

Artificial Intelligence: Implications for Healthcare Practice, Research, and Education

William Hersh, MD

Professor

Division of Informatics, Clinical Epidemiology, and Translational Data Science

Department of Medicine

School of Medicine

Oregon Health & Science University

Portland, OR, USA

Email: hersh@ohsu.edu

Web: <https://billhersh.info/>

BlueSky: [@billhersh.bsky.social](https://bsky.app/profile/billhersh.bsky.social)

References

- Ali, S.R., Dobbs, T.D., Hutchings, H.A., Whitaker, I.S., 2023. Using ChatGPT to write patient clinic letters. *Lancet Digit Health* 5, e179–e181. [https://doi.org/10.1016/S2589-7500\(23\)00048-1](https://doi.org/10.1016/S2589-7500(23)00048-1)
- Artificial intelligence, 2025. . Wikipedia.
- Arvidsson, R., Gunnarsson, R., Entezarjou, A., Sundemo, D., Wikberg, C., 2024. ChatGPT (GPT-4) versus doctors on complex cases of the Swedish family medicine specialist examination: an observational comparative study. *BMJ Open* 14, e086148. <https://doi.org/10.1136/bmjopen-2024-086148>
- Attia, Z.I., Friedman, P.A., Noseworthy, P.A., Lopez-Jimenez, F., Ladewig, D.J., Satam, G., Pellikka, P.A., Munger, T.M., Asirvatham, S.J., Scott, C.G., Carter, R.E., Kapa, S., 2019. Age and Sex Estimation Using Artificial Intelligence From Standard 12-Lead ECGs. *Circ Arrhythm Electrophysiol* 12, e007284. <https://doi.org/10.1161/CIRCEP.119.007284>
- Avramovic, S., Avramovic, I., Wojtusiak, J., 2024. Exploring the Impact of GitHub Copilot on Health Informatics Education. *Appl Clin Inform* 15, 1121–1129. <https://doi.org/10.1055/a-2414-7790>
- Ayers, J.W., Poliak, A., Dredze, M., Leas, E.C., Zhu, Z., Kelley, J.B., Faix, D.J., Goodman, A.M., Longhurst, C.A., Hogarth, M., Smith, D.M., 2023a. Comparing Physician and Artificial Intelligence Chatbot Responses to Patient Questions Posted to a Public Social Media Forum. *JAMA Intern Med* 183, 589–596. <https://doi.org/10.1001/jamainternmed.2023.1838>
- Ayers, J.W., Zhu, Z., Poliak, A., Leas, E.C., Dredze, M., Hogarth, M., Smith, D.M., 2023b. Evaluating Artificial Intelligence Responses to Public Health Questions. *JAMA Netw Open* 6, e2317517. <https://doi.org/10.1001/jamanetworkopen.2023.17517>
- Ball, P., 2023. Is AI leading to a reproducibility crisis in science? *Nature* 624, 22–25. <https://doi.org/10.1038/d41586-023-03817-6>
- Baxter, S.L., Longhurst, C.A., Millen, M., Sitapati, A.M., Tai-Seale, M., 2024. Generative artificial intelligence responses to patient messages in the electronic health record: early lessons learned. *JAMIA Open* 7, ooae028. <https://doi.org/10.1093/jamiaopen/ooae028>

- Bensoussan, Y., Elemento, O., Rameau, A., 2024. Voice as an AI Biomarker of Health-Introducing Audiomics. *JAMA Otolaryngol Head Neck Surg* 150, 283–284. <https://doi.org/10.1001/jamaoto.2023.4807>
- Cabral, S., Restrepo, D., Kanjee, Z., Wilson, P., Crowe, B., Abdunour, R.-E., Rodman, A., 2024. Clinical Reasoning of a Generative Artificial Intelligence Model Compared With Physicians. *JAMA Intern Med.* <https://doi.org/10.1001/jamainternmed.2024.0295>
- Chen, A., Chen, D.O., Tian, L., 2023. Benchmarking the symptom-checking capabilities of ChatGPT for a broad range of diseases. *J Am Med Inform Assoc* ocad245. <https://doi.org/10.1093/jamia/ocad245>
- Cheng, L., Li, X., Bing, L., 2023. Is GPT-4 a Good Data Analyst?, in: Bouamor, H., Pino, J., Bali, K. (Eds.), *Findings of the Association for Computational Linguistics: EMNLP 2023*. Presented at the Findings 2023, Association for Computational Linguistics, Singapore, pp. 9496–9514. <https://doi.org/10.18653/v1/2023.findings-emnlp.637>
- Chin, M.H., Afsar-Manesh, N., Bierman, A.S., Chang, C., Colón-Rodríguez, C.J., Dullabh, P., Duran, D.G., Fair, M., Hernandez-Boussard, T., Hightower, M., Jain, A., Jordan, W.B., Konya, S., Moore, R.H., Moore, T.T., Rodriguez, R., Shaheen, G., Snyder, L.P., Srinivasan, M., Umscheid, C.A., Ohno-Machado, L., 2023. Guiding Principles to Address the Impact of Algorithm Bias on Racial and Ethnic Disparities in Health and Health Care. *JAMA Netw Open* 6, e2345050. <https://doi.org/10.1001/jamanetworkopen.2023.45050>
- Choi, J.H., Monahan, A., Schwarcz, D., 2023. Lawyering in the Age of Artificial Intelligence. <https://doi.org/10.2139/ssrn.4626276>
- Cooper, A., Rodman, A., 2023. AI and Medical Education — A 21st-Century Pandora’s Box. *New England Journal of Medicine.* <https://doi.org/10.1056/NEJMp2304993>
- Coyner, A.S., Singh, P., Brown, J.M., Ostmo, S., Chan, R.V.P., Chiang, M.F., Kalpathy-Cramer, J., Campbell, J.P., Imaging and Informatics in Retinopathy of Prematurity Consortium, 2023. Association of Biomarker-Based Artificial Intelligence With Risk of Racial Bias in Retinal Images. *JAMA Ophthalmol* 141, 543–552. <https://doi.org/10.1001/jamaophthalmol.2023.1310>
- Decker, H., Trang, K., Ramirez, J., Colley, A., Pierce, L., Coleman, M., Bongiovanni, T., Melton, G.B., Wick, E., 2023. Large Language Model-Based Chatbot vs Surgeon-Generated Informed Consent Documentation for Common Procedures. *JAMA Netw Open* 6, e2336997. <https://doi.org/10.1001/jamanetworkopen.2023.36997>
- Dell’Acqua, F., McFowland, E., Mollick, E.R., Lifshitz-Assaf, H., Kellogg, K., Rajendran, S., Krayner, L., Candelon, F., Lakhani, K.R., 2023. Navigating the Jagged Technological Frontier: Field Experimental Evidence of the Effects of AI on Knowledge Worker Productivity and Quality. <https://doi.org/10.2139/ssrn.4573321>
- Denny, P., Prather, J., Becker, B.A., Finnie-Ansley, J., Hellas, A., Leinonen, J., Luxton-Reilly, A., Reeves, B.N., Santos, E.A., Sarsa, S., 2024. Computing Education in the Era of Generative AI. *Commun. ACM* 67, 56–67. <https://doi.org/10.1145/3624720>
- Desaire, H., Chua, A.E., Isom, M., Jarosova, R., Hua, D., 2023. Distinguishing academic science writing from humans or ChatGPT with over 99% accuracy using off-the-shelf machine learning tools. *Cell Rep Phys Sci* 4, 101426. <https://doi.org/10.1016/j.xcrp.2023.101426>
- Dhingra, L.S., Aminorroaya, A., Sangha, V., Pedroso, A.F., Asselbergs, F.W., Brant, L.C.C., Barreto, S.M., Ribeiro, A.L.P., Krumholz, H.M., Oikonomou, E.K., Khera, R., 2025. Heart failure risk stratification using artificial intelligence applied to electrocardiogram images: a multinational study. *Eur Heart J* ehae914. <https://doi.org/10.1093/eurheartj/ehae914>

Dratsch, T., Chen, X., Rezazade Mehrizi, M., Kloeckner, R., Mähringer-Kunz, A., Püsken, M., Baeßler, B., Sauer, S., Maintz, D., Pinto Dos Santos, D., 2023. Automation Bias in Mammography: The Impact of Artificial Intelligence BI-RADS Suggestions on Reader Performance. *Radiology* 307, e222176. <https://doi.org/10.1148/radiol.222176>

Dubey, A., Jauhri, A., Pandey, A., Kadian, A., Al-Dahle, A., Letman, A., Mathur, A., Schelten, A., Yang, Amy, Fan, A., Goyal, A., Hartshorn, A., Yang, Aobo, Mitra, A., Sravankumar, A., Korenev, A., Hinsvark, A., Rao, A., Zhang, A., Rodriguez, A., Gregerson, A., Spataru, A., Roziere, B., Biron, B., Tang, B., Chern, B., Caucheteux, C., Nayak, C., Bi, C., Marra, C., McConnell, C., Keller, C., Touret, C., Wu, C., Wong, C., Ferrer, C.C., Nikolaidis, C., Allonsius, D., Song, D., Pintz, D., Livshits, D., Esiobu, D., Choudhary, D., Mahajan, D., Garcia-Olano, D., Perino, D., Hupkes, D., Lakomkin, E., AlBadawy, E., Lobanova, E., Dinan, E., Smith, E.M., Radenovic, F., Zhang, F., Synnaeve, G., Lee, G., Anderson, G.L., Nail, G., Mialon, G., Pang, G., Cucurell, G., Nguyen, H., Korevaar, H., Xu, H., Touvron, H., Zarov, I., Ibarra, I.A., Kloumann, I., Misra, I., Evtimov, I., Copet, J., Lee, Jaewon, Geffert, J., Vranes, J., Park, Jason, Mahadeokar, J., Shah, J., van der Linde, J., Billock, J., Hong, J., Lee, Jenya, Fu, J., Chi, J., Huang, J., Liu, J., Wang, Jie, Yu, J., Bitton, J., Spisak, J., Park, Jongsoo, Rocca, J., Johnstun, J., Saxe, J., Jia, J., Alwala, K.V., Upasani, K., Plawiak, K., Li, Ke, Heafield, K., Stone, K., El-Arini, K., Iyer, K., Malik, K., Chiu, K., Bhalla, K., Rantala-Yeary, L., van der Maaten, L., Chen, Lawrence, Tan, L., Jenkins, L., Martin, L., Madaan, L., Malo, L., Blecher, L., Landzaat, L., de Oliveira, L., Muzzi, M., Pasupuleti, M., Singh, M., Paluri, M., Kardas, M., Oldham, M., Rita, M., Pavlova, M., Kambadur, M., Lewis, M., Si, M., Singh, M.K., Hassan, M., Goyal, N., Torabi, N., Bashlykov, N., Bogoychev, N., Chatterji, N., Duchenne, O., Çelebi, O., Alrassy, P., Zhang, P., Li, P., Vasic, P., Weng, P., Bhargava, P., Dubal, P., Krishnan, P., Koura, P.S., Xu, P., He, Q., Dong, Q., Srinivasan, R., Ganapathy, R., Calderer, R., Cabral, R.S., Stojnic, R., Raileanu, R., Girdhar, R., Patel, R., Sauvestre, R., Polidoro, R., Sumbaly, R., Taylor, R., Silva, R., Hou, R., Wang, Rui, Hosseini, S., Chennabasappa, S., Singh, S., Bell, S., Kim, S.S., Edunov, S., Nie, S., Narang, S., Raparthy, S., Shen, S., Wan, S., Bhosale, S., Zhang, Shun, Vandenheide, S., Batra, S., Whitman, S., Sootla, S., Collot, S., Gururangan, S., Borodinsky, S., Herman, T., Fowler, T., Sheasha, T., Georgiou, T., Scialom, T., Speckbacher, T., Mihaylov, T., Xiao, T., Karn, U., Goswami, V., Gupta, V., Ramanathan, V., Kerkez, V., Gonguet, V., Do, V., Vogeti, V., Petrovic, V., Chu, W., Xiong, W., Fu, W., Meers, W., Martinet, X., Wang, Xiaodong, Tan, X.E., Xie, X., Jia, X., Wang, Xuwei, Goldschlag, Y., Gaur, Y., Babaei, Y., Wen, Y., Song, Y., Zhang, Yuchen, Li, Yue, Mao, Y., Coudert, Z.D., Yan, Z., Chen, Z., Papakipos, Z., Singh, A., Grattafiori, A., Jain, A., Kelsey, A., Shajnfeld, A., Gangidi, A., Victoria, A., Goldstand, A., Menon, A., Sharma, A., Boesenberg, A., Vaughan, A., Baevski, A., Feinstein, A., Kallet, A., Sangani, A., Yunus, A., Lupu, A., Alvarado, A., Caples, A., Gu, A., Ho, A., Poulton, A., Ryan, A., Ramchandani, A., Franco, A., Saraf, A., Chowdhury, A., Gabriel, A., Bharambe, A., Eisenman, A., Yazdan, A., James, B., Maurer, B., Leonhardi, B., Huang, B., Loyd, B., De Paola, B., Paranjape, B., Liu, B., Wu, B., Ni, B., Hancock, B., Wasti, B., Spence, B., Stojkovic, B., Gamido, B., Montalvo, B., Parker, C., Burton, C., Mejia, C., Wang, C., Kim, C., Zhou, C., Hu, C., Chu, C.-H., Cai, C., Tindal, C., Feichtenhofer, C., Civin, D., Beaty, D., Kreymer, D., Li, D., Wyatt, D., Adkins, D., Xu, D., Testuggine, D., David, D., Parikh, D., Liskovich, D., Foss, D., Wang, D., Le, D., Holland, D., Dowling, E., Jamil, E., Montgomery, E., Presani, E., Hahn, E., Wood, E., Brinkman, E., Arcaute, E., Dunbar, E.,

- Smothers, E., Sun, F., Kreuk, F., Tian, F., Ozgenel, F., Caggioni, F., Guzmán, F., Kanayet, F., Seide, F., Florez, G.M., Schwarz, G., Badeer, G., Swee, G., Halpern, G., Thattai, G., Herman, G., Sizov, G., Guangyi, Zhang, Lakshminarayanan, G., Shojanazeri, H., Zou, H., Wang, H., Zha, H., Habeeb, H., Rudolph, H., Suk, H., Aspegren, H., Goldman, H., Damlaj, I., Molybog, I., Tufanov, I., Veliche, I.-E., Gat, I., Weissman, J., Geboski, J., Kohli, J., Asher, J., Gaya, J.-B., Marcus, J., Tang, J., Chan, J., Zhen, J., Reizenstein, J., Teboul, J., Zhong, J., Jin, J., Yang, J., Cummings, J., Carvill, J., Shepard, J., McPhie, J., Torres, J., Ginsburg, J., Wang, Junjie, Wu, K., U, K.H., Saxena, K., Prasad, K., Khandelwal, K., Zand, K., Matosich, K., Veeraraghavan, K., Michelena, K., Li, Keqian, Huang, Kun, Chawla, K., Lakhotia, K., Huang, Kyle, Chen, Lailin, Garg, L., A, L., Silva, L., Bell, L., Zhang, L., Guo, L., Yu, L., Moshkovich, L., Wehrstedt, L., Khabisa, M., Avalani, M., Bhatt, M., Tsimpoukelli, M., Mankus, M., Hasson, M., Lennie, M., Reso, M., Groshev, M., Naumov, M., Lathi, M., Keneally, M., Seltzer, M.L., Valko, M., Restrepo, M., Patel, M., Vyatskov, M., Samvelyan, M., Clark, M., Macey, M., Wang, M., Hermoso, M.J., Metanat, M., Rastegari, M., Bansal, M., Santhanam, N., Parks, N., White, N., Bawa, N., Singhal, N., Egebo, N., Usunier, N., Laptev, N.P., Dong, N., Zhang, N., Cheng, N., Chernoguz, O., Hart, O., Salpekar, O., Kalinli, O., Kent, P., Parekh, P., Saab, P., Balaji, P., Rittner, P., Bontrager, P., Roux, P., Dollar, P., Zvyagina, P., Ratanchandani, P., Yuvraj, P., Liang, Q., Alao, R., Rodriguez, R., Ayub, R., Murthy, R., Nayani, R., Mitra, R., Li, R., Hogan, R., Battey, R., Wang, Rocky, Maheswari, R., Howes, R., Rinott, R., Bondu, S.J., Datta, S., Chugh, S., Hunt, S., Dhillon, S., Sidorov, S., Pan, S., Verma, S., Yamamoto, S., Ramaswamy, S., Lindsay, S., Lindsay, S., Feng, S., Lin, S., Zha, S.C., Shankar, S., Zhang, Shuqiang, Zhang, Shuqiang, Wang, S., Agarwal, S., Sajuyigbe, S., Chintala, S., Max, S., Chen, S., Kehoe, S., Satterfield, S., Govindaprasad, S., Gupta, S., Cho, S., Virk, S., Subramanian, S., Choudhury, S., Goldman, S., Remez, T., Glaser, T., Best, T., Kohler, T., Robinson, T., Li, T., Zhang, T., Matthews, T., Chou, T., Shaked, T., Vontimitta, V., Ajayi, V., Montanez, V., Mohan, V., Kumar, V.S., Mangla, V., Albiero, V., Ionescu, V., Poenaru, V., Mihailescu, V.T., Ivanov, V., Li, W., Wang, W., Jiang, W., Bouaziz, W., Constable, W., Tang, X., Wang, Xiaofang, Wu, Xiaojian, Wang, Xiaolan, Xia, X., Wu, Xilun, Gao, X., Chen, Y., Hu, Y., Jia, Y., Qi, Y., Li, Yenda, Zhang, Yilin, Zhang, Ying, Adi, Y., Nam, Y., Yu, Wang, Hao, Y., Qian, Y., He, Y., Rait, Z., DeVito, Z., Rosnbrick, Z., Wen, Z., Yang, Z., Zhao, Z., 2024. The Llama 3 Herd of Models. <https://doi.org/10.48550/arXiv.2407.21783>
- Duggan, M.J., Gervase, J., Schoenbaum, A., Hanson, W., Howell, J.T., Sheinberg, M., Johnson, K.B., 2025. Clinician Experiences With Ambient Scribe Technology to Assist With Documentation Burden and Efficiency. *JAMA Netw Open* 8, e2460637. <https://doi.org/10.1001/jamanetworkopen.2024.60637>
- Edwards, C., 2024. Teaching Transformed. *Commun. ACM* 67, 12–13. <https://doi.org/10.1145/3637208>
- Finlayson, S.G., Subbaswamy, A., Singh, K., Bowers, J., Kupke, A., Zittrain, J., Kohane, I.S., Saria, S., 2021. The Clinician and Dataset Shift in Artificial Intelligence. *N Engl J Med* 385, 283–286. <https://doi.org/10.1056/NEJMc2104626>
- Gao, Y., Xiong, Y., Gao, X., Jia, K., Pan, J., Bi, Y., Dai, Y., Sun, J., Wang, M., Wang, H., 2024. Retrieval-Augmented Generation for Large Language Models: A Survey. <https://doi.org/10.48550/arXiv.2312.10997>
- Gichoya, J.W., Banerjee, I., Bhimireddy, A.R., Burns, J.L., Celi, L.A., Chen, L.-C., Correa, R., Dullerud, N., Ghassemi, M., Huang, S.-C., Kuo, P.-C., Lungren, M.P., Palmer, L.J., Price,

- B.J., Purkayastha, S., Pyrros, A.T., Oakden-Rayner, L., Okechukwu, C., Seyyed-Kalantari, L., Trivedi, H., Wang, R., Zaiman, Z., Zhang, H., 2022. AI recognition of patient race in medical imaging: a modelling study. *Lancet Digit Health* 4, e406–e414. [https://doi.org/10.1016/S2589-7500\(22\)00063-2](https://doi.org/10.1016/S2589-7500(22)00063-2)
- Goh, E., Gallo, R., Hom, J., Strong, E., Weng, Y., Kerman, H., Cool, J.A., Kanjee, Z., Parsons, A.S., Ahuja, N., Horvitz, E., Yang, D., Milstein, A., Olson, A.P.J., Rodman, A., Chen, J.H., 2024. Large Language Model Influence on Diagnostic Reasoning: A Randomized Clinical Trial. *JAMA Netw Open* 7, e2440969. <https://doi.org/10.1001/jamanetworkopen.2024.40969>
- Gorecki, G.-P., Tomescu, D.-R., Pleş, L., Panaitescu, A.-M., Dragosloveanu, Şerban, Scheau, C., Sima, R.-M., Coman, I.-S., Grigorean, V.-T., Cochior, D., 2024. Implications of using artificial intelligence in the diagnosis of sepsis/sepsis shock. *Germs* 14, 77–84. <https://doi.org/10.18683/germs.2024.1419>
- Gupta, D., Demner-Fushman, D., Hersh, W., Bedrick, S., Roberts, K., 2024. Overview of TREC 2024 Biomedical Generative Retrieval (BioGen) Track. <https://doi.org/10.48550/arXiv.2411.18069>
- Hagen, L., 2025. Elon Musk’s AI chatbot, Grok, started calling itself “MechaHitler.” NPR.
- Hersh, W., 2024. Search still matters: information retrieval in the era of generative AI. *J Am Med Inform Assoc* 31, 2159–2161. <https://doi.org/10.1093/jamia/ocae014>
- Hersh, W., 2023. Physician and Medical Student Competence in AI Must Include Broader Competence in Clinical Informatics. *Informatics Professor*. URL <https://informaticsprofessor.blogspot.com/2023/09/physician-and-medical-student.html> (accessed 9.15.23).
- Hersh, W., Ehrenfeld, J., 2020. Clinical Informatics, in: *Health Systems Science*, 2nd Edition. Elsevier, pp. 156–170.
- Hersh, W., Fultz Hollis, K., 2024. Results and implications for generative AI in a large introductory biomedical and health informatics course. *NPJ Digit Med* 7, 247. <https://doi.org/10.1038/s41746-024-01251-0>
- Hersh, W.R., Gorman, P.N., Biagioli, F.E., Mohan, V., Gold, J.A., Mejicano, G.C., 2014. Beyond information retrieval and electronic health record use: competencies in clinical informatics for medical education. *Adv Med Educ Pract* 5, 205–212. <https://doi.org/10.2147/AMEP.S63903>
- Hinton, G.E., Osindero, S., Teh, Y.-W., 2006. A fast learning algorithm for deep belief nets. *Neural Comput* 18, 1527–1554. <https://doi.org/10.1162/neco.2006.18.7.1527>
- Holmstrom, L., Christensen, M., Yuan, N., Weston Hughes, J., Theurer, J., Jujjavarapu, M., Fatehi, P., Kwan, A., Sandhu, R.K., Ebinger, J., Cheng, S., Zou, J., Chugh, S.S., Ouyang, D., 2023. Deep learning-based electrocardiographic screening for chronic kidney disease. *Commun Med (Lond)* 3, 73. <https://doi.org/10.1038/s43856-023-00278-w>
- Hong, S., Lin, Y., Liu, Bang, Liu, Bangbang, Wu, B., Li, D., Chen, J., Zhang, J., Wang, J., Zhang, Li, Zhang, Lingyao, Yang, M., Zhuge, M., Guo, T., Zhou, T., Tao, W., Wang, W., Tang, X., Lu, X., Zheng, X., Liang, X., Fei, Y., Cheng, Y., Xu, Z., Wu, C., 2024. Data Interpreter: An LLM Agent For Data Science. <https://doi.org/10.48550/arXiv.2402.18679>
- Horvitz, E., Nori, H., Usuyama, N., 2024. Run-time strategies in foundation models: from Medprompt to OpenAI o1-preview. *Microsoft Research*. URL <https://www.microsoft.com/en-us/research/blog/advances-in-run-time-strategies-for-next-generation-foundation-models/> (accessed 12.2.24).

- Huang, J., Neill, L., Wittbrodt, M., Melnick, D., Klug, M., Thompson, M., Bailitz, J., Loftus, T., Malik, S., Phull, A., Weston, V., Heller, J.A., Etemadi, M., 2023. Generative Artificial Intelligence for Chest Radiograph Interpretation in the Emergency Department. *JAMA Netw Open* 6, e2336100. <https://doi.org/10.1001/jamanetworkopen.2023.36100>
- Idrisoglu, A., Dallora, A.L., Anderberg, P., Berglund, J.S., 2023. Applied Machine Learning Techniques to Diagnose Voice-Affecting Conditions and Disorders: Systematic Literature Review. *J Med Internet Res* 25, e46105. <https://doi.org/10.2196/46105>
- James, C.A., Wachter, R.M., Woolliscroft, J.O., 2022. Preparing Clinicians for a Clinical World Influenced by Artificial Intelligence. *JAMA* 327, 1333–1334. <https://doi.org/10.1001/jama.2022.3580>
- Johnson, M., 2024. Generative AI and CS Education. *Commun. ACM* 67, 23–24. <https://doi.org/10.1145/3632523>
- Johri, S., Jeong, J., Tran, B.A., Schlessinger, D.I., Wongvibulsin, S., Barnes, L.A., Zhou, H.-Y., Cai, Z.R., Van Allen, E.M., Kim, D., Daneshjou, R., Rajpurkar, P., 2025. An evaluation framework for clinical use of large language models in patient interaction tasks. *Nat Med*. <https://doi.org/10.1038/s41591-024-03328-5>
- Jumper, J., Evans, R., Pritzel, A., Green, T., Figurnov, M., Ronneberger, O., Tunyasuvunakool, K., Bates, R., Židek, A., Potapenko, A., Bridgland, A., Meyer, C., Kohl, S.A.A., Ballard, A.J., Cowie, A., Romera-Paredes, B., Nikolov, S., Jain, R., Adler, J., Back, T., Petersen, S., Reiman, D., Clancy, E., Zielinski, M., Steinegger, M., Pacholska, M., Berghammer, T., Bodenstein, S., Silver, D., Vinyals, O., Senior, A.W., Kavukcuoglu, K., Kohli, P., Hassabis, D., 2021. Highly accurate protein structure prediction with AlphaFold. *Nature* 596, 583–589. <https://doi.org/10.1038/s41586-021-03819-2>
- Kanjee, Z., Crowe, B., Rodman, A., 2023. Accuracy of a Generative Artificial Intelligence Model in a Complex Diagnostic Challenge. *JAMA* 330, 78–80. <https://doi.org/10.1001/jama.2023.8288>
- Kapoor, S., Narayanan, A., 2023. Leakage and the reproducibility crisis in machine-learning-based science. *Patterns (N Y)* 4, 100804. <https://doi.org/10.1016/j.patter.2023.100804>
- Katz, U., Cohen, E., Shachar, E., Somer, J., Fink, A., Morse, E., Shreiber, B., Wolf, I., 2024. GPT versus Resident Physicians — A Benchmark Based on Official Board Scores. *NEJM AI* 0, AIdbp2300192. <https://doi.org/10.1056/AIdbp2300192>
- Kimothi, A., 2025. A Simple Guide to Retrieval Augmented Generation.
- King, M., 2023. How Search Generative Experience works and why retrieval-augmented generation is our future [WWW Document]. Search Engine Land. URL <https://searchengineland.com/how-search-generative-experience-works-and-why-retrieval-augmented-generation-is-our-future-433393> (accessed 12.10.23).
- Koopman, B., Zuccon, G., 2023. Dr ChatGPT tell me what I want to hear: How different prompts impact health answer correctness, in: Bouamor, H., Pino, J., Bali, K. (Eds.), *Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing*. Presented at the EMNLP 2023, Association for Computational Linguistics, Singapore, pp. 15012–15022. <https://doi.org/10.18653/v1/2023.emnlp-main.928>
- Kung, T.H., Cheatham, M., Medenilla, A., Sillos, C., De Leon, L., Elepaño, C., Madriaga, M., Aggabao, R., Diaz-Candido, G., Maningo, J., Tseng, V., 2023. Performance of ChatGPT on USMLE: Potential for AI-assisted medical education using large language models. *PLOS Digit Health* 2, e0000198. <https://doi.org/10.1371/journal.pdig.0000198>

- Lambert, N., Castricato, L., von Werra, L., Havrilla, A., 2022. Illustrating Reinforcement Learning from Human Feedback (RLHF) [WWW Document]. Hugging Face. URL <https://huggingface.co/blog/rlhf> (accessed 12.10.23).
- Langlotz, C.P., 2019. Will Artificial Intelligence Replace Radiologists? *Radiol Artif Intell* 1, e190058. <https://doi.org/10.1148/ryai.2019190058>
- Lee, B.K., Mayhew, E.J., Sanchez-Lengeling, B., Wei, J.N., Qian, W.W., Little, K.A., Andres, M., Nguyen, B.B., Moloy, T., Yasonik, J., Parker, J.K., Gerkin, R.C., Mainland, J.D., Wiltschko, A.B., 2023. A principal odor map unifies diverse tasks in olfactory perception. *Science* 381, 999–1006. <https://doi.org/10.1126/science.ade4401>
- Lewis, A.E., Weiskopf, N., Abrams, Z.B., Foraker, R., Lai, A.M., Payne, P.R.O., Gupta, A., 2023. Electronic health record data quality assessment and tools: a systematic review. *J Am Med Inform Assoc* ocad120. <https://doi.org/10.1093/jamia/ocad120>
- Li, D., Gupta, K., Bhaduri, M., Sathiadoss, P., Bhatnagar, S., Chong, J., 2024. Comparing GPT-3.5 and GPT-4 Accuracy and Drift in Radiology Diagnosis Please Cases. *Radiology* 310, e232411. <https://doi.org/10.1148/radiol.232411>
- Liang, W., Izzo, Z., Zhang, Y., Lepp, H., Cao, H., Zhao, X., Chen, L., Ye, H., Liu, S., Huang, Z., McFarland, D.A., Zou, J.Y., 2024. Monitoring AI-Modified Content at Scale: A Case Study on the Impact of ChatGPT on AI Conference Peer Reviews. <https://doi.org/10.48550/arXiv.2403.07183>
- Liang, W., Yuksekogonul, M., Mao, Y., Wu, E., Zou, J., 2023. GPT detectors are biased against non-native English writers. *Patterns (N Y)* 4, 100779. <https://doi.org/10.1016/j.patter.2023.100779>
- Liu, P., Yuan, W., Fu, J., Jiang, Z., Hayashi, H., Neubig, G., 2023. Pre-train, Prompt, and Predict: A Systematic Survey of Prompting Methods in Natural Language Processing. *ACM Comput. Surv.* 55, 195:1-195:35. <https://doi.org/10.1145/3560815>
- Ma, S.P., Liang, A.S., Shah, S.J., Smith, M., Jeong, Y., Devon-Sand, A., Crowell, T., Delahaie, C., Hsia, C., Lin, S., Shanafelt, T., Pfeffer, M.A., Sharp, C., Garcia, P., 2025. Ambient artificial intelligence scribes: utilization and impact on documentation time. *J Am Med Inform Assoc* 32, 381–385. <https://doi.org/10.1093/jamia/ocae304>
- McCarthy, J., Feigenbaum, E.A., 1990. In Memoriam: Arthur Samuel: Pioneer in Machine Learning. *AIMag* 11, 10–10. <https://doi.org/10.1609/aimag.v11i3.840>
- Meskó, B., 2023. Prompt Engineering as an Important Emerging Skill for Medical Professionals: Tutorial. *J Med Internet Res* 25, e50638. <https://doi.org/10.2196/50638>
- Mollick, E., 2024. Post-apocalyptic education [WWW Document]. One Useful Thing. URL <https://www.oneusefulthing.org/p/post-apocalyptic-education> (accessed 9.4.24).
- Mollick, E., 2023. The Homework Apocalypse [WWW Document]. One Useful Thing. URL <https://www.oneusefulthing.org/p/the-homework-apocalypse> (accessed 3.20.24).
- Nam, J., 2023. 56% of College Students Have Used AI on Assignments or Exams | BestColleges [WWW Document]. BestColleges.com. URL <https://www.bestcolleges.com/research/most-college-students-have-used-ai-survey/> (accessed 12.13.23).
- Ng, F.Y.C., Thirunavukarasu, A.J., Cheng, H., Tan, T.F., Gutierrez, L., Lan, Y., Ong, J.C.L., Chong, Y.S., Ngiam, K.Y., Ho, D., Wong, T.Y., Kwek, K., Doshi-Velez, F., Lucey, C., Coffman, T., Ting, D.S.W., 2023. Artificial intelligence education: An evidence-based medicine approach for consumers, translators, and developers. *Cell Rep Med* 4, 101230. <https://doi.org/10.1016/j.xcrm.2023.101230>

- Nori, H., Lee, Y.T., Zhang, S., Carignan, D., Edgar, R., Fusi, N., King, N., Larson, J., Li, Y., Liu, W., Luo, R., McKinney, S.M., Ness, R.O., Poon, H., Qin, T., Usuyama, N., White, C., Horvitz, E., 2023. Can Generalist Foundation Models Outcompete Special-Purpose Tuning? Case Study in Medicine. <https://doi.org/10.48550/arXiv.2311.16452>
- Nori, H., Usuyama, N., King, N., McKinney, S.M., Fernandes, X., Zhang, S., Horvitz, E., 2024. From Medprompt to o1: Exploration of Run-Time Strategies for Medical Challenge Problems and Beyond. <https://doi.org/10.48550/arXiv.2411.03590>
- Norlen, N., Barrett, G., 2023. Word of the Year 2023 [WWW Document]. Dictionary.com. URL <https://content.dictionary.com/word-of-the-year-2023/> (accessed 10.9.24).
- Odri, G.-A., Yun Yoon, D.J., 2023. Detecting generative artificial intelligence in scientific articles: evasion techniques and implications for scientific integrity. *Orthop Traumatol Surg Res* 103706. <https://doi.org/10.1016/j.otsr.2023.103706>
- Omiye, J.A., Gui, H., Rezaei, S.J., Zou, J., Daneshjou, R., 2024. Large Language Models in Medicine: The Potentials and Pitfalls : A Narrative Review. *Ann Intern Med* 177, 210–220. <https://doi.org/10.7326/M23-2772>
- Omiye, J.A., Lester, J.C., Spichak, S., Rotemberg, V., Daneshjou, R., 2023. Large language models propagate race-based medicine. *npj Digit. Med.* 6, 1–4. <https://doi.org/10.1038/s41746-023-00939-z>
- Owens, L.M., Wilda, J.J., Grifka, R., Westendorp, J., Fletcher, J.J., 2024. Effect of Ambient Voice Technology, Natural Language Processing, and Artificial Intelligence on the Patient-Physician Relationship. *Appl Clin Inform* 15, 660–667. <https://doi.org/10.1055/a-2337-4739>
- Palmer, K., 2023. The 'model-eat-model world' of clinical AI: How predictive power becomes a pitfall. *STAT*. URL <https://www.statnews.com/2023/10/10/the-model-eat-model-world-of-clinical-ai-how-predictive-power-becomes-a-pitfall/> (accessed 11.28.23).
- Poldrack, R.A., Lu, T., Beguš, G., 2023. AI-assisted coding: Experiments with GPT-4. <https://doi.org/10.48550/arXiv.2304.13187>
- Poplin, R., Varadarajan, A.V., Blumer, K., Liu, Y., McConnell, M.V., Corrado, G.S., Peng, L., Webster, D.R., 2018. Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning. *Nat Biomed Eng* 2, 158–164. <https://doi.org/10.1038/s41551-018-0195-0>
- Powell, K., Fishman, E.K., Chu, L.C., Rowe, S.P., Crawford, C.K., 2025. Agentic AI: The Power to Change Medicine and Our World. *J Am Coll Radiol* S1546-1440(25)00342–4. <https://doi.org/10.1016/j.jacr.2025.06.032>
- Pyrros, A., Borstelmann, S.M., Mantravadi, R., Zaiman, Z., Thomas, K., Price, B., Greenstein, E., Siddiqui, N., Willis, M., Shulhan, I., Hines-Shah, J., Horowitz, J.M., Nikolaidis, P., Lungren, M.P., Rodríguez-Fernández, J.M., Gichoya, J.W., Koyejo, S., Flanders, A.E., Khandwala, N., Gupta, A., Garrett, J.W., Cohen, J.P., Layden, B.T., Pickhardt, P.J., Galanter, W., 2023. Opportunistic detection of type 2 diabetes using deep learning from frontal chest radiographs. *Nat Commun* 14, 4039. <https://doi.org/10.1038/s41467-023-39631-x>
- Rajkumar, A., Oren, E., Chen, K., Dai, A.M., Hajaj, N., Hardt, M., Liu, P.J., Liu, X., Marcus, J., Sun, M., Sundberg, P., Yee, H., Zhang, K., Zhang, Y., Flores, G., Duggan, G.E., Irvine, J., Le, Q., Litsch, K., Mossin, A., Tansuwan, J., Wang, D., Wexler, J., Wilson, J., Ludwig, D., Volchenboun, S.L., Chou, K., Pearson, M., Madabushi, S., Shah, N.H., Butte, A.J., Howell, M.D., Cui, C., Corrado, G.S., Dean, J., 2018. Scalable and accurate deep learning with

- electronic health records. *npj Digital Medicine* 1, 1–10. <https://doi.org/10.1038/s41746-018-0029-1>
- Rajpurkar, P., Chen, E., Banerjee, O., Topol, E.J., 2022. AI in health and medicine. *Nat Med* 1–8. <https://doi.org/10.1038/s41591-021-01614-0>
- Rajpurkar, P., Lungren, M.P., 2023. The Current and Future State of AI Interpretation of Medical Images. *N Engl J Med* 388, 1981–1990. <https://doi.org/10.1056/NEJMra2301725>
- Rao, A., Pang, M., Kim, J., Kamineni, M., Lie, W., Prasad, A.K., Landman, A., Dreyer, K., Succi, M.D., 2023. Assessing the Utility of ChatGPT Throughout the Entire Clinical Workflow: Development and Usability Study. *J Med Internet Res* 25, e48659. <https://doi.org/10.2196/48659>
- Roberts, G., 2022. AI Training Datasets: the Books1+Books2 that Big AI eats for breakfast - Musings of Freedom. *Musings of Freedom*. URL <https://gregoreite.com/drilling-down-details-on-the-ai-training-datasets/> (accessed 9.6.23).
- Saab, K., Tu, T., Weng, W.-H., Tanno, R., Stutz, D., Wulczyn, E., Zhang, F., Strother, T., Park, C., Vedadi, E., Chaves, J.Z., Hu, S.-Y., Schaekermann, M., Kamath, A., Cheng, Y., Barrett, D.G.T., Cheung, C., Mustafa, B., Palepu, A., McDuff, D., Hou, L., Golany, T., Liu, L., Alayrac, J., Houlsby, N., Tomasev, N., Freyberg, J., Lau, C., Kemp, J., Lai, J., Azizi, S., Kanada, K., Man, S., Kulkarni, K., Sun, R., Shakeri, S., He, L., Caine, B., Webson, A., Latysheva, N., Johnson, M., Mansfield, P., Lu, J., Rivlin, E., Anderson, J., Green, B., Wong, R., Krause, J., Shlens, J., Dominowska, E., Eslami, S.M.A., Chou, K., Cui, C., Vinyals, O., Kavukcuoglu, K., Manyika, J., Dean, J., Hassabis, D., Matias, Y., Webster, D., Barral, J., Corrado, G., Sementur, C., Mahdavi, S.S., Gottweis, J., Karthikesalingam, A., Natarajan, V., 2024. Capabilities of Gemini Models in Medicine. <https://doi.org/10.48550/arXiv.2404.18416>
- Sadasivan, V.S., Kumar, A., Balasubramanian, S., Wang, W., Feizi, S., 2023. Can AI-Generated Text be Reliably Detected? <https://doi.org/10.48550/arXiv.2303.11156>
- Sarraf, A., Bruemmer, D., Van Iterson, E., Cho, L., Rodriguez, F., Laffin, L., 2023. Appropriateness of Cardiovascular Disease Prevention Recommendations Obtained From a Popular Online Chat-Based Artificial Intelligence Model. *JAMA*. <https://doi.org/10.1001/jama.2023.1044>
- Scarfe, P., Watcham, K., Clarke, A., Roesch, E., 2024. A real-world test of artificial intelligence infiltration of a university examinations system: A “Turing Test” case study. *PLoS One* 19, e0305354. <https://doi.org/10.1371/journal.pone.0305354>
- Shah, S.J., Devon-Sand, A., Ma, S.P., Jeong, Y., Crowell, T., Smith, M., Liang, A.S., Delahaie, C., Hsia, C., Shanafelt, T., Pfeffer, M.A., Sharp, C., Lin, S., Garcia, P., 2025. Ambient artificial intelligence scribes: physician burnout and perspectives on usability and documentation burden. *J Am Med Inform Assoc* 32, 375–380. <https://doi.org/10.1093/jamia/ocae295>
- Shao, M., Basit, A., Karri, R., Shafique, M., 2024. Survey of Different Large Language Model Architectures: Trends, Benchmarks, and Challenges. *IEEE Access* 12, 188664–188706. <https://doi.org/10.1109/ACCESS.2024.3482107>
- Small, W.R., Wiesenfeld, B., Brandfield-Harvey, B., Jonassen, Z., Mandal, S., Stevens, E.R., Major, V.J., Lostraglio, E., Szerencsy, A., Jones, S., Aphinyanaphongs, Y., Johnson, S.B., Nov, O., Mann, D., 2024. Large Language Model-Based Responses to Patients’ In-Basket Messages. *JAMA Netw Open* 7, e2422399. <https://doi.org/10.1001/jamanetworkopen.2024.22399>

- Stults, C.D., Deng, S., Martinez, M.C., Wilcox, J., Szwedinski, N., Chen, K.H., Driscoll, S., Washburn, J., Jones, V.G., 2025. Evaluation of an Ambient Artificial Intelligence Documentation Platform for Clinicians. *JAMA Netw Open* 8, e258614. <https://doi.org/10.1001/jamanetworkopen.2025.8614>
- Swanson, K., Liu, G., Catacutan, D.B., Arnold, A., Zou, J., Stokes, J.M., 2024. Generative AI for designing and validating easily synthesizable and structurally novel antibiotics. *Nat Mach Intell* 6, 338–353. <https://doi.org/10.1038/s42256-024-00809-7>
- Tang, A.S., Rankin, K.P., Ceronio, G., Miramontes, S., Mills, H., Roger, J., Zeng, B., Nelson, C., Soman, K., Woldemariam, S., Li, Y., Lee, A., Bove, R., Glymour, M., Aghaeepour, N., Oskotsky, T.T., Miller, Z., Allen, I.E., Sanders, S.J., Baranzini, S., Sirota, M., 2024. Leveraging electronic health records and knowledge networks for Alzheimer’s disease prediction and sex-specific biological insights. *Nat Aging* 4, 379–395. <https://doi.org/10.1038/s43587-024-00573-8>
- Tang, J., LeBel, A., Jain, S., Huth, A.G., 2023. Semantic reconstruction of continuous language from non-invasive brain recordings. *Nat Neurosci* 26, 858–866. <https://doi.org/10.1038/s41593-023-01304-9>
- Tang, R., Chuang, Y.-N., Hu, X., 2024. The Science of Detecting LLM-Generated Text. *Commun. ACM* 67, 50–59. <https://doi.org/10.1145/3624725>
- Topol, E., 2022. The amazing power of “machine eyes.” Ground Truths. URL <https://erictopol.substack.com/p/the-amazing-power-of-machine-eyes> (accessed 10.14.22).
- Topol, E., 2019. *Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again*, Illustrated Edition. ed. Basic Books, New York.
- Tu, T., Palepu, A., Schaekermann, M., Saab, K., Freyberg, J., Tanno, R., Wang, A., Li, B., Amin, M., Tomasev, N., Azizi, S., Singhal, K., Cheng, Y., Hou, L., Webson, A., Kulkarni, K., Mahdavi, S.S., Semturs, C., Gottweis, J., Barral, J., Chou, K., Corrado, G.S., Matias, Y., Karthikesalingam, A., Natarajan, V., 2024. Towards Conversational Diagnostic AI. <https://doi.org/10.48550/arXiv.2401.05654>
- Tu, X., Zou, J., Su, W., Zhang, L., 2024. What Should Data Science Education Do With Large Language Models? *Harvard Data Science Review* 6. <https://doi.org/10.1162/99608f92.bff007ab>
- Vaid, A., Sawant, A., Suarez-Farinas, M., Lee, J., Kaul, S., Kovatch, P., Freeman, R., Jiang, J., Jayaraman, P., Fayad, Z., Argulian, E., Lerakis, S., Charney, A.W., Wang, F., Levin, M., Glicksberg, B., Narula, J., Hofer, I., Singh, K., Nadkarni, G.N., 2023. Implications of the Use of Artificial Intelligence Predictive Models in Health Care Settings : A Simulation Study. *Ann Intern Med*. <https://doi.org/10.7326/M23-0949>
- Walters, W.H., Wilder, E.I., 2023. Fabrication and errors in the bibliographic citations generated by ChatGPT. *Sci Rep* 13, 14045. <https://doi.org/10.1038/s41598-023-41032-5>
- Weiss, J., Raghu, V.K., Paruchuri, K., Zinzuwadia, A., Natarajan, P., Aerts, H.J.W.L., Lu, M.T., 2024. Deep Learning to Estimate Cardiovascular Risk From Chest Radiographs : A Risk Prediction Study. *Ann Intern Med*. <https://doi.org/10.7326/M23-1898>
- Widner, K., Virmani, S., Krause, J., Nayar, J., Tiwari, R., Pedersen, E.R., Jeji, D., Hammel, N., Matias, Y., Corrado, G.S., Liu, Y., Peng, L., Webster, D.R., 2023. Lessons learned from translating AI from development to deployment in healthcare. *Nat Med* 29, 1304–1306. <https://doi.org/10.1038/s41591-023-02293-9>
- Williams, C.Y.K., Zack, T., Miao, B.Y., Sushil, M., Wang, M., Kornblith, A.E., Butte, A.J., 2024. Use of a Large Language Model to Assess Clinical Acuity of Adults in the

- Emergency Department. JAMA Netw Open 7, e248895.
<https://doi.org/10.1001/jamanetworkopen.2024.8895>
- Xu, S., Yang, L., Kelly, C., Sieniek, M., Kohlberger, T., Ma, M., Weng, W.-H., Kiraly, A., Kazemzadeh, S., Melamed, Z., Park, J., Strachan, P., Liu, Y., Lau, C., Singh, P., Chen, C., Etemadi, M., Kalidindi, S.R., Matias, Y., Chou, K., Corrado, G.S., Shetty, S., Tse, D., Prabhakara, S., Golden, D., Pilgrim, R., Eswaran, K., SELLERGRÉN, A., 2023. ELIXR: Towards a general purpose X-ray artificial intelligence system through alignment of large language models and radiology vision encoders [WWW Document]. arXiv.org. URL <https://arxiv.org/abs/2308.01317v2> (accessed 9.26.23).
- Yan, S., Knapp, W., Leong, A., Kadkhodazadeh, S., Das, S., Jones, V.G., Clark, R., Grattendick, D., Chen, K., Hladik, L., Fagan, L., Chan, A., 2024. Prompt engineering on leveraging large language models in generating response to InBasket messages. J Am Med Inform Assoc ocae172. <https://doi.org/10.1093/jamia/ocae172>
- Yin, C., Chen, P.-Y., Yao, B., Wang, D., Caterino, J., Zhang, P., 2024. SepsisLab: Early Sepsis Prediction with Uncertainty Quantification and Active Sensing, in: Proceedings of the 30th ACM SIGKDD Conference on Knowledge Discovery and Data Mining, KDD '24. Association for Computing Machinery, New York, NY, USA, pp. 6158–6168.
<https://doi.org/10.1145/3637528.3671586>
- Yu, F., Moehring, A., Banerjee, O., Salz, T., Agarwal, N., Rajpurkar, P., 2024. Heterogeneity and predictors of the effects of AI assistance on radiologists. Nat Med 30, 837–849.
<https://doi.org/10.1038/s41591-024-02850-w>
- Zakka, C., Shad, R., Chaurasia, A., Dalal, A.R., Kim, J.L., Moor, M., Fong, R., Phillips, C., Alexander, K., Ashley, E., Boyd, J., Boyd, K., Hirsch, K., Langlotz, C., Lee, R., Melia, J., Nelson, J., Sallam, K., Tullis, S., Vogelsong, M.A., Cunningham, J.P., Hiesinger, W., 2024. Almanac — Retrieval-Augmented Language Models for Clinical Medicine. NEJM AI 1, AIoa2300068. <https://doi.org/10.1056/AIoa2300068>
- Zanon, C., Toniolo, A., Bini, C., Quaia, E., 2023. ChatGPT Goes to The Radiology Department: A Pictorial Review. <https://doi.org/10.20944/preprints202312.0714.v1>
- Zou, J., Topol, E.J., 2025. The rise of agentic AI teammates in medicine. Lancet 405, 457.
[https://doi.org/10.1016/S0140-6736\(25\)00202-8](https://doi.org/10.1016/S0140-6736(25)00202-8)



Artificial Intelligence: Implications for Healthcare Practice, Research, and Education

William Hersh, MD, FACMI, FAMIA, FIAHSI, FACP
Professor
Oregon Health & Science University
Portland, OR, USA

1

Overview

- Uses, successes, and limitations of AI in medicine
- AI in education
- AI impacts on how we find and apply information

AI Implications Healthcare

2



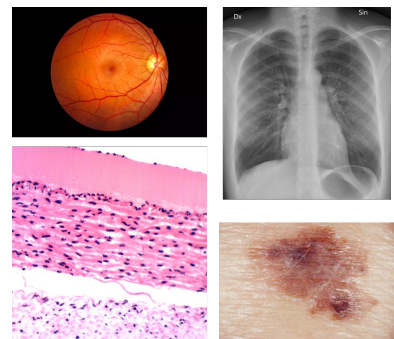
2

Artificial intelligence (AI)

- AI – information systems and algorithms capable of performing tasks associated with human intelligence (Wikipedia, 2025; Hersh, 2025)
 - Some classify AI into two broad categories
 - Predictive AI – use of data and algorithms to predict some output (e.g., diagnosis, treatment recommendation, prognosis, etc.)
 - Generative AI – generates new output based on prompts (e.g., text, images, etc.)
- A large part of modern success of AI due to machine learning (ML) – “computer programs that learn without being explicitly programmed” (McCarthy, 1990, attributed to Samuel, 1959)
 - Most success with deep learning, based on many-layered neural networks

Predictive AI in medicine

- “Predictive AI” driven by advances in ML, increasing availability of data, and more powerful computers and networks (Topol, 2019; Rajpurkar, 2022)
 - Deep learning in imaging breakthroughs by Hinton (2006) – led to Nobel Prize for Physics 2024
- Most success in image interpretation (Rajpurkar, 2023); examples include
 - Radiology – chest x-rays for diagnosis of pneumonia and tuberculosis
 - Ophthalmology – retinal images for diagnosis of diabetic retinopathy
 - Dermatology – skin lesions for diagnosis of cancer
 - Pathology – breast cancer slides to predict metastasis



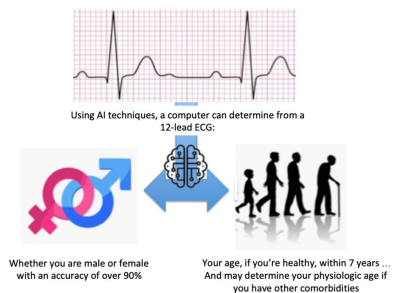
Predictive AI not limited to imaging

- Adverse events in hospitalizations from electronic health record (EHR) data (Rajkomar, 2018)
- Protein folding from amino acid sequences (Jumper, 2021) – led to Nobel Prize for Chemistry 2024
- Semantic reconstruction of continuous language from fMRI brain recordings (Tang, 2023)
- Map chemicals to odors perceived by humans (Lee, 2023)
- Predict Alzheimer's Disease from EHR data up to 7 years before diagnosis (Tang, 2024)
- Voice as a biomarker in Parkinson's Disease, Alzheimer's Disease, cognitive impairment, COVID-19, and others (Idrisoglu, 2023; Bensoussan, 2024)
- The list goes on and on, especially with addition of generative AI...



Also success in “seeing” where humans cannot (Topol, 2022)

- Retinal images
 - Age, biological sex, and cardiovascular risk determination from retinal images (Poplin, 2018)
 - Race (Coyner, 2023)
- Electrocardiograms (ECGs)
 - Age and biological sex determination (Attia, 2019)
 - Chronic kidney disease (Holmstrom, 2023)
- Chest x-rays
 - Race (Gichoya, 2022)
 - Diabetes (Pyrros, 2023)
 - Cardiac risk as accurately as common models, e.g., atherosclerotic cardiovascular disease (ASCVD) (Weiss, 2024)
 - Risk of future heart failure (Dhingra, 2025)



And now, generative AI

- Introduction of ChatGPT on November 30, 2022 brought new type of AI into focus: generative AI
- Based on large language models (LLMs) processed by deep neural networks using large amounts of training data and tuned for specific tasks (Omiye, 2024)
 - Trained on massive amounts of text and other content, e.g., large Web crawls, books, Wikipedia, and more for GPT (Roberts, 2022)
 - Use transformer models that predict words in sequence from billions/trillions of words and add measure of importance to “attention” words (Shao, 2024)
 - Fine-tuned with reinforcement learning from human feedback (RLHF) (Lambert, 2022)
 - Activated by (and importance of) prompting (Liu, 2023; Meskó, 2023)

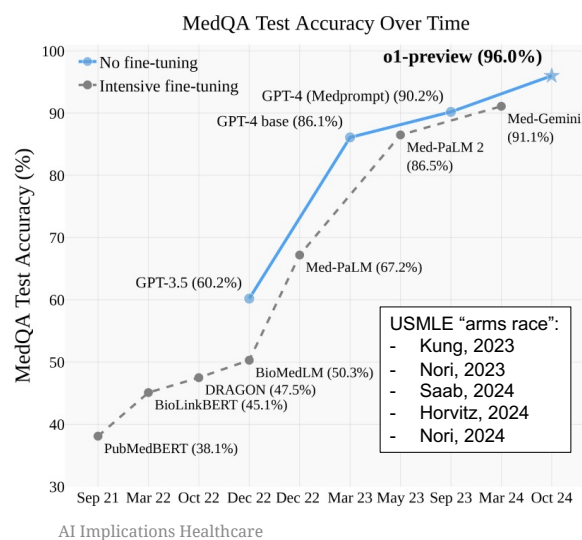
AI Implications Healthcare

7



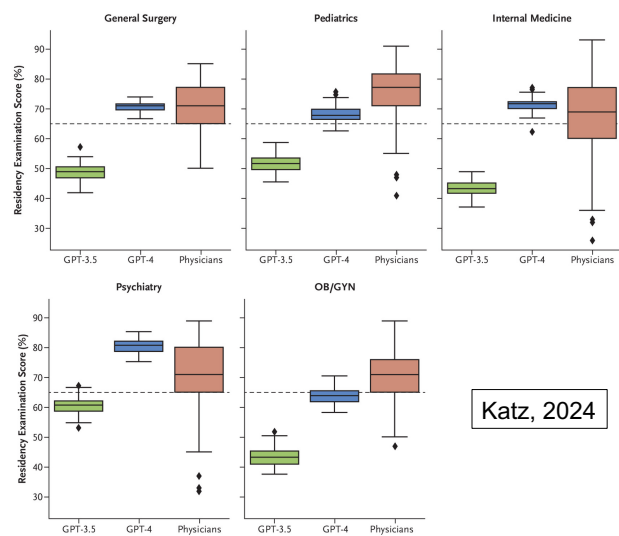
7

Some successes of generative AI in medicine – medical board exams



AI Implications Healthcare

8



8

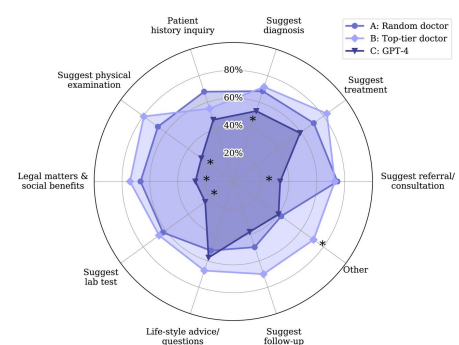
Successes of LLMs – solving clinical cases

- Comparable to but not better than expert humans (Kanjee, 2023; Rao, 2023; Chen, 2023)
- In simulated (text-based) objective structured clinical exam (OSCE) format, Google's Articulate Medical Intelligence Explorer (AMIE) outperformed primary care physicians in text-based dialogue in history-taking, diagnostic accuracy, management reasoning, communication skills, and empathy (Tu, 2024)
- For 20 clinical cases, GPT-4 performed comparable to attending physicians and residents in diagnostic accuracy, correct clinical reasoning, and cannot-miss diagnosis inclusion (Cabral, 2024)
- In randomized vignette study of diagnostic reasoning (Goh, 2024)
 - Physicians scored comparably with or without GPT-4 (76.3% vs. 73.7%, NS)
 - GPT-4 alone did better (92.1%, SS)



Successes of LLMs – solving cases, mixed results

- Comparison of responses from ChatGPT-4 and physicians for cases from Swedish family medicine specialist examination, scored by blinded reviewers (Arvidsson, 2024)
 - Higher scores for average physicians than GPT-4 or GPT-4o
- Conversational Reasoning Assessment Framework for Testing in Medicine (CRAFT-MD) focuses on natural dialogues, using simulated agents to interact with LLMs in controlled environment (Johri, 2025)
 - Performed worse in “conversational” than “examination-based” settings



Successes of LLMs (cont.)

- Communicating with patients
 - Answering questions in public forums (Sarraju, 2023; Ayers, 2023)
 - Writing letters with comparable or better empathy (Ali, 2023, Ayers, 2023)
- Closing the loop with predictive AI
 - Classifying CXR findings based on previous images and reports (Xu, 2023)
 - Predicting cardiovascular risk comparable to Framingham models (Han, 2023)
 - Designing and validating easily synthesizable antibiotics (Swanson, 2024)
 - Predicting acuity of patients in emergency department (Williams, 2024)



But some downsides to generative AI

- Dictionary.com 2023 word of year: *hallucinate* (Norlen, 2023)
- Fabrication and errors in the bibliographic citations – asked to produce short literature reviews on 42 multidisciplinary topics (Walters, 2023)
 - 55% of GPT-3.5 citations and 18% of GPT-4 citations fabricated
 - 43% of real (non-fabricated) GPT-3.5 citations and 24% of real GPT-4 citations include substantive errors



Downsides to generative AI (cont.)

- 8 clinical questions asked of 4 LLMs recapitulated “harmful, race-based medicine” (Omiye, 2023)
- Automated GPT detectors have mixed results (Sadasivan, 2023; Odri, 2023; Desaire, 2023; Tang, 2024)
 - More likely to classify non-native English writing as AI-generated (Liang, 2023)
 - Humans not able to discern AI writing either (Dell'Acqua, 2023)
- Attempts at fine-tuning can go awry, e.g., Grok (Hagen, 2025)



And some downsides to AI in general

- After clinical models deployed, performance may decline due to actual real-world use (Vaid, 2023; Palmer, 2023)
- Implementing diabetic retinopathy screening in rural Thailand and India found (Widner, 2023)
 - Challenges related to equipment operation, workflows, and image quality
 - Need for training and attention to human factors
- ML algorithms, especially generative AI, have large carbon footprints, although details sometimes not known due to lack of company transparency (Kirkpatrick, 2023)
 - One estimate is that electricity consumption of AI request is 10-fold more than Google search (de Vries, 2023)



Downsides to AI in general (cont.)

- Variable impacts on different levels of radiologists, leading to automation bias and detrimental effects of incorrect AI (Dratsch, 2023; Yu, 2024)
- Concerns about reproducibility (Ball, 2023)
 - Data bias (especially from EHR – Lewis, 2023; Chin, 2023)
 - Data leakage (Kapoor, 2023)
 - Data drift/shift (Finlayson, 2021; Li, 2024; Nelson, 2025)



More recent advances in generative AI

- Retrieval augmented generation (RAG) (Gao, 2024; Kimothi, 2025)
 - Training large models consumes time and resources; cannot be done frequently
 - RAG allows new information (articles, Web pages, and even books) to be entered into context window of LLM to augment prompt
- Agentic AI (Powell, 2025; Zou, 2025)
 - Interaction of AI systems (agents) to solve specific tasks, e.g., medical diagnoses, treatment recommendations, etc.



What is ultimate role for AI in healthcare?

- Real-world use still modest; most widely used applications include
 - Predictive models, e.g., sepsis (Gorecki, 2024; Yin, 2024)
 - Drafting replies to patient messages (Yan, 2024; Baxter, 2024; Small, 2024; Tai-Seale, 2024)
 - Ambient dictation (Shah, 2025; Ma, 2025; Duggan, 2025; Stults, 2025)
- “AI won’t replace radiologists, but radiologists who use AI will replace radiologists who don’t,” (Langlotz, 2019)
 - (Plug in your health profession)



AI impact on education and search

- Impact on education (Hersh, 2025)
 - How do we learn and assess what we learn?
- Search still matters (Hersh, 2024)
 - In many circumstances, who said what is more important than providing a generated answer



Annual Review of Biomedical Data Science
Generative Artificial
Intelligence: Implications for
Biomedical and Health
Professions Education

William Hersh

Division of Informatics, Clinical Epidemiology and Translational Sciences, Department of
Medicine, School of Medicine, Oregon Health & Science University, Portland, Oregon, USA;
email: herish@ohsu.edu

Journal of the American Medical Informatics Association, 2024, 1–3
<https://doi.org/10.1093/jamia/ocae014>
Perspective



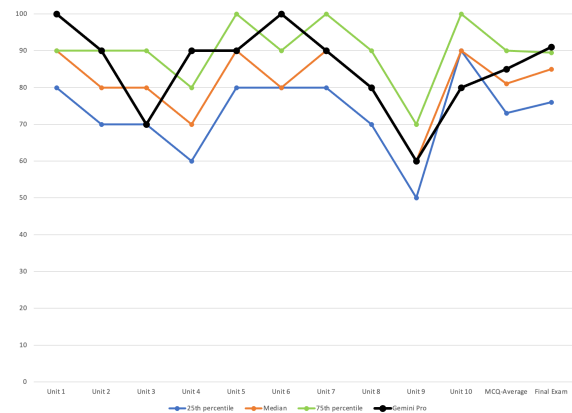
Perspective

**Search still matters: information retrieval in the era of
generative AI**

William Hersh MD*

Impact on education in biomedical informatics

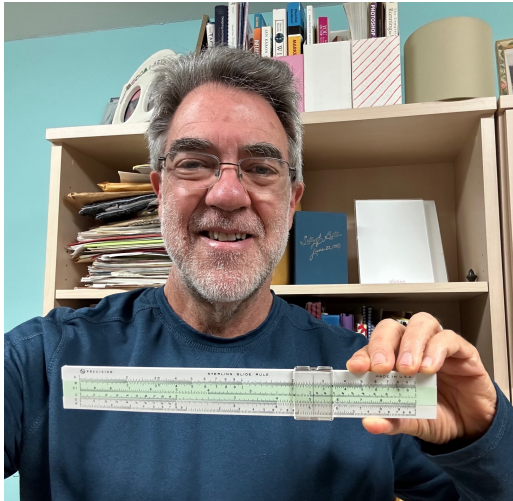
- Well-known, highly subscribed introductory course taught at graduate, continuing education, and medical student levels (Hersh, 2024)
 - Commercial LLMs prompted using interactive Web interface for multiple-choice and final exam questions from 2023 course materials
 - Highest score by Gemini Pro at about 75th percentile for 139 students, other LLMs close behind
- GitHub CoPilot in health informatics programming course (Avramovic, 2024)
 - For problems in SQL and Python, generated solutions worked well for simple tasks but less so for complex ones
 - Some solutions correct but not most efficient approach



Challenges for educators in many disciplines

- May be causing “homework apocalypse” (Mollick, 2023) but also provides opportunity to improve teaching and learning (Mollick, 2024)
- Impact in many disciplines beyond medicine, including
 - Passing college entrance and AP exams (Dubey, 2024)
 - Writing computer programs (Poldrack 2024; Denny, 2024; Johnson, 2024)
 - Creating data science pipelines (Cheng, 2024; Hong, 2024)
 - Writing legal briefs (Choi, 2023)
 - In 5 undergraduate psychology courses, scored above average among students on take-home exams with only 6% detection (Scarfe, 2024)

Now what? Educational cusps in my lifetime



AI Implications Healthcare



21



21

Also critical is education of clinicians and informaticians

- AI should build on competencies in clinical informatics (Hersh, 2014; Hersh 2020; Hersh, 2023)
- Others note
 - Clinicians must be prepared to practice in a world of AI (James, 2022)
 - Medical schools face dual challenges of needing to teach about AI in practice but also adapt to its use by learners and faculty (Cooper, 2023)

AI Implications Healthcare

22

1. Find, search, and apply knowledge-based information to patient care and other clinical tasks
2. Effectively read from, and write to, the electronic health record (EHR) for patient care and other clinical activities
3. Use and guide implementation of clinical decision support (CDS)
4. Provide care using population health management approaches
5. Protect patient privacy and security
6. Use information technology to improve patient safety
7. Engage in quality measurement selection and improvement
8. Use health information exchange (HIE) to identify and access patient information across clinical settings
9. Engage patients to improve their health and care delivery through personal health records and patient portals
10. Maintain professionalism in use of information technology tools, including social media
11. Provide clinical care via telemedicine and refer patients as indicated
12. Apply personalized/precision medicine
13. Participate in practice-based clinical and translational research
14. Use and critique artificial intelligence (AI) applications in clinical care

22

Conclusions

- AI will profoundly impact the practice and education of all health professions
- But research in best uses of AI is a necessity (and opportunity)
- Educators must develop new approaches to teaching and student assessment in era of generative AI
- Healthcare, informatics, and educational professionals must be competent with AI as much as any other tool in clinical practice

AI Implications Healthcare

23



23

Questions?

William Hersh, MD, FACMI, FAMIA, FIAHSI, FACP
Professor
Oregon Health & Science University
Portland, OR, USA
Email

hersh@ohsu.edu

Web

<https://billhersh.info/>

Textbook

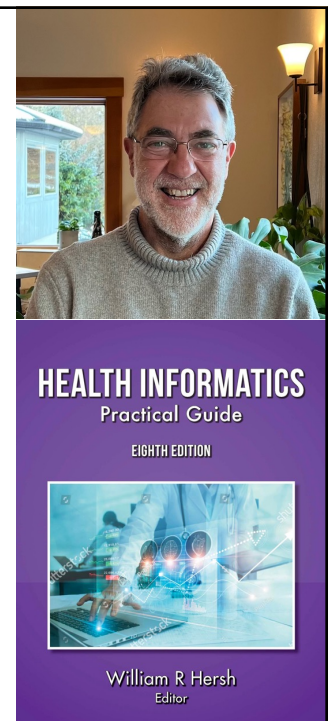
<https://informaticsbook.info/>

What is Informatics?

<https://informatics.health/>

AI Implications Healthcare

24



24