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Research article

Teleophthalmology provides earlier eye care access for patients with newly-diagnosed diabetes

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ABSTRACT

Purpose: Timely diagnosis of diabetic retinopathy is important in preventing vision loss. This study aims to determine if remote retinal imaging enables earlier eye care access among newly-diagnosed diabetic patients.
Design: Retrospective cohort study.
Methods: Using the OptumLabs® Data Warehouse – a longitudinal, real-world dataset containing deidentified administrative claims and electronic health record (EHR) data, we included 968 846 adults with newly diagnosed type 2 diabetes and at least 1 year of continuous enrollment. We compared time from initial diabetes diagnosis to first eye exam by remote screening or in-person eye exam.
Results: We found that at year 1 after diagnosis, 5459 (0.56%) patients underwent remote imaging and 208 023 (21.5%) underwent in-person exam. The mean (95% CI) time to eye exam was 3.48 (3.38–3.58) months for remote imaging and 4.22 (4.20–4.23) months for in-person visits ($p < 0.0001$). Interestingly, 27.5% of remote screenings were performed on the same day of diabetes diagnosis. Excluding same-day encounters, mean time to eye exam was 4.80 (4.68–4.91) months for remote imaging and 4.85 (4.83–4.86) months for in-person eyecare ($p = 0.4$).
Conclusions: Thus, teleophthalmology may enable earlier eye care access among patients with newly-diagnosed diabetes, primarily with same-day screenings. Increased adoption of teleretinal screening may enable earlier detection of diabetic retinopathy and prevent vision loss.

1. Introduction

Diabetes mellitus (DM) affects 34.2 million people in the United States, and diabetic retinopathy (DR), which affects 30% of diabetic patients age 40 years or over, is the leading cause of preventable vision loss and blindness among working-aged adults [1,2]. To reduce the burden of the disease and prevent vision loss, the American Academy of Ophthalmology (AAO) recommends annual eye

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screening for DR [3]. However, only around 50% of vulnerable patients obtain their first screening within a year of diagnosis of DM [4,5]. Recurrent screening is even more dismal. Fewer than 40% of diabetic patients undergo the annual eye exam in the first 5 years after diagnosis of DM and only 15.3% adhere to the recommended eye exam intervals [6,7].

Teleophthalmology using remote retinal imaging enables point-of-care diabetic eye screening at primary care or other non-eyecare facilities. Remote screening for DR has been shown to improve access to ophthalmic care [8–10]. These programs can reduce cost, improve screening rates and patient education, identify eyes at risk for blindness, reduce the need for in-person ophthalmologist visits, and improve access in areas with few eyecare providers [8,11–13].

However, the expansion of teleophthalmology programs has been hindered by inconsistencies in insurance coverage and reimbursements. At a large integrated health system in Northern California, Ellis et al. found that 55% of charges for remote DR screening using telehealth codes were denied by non-capitated insurance plans, and 40% were denied by private insurers [14]. Despite the rapid increase in teleophthalmology utilization across the U.S., insurance coverage has declined according to national insurance claims data, with disproportionate impact on vulnerable populations such as older, Black, and lower-income patients [15]. Building evidence to support the clinical benefit of remote DR screening may help encourage insurance payers to expand coverage for teleophthalmology services. In this study, we compared the timing to eye care access using teleophthalmology versus in-person visits in newly-diagnosed type 2 DM patients using a large, national insurance claims database.

2. Methods

2.1. Data acquisition

Our study was exempt from the University of California Davis Institutional Review Board review since it did not include human subjects. This study complied with the Health Insurance Portability and Accountability Act and adhered to the tenets of the Declaration of Helsinki. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline. We obtained data from the OptumLabs Data Warehouse, a longitudinal real-world dataset which contains more than 200 million de-identified administrative claims for commercial and Medicare Advantage enrollees between the years 2011–2020 [16]. This data warehouse includes individuals from all 50 states, District of Columbia and Puerto Rico. We obtained demographic information (age, sex, race/ethnicity), socioeconomic status (education level and household income), Rural Urban Commuting Area (RUCA) codes, and insurance details (Supplemental Table 1). The socioeconomic data were generated using proprietary analytic and demographic models [16]. Education level was a census-block level variable estimated from the U.S. Census Bureau's American Community Survey median education level among respondents 25 years and older. RUCA codes were assigned to claims broken down into metropolitan (urbanized area), micropolitan (urban cluster of 10 000 to 49 999), small town (urban cluster of 2500 to 9999), and rural areas (outside of an urbanized area or urban cluster).

2.2. Patient identification

We identified all individuals with a new diagnosis of type 2 DM based on the International Classification of Diseases, 9th Revision (ICD-9) codes (ICD-9 codes 250.x0 or 250.x2) and ICD-10 codes (E11). To be included in the study, the individual had to have at least 2 encounters with one of the above ICD codes; and we defined the index date as the first of those 2 encounters. We excluded individuals who were not continuously enrolled for at least one year before the index date of DM diagnosis (eTable 1) to increase the likelihood that DM was newly diagnosed. Additionally, we excluded individuals who underwent an eye exam (in person or remote) in the year prior to the index date of DM diagnosis to reduce those already undergoing routine eye care for unrelated conditions.

2.3. Outcomes

The primary outcome measure was time to eye exam within 1 year as indicated by remote retinal imaging or an in-person visit to an eye care provider. A claim was classified as remote screening if it included Current Procedural Terminology (CPT) codes for remote retinal imaging (92227 or 92228) by any provider, or for fundus photography (92250) billed by a non-eyecare provider, as previously described [15]. Otherwise, a claim was considered an in-person eyecare visit if the physician specialty was "ophthalmologist" or "optometrist," and did not fall under the definition of remote screening. We also analyzed patients who underwent eye screening within 1 year, 2 years, and 5 years after the initial diagnosis of DM.

2.4. Statistical analysis

Chi-square tests were used for categorical, univariable comparisons. We generated Kaplan-Meier survival curves to determine the proportion of eyes that underwent eye screening within the first year after the index date. The data was right censored with the censoring event including changing insurance, death, and end of the study. Right censoring time was assumed to be independent of time to first eye exam. Because many teleophthalmology screenings were performed on the same day as the index date of DM diagnosis; an additional analysis was conducted to exclude same-day screenings. Statistical analyses were conducted in SAS (v9.4; SAS Institute Inc.) and R (v4.1.2; R Foundation for Statistical Computing) [17].

3. Results

3.1. Study demographics

Between 2011 and 2020, we identified 1 408 269 patients with newly diagnosed type 2 DM, among whom 968 846 (68.8%) met the inclusion criteria and were included in the analyses. In the first year after diagnosis, 5459 (0.56%) of patients underwent remote eye imaging, 208 023 (21.5%) had in-person eye exams, and 755 364 (78.0%) did not receive any eye care (Table 1). The mean (standard deviation [SD]) age of patients at diagnosis was 54.1 (3.8) years and 48.6% were female. Patients who underwent remote imaging were slightly younger (mean 53.4 years, SD 14.4) than those who received in-person eye exams (mean 59.3 years, SD 12.7) within the first year (Table 1). A smaller proportion of patients who underwent remote retinal imaging were women (34.8%), as compared to those who had in-person visits (51.8%; odds ratio [OR] 0.58, 95% confidence interval [CI] 0.55–0.62) or as compared to those who received no documented eye care (47.7%; OR 0.58, 95% CI 0.55–0.62) in year 1 (Table 1). Annual household income, education levels, or population densities of the geographic region were similar between the groups. However, there was a smaller proportion of individuals with Medicare associated with remote imaging (14.4%) compared to in-person visits (26.9%; OR 0.45, 95% CI 0.42–0.49) and patients without eye care (15.9%; OR 0.88, 95% CI 0.82–0.95) (Table 1). As expected, a greater proportion of eyes received remote eye imaging in more recent years (2016–2019), consistent with increased telehealth utilization over the past decade [15].

3.2. Time to eye care

Among patients who received eye screening within 1 year after diagnosis of DM, the mean time to remote retinal imaging was

Table 1
Demographics and clinical Characteristics 1-year continuous enrollment, %.

	Remote	In-Person	None	Overall	OR (95% CI)	OR (95% CI)
Patient Characteristics	$n = 5459$	$n = 208\,023$	$n = 755\,364$	$n = 968\,846$	*Remote vs. In-Person*	*Remote vs. None*
Age, years						
<18	0.8	0.9	1.4	1.3	0.67 (0.48–0.90)	0.47 (0.34–0.64)
18-39	13.0	8.1	17.0	15.1	1.26 (1.16–1.37)	0.69 (0.64–0.75)
40-64	66.9	52.5	60.7	59.0	Ref	Ref
65-74	16.1	24.1	13.3	15.6	0.52 (0.49–0.56)	1.09 (1.01–1.18)
≥75	3.3	14.5	7.5	9.0	0.17 (0.15–0.21)	0.40 (0.34–0.46)
Sex						
Male	65.2	48.2	52.2	51.4	Ref	Ref
Female	34.8	51.8	47.7	48.6	0.58 (0.55–0.62)	0.58 (0.55–0.62)
Household Income, USD						
<40 000	25.0	25.3	22.6	23.2	Ref	Ref
40 000–74 999	22.3	22.8	20.8	21.2	0.99 (0.91–1.07)	0.96 (0.89–1.04)
75 000–124 999	15.2	17.6	16.6	16.8	0.87 (0.80–0.95)	0.82 (0.76–0.89)
125 000–199 999	5.0	6.9	6.8	6.8	0.74 (0.65–0.84)	0.67 (0.59–0.76)
200 000 +	1.9	3.3	3.1	3.2	0.58 (0.47–0.71)	0.55 (0.44–0.66)
Unknown	30.6	24.1	30.1	28.8	1.28 (1.19–1.37)	0.91 (0.85–0.94)
Education Level						
<12th grade	3.9	1.9	2.1	2.1	2.04 (1.76–2.35)	1.72 (1.49–1.98)
High school diploma	37.3	36.7	35.7	35.9	Ref	Ref
Less than bachelor's degree	30.9	35.5	32.7	33.3	0.86 (0.53–0.91)	0.90 (0.85–0.97)
Bachelor's degree or more	4.7	7.7	6.5	6.8	0.61 (0.53–0.69)	0.69 (0.61–0.78)
Unknown	23.2	18.2	22.9	21.9	1.26 (1.17–1.35)	0.97 (0.90–1.04)
Rural-Urban Category						
Metropolitan	90.4	89.5	90.1	90.0	Ref	Ref
Micropolitan	5.6	5.9	5.6	5.7	0.94 (0.84–1.06)	1.00 (0.89–1.12)
Rural	1.2	1.6	1.3	1.4	0.74 (0.57–0.94)	0.91 (0.71–1.16)
Small Town	2.5	2.8	2.6	2.7	0.90 (0.76–1.06)	0.96 (0.80–1.13)
Unknown	0.2	0.2	0.4	0.3	0.98 (0.50–1.69)	0.54 (0.28–0.93)
Insurance Type						
Commercial	85.6	73.1	84.1	81.7	Ref	Ref
Medicare	14.4	26.9	15.9	18.3	0.45 (0.42–0.49)	0.88 (0.82–0.95)
Year of Diabetes Diagnosis						
2011	6.4	10.9	11.6	11.4	Ref	Ref
2012	6.2	10.8	11.5	11.3	0.99 (0.85–1.15)	0.99 (0.85–1.15)
2013	5.9	10.0	10.9	10.7	1.01 (0.86–1.17)	0.98 (0.84–1.14)
2014	7.7	9.5	10.4	10.2	1.38 (1.20–1.60)	1.34 (1.15–1.54)
2015	8.6	11.0	10.8	10.8	1.34 (1.16–1.54)	1.45 (1.27–1.67)
2016	11.4	10.4	10.7	10.6	1.88 (1.65–2.15)	1.94 (1.71–2.22)
2017	16.8	14.7	11.7	12.4	1.95 (1.72–2.21)	2.60 (2.30–2.95)
2018	18.7	11.9	11.2	11.4	2.68 (2.37–3.03)	3.02 (2.68–3.42)
2019	18.4	10.9	11.2	11.2	2.87 (2.54–3.25)	2.97 (2.62–3.36)

shorter than that for in-person exam (mean (95% CI) time: 3.48 (3.38–3.58) vs. 4.22 (4.20–4.23) months; $p < 0.0001$; Fig. 1A). Interestingly, 27.5% of patients in the remote eye imaging group had the procedure performed on the same day as the index date of diagnosis, compared to 12.7% of in-person exams. After excluding patients with same-day eye care, the difference in time to eye care was no longer apparent (4.80 (4.68–4.91) vs. 4.85 (4.83–4.86) months; $p = 0.4$; Fig. 1B). To confirm this finding, we separately analyzed encounters using only teleophthalmology CPT codes 92227/92228 and the less stringent 92250 code from non-eyecare providers. Consistently, the mean (95% CI) time to remote imaging was similar between the two definitions of remote eye imaging encounters (3.45 (3.16–3.74) months for 92227/92228 vs. 3.48 (3.38–3.59) months for 92250 by non-eyecare providers; Supplemental Fig. 1A), with a similar convergence of the survival curves when same-day encounters were excluded (Supplemental Fig. 1B).

3.3. Long-term eye screening rates

Of the original cohort of 968 846 patients, 671 494 (69.3%) had 2 years of continuous enrollment and 211 114 (21.8%) had 5 years of follow-up. The cumulative proportion of patients who received any eye care after DM diagnosis increased from 22.0% in the first year to 32.8% at the end of year 2 and 44.2% at the end of year 5 (Fig. 2). After year 1, the proportion of patients that underwent remote imaging remained stable at 0.75% in year 2 and 0.7% in year 5, while the proportion that received in-person eye exams increased slowly to 32.1% and 43.5% at years 2 and 5, respectively. The demographics between these different cohorts were similar (eTable 2). These results suggest that while teleophthalmology enables earlier eye care access, likely by increasing same-day eye screening at the time of initial diagnosis, continued access to eye care after the first year occurs primarily through in-person encounters with eyecare providers.

4. Discussion

In this study of 968 846 patients with newly-diagnosed type 2 DM and at least one year of continuous enrollment in a national insurance claims database, we found that only a small proportion of patients with new-onset DM received an eye exam within 1 year of diagnosis [6,18,19]. These statistics fall short of the AAO and the American Diabetes Association guidelines which recommend a dilated eye examination at the time of newly diagnosing type 2 DM [3,20]. Lower adherence to screening guidelines have been reported in non-white populations, and patients from lower socioeconomic and education background, likely due to poor access to healthcare resources, lack of understanding of the importance of screening, and cultural and linguistic barriers.[6,21] For example, diabetic patients with a poverty-income ratio (PIR) of less than 1.50 were likely to undergo eye screening as compared to those with a PIR of 5.0 [22]. Patients with food or housing insecurity, as well as those with mental health concerns are also associated with lower likelihood of receiving eye care [23]. Health literacy is an additional barrier – only 42% of Blacks believed that annual diabetic eye exams are required [24], and only 36% had ever heard of diabetic retinopathy [25]. Patients who valued practitioner concordance were also less likely to pursue eye care [23]. These trends are especially alarming as these vulnerable populations are also prone to more severe retinopathy and higher risk of vision loss. Such disparities cannot be accounted for by a lack of health insurance as our data are taken from continuously-insured subjects. Instead, evidence suggests that public health education is necessary to promote adherence to DR screening guidelines. In our study, we found that women, older individuals, and Medicare Advantage beneficiaries were also less likely to utilize teleophthalmology, consistent with a prior report that showed lower reimbursements by Medicare Advantage plans which resulted in lower insurance coverage for these services among older individuals [15].

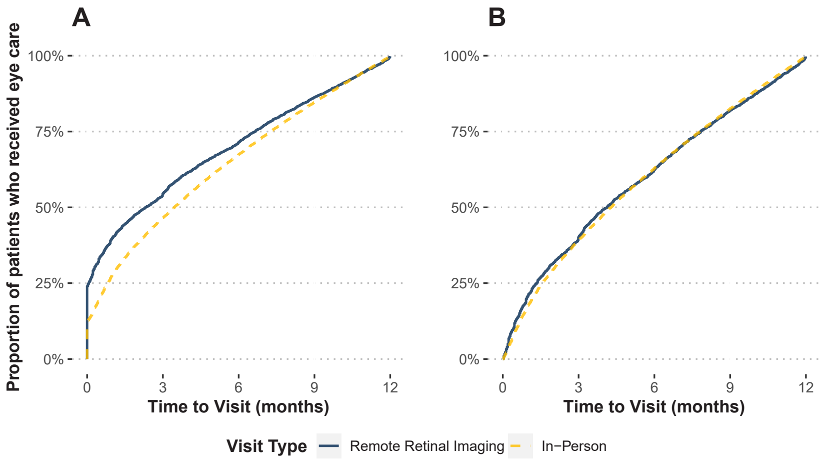

Fig. 1. Time to remote or in-person eye care among patients with newly-diagnosed type 2 diabetes mellitus.
Kaplan-Meier survival curves showing proportion of patients with newly-diagnosed type 2 diabetes mellitus, at least 1-year continuous enrollment, and underwent an eye exam by remote retinal imaging (solid line) or in-person visits to an eyecare provider (dashed line) within one year of diabetes diagnosis, **(A)** including or **(B)** excluding patients who received an initial diagnosis and eye care on the same day.

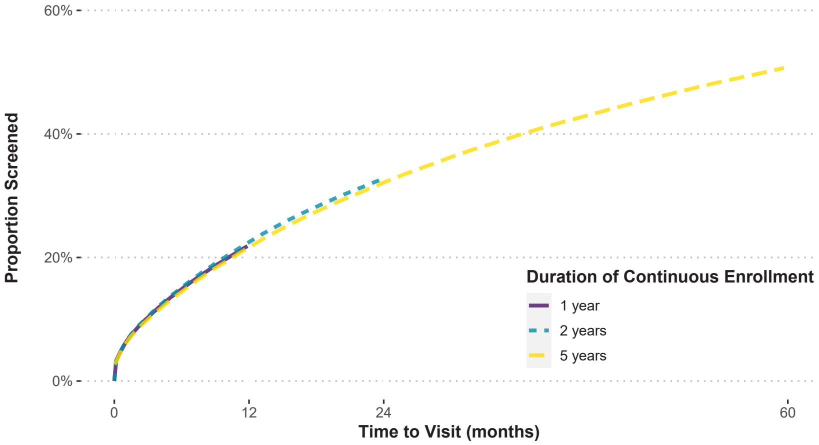

Fig. 2. Proportion of patients with type 2 diabetes mellitus who underwent eye screening.
Kaplan-Meier survival curve showing proportion of patients with newly-diagnosed type 2 diabetes mellitus and continuous enrollment for at least 1 year (solid blue line), 2 years (dashed green line), and 5 years (dashed yellow line). Each line separately represents the cohort with 1 year, 2 years, or 5 years of continuous enrollment.

Our study found that teleophthalmology enabled earlier access to eye care than conventional referral to an eyecare specialist, likely by facilitating same-day eye screening at the time of diagnosis. The availability of low cost, non-mydriatic cameras deployed in primary care settings allows DR screening to be performed during a single visit to an internist or general practitioner, overcoming the logistic barriers of scheduling a separate visit to an ophthalologist [26]. In our study, nearly one-third of remote retinal imaging appeared to be performed at the time of DM diagnosis. However, without the immediacy afforded by teleophthalmology (i.e. when same-day eye visits were excluded), the availability of remote imaging did not appear to provide any additional advantage in facilitating access. In fact, ophthalmic encounters after the first year of diagnosis occurred mostly through in-person visits, likely because the reason for these later presentations to eyecare specialists may no longer be related to DR screening. Interestingly, we found that 12.7% of in-person visits to eye providers also occurred on the index date of diagnosis, which was unexpectedly high. We hypothesize that some of these instances may indicate ophthalmologists or optometrists who made the initial diagnosis of DM from their eye exam, patients without DM who were inaccurately coded with this diagnosis, or those with pre-existing DM who were not appropriately encoded with the diagnosis prior to the index date. Our study included only patients who were continuously-enrolled for at least 1 year before the index date to minimize these scenarios and improve ascertainment of initial DM diagnosis. Together, our findings support the need to expand insurance coverage of teleophthalmology services as a means of low-cost preventive care that can expand and improve eye care access for patients who are diagnosed with type 2 DM.

Teleophthalmology has been shown to reduce healthcare costs, increase care access in underserved areas, and enhance DR screening among vulnerable individuals [8,15]. As most diabetic patients visit their primary care providers at least annually, screening performed in primary care clinics can improve screening rates and reduce barriers to care, especially in remote and rural regions. [8,27] Additionally, remote retinal screening can lead to earlier detection of DR and facilitate evaluation and treatment of potentially blinding disease. Despite the proven effectiveness of teleophthalmology screening programs, significant barriers to widespread implementation still exist and adoption of this technology has been slow. [28–31] Our data showed that rates of remote retinal screening did not increase from initial diagnosis to long-term follow-up, likely because a large proportion of the population lack access to telehealth services. Unavailability of equipment in primary care settings, inconsistent insurance coverage, as well as limited and unclear reimbursements models are among the main barriers suggested by previous groups [15,26,32]. For example, although the Centers for Medicare and Medicaid Services updates in 2021 revised the 92227 and 92228 billing codes to be distinguished based on health professional review rather than the presence of existing retinopathy [33], some Medicare contractors lag behind in updating their coverage policies [34]. And while the advent of automated DR detection using machine learning may circumvent bottlenecks and enhance scalability, the reimbursement landscape for these new technologies remain uncertain.

This study has several limitations. The OptumLabs Data Warehouse includes only commercially insured and Medicare Advantage enrollees, and thus may not be generalizable to markets with different payer mixes. By relying on claims data, our study may also miss exams performed outside of patients' insurance plans. We were also unable to study factors that could affect screening access, such as visual loss and ophthalmologic disease severity, because they are not routinely captured in billing data or unreliably encoded by providers [35,36]. While we employed a DM and eyecare-free interval of 1 year prior to the index date to define incident DM or eye care access, similar to published studies, longer look back periods may be needed to increase the accuracy of our patient selection [6,35]. To define remote retinal imaging, we employed CPT codes 92227 and 92228 which are generally used for asynchronous or "store-and-forward" teleophthalmology, which may not capture remote eye care using synchronous or live interfaces [36]. Also, because we included 92250 billed by non-eyecare providers only, ophthalmologists who bill 92250 for remote interpretation would be excluded, while non-ophthalmic physicians who interpret fundus photographs without forwarding to an eyecare provider could be inaccurately captured. Nevertheless, the trends we observed were consistent across both the 92227/92228 and 92250 cohorts, suggesting a lower probability of misclassification.

In summary, teleophthalmology using remote retinal imaging appears to enable earlier access to eye care among patients with newly-diagnosed type 2 DM, likely by enabling same-day screening at the time of diagnosis. Improved awareness and insurance coverage of teleophthalmology services may increase eye care access to enable earlier detection of diabetic retinopathy and prevent vision loss. Additional interventions may include efforts to improve health literacy, automate patient reminders, and enhance provider training in cultural competence and health disparities. Future research to identify perceived barriers to teleretinal eye screening from patients, physicians, and other stakeholders will be necessary to expand eye care access.

CRediT authorship contribution statement

Monica K. Lieng: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis. **Parisa Emami-Naeini:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Sophie C. Lee:** Writing – review & editing, Visualization, Investigation. **Susan Alber:** Writing – review & editing, Visualization, Investigation, Formal analysis. **Glenn Yiu:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Glenn Yiu reports financial support was provided by National Institutes of Health. Glenn Yiu reports financial support was provided by BrightFocus Foundation. Glenn Yiu reports financial support was provided by Macula Society. Glenn Yiu reports financial support was provided by University of California Office of the President. Susan Alber reports financial support was provided by National Institutes of Health. Glenn Yiu reports a relationship with AbbVie Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Adverum Biotechnologies Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Alimera Sciences Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Bausch & Lomb Americas Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Boehringer Ingelheim Corp USA that includes: consulting or advisory. Glenn Yiu reports a relationship with Carl Zeiss Meditec Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Clearside Biomedical Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Genentech Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Gyroscope Therapeutics that includes: consulting or advisory. Glenn Yiu reports a relationship with Gyroscope Therapeutics that includes: consulting or advisory. Glenn Yiu reports a relationship with Intergalactic Therapeutics Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with IRIDEX Corporation that includes: consulting or advisory. Glenn Yiu reports a relationship with Janssen Pharmaceuticals Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Myrobalan that includes: consulting or advisory. Glenn Yiu reports a relationship with NGM Biopharmaceuticals Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Novartis that includes: consulting or advisory. Glenn Yiu reports a relationship with Ray Therapeutics that includes: consulting or advisory. Glenn Yiu reports a relationship with Regeneron Pharmaceuticals Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with REGENXBIO Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Stealth BioTherapeutics Inc that includes: consulting or advisory. Glenn Yiu reports a relationship with Théa Pharma that includes: consulting or advisory. Glenn Yiu reports a relationship with Topcon Medical Systems Inc that includes: consulting or advisory. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e25845.

Dataset: OptumLabs® Data Warehouse (2011–2020) last accessed Sept 2021. Access available through annual research proposal calls from OptumLabs.

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