Artificial Intelligence: Promise and Peril

Introduction to Health Informatics
Claremont Graduate University

February 28, 2024

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Artificial Intelligence: Promise and Peril

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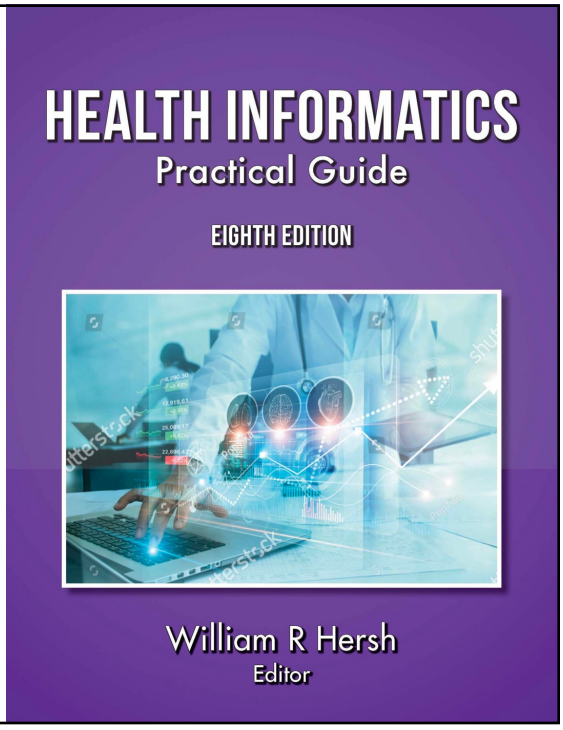
1

Objectives

- Of all the chapters in textbook, the one most out-of-date is Chapter 6
- The goal of this lecture is to update the topic and for you to be able to
  - Define major types of AI and their successes and limitations
  - Building the evidence base for AI
  - Role of AI in finding and applying information



2

Artificial intelligence (AI) defined

- AI – "information systems and algorithms capable of performing tasks associated with human intelligence" (Rajpurkar, 2022)
- Some classify AI into two broad categories (Khare, 2023)
  - 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; Shah, 2023)
  - Most success with deep learning, based on many-layered neural networks

3

History of AI – first era in mid-20th century

- Earliest paper related to AI and biomedical informatics attributed to Ledley and Lusted (1959, 1960) aiming to model physician reasoning through symbolic logic and probability
- Warner (1961) developed mathematical model for diagnosing congenital heart disease
- In 1960s-1970s, emergence of "expert systems" – computer programs aiming to mimic human expertise (historical overview – Lea, 2023)
  - Rule-based systems – PhD dissertation of Shortliffe (1975) and subsequent work (Clancey, 1984)
  - Disease profiles and scoring algorithms – INTERNIST-1 (Miller, 1982) and DxPlain (Barnett, 1987)
- Limited by approach of manual construction and maintenance of knowledge
  - Not scalable or sustainable
  - Led to "AI winter" between 1990-2010
  - Main remnant is clinical decision support (CDS) for electronic health records (EHRs) that emerged in 1990s for electronic health records (Greenes, 2023)

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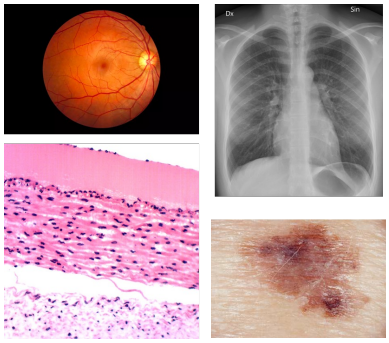
Re-emergence of AI in 21st century

- "Predictive AI" driven by advances in machine learning, increasing availability of data, and more powerful computers and networks (Topol, 2019; Rajpurkar, 2022)
  - Deep learning in imaging breakthroughs by Hinton (2006)
- 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

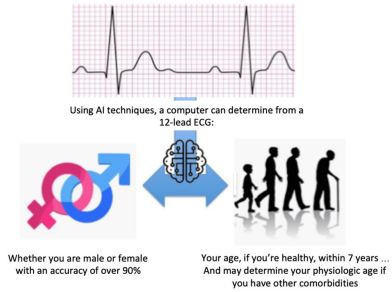


Predictive AI not limited to imaging

- Adverse events in hospitalizations from EHR data (Rajkomar, 2018)
- Generating clinical notes from patient and physician verbal interaction (Rajkomar, 2019)
- Protein folding from amino acid sequences (Jumper, 2021)
- ML model based on past ICD-10 codes and lab results to predict future diagnoses in office visits (Mukherjee, 2023)
- Semantic reconstruction of continuous language from fMRI brain recordings (Tang, 2023)
- Map chemicals to odors perceived by humans (Lee, 2023)

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)
  - Left ventricular systolic dysfunction from ECG images (Sangha, 2023)
- Chest x-rays
  - Race (Gichoya, 2022)
  - Cardiac function and valvular heart diseases (Ueda, 2023)
  - Diabetes (Pyrros, 2023)
  - Correlation with chronological age in healthy cohorts and, for various chronic diseases, difference between estimated age and chronological age (Mitsuyama, 2023)



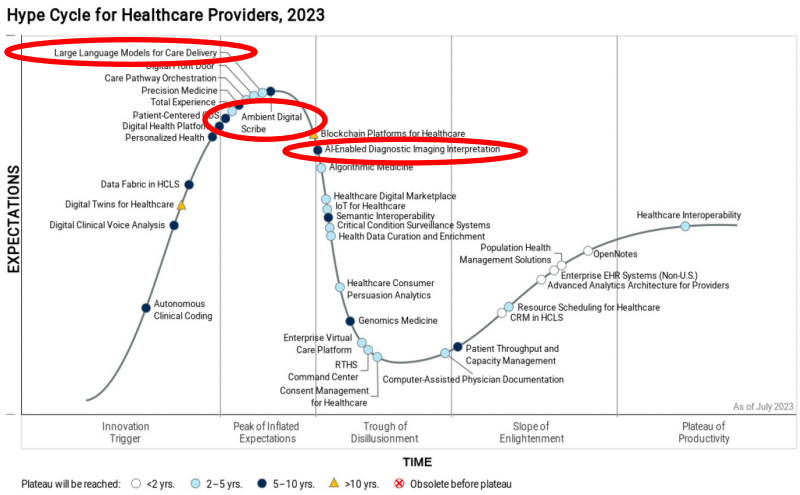
And now, "generative AI"

- 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 (Raschka, 2023)
  - Fine-tuned with reinforcement learning from human feedback (RLHF) (Lambert, 2022)
  - Activated by (and importance of) prompting (Liu, 2023; Meskó, 2023)

Generative AI is more than ChatGPT

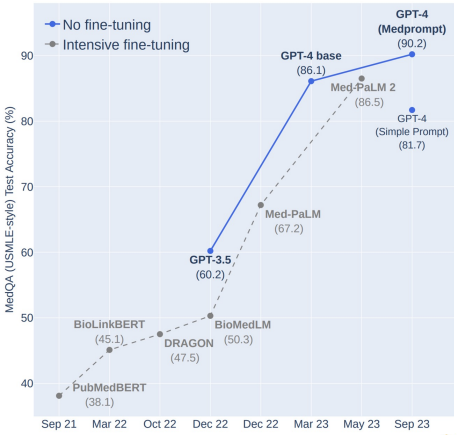
- Adding generative AI to search, including retrieval-augmented generation (RAG) (King, 2023)
  - CoPilot – GPT-4 integrated into Microsoft Bing
  - Google – Bard and now Gemini
- Plugins enhance functionality
  - BrowserPilot – access live Web sites
  - ScholarAI – search PubMed and other research databases
  - SmartSlides – generate (short) Powerpoint presentations
  - SciSummary – summarize scientific papers
- "Small" language models – Phi-2, Mistral, etc.
  - Clinically-oriented models, e.g., Almanac (Zakka, 2024)

Generative AI at peak of inflated expectations (Meyer, 2023)



Results of ChatGPT and other LLMs

- Medical board exam questions
  - USMLE "arms race," starting with (Kung, 2023)
    - Now best with GPT-4 and specific types of prompting (Nori, 2023)
    - Even on "soft skills" (e.g., communication skills, ethics, empathy, and professionalism) questions (Brin, 2023)
  - Passing level on most board exam questions (clinical informatics – Kumah-Crystal, 2023; radiology – Bhayana, 2023; neurology – Schubert, 2023) but not others (neonatology – Beam, 2023, used only GPT-3.5)
- Answering questions
  - Vary by subject domain and type, but sometimes wrong and/or incomplete (e.g., Antaki, 2023; Chen, 2023; Goodman, 2023)
- Solving clinical cases
  - Comparable to but not better than expert humans (e.g., Levine, 2023; Kanjee, 2023; Rao, 2023; Benoit, 2023; Levkovich, 2023)



Results of ChatGPT and other 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)
  - Generating surgical consent forms better than surgeons (Decker, 2023)
  - In simulated (text-based) objective structured clinical exam (OSCE) format, LLM optimized for clinical dialogue achieved better accuracy and communication skills than (with caveats) primary and specialist physicians (Tu, 2024)
- Closing the loop with predictive AI
  - Classifying CXR findings based on previous images and reports (Xu, 2023)
  - Generating CXR reports from new images in ED from prior images and reports (Huang, 2023)
  - Predicting cardiovascular risk comparable to Framingham models (Han, 2023)

But there are some downsides to generative AI

- Dictionary.com 2023 word of year: hallucinate
  - https://content.dictionary.com/word-of-the-year-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
- LLMs reflect content (and bias) of text used for training (Schaul, 2023)

Downsides to generative AI (cont.)

- 8 clinical questions asked of 4 LLMs recapitulated "harmful, race-based medicine" (Omiye, 2023)
- Equally compelling disinformation – humans cannot distinguish between true and false tweets generated by GPT-3 and written by real Twitter users (Spitale, 2023)
- Automated GPT detectors have mixed results (Sadasivan, 2023; Odri, 2023; Desaire, 2023)
  - More likely to classify non-native English writing as AI-generated (Liang, 2023)
  - Humans not able to discern AI writing either (Dell'Acqua, 2023)

And some downsides to AI in general

- After clinical models deployed, performance may decline due to actual real-world use (Vaid, 2023; Palmer, 2023)
- Inexperienced, moderately experienced, and very experienced radiologists reading mammograms are prone to different types of automation bias when supported by AI-based system (Dratsch, 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

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Downsides to AI in general (cont.)

- 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)
  - "Literature demonstrates incomplete reporting, absence of external validation, and infrequent clinical implementation" (Heneghan, 2023)

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Will AI help or hinder healthcare?

- Real-world use still modest
  - As of Sept 2023, only 21% of medical groups using AI applications in practice (MGMA, 2023)
  - EHR usability, patient communications, and billing outrank AI as top tech priorities among medical groups (MGMA, 2023)
  - AI tools used by only 38% of physicians (AMA, 2023)
- "AI won't replace radiologists, but radiologists who use AI will replace radiologists who don't," (Langlotz, 2019)
  - (Plug in your health profession)

What do we need for AI applications to make it to the plateau of productivity?

- Translational AI (Hersh, 2024)
  - Show us the evidence
- Search still matters (Hersh, 2024)
  - In many circumstances, who said what is more important than providing a generated answer

How do we "show the evidence?"

- From evidence-based medicine (EBM), best evidence for any clinical intervention is from randomized controlled trials (RCTs) or systematic reviews of RCTs
- Although not as easy to carry out as RCTs of drugs or devices (and placebos), AI must demonstrate benefit for patient outcomes and/or healthcare delivery improvement
  - Additional issues for RCTs of AI (Liu, 2020)
- As with drugs and devices, we need to move from "basic science" to "clinical science"
- Not everything can be studied in an RCT and RCTs cannot be done for every last clinical question (Greenhalgh, 2022)

What is the evidence so far?

- Many, many papers published about models and simulated use (basic science), including systematic reviews of those papers
- Very few RCTs demonstrating value from real-world use (clinical science) – systematic reviews of RCTs show (Zhou, 2021; Plana, 2022; Han, 2023)
  - Much smaller numbers of RCTs – about 100, depending on how we count
  - 65-82% of RCT showed positive outcomes
  - Many RCTs showed aspects of "risk of bias"

Learning from some specific examples

- Computer-aided detection (CADe) of polyps in colonoscopy
  - One of earliest and most widely-studied applications of AI
  - Recent systematic review shows polyps missed by colonoscopists are discovered, but mostly small and clinically inconsequential (Hassan, 2023)
  - RCT of CADe found no increased detection of advanced neoplasias (Mangas-Sanjuan, 2023)
- 30-day hospital readmissions
  - After implementation of CMS penalty, proliferation of highly accurate predictive models published in mid-2010s
  - Recent RCT showed use of high-quality model and implementation of program around it did not reduce readmissions (Donzé, 2023)

Examples (cont.)

- RCT to assess whether use of previously validated hospital-acquired venous thromboembolism (HA-VTE) prognostic model, together with pediatric hematologist review, could reduce pediatric inpatient rates of HA-VTE (Walker, 2023)
  - No difference for intervention group randomized to use model
  - Reluctance to use model by primary care physicians – used only 26% of time
  - Even for children in intervention arm, model mostly not used, i.e., the “Cassandra Problem” (Wilson, 2023)

How do we get to "translational AI?"

- Singh, X, Feb 8 2024: *Researched models aren't implemented. Implemented models aren't researched*
- Clinicians, informaticians, and others must have competence and education (Russell, 2023; Hersh, 2023)
- Postmarket surveillance, e.g., algorithmovigilance (Embi, 2021)
- Responsible use of AI (Dorr, 2023)
- Building the evidence base (Hersh, 2024)

Search still matters (Hersh, 2024)

- Generative AI systems such as ChatGPT are cool and fun, but
  - For some tasks that many of us do, need more than answers, e.g.,
    - Clinical – patient-care questions
    - Research – methods and insights
    - Teaching – synthesizing knowledge for our students
  - Where the information comes from is as important what it says
- Information retrieval (IR) systems "do not inform user about a subject; indicate the existence (or nonexistence) and whereabouts of documents related to an information request" (Lancaster, 1978)

Search in the era of generative AI

- Another adage of EBM
  - Gen AI for background questions
  - Search and critical appraisal for foreground questions
- Retrieval-augmented generation (RAG) for improving Gen AI but do we need "generation-augmented retrieval" for LLMs to aid search?
  - Evidence modest so far, e.g., using ChatGPT for generating Boolean queries did not improve search results (Wang, 2023)
  - Best LLM with RAG (GPT-4 in CoPilot) achieved about 70% statement-level support and <50% for others (GPT-4, Claude, Mistral, Gemini Pro) (Wu, 2024)
    - Even GPT-4 in CoPilot returned 0 sources 20% of time
    - Most sources from public open sites and not behind firewalls like most journals

Conclusions

- AI will profoundly impact the practice and education of all health professions
- Healthcare, informatics, and other professionals must be competent with AI as much as any other tool in clinical practice
- Translational AI is a necessity and opportunity for informatics
- Generative AI systems must support their output

Questions?

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