Artificial Intelligence (AI): Promise and Peril

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1

Artificial Intelligence: Promise and Peril

- Definitions
- Historical perspectives
- Current accomplishments
- Evidence base for AI interventions
- Future directions

2

Definitions and terminology related to artificial intelligence (AI)

- AI – “information systems and algorithms capable of performing tasks associated with human intelligence” (Rajpurkar, 2022; Sahni, 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 – “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
- Other terms
  - Data science – science of learning from data (Donoho, 2017)
  - Data analytics – use of data and statistical analysis to build explanatory and predictive models and drive decisions and actions (Davenport, 2017)
  - Big Data – data characterized by large volume, velocity, variety and variability (Chang, 2019)

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Machine learning (ML) (Shah, 2023)

- Overall goal is to build models that learn from data
- Initially two categories of models
  - Supervised – learn to predict from labeled data
  - Unsupervised – learn from naturally occurring patterns or groupings within data
- Now variations
  - Reinforcement learning – learning from experience with existing models
  - Transfer learning – applying learning trained for one task to another
  - Self-supervised learning – identify labels from patterns in data

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Functionality of ML

Classification

- Models typically trained via supervised learning
- Clinical functions may include
  - Diagnosis
  - Treatment
  - Patient outcomes
- Methods include
  - Logistic regression
  - Bayesian
  - k-nearest neighbors (kNN)
  - Support vector machine (SVM)
  - Random forest
  - Neural networks

Regression

- Models typically trained via unsupervised learning
- Clinical functions may include
  - Risk stratification
  - Fitting line
  - Clustering
- Methods include
  - Linear regression
  - Bayesian
  - k-nearest neighbors (kNN)
  - Support vector machine (SVM)
  - Random forest
  - Neural networks

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5

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

- Earliest paper related to AI and biomedical informatics attributed to Ledley and Lusted (1959) 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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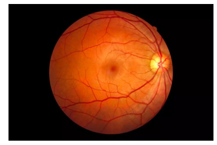
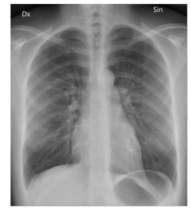
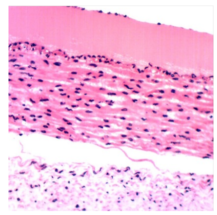
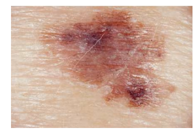
6

Re-emergence of AI in 21st century

- "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 advanced 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

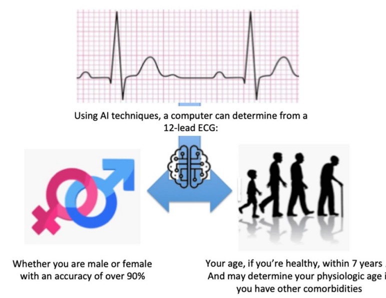





Predictive AI not limited to imaging

- 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)
- Use across spectrum of infectious disease surveillance, tracking, and forecasting (Brownstein, 2023)

Also success in “seeing” where humans cannot (Topol, 2023)

- 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)
  - Diagnosis and risk stratification in occlusive myocardial infarction (Al-Zaiti, 2023)
  - 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 in November, 2022 brought new type of AI into focus: generative AI
  - Initially based on GPT-3.5 model; added larger GPT-4 soon after
- Based on large language models (LLMs) processed by deep neural networks using large amounts of training data and tuned for specific tasks
  - Trained on massive amounts of text and other content, e.g., large Web crawls, books, Wikipedia, and more for ChatGPT (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 for specific tasks (Chung, 2022)
  - Activated by (and importance of) prompting (Liu, 2023)

Results of ChatGPT and other LLMs

- Medical board exams
  - USMLE "arms race," starting with (Kung, 2023)
    - Claimed best – https://www.openevidence.com/blog/openevidence-ai-first-ai-score-above-90-percent-on-the-usmle
    - Even on "soft skills" (e.g., communication skills, ethics, empathy, and professionalism) questions (Brin, 2023)
  - Passing level on some board exams (clinical informatics – Kumah-Crystal, 2023; radiology – Bhayana, 2023) but not others (neonatology – Beam, 2023)
- Answering questions
  - Vary by subject domain and type, but sometimes wrong and/or incomplete (e.g., Antaki, 2023; Chen, 2023; Goodman, 2023)
  - Consistently provided evidence-based answers to public health questions, although primarily offered advice rather than referrals (Ayers, 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
  - Answer questions in public forums (Sarraju, 2023)
  - Write letters with comparable or better empathy (Ali, 2023, Ayers, 2023)
- Use of predictive AI (closing the AI loop)
  - 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 downsides to generative AI

- Equally compelling disinformation – humans cannot distinguish between true and false tweets generated by GPT-3 and written by real Twitter users (Spitale, 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
- 8 dermatology questions asked of 4 LLMs recapitulated "harmful, race-based medicine" (Omiye, 2023)
- Performs worse than humans in abstraction and analogy problems (Moskvichev, 2023)
- Automated GPT detectors do not work well (Sadasivan, 2023; Odri, 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)

What is the evidence base for AI?

- Models are an important foundation (basic science) but need evidence of improved patient outcomes, care delivery, or other benefits (clinical science)
- Best evidence for any clinical intervention is randomized controlled trial (RCT) or systematic review of RCTs
- Three recent systematic reviews (Zhou, 2021; Plana, 2022; Han, 2023)
  - Small numbers of RCTs (40-80) relative to modeling papers
  - Many papers with methodological concerns, i.e., risk of bias
  - Unequal distribution of topical coverage, e.g., excess of colonoscopy imaging studies

Will AI help or hinder medicine?

- Real-world use and evidence base still modest – only 21% of physicians in group practices have used AI applications (MGMA, 2023)
- “AI won’t replace radiologists, but radiologists who use AI will replace radiologists who don’t,” (Langlotz, 2019)
- Must also address bias in data and algorithms
  - AI may compromise care if not used properly (DeCamp, 2023)
  - Must be implemented in responsible (Dorr, 2023) and fair (Chen, 2023) ways

15

Questions?

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16