Patients' Perception of Robot-Driven Technology in the Management of Retinal Diseases

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ORIGINAL RESEARCH

Patients' Perception of Robot-Driven Technology in the Management of Retinal Diseases

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ABSTRACT

Introduction: There is increasing application of robots and other artificial intelligence-driven technologies in the management of retinal disease. These technologies have the potential to meet increasing demands for retinal diseases. However, there is currently a lack of understanding of patients' attitudes towards use of robots in ophthalmology. This study investigates patients' attitudes towards robot-led management of retinal disease.

Methods: Paper questionnaires were distributed to 177 patients attending intravitreal treatment (IVT) at the Princess Alexandra Eye Pavilion between 1 October 2022 and 31 January 2023. The questionnaire collected information on age, sex, diagnosis and postcode. In the questionnaire, patients responded to questions about their attitudes towards robot-led diagnosis, treatment decisions and IVT injections. Responses were collected using a 5-category Likert scale which was analysed using ordinal logistic regression with adjustments for age, sex and deprivation status.

Results: Those from affluent socioeconomic backgrounds were significantly ($p < 0.001$) more accepting of robots diagnosing and deciding on treatment, although the total number of patients who were accepting was only 26 (14.7%). Furthermore, there was an increased proportion of patients who would accept robots if the robot made fewer mistakes than doctors, if the robot reduced waiting or appointment time and if the robot was able to communicate well and have empathy; the same association with socioeconomic background remains ($p < 0.001$). Lastly, 116 patients (65.5%) would not be happy if IVT injections were performed by a robot; this was more likely the case if the patient was female ($p = 0.04$) or from a more deprived socioeconomic background ($p < 0.001$).

Conclusion: Attitudes towards robot involvement in diagnosis and management of retinal disease are significantly associated with socioeconomic backgrounds and sex. Additional studies are required to further investigate these determinants of robot receptiveness to ensure acceptance and compliance with treatment with these new technologies.

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Key Summary Points

Why carry out this study?

Artificial intelligence is being rapidly incorporated into ophthalmological practice.

Understanding patients' perception of this technological shift is key to ensure a smooth transition of current practice into a more automated one.

Patients' perception of robots being used in clinical practice is divided.

What was learned from the study?

Patients from more affluent socioeconomic backgrounds have a greater preference for robots. Male patients were more receptive towards administration of intravitreal injections by robots.

The successful introduction of robots into healthcare needs to take into account and address the underlying concerns and beliefs of all demographics of the population to ensure acceptance of these new technologies.

INTRODUCTION

Artificial intelligence-driven technologies are being rapidly integrated into diagnostics and interventional ophthalmological medicine [1]. We are now seeing the application of robots in facilitating both the diagnosis of retinal diseases [2] and administration of intravitreal treatment (IVT) [3]. For example, deep learning has allowed rapid development in the computer-driven models for the prediction of the requirement and response of anti-vascular endothelial growth factor (VEGF) treatment [4]. Furthermore, there is currently active development of an independent robot for administration of safe and precise intravitreal injections [3]. Assistance by computers and robots may offer improvements in efficiency, movement precision, visualisation, proprioception and tremor cancellation [4].

The incidence of retinal disease is expected to further increase as a result of the ageing population, leading to increased demand in diagnostics and treatment. IVT is currently indicated for neovascular macular disease and foveal-involving macular oedema, with ongoing trials for its use in other retinal diseases [5]. A recent study has demonstrated that the number of intravitreal injections has increased nearly 11-fold from the year 2009 to 2019 in a UK tertiary hospital [6]. With the widening health workforce gap, the timely expansion of artificial intelligence (AI) use could help accommodate this increasing demand for IVT.

However, as it stands, a study has shown that almost 40% of patients were unable to fully comply with intravitreal treatment for a year [7]. Across the globe, patients' non-compliance has been attributed to high treatment regimen burden, anxiety and fear, undermet expectations and lack of motivation; other reasons include lack of understanding of the procedure, vision improvement, inconvenience, physicians' reputation, financial limitation and comorbid systemic diseases [8]. Patients' anxiety, trust, perception and reception of robots must therefore be explored and addressed before the use of robotics is normalised in retinal disease management in order to avoid increased non-compliance.

Despite increasing automation and the use of AI in ophthalmology, there is currently a lack of information on patient's perception of the use of computers and robots in ophthalmology. This study investigates patients' perspective of retinal disease management decision-making and robot-facilitated IVT and looks at various paradigms including patient's perception of empathy, communication, efficiency and safety. We hypothesise that patients' perceptions of robots are influenced by their demographic background.

METHODS

Study Design

Anonymised questionnaires were provided to all consecutive patients attending the IVT clinic at Princess Alexandra Eye Pavilion (PAEP), a tertiary referral ophthalmic centre in the UK, between 1 October 2022 and 31 January 2023. PAEP provides IVT to approximately 300 patients, from across Southeast Scotland each week. The purpose of the study for quality improvement was explained to the patients, and verbal consent was obtained prior to handing out the questionnaire. Patients were asked to fill in the entire questionnaire prior to administration of IVT to ensure their vision was not affected by the procedure. Tenets of the Declaration of Helsinki of 1964 were adhered to. Ethics approval was received from the Quality Improvement Research Committee of the PAEP; members of the committee are Caroline Cleland, Jas Singh and Manjit Mehat. All patients who filled the study questionnaire have been anonymised.

Questionnaire

To guide the creation of the questionnaire, the authors conducted a systematic literature review of patient perception of AI using Embase (Supplementary Materials). The questionnaire collected information on basic demographics: age, sex and postcode. Patients' postcodes were used to determine patients' relative deprivation (socioeconomic background) based on the Scottish Index of Multiple Deprivation (SIMD) tool. SIMD measures across income, employment, health, education, skills and training, housing, geographic access and crime to categorise postcodes into deciles of deprivation, which the authors converted to quintiles. Responses were collected using a 5-category Likert scale and free-text answer. The questionnaire was in English. A sample questionnaire can be found in Supplementary Materials (SM1).

Inclusion Criteria

Patients receiving IVT in the PAEP were included in the study.

Exclusion Criteria

Patients lacking capacity and those who were unable to read were excluded from the study.

Data Collection and Analysis

Data were collected at the end of the active period and their information put into MS Excel and quality checked for data entry. This file was then imported into the analysis software. All questions were analysed using descriptive statistics (count and percentages for categorical data and mean, standard deviation, minimum and maximum for continuous data).

Likert scales were explored using ordinal logistic regression with adjustment for the following covariates: age (included as a continuous variable), sex (male vs. female), and deprivation status (1 = least deprived, 2, 3, 4 and 5 = most deprived) included as a categorical variable in the regression model. Level of statistical significance was set at $P < 0.05$. All analyses were performed using SAS software, version 9.4 (SAS Institute).

Compliance with Ethics Guidelines

Verbal consent was obtained from patients prior to filling out questionnaires. Tenets of the Declaration of Helsinki of 1964 were adhered to. Ethics approval was received from the Quality Improvement Research Committee of the PAEP; members of the committee are Caroline Cleland, Jas Singh and Manjit Mehat. All patients who filled out the study questionnaire have been anonymised.

RESULTS

Overall, 177 patients (see Table 1 for demographics) fully completed the questionnaire and no patients were excluded. The results of the completed questionnaire can be found in Supplementary Materials.

Table 1 Patient demographics

Characteristics	*n* (%)
Age (years)	
< 55	4 (2.3)
55–64	18 (10.2)
65–74	47 (26.6)
75–84	75 (42.4)
> 85	33 (18.6)
Sex	
Female	85 (48.0)
Male	92 (52.0)
Diagnosis	
Age-related macular degeneration	122 (68.9)
Diabetic macular oedema	36 (20.3)
Retinal vein occlusion	16 (9.0)
Other	3 (1.7)
Socioeconomic background (quintile)	
1 (least deprived)	27 (15.3)
2	67 (37.9)
3	31 (17.5)
4	35 (19.8)
5 (most deprived)	17 (9.6)

Anxiety, (Q1)

The questionnaire found that 93 (52.5%) patients were not anxious (score 1) prior to IVT. The anxiety level was associated with age variable (odds ratio (OR) = 0.94, df = 1, Wald $X^2 = 13.35$, $p = 0.0003$), but it was not associated with sex or socioeconomic status. Patients aged 65 years or older were more anxious (score 4 or 5) than those under 65 years old.

Presence of Doctor and Virtual Clinic (Q2 and Q3)

Only 48 (27.3%) patients felt it was very important (score 5) for them to see a doctor at every outpatient appointment. The importance of seeing a doctor was associated with socioeconomic quintile with an OR comparing quintile 1 versus quintiles 2, 3, 4 and 5 of 2.36, 1.38, 3.91 and 2.76 respectively (df = 4, Wald $X^2 = 10.32$, $p = 0.035$) as an unordered categorical variable. However, for 62 (35.3%) patients it was not important (score 1) to see a doctor at every appointment and in fact 68 (38.4%) patients were very happy (score 5) to attend a virtual clinic where they do not see a doctor but receive results via post. The latter group of patients did not have any sex, age or socioeconomic quintile association.

Clinical Decision-Making by Robots (Q4–7)

From the questionnaire only 26 (14.7%) patients were very happy (score 5) for a robot to decide on their diagnosis and treatment whilst 91 (51.4%) were not happy (score 1). This was strongly associated with socioeconomic quintile with OR in quintile 1 versus quintiles 2, 3, 4 and 5 of 0.47, 0.15, 0.04 and 0.09 respectively (df = 4, Wald $X^2 = 43.20$, $p < 0.0001$). So overall patients from more deprived postcodes were less likely to be happy for a robot to decide on their diagnosis and treatment.

However, a greater number of patients ($n = 45$ (25.4%) patients)) would be very happy (score 5) for robots to decide on diagnosis and treatment if the robot made fewer mistakes than doctors. The association with socioeconomic quintile remained with an OR between quintile 1 versus quintiles 2, 3, 4 and 5 of 0.42, 0.13, 0.04 and 0.09 respectively (df = 4, Wald $X^2 = 47.11$, $p < 0.0001$).

Furthermore, 49 (27.7%) patients were very happy (score 5) letting a doctor decide on their diagnosis and treatment if the waiting time was reduced and the appointment was faster. This was also associated with socioeconomic quintile with an OR comparing quintile 1 versus quintiles 2, 3, 4 and 5 of 0.39, 0.10, 0.04 and 0.10 respectively (df = 4, Wald $X^2 = 45.05$, $p < 0.0001$).

Lastly, 44 (25.0%) patients were very happy (score 5) letting a robot decide on their

diagnosis and treatment if the robot was able to communicate well and show human emotions and empathy. This was also associated with socioeconomic quintile with an OR comparing quintile 1 versus quintiles 2, 3, 4 and 5 of 0.60, 0.15, 0.05 and 0.18 respectively (df = 4, Wald $X^2 = 45.14$, $p < 0.0001$).

Robot Injector (Q8)

Finally, 116 (65.5%) patients were not happy (score 1) if their injection was performed by a robot. This was associated with both gender differences with an OR comparing female versus male of 2.12 (df = 1, Wald $X^2 = 4.05$, $p = 0.04$) and socioeconomic quintile differences with an OR of quintile 1 versus vs quintiles 2, 3, 4 and 5 of 0.74, 0.14, 0.02 and 0.03 respectively (df = 4, Wald $X^2 = 57.8$, $p < 0.0001$).

DISCUSSION

Our study shows more patients are unaccepting than accepting of robots diagnosing and treating retinal diseases. However, more patients may be amenable to robots if they made fewer mistakes, were more efficient or showed human emotions. This study also found that attitudes towards robots were associated with socioeconomic status, sex and age. These three factors have been shown by many other studies as factors that influence a person's trust in AI. Recognising these influences specifically in the context of IVT is an important step for avoiding healthcare inequalities when implementing robots in retinal disease management.

Socioeconomic Background

Our study found that those from less deprived postcodes are more open to robot-led care. Social determinants of health and mortality are well documented in the literature, and this is the first study exploring their effects on patients' perception of robots in the context of retinal disease management. The association between socioeconomic status and trust in AI has been seen in a multitude of other studies across a diverse range of general and specific AI applications. This association has mainly been attributed to two constituents of socioeconomic status: education and occupation/income. Those with higher levels of education [5], those in higher income brackets [9] and those in white-collared professions [10] have a more positive view of AI and are more likely to perceive AI as being helpful to society. This is possibly due to a link between tertiary education and knowledge of risk management [11] which could lead to reduced aversion to risk of adoption of AI [12]. Furthermore, higher education may translate to better understanding of technologies underlying robots and AI, and understanding is a key factor when it comes to building trust in AI and robotics [13]. Additionally, individuals in certain occupations have more exposure to AI [14] and previous access to AI application is positively correlated with trust [13]. Lower-skilled, repetitive, and dangerous jobs are among those most likely to be taken over by machines; concern about AI replacing jobs could impede trust in AI and robots [13]. Lastly, past applications of AI have disproportionately harmed those from lower socioeconomic backgrounds [15] which would only erode trust in AI.

Studies have already demonstrated that those from disadvantaged socioeconomic backgrounds are more likely to present with lower baseline visual acuity, have worse long-term outcomes [16, 17], and have a higher rate of IVT non-compliance. This study demonstrating that those from more deprive socioeconomic backgrounds are more averse to robots is concerning for further exacerbation of healthcare inequalities if robots are utilized for the management of retinal diseases.

Sex

The present study also found a statistically significant association between sex and willingness for IVT to be performed by robots, with male patients more receptive to robots conducting intravitreal injections. This finding agrees with several others which have shown that being male is associated with higher level

of trust in robots and AI. One study reported that sex was the most influential factor which affects users' trust in AI [5], more so than socioeconomic status or age. Pinto dos Santos et al. found that female medical students were less trusting of AI than their male counterparts were [18]. Clarifying questions by the study found that more male than female medical students report exposure to AI in their day-to-day life and more male students feel they have knowledge about technologies underlying AI. Although this apparent familiarity and knowledge of AI are self-reported, exposure and knowledge are no doubt individual factors that impact trust in AI [13]. It is unclear why this disparity in sex exists.

Age

With an aging population, there will be increased incidence of retinal disease and thus increased demand for IVT—87.6% of patients in this study were aged 65 years or older [6]. The automation of intravitreal injections may help address this increased demand. However, this study found a statistically significant association between age and anxiety levels, with every patient who reported that they are 'very anxious' (score 5) being 65 years or older. No patients under 65 years old said they were anxious (score 4 or 5). With anxiety being a known cause of non-compliance to IVT, this finding identifies another group of patients (those aged 65 years or older) whose need should be specifically addressed to maximise compliance to robot-facilitated IVT. This study found no significant association between age and acceptance of robots and AI.

Limitations

Our study has some limitations. The study's sample is confined to Edinburgh which is a relatively affluent region in the UK. We attempted to maximise sample heterogeneity by including all patients, and our sample is spread out across all deprivation deciles as a result. Furthermore, a definition for the term robot was not provided to patients in the questionnaire and therefore left open for interpretation; the term may have different connotations for different patients. The mechanical and inhuman nature of the term robot may also artificially induce repulsion of AI. Finally, our sample was just limited to patients undergoing IVT, the target population, and thus may not reflect the broader views of the population.

Our Thoughts

We acknowledge that the results in our study are exploratory rather than conclusive. These preliminary results should be used with available literature to guide the future development of AI. We believe our study raises a few important points to be considered in future studies. Firstly, the desirable characteristics of robots shown in this study include lower margin of error, higher efficiency and the display of human emotions. When developing AI-driven healthcare, large double-blinded trials should be conducted to ascertain which characteristics are most important to patients. Secondly, there is general consensus that communication improves the adoption of disruptive technology [19]. Our study helps distinguish vulnerable groups of patients who may benefit from individualised education and attention. Thirdly, AI has mainly been developed with the aim to optimise processes [20]. Our findings provide further evidence to the literature showing a disparity in AI acceptance between sexes. Although the reasons behind this are unknown, our theory is that this may be partly explained by the different expectations and needs between male and female patients. Optimisation of healthcare should aim to derive the benefits from precise mechanical functionality without forgoing universal patient-centric values such as impartialness, mutualism, good communication and empathy.

CONCLUSION

The overall response from our patients suggests that there is a positive attitude towards robots being incorporated into diagnosis and management of retinal diseases. Positive attitude

towards robots is significantly associated with a more affluent socioeconomic background which may be related to a higher level of education and exposure to robots. Furthermore, male patients had more positive views towards robots than female patients did. Additional studies are required to investigate determinants of robot receptiveness with the aim of easing transition into a more robot-driven healthcare environment. The successful introduction of robots into healthcare needs to take into account and address the underlying concerns and beliefs of all demographics of the population to ensure acceptance of these new technologies, thereby maintaining compliance with treatment, and should not be instituted at the expense of patient-centric care.

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Data Availability. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

REFERENCES

1. Schmidt-Erfurth U, Sadeghipour A, Gerendas BS, Waldstein SM, Bogunović H. Artificial intelligence in retina. Prog Retin Eye Res. 2018;67:1–29.

2. Dong L, He W, Zhang R, et al. Artificial intelligence for screening of multiple retinal and optic nerve diseases. JAMA Netw Open. 2022;5(5):e229960.

3. Ophthorobotics. Product - Ophthorobotics AG. https://ophthorobotics.com/product-en.html. Accessed 1 Apr 2023.

4. Shahriari MH, Sabbaghi H, Asadi F, Hosseini A, Khorrami Z. Artificial intelligence in screening, diagnosis, and classification of diabetic macular

edema: a systematic review. Surv Ophthalmol. 2023;68(1):42–53.

5. Lanzetta P, Loewenstein A. Fundamental principles of an anti-VEGF treatment regimen: optimal application of intravitreal anti-vascular endothelial growth factor therapy of macular diseases. Graefes Arch Clin Exp Ophthalmol. 2017;255(7):1259–73.

6. Chopra R, Preston GC, Keenan TD, et al. Intravitreal injections: past trends and future projections within a UK tertiary hospital. Eye. 2021;36(7):1373–8.

7. Okada M, Mitchell P, Finger RP, et al. Nonadherence or nonpersistence to intravitreal injection therapy for neovascular age-related macular degeneration. Ophthalmology. 2021;128(2):234–47.

8. Polat O, İnan S, Özcan S, et al. Factors affecting compliance to intravitreal anti-vascular endothelial growth factor therapy in patients with age-related macular degeneration. Türk Oftalmoloji Dergisi. 2017;47(4):205–10.

9. Zhang B, Dafoe A. Artificial intelligence: American attitudes and trends. SSRN Electron J. 2019. https://doi.org/10.2139/ssrn.3312874.

10. Jung S. Does education affect risk aversion? Evidence from the British Education Reform. Appl Econ. 2015;47(28):2924–38.

11. Neudert L-M, Knuutila A, Howard PN. Implications for involving artificial intelligence in public service and good governance. Oxford: Oxford Commission on AI & Good Governance. https://oxcaigg.oii.ox.ac.uk/wp-content/uploads/sites/11/2021/12/AI-in-the-Public-Service-Final.pdf. Accessed 7 Oct 2020.

12. Yang R, Wibowo S. User trust in artificial intelligence: a comprehensive conceptual framework. Electron Mark. 2022;32(4):2053–77.

13. Siau K, Wang W. Building trust in artificial intelligence, machine learning, and robotics. Cutter Bus Technol J. 2018;31:47–53.

14. Felten E, Raj M, Seamans R. Occupational, industry, and geographic exposure to artificial intelligence: a novel dataset and its potential uses. Strateg Manag J. 2021;42(12):2195–217.

15. Zhang, B. Public opinion toward Artificial Intelligence. 2021. https://doi.org/10.31219/osf.io/284sm.

16. Saxby E, Cheng K, O'Connell N, Sanders R, Agarwal PK. Is there an association of socioeconomic deprivation with acute primary angle closure? Eye. 2021;36(6):1246–52.

17. Mundy KM, Nichols E, Lindsey J. Socioeconomic disparities in cataract prevalence, characteristics, and management. Semin Ophthalmol. 2016;31(4):358–63.

18. Pinto dos Santos D, Giese D, Brodehl S, et al. Medical students' attitude towards artificial intelligence: a multicentre survey. Eur Radiol. 2018;29(4):1640–6.

19. Hengstler M, Enkel E, Duelli S. Applied Artificial intelligence and trust—the case of autonomous vehicles and medical assistance devices. Technol Forecast Soc Chang. 2016;105:105–20.

20. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019;6(2):94–8.