patients with O-VA measurements. Patients with a chief complaint of blurry vision/vision loss were more likely than those with other chief complaints to have an ED-IOP and ED-VA measured ($p \leq 0.01$). Patients requiring interpreter were more likely to have an ED-IOP measurement ($p < 0.001$). O-IOP was higher in those with ED-IOP measurements than those without ($p = 0.007$). O-VA was better among those with ED-VA measurements and those with ED-IOP measurements compared to those without ($p < 0.001$). Of 1395 patients who received an IOP measurement by ophthalmology, 9.8% had IOP > 25 mmHg in either eye. Of 1402 patients who received a VA assessment by ophthalmology, 65.0% had VA logMAR >0.3 (worse than 20/40) in either eye.

The use of the ED-IOP and ED-VA measurements as a screening tool for abnormal O-IOP (>25 mmHg) and abnormal O-VA (logMAR >0.3, ie, Snellen worse than 20/40) in either eye was evaluated using receiver operator curves (Figure 1). The AUC was 0.846 for detecting an abnormal IOP and 0.863 for detecting an abnormal visual acuity (Figure 1A and B). The sensitivity, specificity, positive predictive value, and negative predictive value of using a range of thresholds for ED-IOP and ED-VA are shown in Figure 1C and D. Table 3 shows the results if the ED measurement thresholds are set to the same numerical values as the targeted levels of O-IOP and O-VA. The sensitivity, specificity, PPV, and NPV of an ED-IOP measurement >25 mmHg in either eye and an ED-VA measurement of logMAR >0.3 (worse than 20/40) in either eye are listed in Table 3. The sensitivity of a value >25 mmHg on ED IOP testing was 0.78 (95% CI 0.69–0.87), and the specificity was 0.84 (95% CI 0.80–0.87). The sensitivity of a value logMAR >0.3 (worse than 20/40) on ED VA screening was 0.88 (95% CI 0.85–0.91), and the specificity was 0.59 (95% CI 0.54–0.65). A calculator allowing a range of user inputs for both the thresholds applied to ED measurements and the desired targets for detection with regard to Ophthalmology IOP and VA can be found in Supplemental File 1.

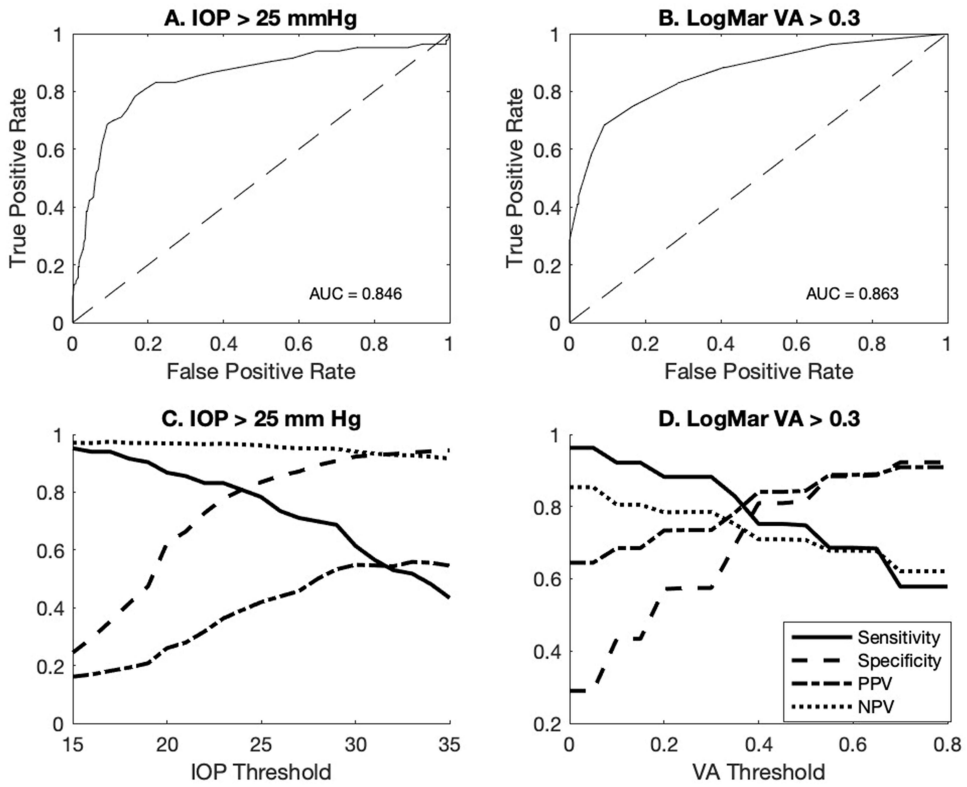

Figure 1 Top row: Receiver operator curve for using the ED measurements as screening for (**A**) O-IOP greater than 25 in the either eye (**B**) logMAR O-VA > 0.3 (worse than 20/40) in either eye. Bottom row: The sensitivity, specificity, positive predictive value, and negative predictive value of different ED thresholds of IOP (**C**) and VA (**D**) in detecting an elevated O-IOP (>25 mmHg) or decreased O-VA (logMAR > 0.3).

Table 3 Sensitivity, Specificity, and Predictive Values of ED-IOP >25 mm Hg and logMAR ED-VA >0.3 as Screening Tools for Abnormal O-IOP (>25 mmHg) and Abnormal O-VA (logMAR > 0.3), Respectively

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
ED-IOP > 25 mmHg	0.78 (0.69–0.87)	0.84 (0.80–0.87)	0.42 (0.34–0.50)	0.96 (0.95–0.98)
ED-VA LogMAR > 0.3[a]	0.88 (0.85–0.91)	0.59 (0.54–0.65)	0.76 (0.70–0.82)	0.78 (0.74–0.81)

Notes [a] worse than 20/40.

Patients with true positive results were older compared to those with false-positive results for both IOP (p=0.025) and VA (p<0.001) (Supplemental Tables 1 and 2). Those with false-negative VA results more frequently had a chief complaint of flashes/floaters or other (vs pain or redness or decrease in vision) (p < 0.001) and were slightly less likely to require an interpreter (p = 0.02) (Supplemental Table 2). The agreement between the ED and ophthalmology measured IOP and VA for left and right eyes is shown in Supplemental Table 3.

Discussion

The ED is often the first to evaluate and triage patients with eye-related complaints. Appropriate ED evaluation of ocular vital signs including IOP and VA can help to determine the next steps in the patient's care, which may be critical to preventing permanent vision loss. The measurements obtained by the ED can be considered as a screening tool for abnormal values obtained on ophthalmic consultation.

This study shows a low rate of IOP and VA acquisition in the ED for patients presenting with ophthalmic complaints, similar to other studies.[11–13] Reasons reported in the literature include the large burden of clinical care placed on ED providers[16] and the lack of substantial ophthalmology training in most medical schools,[17–19] advanced practitioner training programs, and EM residencies.[9,10,20] Specifically, for this study, the low rates of measured ED-VA and ED-IOP might reflect the lack of time and resources in a high pathology setting due to the unique role of one hospital as the only level 1 trauma center in a large geographic area, and both hospitals serving as large academic tertiary care referral centers.[21] Second, a readily available ophthalmology consultation service may lead to deferred exams by the ED when the chief complaint suggests a need for an ophthalmic consultation or when patients have been transferred from another hospital for an ophthalmic consultation. The fact that O-VA was worse among those without ED-IOP and ED-VA measurements also suggests that the ED may consult ophthalmology without VA and IOP testing when there is severe vision loss reported. The ED may also have a targeted approach to IOP assessment, given higher O-IOP among those with ED-IOP measurements than those without. Acquisition of ED-IOP and ED-VA was at the discretion of the ED staff and consulting ophthalmologist; however, standardized protocols for IOP and VA screening by the ED staff for ophthalmology and vision complaints may be helpful for ophthalmology triage.

When the ED-IOP and ED-VA are used as a binary cut-off test to detect high O-IOP (defined as IOP above 25mmHg) and poor O-VA (defined as VA logMAR > 0.3), the ED measurements perform quite well, with ROC curves for both IOP and VA producing AUC values greater than 0.84. The AUC and sensitivity/specificity values for ED IOP and VA assessments in our study are comparable to other ED tools for screening for sepsis,[22] early identification of myocardial infarctions using electrocardiograms,[23] and use of erythrocyte sedimentation rate for identifying GCA.[24] Furthermore, the higher the ED-IOP and worse the ED-VA, the higher the PPV for abnormal ophthalmology-obtained values. Table 3 shows the predictive value of ED measurements using the same thresholds for defining abnormal for both ED and ophthalmology assessment, but as seen in Figure 1C and D, a higher binary threshold for what is considered abnormal in the ED improves the PPV for abnormal findings on ophthalmology evaluation. For example, in our patient population, ED-IOP of >30 mm Hg had around a 55% chance of yielding O-IOP >25 mm Hg, vs 42% for ED-IOP >25 mm Hg. Similarly, an ED-VA of logMAR >0.4 had an 86% chance of yielding an O-VA of worse than 0.3, vs 76% for ED-VA >0.3. For ED-VA thresholds between 0.3 and 0.4, the negative predictive value of a passing ED-VA varies from 70% to 80%. The negative predictive value of an ED-IOP of 30 or lower, meanwhile, is extremely high at 96%.

The specific clinical context is of course always relevant to the interpretation of screening test data. Even assuming invariant sensitivity and specificity, positive predictive value will vary across subsets of the ED patient population depending on the underlying prevalence of disease, as illustrated by the fact that patients with true positive findings were more likely to be older, reflecting the higher disease prevalence and therefore higher positive predictive value of ED screening in older patients.

The ED exam performs well as a screening exam, but similar to previous reports,[11–13] there is only modest absolute agreement in VA and IOP measurements between the ED and ophthalmology exam. The 95% limits of agreement (LoA) between ED-IOP and O-IOP spanned over 30 mmHg with the ED-IOP ranging from about 12 mmHg lower to about 20 mmHg higher than the O-IOP (Supplemental Table 3). Similarly, the 95% LoA for visual acuity measurements spanned from approximately −1 to +1.2 logMAR, clinically indicating the difference in visual acuity from 20/20 to 20/200. The wide LoA prohibits accurate interpretation of any individual measure of ED-IOP and ED-VA; the ED exam does not supplant the ophthalmology assessment of IOP and VA but is useful as a screening exam to aid in appropriate referral to the ophthalmology service.

It is important to note that a large proportion of ED patients with ocular complaints did not have IOP and VA measured in the ED. This could introduce potential selection bias, which may affect PPV and NPV. Additionally, we report findings for tertiary, university-based medical center EDs, which serve as major referral centers. This may limit the generalizability of findings as each ED may have different rates of pathology, demographic characteristics, as well as different protocols for obtaining IOP and VA measurements, and different levels of expertise in doing so. The ED operator's training may affect the utility of ED-IOP and ED-VA measurements, but the individuals acquiring the measurements were not consistently recorded in the patient chart and could not be analyzed.

The purpose of this study was to evaluate the utility of ED measurements as screening tools for true abnormalities of VA and IOP, not as screening tools for specific diagnoses. In a real-world situation, care of the patient and determination for the need of an ophthalmic consultant would not only rely on VA and IOP measurements without consideration of the clinical context. In addition, although we analyzed the predictive value of ED eye vital sign measurements in isolation, we acknowledge that in clinical practice, ED measurements are interpreted in the context of the clinical history and other ED examination findings. The targets for O-IOP and O-VA were set at 25 mmHg and logMAR of 0.3, respectively, for the primary analyses, but differing circumstances and chief complaints may warrant different thresholds for clinical decision-making. The calculator that we have made available allows readers to set their own thresholds.

Conclusion

Our data suggest that ED acquired measurements of IOP and VA are useful to screen for abnormalities in IOP and VA on the ophthalmology exam. However, ED measurements are under-obtained and can be inaccurate. Automated techniques that do not require specialized training also hold promise for increasing acquisition and standardization of eye vitals, such as is done for systemic vital signs. While efforts have been made to improve subjective VA testing through standardization of eye charts[25–27] and digital mobile and virtual applications,[28,29] emerging computerized and machine learning applications of grating and Vernier discrimination,[30] optokinetic nystagmus,[31] and/or visual evoked potential[32–34] may hold the key to objective VA measurements that are valid and reproducible. Likewise, as technology advances and costs decrease, non-contact tonometry[35] and handheld rebound tonometry[36,37] may provide accurate results that eliminate the need for barriers such as topical anesthesia, eyelid holding, and specialized training. Initial ED evaluations are helpful screening tools to identify abnormal IOP and VA, and further developments could provide improvement in screening and opportunities for teleophthalmology in resource-limited settings.

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Disclosure

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