Diagnostic accuracy of tele-ophthalmology versus face-to-face consultation: abridged secondary publication

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KEY MESSAGES

1. Tele-ophthalmology highly agrees with face-to-face consultation in the diagnosis and grading of cataracts, glaucoma, and age-related macular degeneration (AMD).
2. Tele-ophthalmology is highly sensitive and specific for AMD, highly specific but less sensitive for cataracts, and highly sensitive but less specific for glaucoma.
3. Tele-ophthalmology results in higher downstream costs than face-to-face consultation, because tele-ophthalmology over-diagnoses cataracts and its severity.

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Introduction

Telemedicine is a viable care model during the COVID-19 pandemic. Tele-ophthalmology has benefits in healthcare beyond the pandemic.[1] Timely diagnosis and treatment of ocular diseases may prevent blindness. Tele-ophthalmology enables access to specialist health care services by underprivileged and disabled patients in areas with limited expertise. Nonetheless, tele-ophthalmology has been mostly used for screening a single disease such as diabetic retinopathy.[2] The accuracy of tele-ophthalmology for various diseases has not been established, although tele-ophthalmology and face-to-face consultation are comparable in terms of diagnostic outcomes.[3,4] Previous studies of tele-ophthalmology are limited by the lack of robust clinical trials, small sample sizes, and absence of quality data, making assessment of economical and clinical benefits difficult.

This study aims to determine the diagnostic accuracy of tele-ophthalmology for cataracts, glaucoma, and age-related macular degeneration (AMD), with face-to-face consultation as the gold standard, and to compare tele-ophthalmology with face-to-face consultation in terms of diagnosis, severity, and downstream costs.

Methods

This prospective comparative study was conducted between 1 August 2019 and 31 July 2021. Consecutive patients aged ≥40 years who were referred to the specialist ophthalmology clinic of Grantham Hospital, Hong Kong for blurred vision of ≥3 months were recruited. Those with a history of diabetes, inability to communicate verbally, or acute eye symptoms or ocular trauma requiring immediate ophthalmic care were excluded, as were those with un-readable slit lamp or retina images.

Participants underwent face-to-face consultation by an ophthalmologist for medical history taking, slit-lamp biomicroscopy, intraocular pressure measurement via applanation tonometry, mydriatic retinal examination with an indirect ophthalmoscope, and completion of the assessment form A. An optometrist performed a Snellen Chart distant visual acuity test with pinhole. Cataract was defined as cloudiness and/or yellow discoloration of the crystalline lens. Glaucoma was defined as pathological cupping of the optic disc. AMD was defined as the presence of drusen, geographical atrophy (dry AMD), and/or choroidal neovascularisation in the macular area (wet AMD).

For the tele-ophthalmology arm, a store-and-forward consultation model was used. The ophthalmologist completed the assessment form B after assessing the clinical data and ocular images that were collected by others. The optometrist captured colour photos of the anterior segment of the eye through a digital compact camera attached to a slit lamp biomicroscope. Anterior segment photographs were captured under low magnification (7.5x), with diffuse illumination of the cornea and the bulbar conjunctiva and parallelepiped section of the corneal stroma and central anterior chamber. Digital photographs of the retina that covered two standard fields and focused on the optic disc and macula were taken with a mydriatic fundus camera.

The pinhole visual acuity (VA), intraocular pressure (IOP), and referral letter were transmitted to the ophthalmologist.

Statistical analysis was performed using SPSS (Windows version 27.0; IBM Corp, Armonk [NY], US). The prevalences of cataract, glaucoma, and AMD, and their severity based on face-to-face consultation and tele-ophthalmology were compared using the Chi-squared test or post hoc test. The agreements between face-to-face consultation and tele-ophthalmology in terms of diagnosis and severity of cataracts, glaucoma, and AMD were assessed using the Cohen's Kappa statistic. Diagnostic accuracy (sensitivity, specificity, and positive and negative predictive values) of tele-ophthalmology was calculated, with face-to-face consultation as the gold standard. Improvement in agreement and diagnostic accuracy by adding VA or IOP data was determined. A two-tailed P value of <0.05 was considered statistically significant.

Results

A total of 860 eyes from 248 women and 182 men were assessed. The mean age of participants was 67±11 years. The two ophthalmologists took turns for face-to-face consultation and tele-ophthalmology for 44.9% and 55.1% of the time, respectively.

Using face-to-face consultation as the gold standard for diagnosis, 75.3% of eyes had cataracts, 31.6% of eyes had possible glaucoma, and 12.4% of eyes had AMD (Table 1). Agreement between face-to-face consultation and tele-ophthalmology was high across all three ocular diseases (Table 2). Additional VA data for cataract significantly improved the agreement from 79% to 89% in cataract severity, but additional VA and IOP data did not improve agreement in other diseases.

Diagnostic accuracy of tele-ophthalmology was highest for AMD, with >99% sensitivity and specificity. For cataract, the specificity was >99% but the sensitivity was 87.3%, which improved to 87.8% after adding VA data. For glaucoma, the sensitivity was >98% but the specificity was 75.7%, which improved to 76.5% after adding IOP data (Table 3).

The estimated cost per patient per 6 months was higher for tele-ophthalmology than for face-to-face consultation, with a difference of HK$547.16 (US$70.24) when VA and IOP data were not added. The difference was HK$99.86 (US$12.82) when VA and IOP data were added.

Discussion

The agreement was high between face-to-face consultation and tele-ophthalmology in terms of diagnosis and severity of cataracts, glaucoma, and AMD. In experienced ophthalmologists, diagnosis and severity can be accurately determined through slit lamp and fundus images alone and can be further improved by adding VA and IOP data. The lower agreement levels for glaucoma and cataracts were likely due to the inability of the current imaging techniques to differentiate subtle differences in disease stages and to identify early disease forms.

Tele-ophthalmology was highly sensitive and specific for AMD (both >99%). In diagnosing cataracts, the sensitivity was 87.3%, which was likely due to the relatively inconspicuous appearance of early cataracts, in that the 'yellowing' of the lens can

TABLE 1. Prevalence of cataract, glaucoma, and age-related macular degeneration (AMD) based on face-to-face consultation or tele-ophthalmology

Ocular disease	Prevalence, %			χ^2 statistic	P value
	Face-to-face consultation	Tele-ophthalmology (without visual acuity and intraocular pressure data)	Tele-ophthalmology (with visual acuity and intraocular pressure data)		
Cataracts	75.3 (671/860)	80.4 (691/860)	80.2 (690/860)	1.8	0.400
Early	64.4 (432/671)	60.6 (419/691)	64.4 (444/690)		
Moderate	31.7 (213/671)	36.0 (249/691)	32.5 (224/690)		
Severe	3.6 (24/671)	3.33 (23/691)	3.19 (22/690)		
Possible glaucoma	31.6 (272/860)	24.9 (214/860)	25.12 (216/860)	12.6	0.002
Glaucoma suspect	84.6 (230/272)	91.1 (195/214)	90.2 (193/216)		
Definite glaucoma	17.6 (48/272)	8.88 (19/214)	10.7 (23/216)		
AMD	12.4 (107/860)	12.3 (106/860)	12.3 (106/860)	0.1	1.000
Drusen only	53.3 (57/107)	58.5 (62/106)	58.5 (62/106)		
Dry AMD	22.4 (24/107)	14.2 (15/106)	14.2 (15/106)		
Dry AMD with geographical atrophy	21.5 (23/107)	23.6 (25/106)	23.6 (25/106)		
Wet AMD	2.80 (3/107)	3.70 (4/106)	3.70 (4/106)		

TABLE 2. Agreement between tele-ophthalmology and face-to-face consultation in terms of diagnosis and severity of cataract, glaucoma, and age-related macular degeneration (AMD)

Diagnosis and severity	Agreement, %	Kappa value (95% confidence interval)	P value
Cataract			
Diagnosis			
Without visual acuity data	96.7 (832/860)	0.90 (0.86-0.93)	<0.001
With visual acuity data	96.9 (833/860)	0.91 (0.87-0.94)	<0.001
Severity			
Without visual acuity data	86.5 (744/860)	0.79 (0.75-0.82)	<0.001
With visual acuity data	93.2 (800/860)	0.89 (0.86-0.92)	<0.001
Glaucoma			
Diagnosis			
Without intraocular pressure data	91.7 (789/860)	0.79 (0.74-0.84)	<0.001
With intraocular pressure data	91.9 (790/860)	0.80 (0.75-0.84)	<0.001
Severity			
Without intraocular pressure data	88.1 (758/860)	0.72 (0.66-0.77)	<0.001
With intraocular pressure data	88.9 (765/860)	0.74 (0.69-0.78)	<0.001
AMD			
Diagnosis			
Without visual acuity data	99.2 (853/860)	0.96 (0.93-0.99)	<0.001
With visual acuity data	99.2 (853/860)	0.96 (0.93-0.99)	<0.001
Severity			
Without visual acuity data	97.3 (837/860)	0.88 (0.84-0.93)	<0.001
With visual acuity data	97.3 (837/860)	0.88 (0.84-0.93)	<0.001

TABLE 3. Diagnostic accuracy of tele-ophthalmology for cataract, glaucoma, and age-related macular degeneration (AMD)

Ocular disease	Sensitivity, %	Specificity, %	Positive predictive value, %	Negative predictive value, %
Cataract (without visual acuity data)	87.3	99.4	97.6	96.5
Cataract (with visual acuity data)	87.8	99.4	97.6	96.7
Glaucoma (without intraocular pressure data)	98.7	75.7	90.2	96.3
Glaucoma (with intraocular pressure data)	98.7	76.5	90.5	96.3
AMD (without visual acuity data)	99.7	99.5	99.3	98.1
AMD (with visual acuity data)	99.7	99.5	99.3	98.1

be very subtle and may not be adequately captured on slit lamp photographs. In diagnosing glaucoma, the specificity was 75.7%, which was likely due to the use of two-dimensional retinal photographs for assessment of optic disc cupping. Without stereopsis, the cupping is less adequately evaluated. A study that used stereoscopic images of the optic nerve head reported accurate remote diagnosis and monitoring of glaucoma.[5] However, this type of fundus camera is not yet commercially viable for primary care settings in Hong Kong.

Tele-ophthalmology was more costly per patient per 6 months than face-to-face consultation, with a difference of US$12.82, because tele-ophthalmology over-diagnosed cataracts and its severity. Diagnostic accuracy is the most important determinant on the cost-effectiveness of tele-ophthalmology in the long run. In addition, the potential medicolegal costs and loss of quality of life that unnecessary cataract surgeries and missed glaucoma secondary to tele-ophthalmology should be considered.

Conclusions

Tele-ophthalmology is accurate and viable alternative for face-to-face consultation, but it still has diagnostic

and grading limitations, particularly for cataracts and glaucoma. The accuracy of tele-ophthalmology can be improved by using high-resolution cameras in primary care and using machine learning to aid diagnosis and management.

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Disclosure

The results of this research have been previously published in:

1. Wong JK, Zhu MM, Lam JC, et al. Prospective comparative study investigating agreement between tele-ophthalmology and face-to-face consultations in patients presenting with chronic visual loss. Ophthalmol Ther 2022;11:1199-213.

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