

Performance of ChatGPT in Diagnosis of Corneal Eye Diseases

Mohammad Delsoz¹, MD, Yeganeh Madadi¹, PhD, Wuqaas M Munir², MD, Brendan Tamm², MD, Shiva Mehravaran³, PhD, Mohammad Soleimani^{4,5}, MD, Ali Djalilian⁴, MD, and Siamak Yousefi^{1,6}

¹Hamilton Eye Institute, Department of Ophthalmology, University of Tennessee Health Science Center, Memphis, TN, USA

²Department of Ophthalmology and Visual Sciences, University of Maryland School of Medicine, Baltimore, MD, USA

³School of Computer, Mathematical, and Natural Sciences, Morgan State University, Baltimore, MD, USA

⁴Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, Illinois, USA

⁵Eye Research Center, Farabi Eye Hospital, Tehran University of Medical Sciences, Tehran, Iran

⁶Department of Genetics, Genomics, and Informatics, University of Tennessee Health Science Center, Memphis, TN, USA

Abbreviations:

LLM: Large Language Model

AI: Artificial Intelligence

ChatGPT: Chat Generative Pretrained Transformer

ICK: Infectious Crystalline Keratopathy

PPCD: Posterior Polymorphous Corneal Dystrophy

PBK: Pseudophakic Bullous Keratopathy

SND: Salzmann's Nodular Degeneration

IRB: Institutional Review Board

RLHF: Reinforcement Learning from Human Feedback

NLP: Natural Language Processing

FECD: Fuchs' Endothelial Corneal Dystrophy

MCD: Meesmann Corneal Dystrophy

CHED: Congenital Hereditary Endothelial Dystrophy

Correspondence to: Siamak Yousefi, 930 Madison Ave., Suite 471, Memphis, TN 38163, USA, Phone: 9014487831, Email: Siamak.Yousefi@uthsc.edu

Corresponding author hereby declare that this manuscript is not under simultaneous consideration for publication in another journal nor has it been published elsewhere.

43

ABSTRACT

44 **Introduction:** Assessing the capabilities of ChatGPT-4.0 and ChatGPT-3.5 for diagnosing
45 corneal eye diseases based on case reports and compare with human experts.

46 **Methods:** We randomly selected 20 cases of corneal diseases including corneal infections,
47 dystrophies, degenerations, and injuries from a publicly accessible online database from the
48 University of Iowa. We then input the text of each case description into ChatGPT-4.0 and
49 ChatGPT3.5 and asked for a provisional diagnosis. We finally evaluated the responses based on
50 the correct diagnoses then compared with the diagnoses of three cornea specialists (Human
51 experts) and evaluated interobserver agreements.

52 **Results:** The provisional diagnosis accuracy based on ChatGPT-4.0 was 85% (17 correct out of
53 20 cases) while the accuracy of ChatGPT-3.5 was 60% (12 correct cases out of 20). The accuracy
54 of three cornea specialists were 100% (20 cases), 90% (18 cases), and 90% (18 cases),
55 respectively. The interobserver agreement between ChatGPT-4.0 and ChatGPT-3.5 was 65%
56 (13 cases) while the interobserver agreement between ChatGPT-4.0 and three cornea specialists
57 were 85% (17 cases), 80% (16 cases), and 75% (15 cases), respectively. However, the
58 interobserver agreement between ChatGPT-3.5 and each of three cornea specialists was 60%
59 (12 cases).

60 **Conclusions:** The accuracy of ChatGPT-4.0 in diagnosing patients with various corneal
61 conditions was markedly improved than ChatGPT-3.5 and promising for potential clinical
62 integration.

63

64 **Keywords:** ChatGPT, Large Language Models (LLM), Generative Pre-trained Transformer
65 (GPT), Artificial Intelligence (AI), Corneal eye diseases, Provisional Diagnosis

66

67 **Key summary points:**

- 68 - The aim of this work was to evaluate the performance of ChatGPT-4 and ChatGPT-3.5 for
69 providing the provisional diagnosis of different corneal eye diseases based on case
70 descriptions and compared them with three cornea specialists.
- 71 - The accuracy of ChatGPT-4.0 in diagnosing patients with various corneal conditions was
72 significantly better than ChatGPT-3.5 based on the specific cases.
- 73 - The interobserver agreement between ChatGPT-4.0 and ChatGPT-3.5 was 65% while the
74 interobserver agreement between ChatGPT-4.0 and three cornea specialists were 85%,
75 80%, and 75%, respectively.

76

77 **INTRODUCTION**

78 The cornea is a clear, non-vascularized tissue that serves as a structural barrier, offering defense
79 against infections to the eye¹. Corneal eye diseases encompass a diverse range of conditions,
80 including but not limited to corneal infections, dystrophies, degenerations, and injuries².
81 Identifying corneal diseases can be challenging and time-consuming particularly when access to
82 specialized eye care provider is limited^{3,4}. Accurate and timely diagnosis of these conditions is
83 paramount to preserving visual acuity and ensuring optimal patient outcomes.

84

85 In recent years, the integration of artificial intelligence (AI) into various medical disciplines has
86 paved the way for innovative approaches to diagnosis and patient care⁵. Ophthalmology, one of
87 the most imaging intensive fields of medicine, has witnessed a significant transformation with the
88 emergence of AI-powered diagnostic tools⁶⁻⁸. However, AI applications in the anterior segment
89 parts of the eye including cornea⁹⁻¹² have received less attention compared to the AI applications
90 in posterior segment of the eye including retina.¹³⁻¹⁶

91 Among AI tools, ChatGPT, a cutting-edge large language model (LLM) developed by OpenAI
92 (San Francisco, California), has recently received attention, and holds great potential for
93 comprehending clinical expertise and delivering relevant information^{17,18}. ChatGPT employs deep
94 learning techniques to generate coherent and contextually relevant text based on user inputs¹⁹.
95 This AI-driven tool has shown remarkable capabilities in diverse domains since its inception²⁰⁻²²,
96 and its use in the field of ophthalmology is highly promising particularly in the landscape of
97 diagnostics^{20,23}.

98 This article explores the capabilities of ChatGPT-4.0 (commercially available version 4.0, updated
99 on March 13, 2023) and ChatGPT-3.5 (publicly available version 3.5, updated on August 3, 2022)

100 in diagnosing corneal eye diseases based on detailed case descriptions and comparing with
101 human experts. Gaining insight into the capacities and limitations of such tools can shape the
102 creation of enhanced systems for supporting the diagnoses in an automated way. This, in turn,
103 may enhance triaging as well as patient care for those with corneal eye diseases and mitigate the
104 demands for specialized ophthalmic services particularly in underserved regions.

105 **METHODS**

106 **Case Collection**

107 We selected a total of 20 cases with various corneal eye diseases from the openly available
108 database offered by the Department of Ophthalmology and Visual Sciences at the University of
109 Iowa (<https://webeye.ophth.uiowa.edu/eyeforum/cases.htm>). These 20 cases were selected from
110 over 200 cases which were categorized based on ophthalmic subspecialty. The underlying
111 corneal conditions included corneal infections, dystrophies, degenerations, and injuries including
112 Acanthamoeba keratitis, Acute corneal Hydrops, Atopic Keratoconjunctivitis, Calcific Band
113 Keratopathy, Cogan's syndrome, Corneal Marginal Ulcer, Cystinosis, Cytarabine induced
114 keratoconjunctivitis, Exposure Keratopathy, Fabry disease, Fuchs' Endothelial Corneal
115 Dystrophy, Herpes Simplex Viral (HSV) Keratitis, Infectious Crystalline Keratopathy (ICK), Lattice
116 corneal dystrophy type II (Meretoja's syndrome), Megalocornea, Peripheral Ulcerative Keratitis,
117 Posterior Polymorphous Corneal Dystrophy (PPCD), Pseudophakic Bullous Keratopathy (PBK),
118 Salzmann's Nodular Degeneration (SND), and Amiodarone-Induced Corneal Deposits (Corneal
119 Verticillata). Details of every case encompassed patient's demographics, chief complaint, present
120 illness, and major examination findings. Case reports that required specialized exam maneuvers
121 to establish the diagnosis (e.g., Fungal Keratitis-Fusarium) or case reports that are overly obvious
122 (e.g., Chemical Eye Injury) were excluded. Institutional review board (IRB) approval was not
123 required per the direction of our local IRB office as we used a publicly accessible dataset with no
124 patient's information in this analysis. This study was compliant to the tenets of the Helsinki
125 declaration and ethical aspects was approved by our local research ethics office.

126 **ChatGPT**

127 ChatGPT represents a derivation of the GPT (Generative Pre-trained Transformer) language
128 model tailored for producing text within conversational settings. Through extensive refinement on
129 substantial conversational datasets, it possesses the capability to produce pertinent and logically
130 connected responses in correspondence with provided input²⁴. ChatGPT-4.0 emerged as
131 OpenAI's most recent language model, embodying a substantial enhancement over its

132 forerunners. GPT-3 was initially trained based on about 176 billion parameters while GPT-4.0 is
133 trained based on approximately 1.75 trillion parameters²⁵. GPT-4.0 stands as an advanced
134 multimodal model that leverages diverse data formats to elevate its performance. As such,
135 ChatGPT possesses some level of computer vision-based image interpretation capabilities that
136 are however not yet appropriate for disease diagnosis²⁴.




137 **ChatGPT Diagnosis**

138 We input identical case descriptions into ChatGPT-4.0 and ChatGPT-3.5 and assessed whether
139 the model was able to provide the correct provisional diagnoses. Specifically, we asked: “What is
140 the most likely diagnosis?” (Fig. 1)

141 We then compared the accuracy of ChatGPT-4.0 and ChatGPT-3.5 with respect to the correct
142 diagnosis. Due to possible reinforcement learning from human feedback (RLHF) capabilities of
143 ChatGPT, we recorded and used the first answer of ChatGPT for the comparisons.

✦ GPT-4

D A 62-year-old woman presents with progressive loss of vision in both eyes. Over the last 3 years, there has been gradual, painless loss of vision in both eyes (right greater than left) at both distance and near. She has had 3 updates of her spectacle prescription that have not provided satisfactory vision. There is no diurnal variation in vision. She has a Past Ocular History of Myopia, presbyopia, and astigmatism. Ocular Exam showed:
Visual acuity (VA) with correction:
Right eye (OD): 20/200, pinhole to 20/50-1
Left eye (OS): 20/25+2, pinhole to 20/20
Manifest Refraction:
OD -2.00 + 5.00 × 20 VA 20/60
OS -0.75 + 7.50 × 165 VA 20/25
slit lamp examination of Cornea showed:
OD: Greyish nodules between the corneal epithelium and Bowman's layer in the paracentral superonasal region extending centrally into the visual axis; iron line at inferior border of the lesion
OS: Greyish nodules between the corneal epithelium and Bowman's layer in the paracentral superior and superotemporal regions extending centrally into the visual axis; iron line at inferior border of the lesion. what is most likely the diagnosis?

 Based on the clinical presentation, the most likely diagnosis for this 62-year-old woman is Salzmann's Nodular Degeneration (SND).  

Salzmann's Nodular Degeneration is a degenerative corneal condition that often presents bilaterally with raised greyish or bluish nodules located superficially between the corneal epithelium and Bowman's layer. These nodules can cause irregular astigmatism, which can lead to decreased vision that cannot be fully corrected with glasses or contact lenses. The presence of an iron line at the inferior border of the lesion is also consistent with SND.

The condition is typically found in older individuals and may be associated with prior ocular surface disease, inflammation, or surgery, although it can sometimes occur without any clear underlying cause.

Treatment can range from observation (if the nodules are not affecting vision) to surgical removal if they are causing significant visual impairment or discomfort. Corneal topography would likely show irregular astigmatism, and specular microscopy may be useful to assess the endothelium if surgery is being considered.

144

145 **Figure 1.** A sample case description input into the ChatGPT-4.0 model and corresponding responses.

146

147 **RESULTS**

148 A comprehensive assessment was conducted, utilizing 20 case presentations spanning various
149 corneal eye diseases, to appraise ChatGPT's proficiency in generating provisional diagnoses.
150 ChatGPT-4 made the correct diagnosis in 17 out of 20 cases (85%), while ChatGPT-3.5 correctly
151 diagnosed 12 out of 20 cases (60%). Moreover, the three cornea specialists made correct
152 diagnosis of 100% (20 cases), 90% (18 cases), and 90% (18 cases), respectively. The
153 Interobserver agreement between ChatGPT-4.0 and ChatGPT-3.5 was 13 out of 20 cases (65%)
154 while the interobserver agreement between ChatGPT-4.0 and three cornea specialists were 85%
155 (17 cases), 80% (16 cases), and 75% (15 cases), respectively. However, the interobserver
156 agreement between ChatGPT-3.5 and each of three cornea specialists was 60%. Table 1 shows
157 the details of the provisional diagnosis provided by ChatGPT-4.0, ChatGPT-3.5, and human
158 experts. It took approximately 20-40 minutes for the graders to diagnose 20 cases while it took
159 around a couple of minutes (each case around a few seconds) for ChatGPTs to complete
160 diagnosis.

161 **DISCUSSION**

162 We conducted a prospective study to examine the performance of ChatGPT-4.0 and ChatGPT-
163 3.5 based on 20 cases with different types of corneal eye diseases. The accuracy of ChatGPT-
164 4.0 was 85% while the accuracy of ChatGPT-3.5 was 60%. The interobserver agreement between
165 ChatGPT-4 and the ChatGPT-3.5 was reasonable (65%). We observed that compared to the
166 publicly available ChatGPT-3.5, ChatGPT-4.0, the commercial version, generate markedly
167 improved provisional diagnosis for different corneal eye diseases. These models may assist
168 healthcare providers in generating consistent and useful information regarding the underlying
169 corneal condition.

170 Some of the capabilities and limitations of ChatGPT in ophthalmology have been discussed
171 previously.²⁰ Recently, ChatGPT was investigated in responding to multiple choice questions from
172 the USMLE and it was observed that ChatGPT correctly responded to over 50% of questions and
173 also provided relevant supporting explanations for the selected choices.²¹ More relevant to our
174 study, a recent investigation showed that ChatGPT-3.0 correctly diagnosed 9 out of 10 general
175 ophthalmology case (90%).²⁶ Our accuracy was based on ChatGPT-3.5 was significantly lower
176 (60%) but our ChatGPT-v4.0 accuracy was comparable (85%). Nevertheless, that study assessed
177 general ophthalmology cases while we investigated various corneal conditions that inherently are
178 more challenging to diagnose.

179 Utilizing conversational AI language models such as ChatGPT could significantly assist frontline
180 healthcare professionals in delivering prompt and precise diagnoses to their patients. In near real-
181 time, such language models could assist primary care and emergency doctors in not only
182 assessing and treating patients but also directing patients to specialized care when required.

183 Successful integration of ChatGPT or similar LLMs into ophthalmology and cornea services may
184 offer multifaceted benefits. Firstly, ChatGPT's capability to quickly process large amounts of
185 medical data enhances diagnostic speed and efficiency, leading to quicker patient management
186 and consistent identification of underlying conditions. ChatGPT may transform medical education
187 as well. It could enable students and practitioners to generate interactive and case-based
188 learning materials to foster a deeper understanding of ophthalmic diseases²². Another benefit of
189 ChatGPT-based models is versatility in responding to various kinds of questions, rather than just
190 offering diagnosis based on input images or disease-related parameters. Indeed, ChatGPT was
191 not initially planned to respond to diagnostic support, however, its capability in learning from large
192 corpus has provided ChatGPT to even be applicable in narrowed and specialized areas of disease
193 diagnosis.

194 In addition to diagnostic capabilities and educational purposes, ChatGPT has the potential to be
195 used for patient education as well. For instance, ChatGPT, as a tool with natural language
196 processing (NLP) capabilities, can translate complex medical terms into simple and accessible
197 language leading to enhanced active patient participation. Collectively, these versatile capabilities
198 of ChatGPT makes it a potential tool that may enhance diagnostics, education, and patient
199 engagement.

200 Although ChatGPT-4.0 was relatively accurate in making a correct diagnosis on most of the
201 cases, we observed that human expert is more accurate on rare cases. For instance, both
202 ChatGPT versions were incorrect on two rare cases including ICK (case # 7, Table 1) and Lattice
203 Corneal Dystrophy Type II (case #11, Table 1), human experts were correct on both cases. As
204 such, the use of ChatGPT in real-world clinical practice should be considered with caution.

205 While ChatGPT presents remarkable advantages from several aspects, its potential limitations
206 should be acknowledged as well. The accuracy of ChatGPT lies on the quality and diversity of
207 the training data that it has been exposed to until September 2021²⁷. Therefore, the model may
208 encounter challenges when faced with rare or emerging corneal conditions that lack
209 representation in its training dataset. Additionally, ChatGPT's recommendations should always
210 be validated based on clinical evaluations, as its insights may be derived from non-scientific and
211 publicly available knowledge and historical cases. As such, ChatGPT may generate responses

212 that appear fluent and believable however it may contain factual inaccuracies, a phenomenon
213 often termed as hallucination²⁸.

214 Although our study is one of the first investigations of ChatGPT capabilities in diagnosing corneal
215 conditions, it has several limitations as well. First, we have used an online and publicly available
216 dataset to evaluate ChatGPT thus there is a concern that this database has been exposed to
217 ChatGPT previously. To address this concern, we reviewed the years that the cases were added
218 to this online database and noticed that case # 20 in Table 1 has been added in 2023 to this
219 database, that is after September 2021 that the latest ChatGPT training completed and both
220 ChatGPT versions were correct on this case. Additionally, both ChatGPT versions were incorrect
221 on numerous cases that have been added to this database prior to September 2021. Therefore,
222 the likelihood that ChatGPT has seen this online database is slight. Second, we have evaluated
223 ChatGPT based on 20 cases thus follow up studies are warranted to evaluate ChatGPT based
224 on larger number of cases to verify our findings. However, obtaining larger databases with a
225 greater number of case reports is highly challenging and requires larger multi-center and multi-
226 disciplinary collaborations. One major obstacle however is ethical considerations and data privacy
227 issues. The utilization of patient data for diagnostic purposes raises concerns about data security
228 and patient confidentiality. Therefore, rigorous safeguards and compliance with regulatory
229 standards are imperative to ensure responsible and ethical use of ChatGPT in cornea research
230 and clinical practice.

231 The integration of ChatGPT into the diagnosis of corneal eye diseases marks a significant
232 milestone in the evolution of ophthalmic practice. As AI continues to reshape healthcare,
233 ChatGPT's potential to enhance diagnostic accuracy, expedite patient care, empower medical
234 education, and stimulate research is evident. While challenges exist, a balanced approach that
235 combines AI-generated insights with clinical expertise holds the key to unlocking the full potential
236 of ChatGPT for the diagnosis of corneal conditions. As we peer into the future, the collaboration
237 between AI and ophthalmology promises to redefine the standards of care and elevate patient
238 outcomes in the realm of corneal eye diseases.

239 **CONCLUSION**

240 Corneal diseases encompass a diverse variety of conditions that could be challenging to
241 diagnose. We showed that the accuracy of ChatGPT-4.0 in diagnosing patients with various
242 corneal eye diseases is promising and such models may enhance corneal diagnostics.
243 Additionally, ChatGPT may improve patient interaction and experience as well as medical

244 education. A balanced approach that combines AI-generated insights with clinical findings holds
245 the promise to enhance eye care.

246

247 **ACKNOWLEDGEMENT**

248 **Author Contribution:**

249 Mohammad Delsoz: Research design, data acquisition and research execution, data analysis
250 and interpenetrations, manuscript preparation

251 Yeganeh Madadi: Research design

252 Wuqaas M Munir: Data interpretations and manuscript preparation

253 Brendan Tamm: Data interpretations

254 Shiva Mehravaran: Research design

255 Mohammad Soleimani: Data interpretations

256 Ali Djalilian: Research design

257 Siamak Yousefi: Research design, data analysis and interpenetrations, manuscript preparation

258

259 **Funding**

260 This work was supported by NIH Grants R01EY033005 (SY), R21EY031725 (SY), grants from
261 Research to Prevent Blindness (RPB), New York (SY), and supports from the Hamilton Eye
262 Institute (SY). The funders had no role in study design, data collection and analysis, decision to
263 publish, or preparation of the manuscript.

264

265 **Medical Writing/Editorial Assistance**

266 Not applicable.

267

268 **Data Availability**

269 Dataset is online and publicly available.

270

271 **Ethical Approval**

272 Institutional review board (IRB) approval was not required per the direction of our local IRB office
273 as we used a publicly accessible dataset with no patient's information in this analysis. This study
274 was compliant to the ethical tenets of the Helsinki declaration and was approved by our local
275 ethical team.

276

277 **Conflict of Interest**

278 Mohammad Delsoz: None.

279 Yeganeh Madadi: None

280 Wuqaas M Munir: None

281 Brendan Tamm: None

282 Shiva Mehravaran: None

283 Mohammad Soleimani: None

284 Ali Djalilian: None

285 Siamak Yousefi: Remidio, M&S Technologies, Visrtucal Fields, InsihgtAEye, Enolink

286

287

288

289 **Tables**

290 **Table 1.** Provisional diagnoses provided by ChatGPT-4.0, ChatGPT-3.5 and Human Experts

No	Corneal Eye diseases	ChatGPT4 Diagnosis	ChatGPT3.5 Diagnosis	Human Expert Diagnosis
1	Cystinosis	Cystinosis	Cystinosis	H1: Cystinosis H2: Cystinosis H3: Cystinosis
2	Fuchs' Endothelial Corneal Dystrophy (FECD)	FECD	FECD	H1: FECD H2: FECD H3: FECD
3	Pseudophakic Bullous Keratopathy (PBK)	PBK	Fuchs' Endothelial Corneal Dystrophy	H1: PBK H2: PBK H3: PBK
4	Amiodarone-Induced Corneal Deposits (Corneal Verticillata)	Amiodarone-Induced Corneal Deposits	Amiodarone-Induced Corneal Deposits	H1: Amiodarone-Induced Corneal Deposits H2: Amiodarone-Induced Corneal Deposits H3: Amiodarone-Induced Corneal Deposits
5	Acanthamoeba Keratitis	Acanthamoeba Keratitis	Acanthamoeba Keratitis	H1: Acanthamoeba Keratitis H2: Acanthamoeba Keratitis H3: Acanthamoeba Keratitis
6	Cogan's Syndrome (Interstitial Keratitis & Vertigo)	Scleritis	Ocular Rosacea	H1: Cogan's Syndrome H2: Episcleritis H3: Cogan's Syndrome
7	Infectious Crystalline Keratopathy (ICK)	Fungal Keratitis	Recurrent Herpes Simplex Virus Keratitis	H1: ICK H2: ICK H3: ICK
8	Megalocornea	Megalocornea	Positional Pseudophacodonesis	H1: Megalocornea H2: Megalocornea H3: Megalocornea
9	Herpes Simplex Viral Keratitis	Herpes Simplex Viral Keratitis	Herpes Simplex Viral Keratitis	H1: Herpes Simplex Viral Keratitis H2: Herpes Simplex Viral Keratitis H3: Herpes Simplex Viral Keratitis
10	Atopic Keratoconjunctivitis	Atopic Keratoconjunctivitis	Ocular Cicatricial Pemphigoid (OCP)	H1: Atopic Keratoconjunctivitis H2: Atopic Keratoconjunctivitis H3: OCP
11	Lattice Corneal Dystrophy Type II (Meretoja's syndrome)	Meesmann Corneal Dystrophy (MCD)	MCD	H1: Lattice Corneal Dystrophy Type II H2: Lattice Corneal Dystrophy Type II H3: Lattice Corneal Dystrophy Type II
12	Salzmann's Nodular Degeneration (SND)	SND	SND	H1: SND H2: SND H3: SND
13	Exposure Keratopathy	Exposure Keratopathy	Exposure Keratopathy	H1: Exposure Keratopathy H2: Exposure Keratopathy H3: Exposure Keratopathy
14	Peripheral Ulcerative Keratitis	Peripheral Ulcerative Keratitis	Peripheral Ulcerative Keratitis	H1: Peripheral Ulcerative Keratitis H2: Peripheral Ulcerative Keratitis H3: Peripheral Ulcerative Keratitis
15	Calcific Band Keratopathy	Calcific Band Keratopathy	Superficial Corneal Scar	H1: Calcific Band Keratopathy H2: Calcific Band Keratopathy H3: Calcific Band Keratopathy
16	Posterior Polymorphous Corneal Dystrophy (PPCD)	PPCD	Congenital Hereditary Endothelial Dystrophy (CHED)	H1: PPCD H2: Granular Corneal Dystrophy H3: PPCD
17	Acute Corneal Hydrops	Acute Corneal Hydrops	Acute Corneal Hydrops	H1: Acute Corneal Hydrops H2: Acute Corneal Hydrops H3: Acute Corneal Hydrops

18	Corneal Marginal Ulcer	Corneal Ulceration	Corneal Ulcer	H1: Corneal Marginal Ulcer H2: Corneal Marginal Ulcer H3: Mooren Ulcer
19	Fabry Disease	Fabry Disease	Fabry Disease	H1: Fabry Disease H2: Fabry Disease H3: Fabry Disease
20	Cytarabine Induced Keratoconjunctivitis	Cytarabine Induced Keratoconjunctivitis	Cytarabine Induced Keratoconjunctivitis	H1: Cytarabine Induced Keratoconjunctivitis H2: Cytarabine Induced Keratoconjunctivitis H3: Cytarabine Induced Keratoconjunctivitis

291

292 REFERENCES

- 293 1. Yang AY, Chow J, Liu J. Corneal Innervation and Sensation: The Eye and Beyond. *Yale*
294 *J Biol Med.* Mar 2018;91(1):13-21.
- 295 2. Clinic C. doi:<https://my.clevelandclinic.org/health/diseases/8586-corneal-disease>
- 296 3. Solomon SD, Shoge RY, Ervin AM, et al. Improving Access to Eye Care: A Systematic
297 Review of the Literature. *Ophthalmology.* Oct 2022;129(10):e114-e126.
298 doi:10.1016/j.ophtha.2022.07.012
- 299 4. Gelston CD, Patnaik JL. Ophthalmology training and competency levels in care of
300 patients with ophthalmic complaints in United States internal medicine, emergency medicine
301 and family medicine residents. *J Educ Eval Health Prof.* 2019;16:25.
302 doi:10.3352/jeehp.2019.16.25
- 303 5. Liu PR, Lu L, Zhang JY, Huo TT, Liu SX, Ye ZW. Application of Artificial Intelligence in
304 Medicine: An Overview. *Curr Med Sci.* Dec 2021;41(6):1105-1115. doi:10.1007/s11596-021-
305 2474-3
- 306 6. Ting DSJ, Foo VH, Yang LWY, et al. Artificial intelligence for anterior segment diseases:
307 Emerging applications in ophthalmology. *Br J Ophthalmol.* Feb 2021;105(2):158-168.
308 doi:10.1136/bjophthalmol-2019-315651
- 309 7. Wawer Matos PA, Reimer RP, Rokohl AC, Caldeira L, Heindl LM, Große Hokamp N.
310 Artificial Intelligence in Ophthalmology - Status Quo and Future Perspectives. *Semin*
311 *Ophthalmol.* Apr 2023;38(3):226-237. doi:10.1080/08820538.2022.2139625
- 312 8. Yousefi S. Clinical Applications of Artificial Intelligence in Glaucoma. *J Ophthalmic Vis*
313 *Res.* Jan-Mar 2023;18(1):97-112. doi:10.18502/jovr.v18i1.12730
- 314 9. Al-Timemy AH, Alzubaidi L, Mosa ZM, et al. A Deep Feature Fusion of Improved
315 Suspected Keratoconus Detection with Deep Learning. *Diagnostics (Basel).* May 10
316 2023;13(10)doi:10.3390/diagnostics13101689
- 317 10. Abdelmotaal H, Hazarbasanov R, Taneri S, et al. Detecting dry eye from ocular surface
318 videos based on deep learning. *The ocular surface.* Jan 26 2023;28:90-98.
319 doi:10.1016/j.jtos.2023.01.005
- 320 11. Yousefi S, Yousefi E, Takahashi H, et al. Keratoconus severity identification using
321 unsupervised machine learning. *PLoS One.* 2018;13(11):e0205998.
322 doi:10.1371/journal.pone.0205998
- 323 12. Kamiya K, Ayatsuka Y, Kato Y, et al. Keratoconus detection using deep learning of
324 colour-coded maps with anterior segment optical coherence tomography: a diagnostic accuracy
325 study. *BMJ Open.* Sep 27 2019;9(9):e031313. doi:10.1136/bmjopen-2019-031313

- 326 13. Gulshan V, Peng L, Coram M, et al. Development and Validation of a Deep Learning
327 Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. *JAMA*. Dec 13
328 2016;316(22):2402-2410. doi:10.1001/jama.2016.17216
- 329 14. Abramoff MD, Lou Y, Erginay A, et al. Improved Automated Detection of Diabetic
330 Retinopathy on a Publicly Available Dataset Through Integration of Deep Learning. *Invest*
331 *Ophthalmol Vis Sci*. Oct 1 2016;57(13):5200-5206. doi:10.1167/iovs.16-19964
- 332 15. Yousefi S, Elze T, Pasquale LR, et al. Monitoring Glaucomatous Functional Loss Using
333 an Artificial Intelligence-Enabled Dashboard. *Ophthalmology*. Sep 2020;127(9):1170-1178.
334 doi:10.1016/j.ophtha.2020.03.008
- 335 16. Thakur A, Goldbaum M, Yousefi S. Predicting Glaucoma before Onset Using Deep
336 Learning. *Ophthalmol Glaucoma*. Jul-Aug 2020;3(4):262-268. doi:10.1016/j.ogla.2020.04.012
- 337 17. Nath S, Marie A, Eilershaw S, Korot E, Keane PA. New meaning for NLP: the trials and
338 tribulations of natural language processing with GPT-3 in ophthalmology. *Br J Ophthalmol*. Jul
339 2022;106(7):889-892. doi:10.1136/bjophthalmol-2022-321141
- 340 18. Singhal K, Azizi S, Tu T, et al. Large language models encode clinical knowledge.
341 *Nature*. Aug 2023;620(7972):172-180. doi:10.1038/s41586-023-06291-2
- 342 19. Ramponi M. How ChatGPT actually works. *AssemblyAI*. Dec 23, 2022;
- 343 20. Antaki F, Touma S, Milad D, El-Khoury J, Duval R. Evaluating the Performance of
344 ChatGPT in Ophthalmology: An Analysis of Its Successes and Shortcomings. *Ophthalmol Sci*.
345 Dec 2023;3(4):100324. doi:10.1016/j.xops.2023.100324
- 346 21. Kung TH, Cheatham M, Medenilla A, et al. Performance of ChatGPT on USMLE:
347 Potential for AI-assisted medical education using large language models. *PLOS Digit Health*.
348 Feb 2023;2(2):e0000198. doi:10.1371/journal.pdig.0000198
- 349 22. Dave T, Athaluri SA, Singh S. ChatGPT in medicine: an overview of its applications,
350 advantages, limitations, future prospects, and ethical considerations. *Front Artif Intell*.
351 2023;6:1169595. doi:10.3389/frai.2023.1169595
- 352 23. Michael Balas EBI. Conversational AI Models for ophthalmic diagnosis: Comparison of
353 ChatGPT and the Isabel Pro Differential Diagnosis Generator. *JFO Open Ophthalmology*.
354 2023;doi:<https://doi.org/10.1016/j.jfop.2023.100005>
- 355 24. Ortiz S. What is ChatGPT and why does it matter? *ZDNET Tech*. Aug 2023;
- 356 25. Lubbad M. GPT-4 Parameters: Unlimited guide NLP's Game-Changer. March 2023;
- 357 26. Balas M, Ing EB. Conversational AI Models for ophthalmic diagnosis: Comparison of
358 ChatGPT and the Isabel Pro Differential Diagnosis Generator. *JFO Open Ophthalmology*.
359 2023/03/01/ 2023;1:100005. doi:<https://doi.org/10.1016/j.jfop.2023.100005>
- 360 27. Jungwirth D, Haluza D. Artificial Intelligence and Public Health: An Exploratory Study. *Int*
361 *J Environ Res Public Health*. Mar 3 2023;20(5)doi:10.3390/ijerph20054541
- 362 28. Ji Z, Lee N, Frieske R, et al. Survey of hallucination in natural language generation.
363 *ACM Computing Surveys*. 2023;55(12):1-38.
- 364
- 365
- 366
- 367
- 368