



Medicine to Math: Statistics, Machine Learning, and AI

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Agenda



Why This Talk?

- Medicine increasingly relies on mathematical models
- From bedside decisions to AI-driven care
- Goal: Understand the journey from statistics to AI



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AI in Medicine



Artificial Intelligence has tremendous potential to advance clinical practice and the delivery of patient care.



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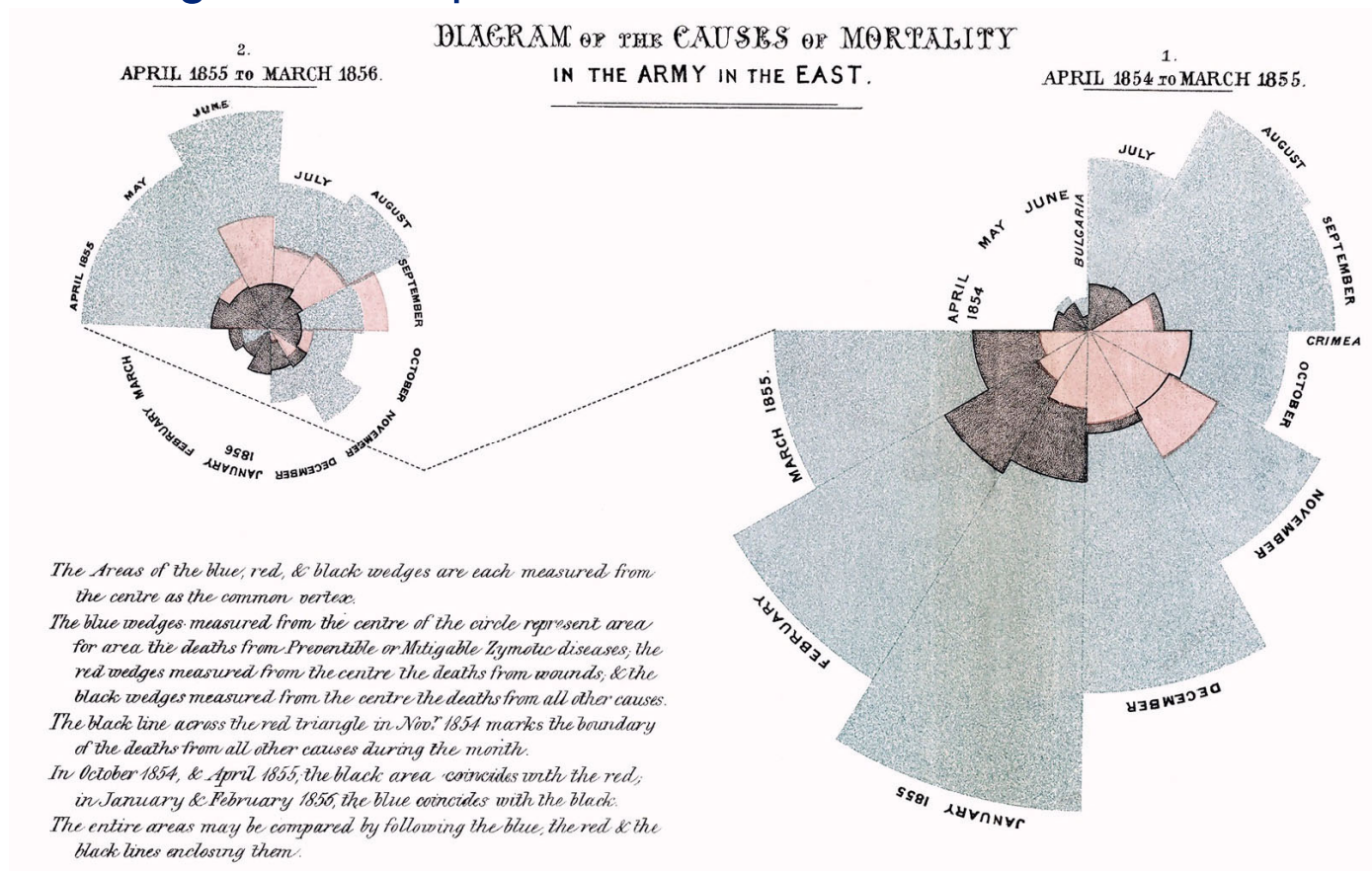


Statistics



Florence Nightingale: Data

- Florence Nightingale: data visualization & mortality stats
- Antiseptic techniques validated statistically
- Math changed clinical practice





BIOMETRIKA.

THE PROBABLE ERROR OF A MEAN.

By STUDENT.

Introduction.

ANY experiment may be regarded as forming an individual of a "population" of experiments which might be performed under the same conditions. A series of experiments is a sample drawn from this population.

Now any series of experiments is only of value in so far as it enables us to form an estimate of the population to which the experiment

William Gosset: A Beer Story

- Developed by William Sealy Gosset at Guinness Brewery
- Used for quality control in beer production
- Compare two small samples to determine significance



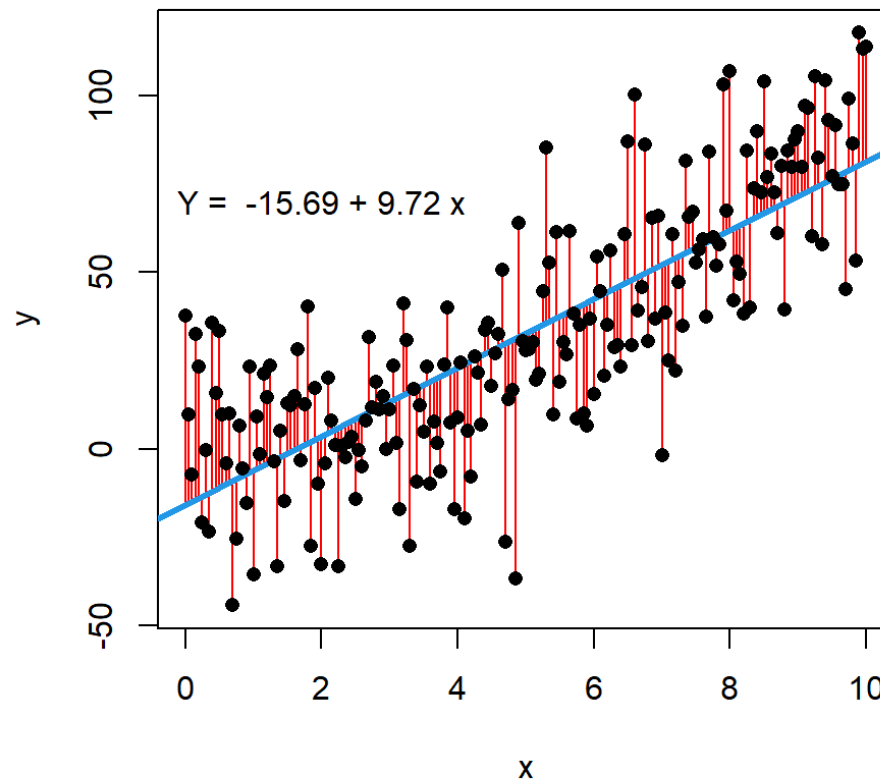
From Evidence to Prediction

- Descriptive Statistics
 - T-test used in medicine to compare treatment vs control
 - Introduced concept of statistical significance
 - P-value
- Evidence-Based Medicine (EBM):
 - Treatment A vs. Treatment B
 - Is there a real difference? (p-value, statistical significance)
- But what's next?
 - Beyond describing differences → predicting outcomes
 - Not just “Which is better?” but “How do variables interact?”
- Shift in focus:
 - From comparing two fields → mapping the landscape
 - Understanding relationships among parameters to forecast what matters most



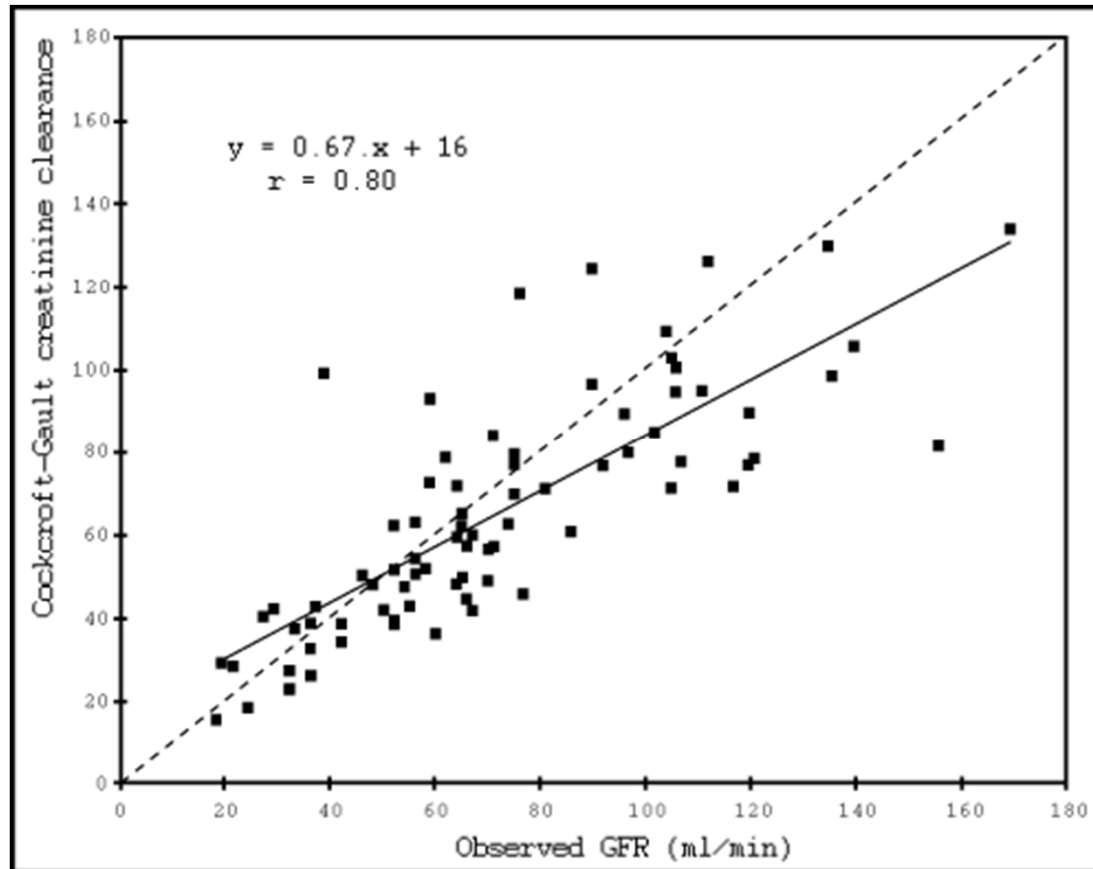
The Rise of Predictive Statistics

- Linear regression: fitting a line through data points
- Predictive formula: $y = mx + b$



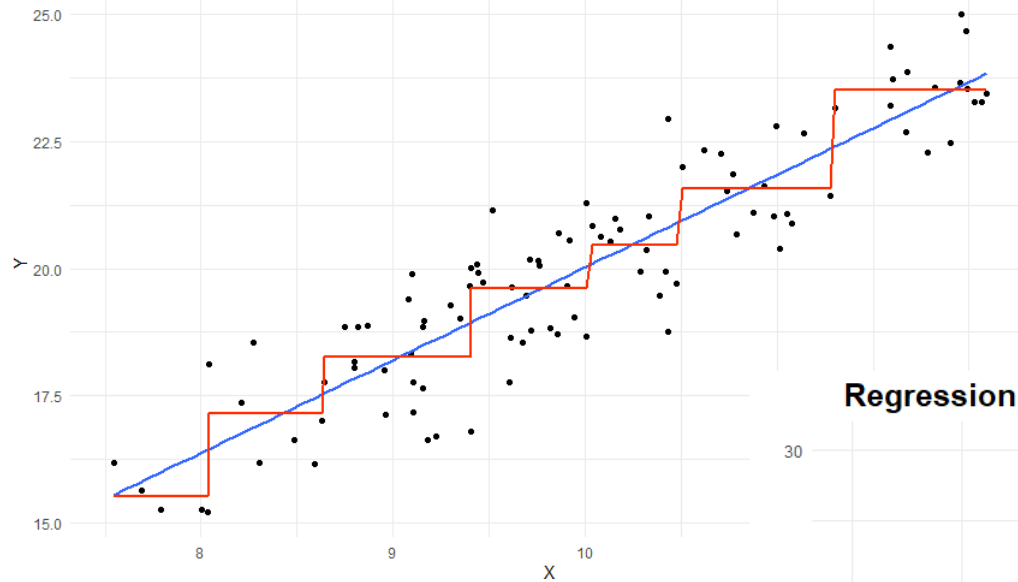
Medical Example

- Creatinine clearance (Cockcroft-Gault equation)
- Predicting GFR from age, weight, serum creatinine

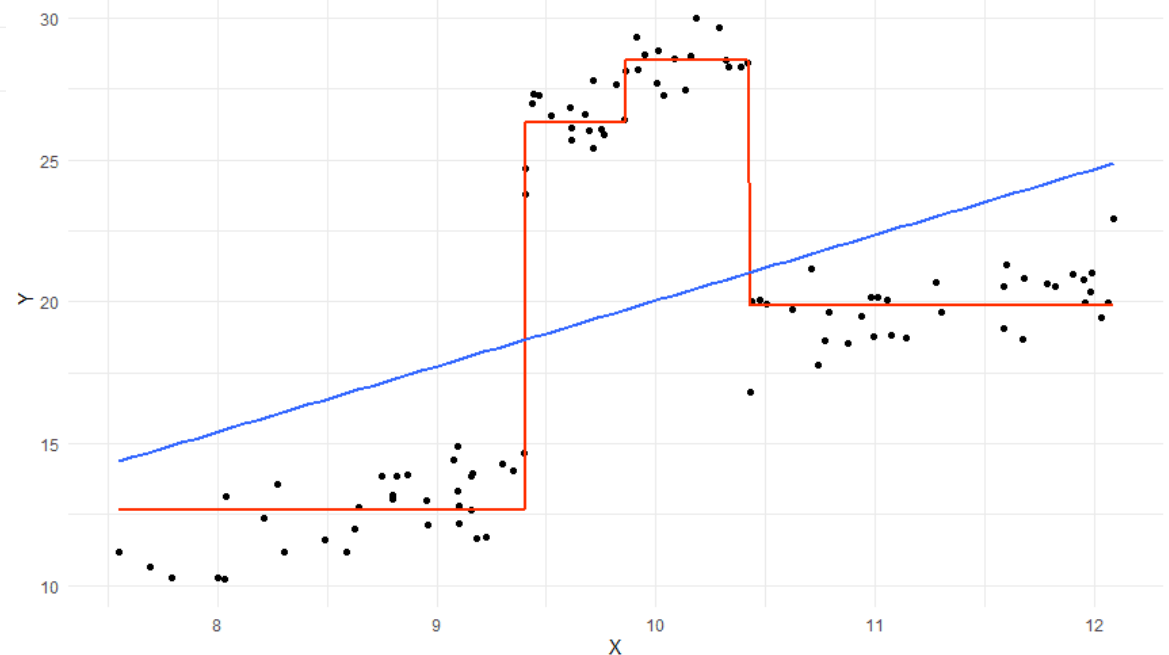


Real life data may not be linear

Linear Regression Fits Linear Data Better than Regression Tree

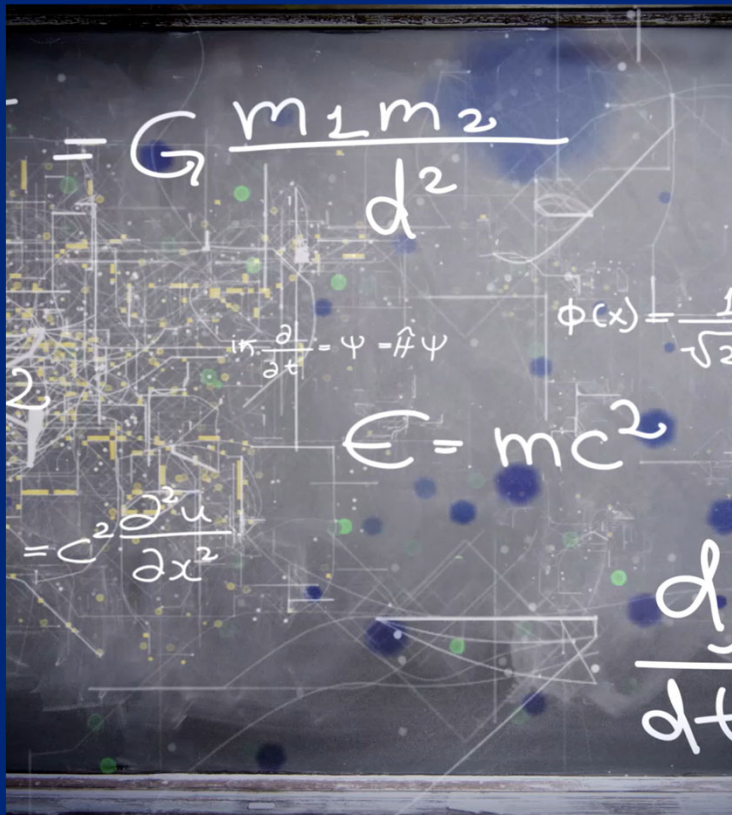


Regression Tree Fits Non-Linear Data Better than Linear Regression





Machine Learning



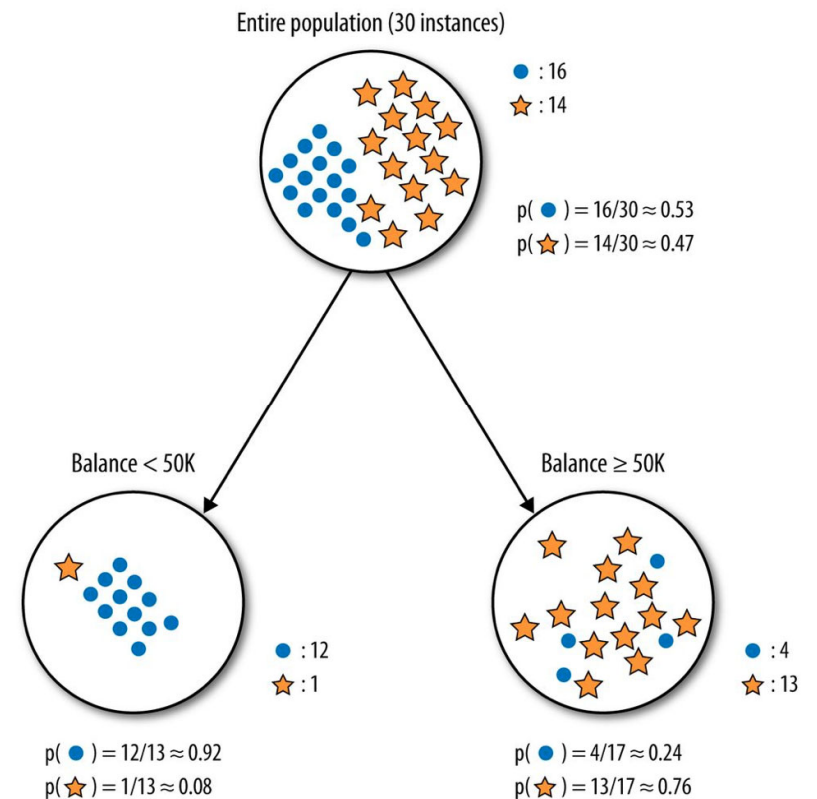
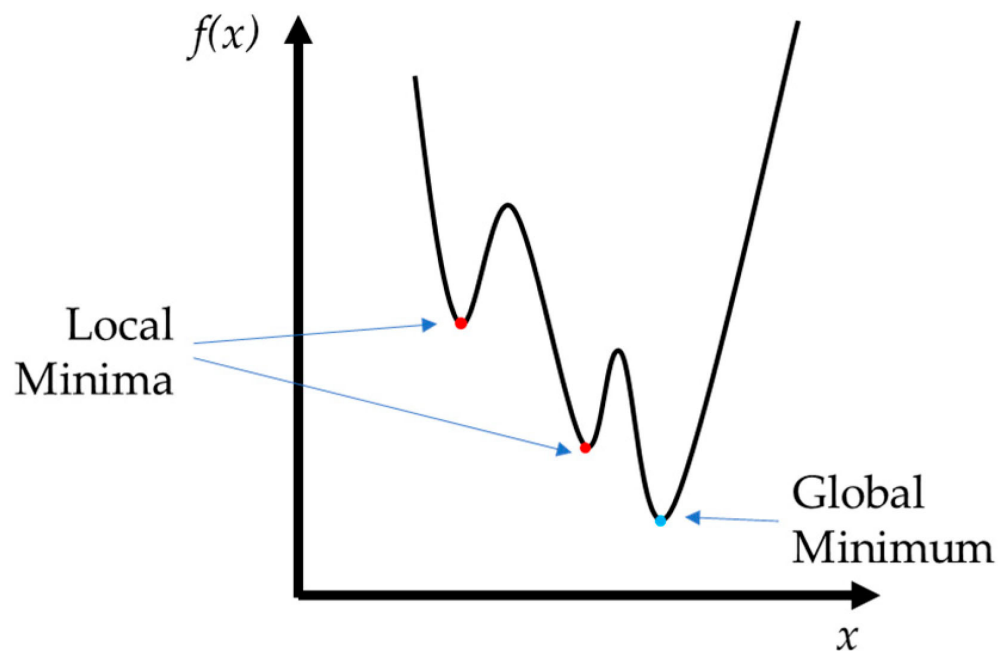
From Regression to Machine Learning

- **Regression:**
 - Fits a single line or curve to predict outcomes
 - Assumes a known functional form (e.g., linear)
- **But real-world data is complex:**
 - Non-linear relationships
 - Multiple interacting variables
- **Enter Machine Learning:**
 - Automates prediction without predefined formulas
 - Uses **branching decisions** (trees) and **iterative optimization**
 - Goal: **Minimize error** across many possible splits and models
- **Think of it as:**
 - Regression on steroids → adaptive, multi-dimensional, data-driven



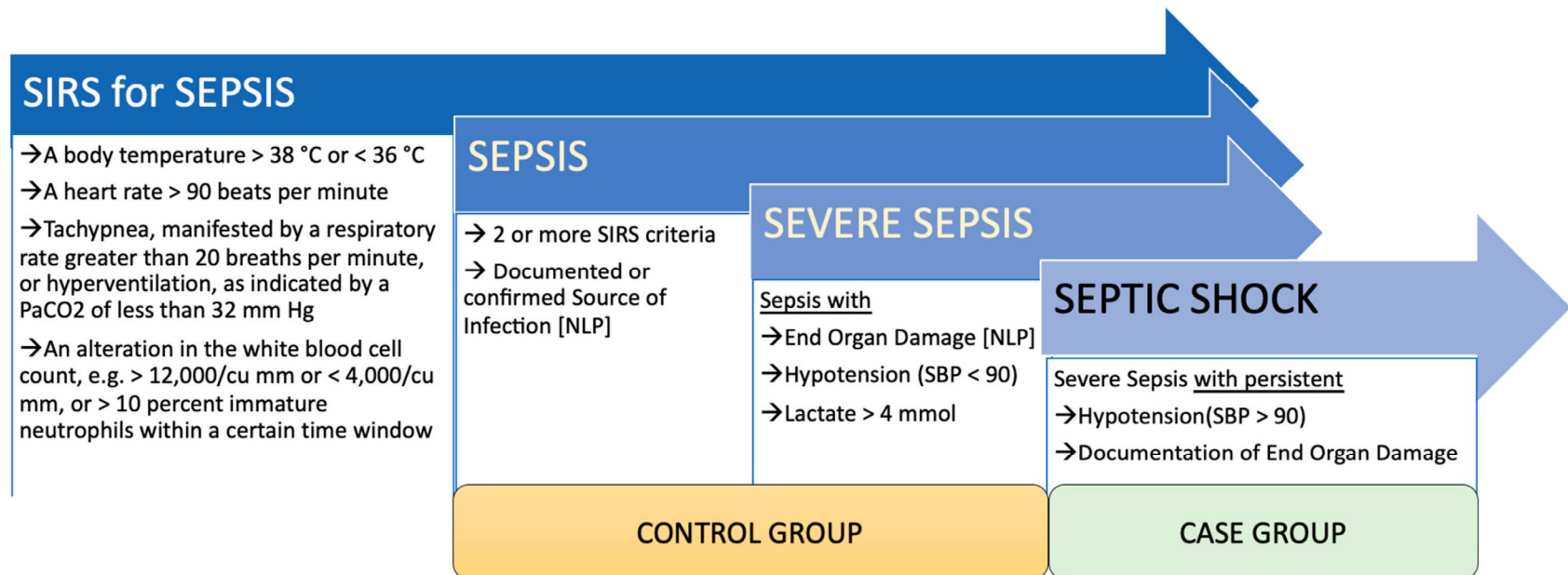
Decision Trees

- Splitting data into branches based on features
- Entropy & information gain
- Analogy to calculus finding minima



Medical Applications

- Predicting readmissions, sepsis alerts, imaging classification
- Utilization management: predicting if the request is going to be an approval

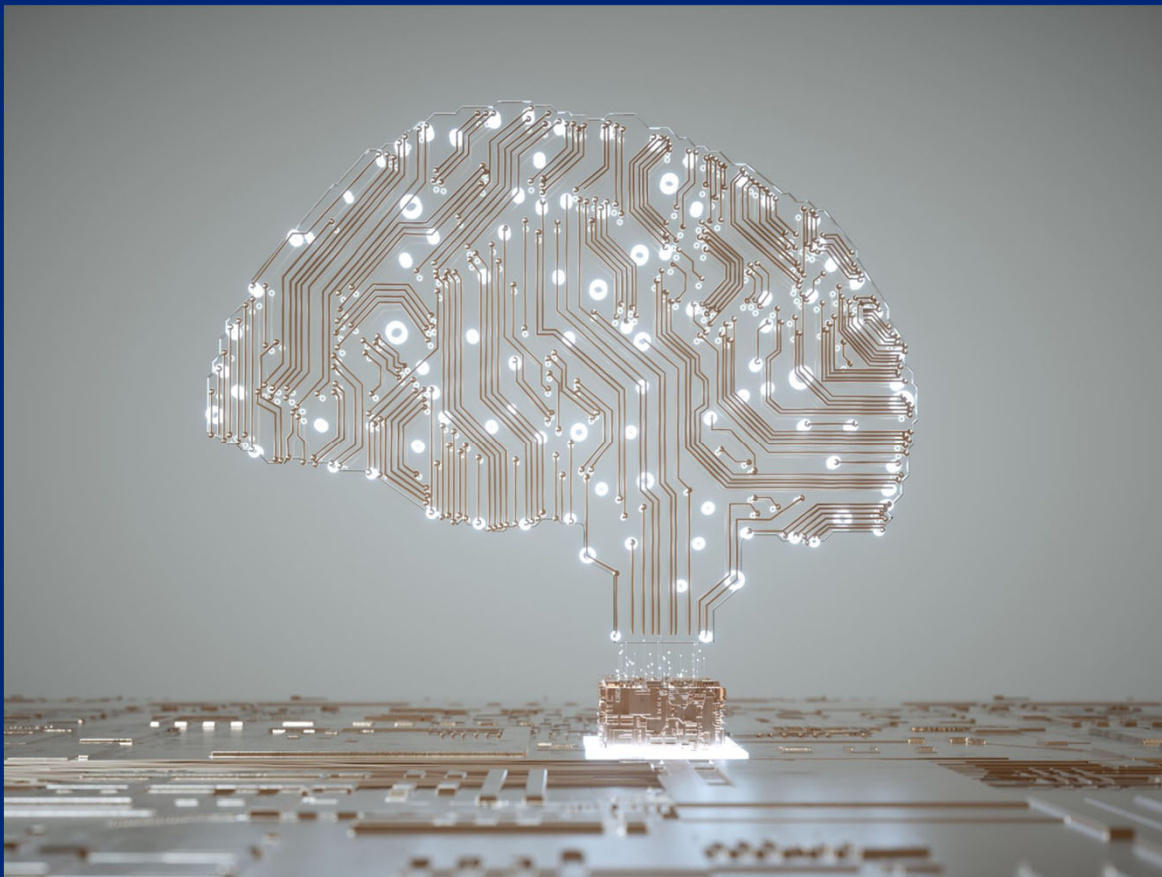


[NLP]: Data extracted using natural language processing applied to provider notes (unstructured sources)





AI: Neural Networks



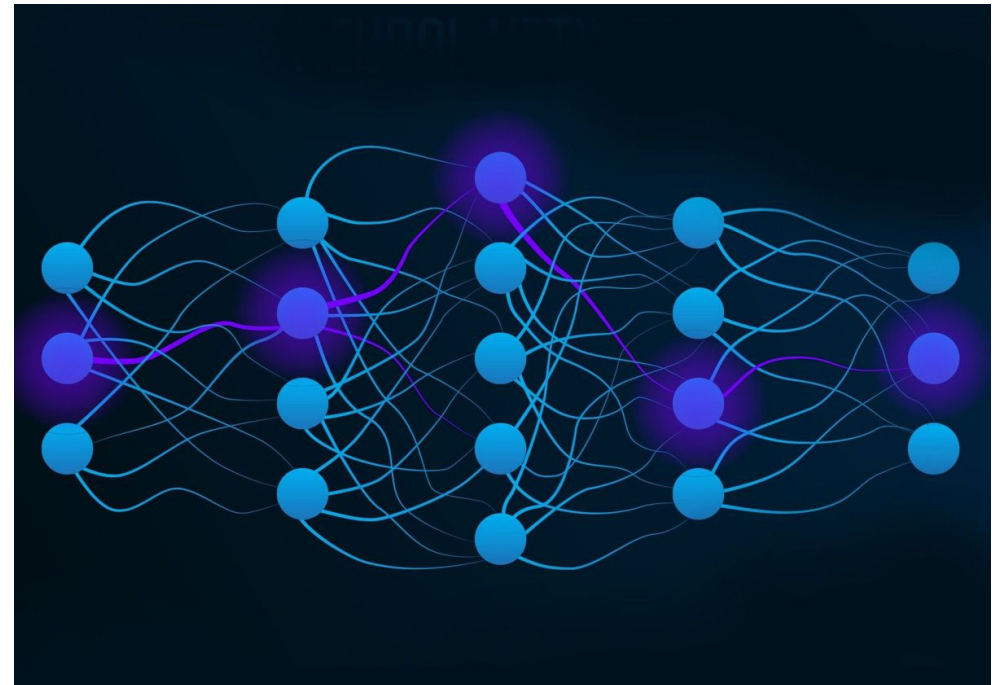
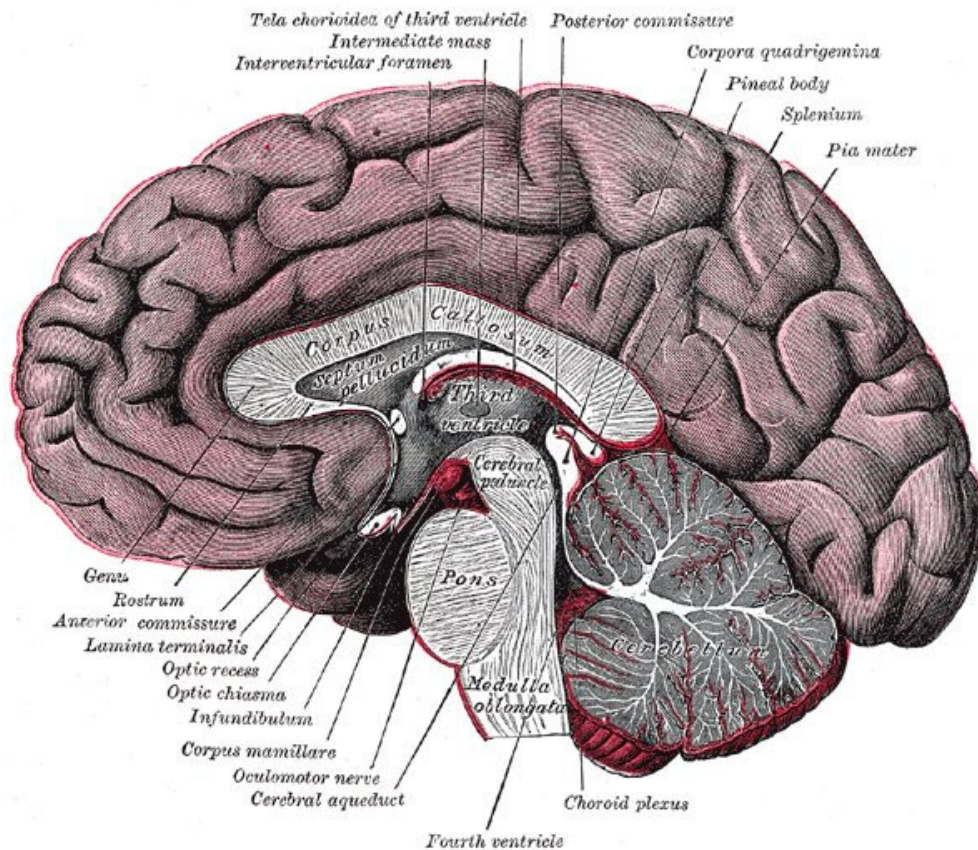
From Features to Context

- **Machine Learning:**
 - Uses features to make predictions
 - Relationships assumed to be fixed
- **But reality is dynamic:**
 - Meaning depends on **order, proximity, and context**
- **Example:**
 - *"Mark, a vegetarian, eats shoots and leaves"*
 - *vs "Mark, the serial murderer, eats, shoots, and leaves"*
- **This is AI today:**
 - Models that **understand patterns in context**, not just features
 - Foundation of **language models and contextual prediction**



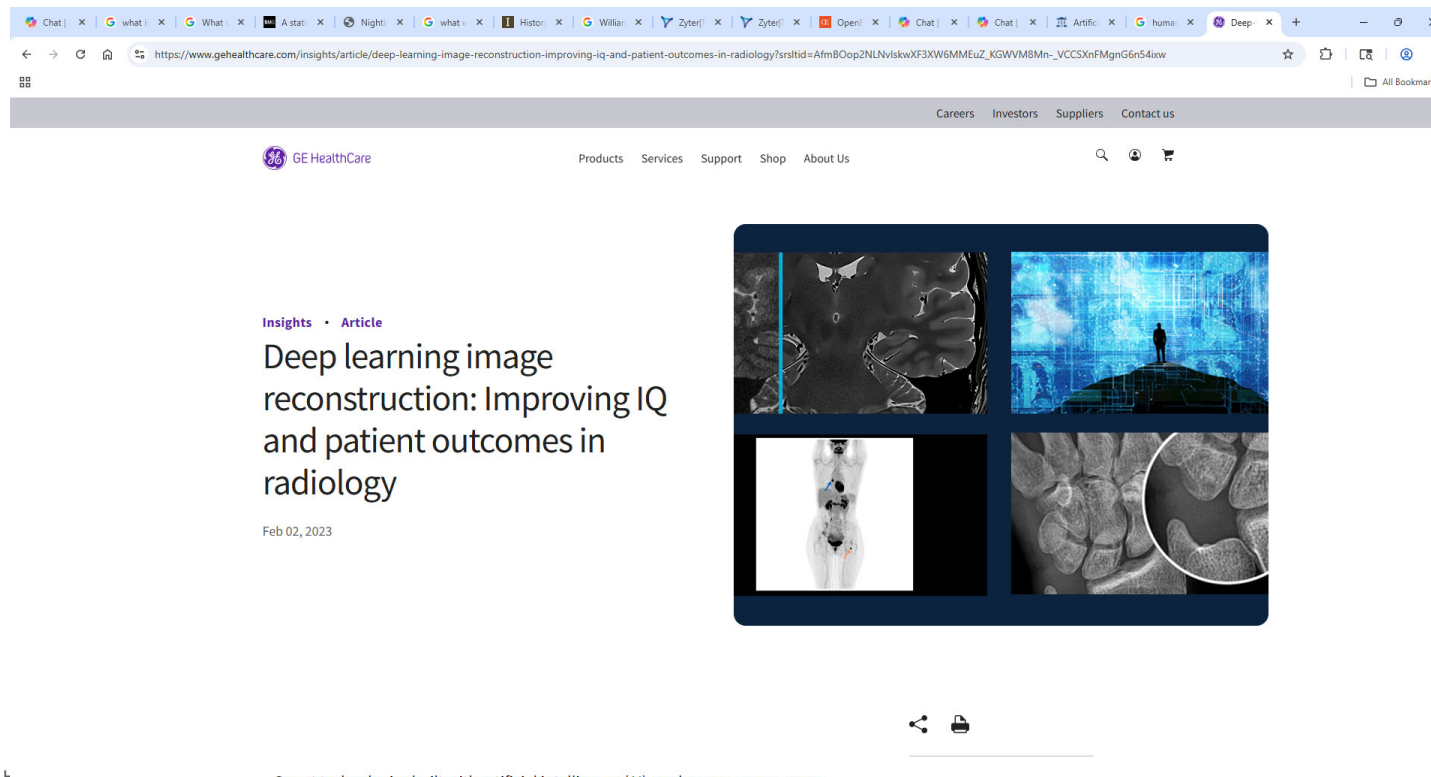
Neural Networks: Inspired by the Brain

- Layers of nodes with weighted connections
- Goal: minimize cost function (error)
- Backpropagation = learning



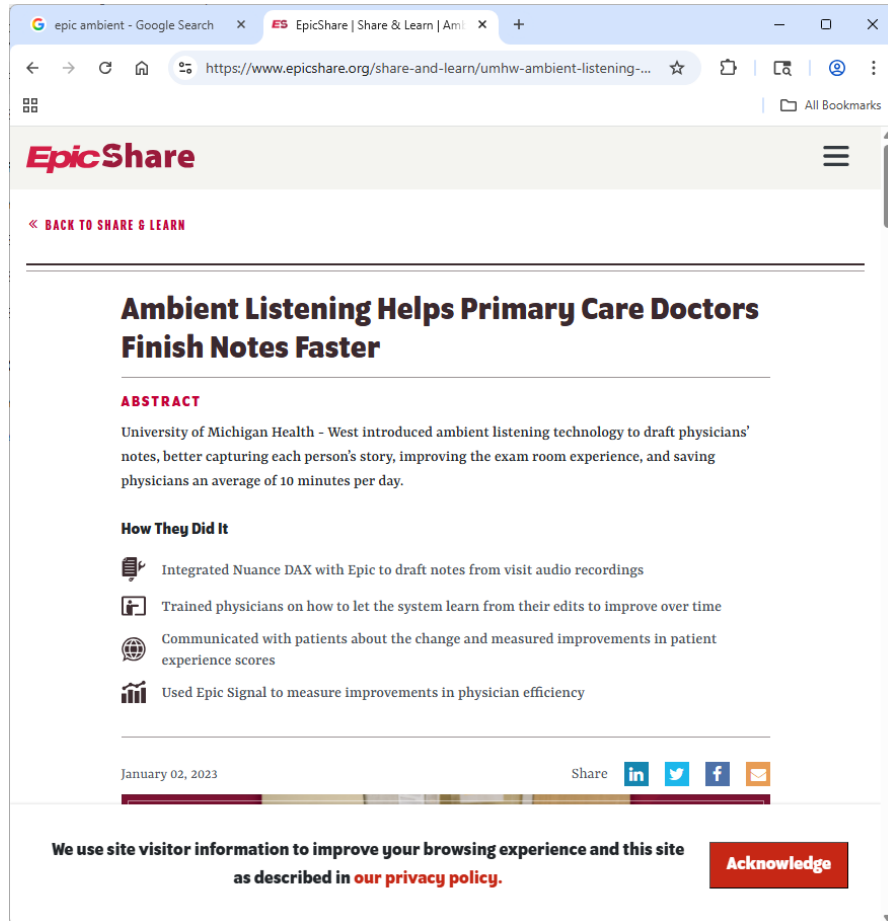
Deep Learning in Medicine

- Radiology: image interpretation
- Pathology: pattern recognition
- Predictive models for disease progression



Large Language Models (LLMs)

- Predicting next word using probabilities
- Trained on massive text corpora
- Emergent reasoning



The screenshot shows a web browser window with the URL <https://www.epicshare.org/share-and-learn/umhw-ambient-listening-...>. The page features the EpicShare logo and a navigation bar. The main article is titled "Ambient Listening Helps Primary Care Doctors Finish Notes Faster". Below the title is an abstract summarizing the University of Michigan Health - West's introduction of ambient listening technology. The article also includes a section titled "How They Did It" with four bullet points describing the implementation. At the bottom, there is a date "January 02, 2023", a share button, and social media icons for LinkedIn, Twitter, Facebook, and Email. A footer notice states: "We use site visitor information to improve your browsing experience and this site as described in our privacy policy." with an "Acknowledge" button.

EpicShare

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Ambient Listening Helps Primary Care Doctors Finish Notes Faster

ABSTRACT

University of Michigan Health - West introduced ambient listening technology to draft physicians' notes, better capturing each person's story, improving the exam room experience, and saving physicians an average of 10 minutes per day.

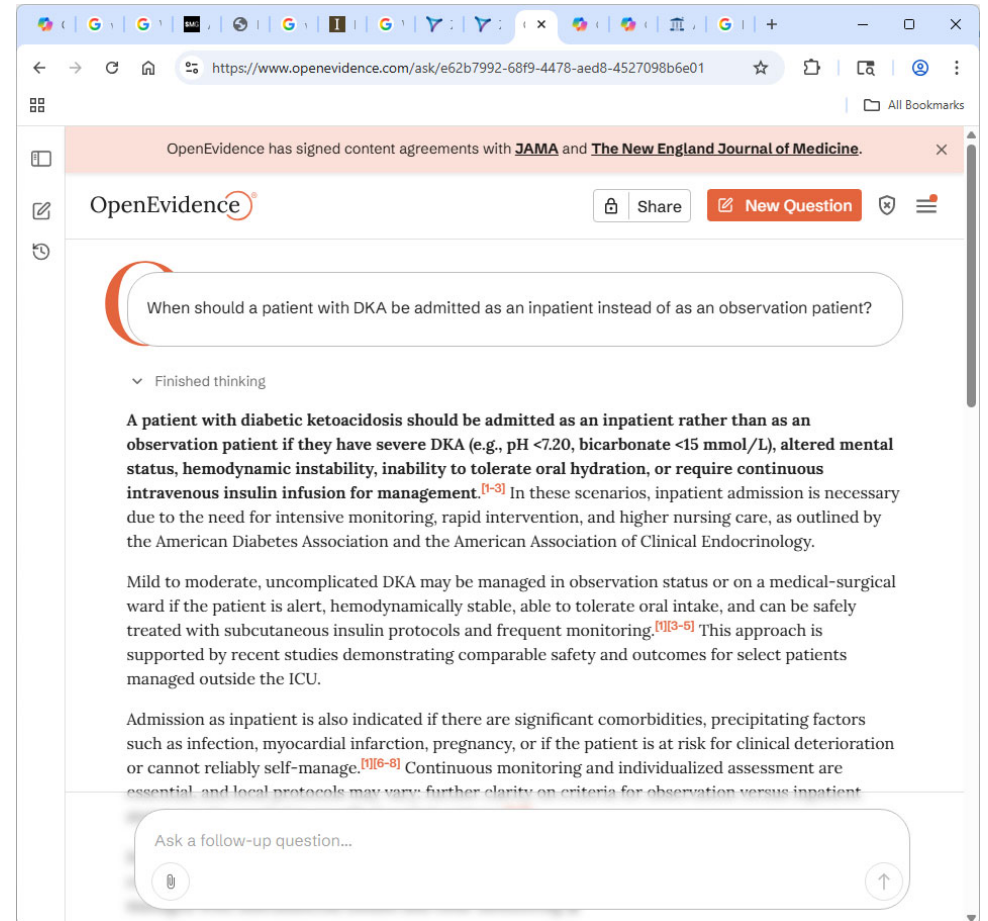
How They Did It

- Integrated Nuance DAX with Epic to draft notes from visit audio recordings
- Trained physicians on how to let the system learn from their edits to improve over time
- Communicated with patients about the change and measured improvements in patient experience scores
- Used Epic Signal to measure improvements in physician efficiency

January 02, 2023

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The screenshot shows a web browser window with the URL <https://www.openevidence.com/ask/e62b7992-68f9-4478-aed8-4527098b6e01>. The page features the OpenEvidence logo and a navigation bar. A banner at the top states: "OpenEvidence has signed content agreements with JAMA and The New England Journal of Medicine." Below the banner is a question input field with the text: "When should a patient with DKA be admitted as an inpatient instead of as an observation patient?". The answer is displayed below the question, starting with "Finished thinking". The answer text is: "A patient with diabetic ketoacidosis should be admitted as an inpatient rather than as an observation patient if they have severe DKA (e.g., pH <7.20, bicarbonate <15 mmol/L), altered mental status, hemodynamic instability, inability to tolerate oral hydration, or require continuous intravenous insulin infusion for management.^[1-3] In these scenarios, inpatient admission is necessary due to the need for intensive monitoring, rapid intervention, and higher nursing care, as outlined by the American Diabetes Association and the American Association of Clinical Endocrinology. Mild to moderate, uncomplicated DKA may be managed in observation status or on a medical-surgical ward if the patient is alert, hemodynamically stable, able to tolerate oral intake, and can be safely treated with subcutaneous insulin protocols and frequent monitoring.^{[1][3-8]} This approach is supported by recent studies demonstrating comparable safety and outcomes for select patients managed outside the ICU. Admission as inpatient is also indicated if there are significant comorbidities, precipitating factors such as infection, myocardial infarction, pregnancy, or if the patient is at risk for clinical deterioration or cannot reliably self-manage.^{[1][6-8]} Continuous monitoring and individualized assessment are essential, and local protocols may vary further clarity on criteria for observation versus inpatient." At the bottom, there is a "Ask a follow-up question..." input field with a button to submit the question.

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When should a patient with DKA be admitted as an inpatient instead of as an observation patient?

Finished thinking

A patient with diabetic ketoacidosis should be admitted as an inpatient rather than as an observation patient if they have severe DKA (e.g., pH <7.20, bicarbonate <15 mmol/L), altered mental status, hemodynamic instability, inability to tolerate oral hydration, or require continuous intravenous insulin infusion for management.^[1-3] In these scenarios, inpatient admission is necessary due to the need for intensive monitoring, rapid intervention, and higher nursing care, as outlined by the American Diabetes Association and the American Association of Clinical Endocrinology.

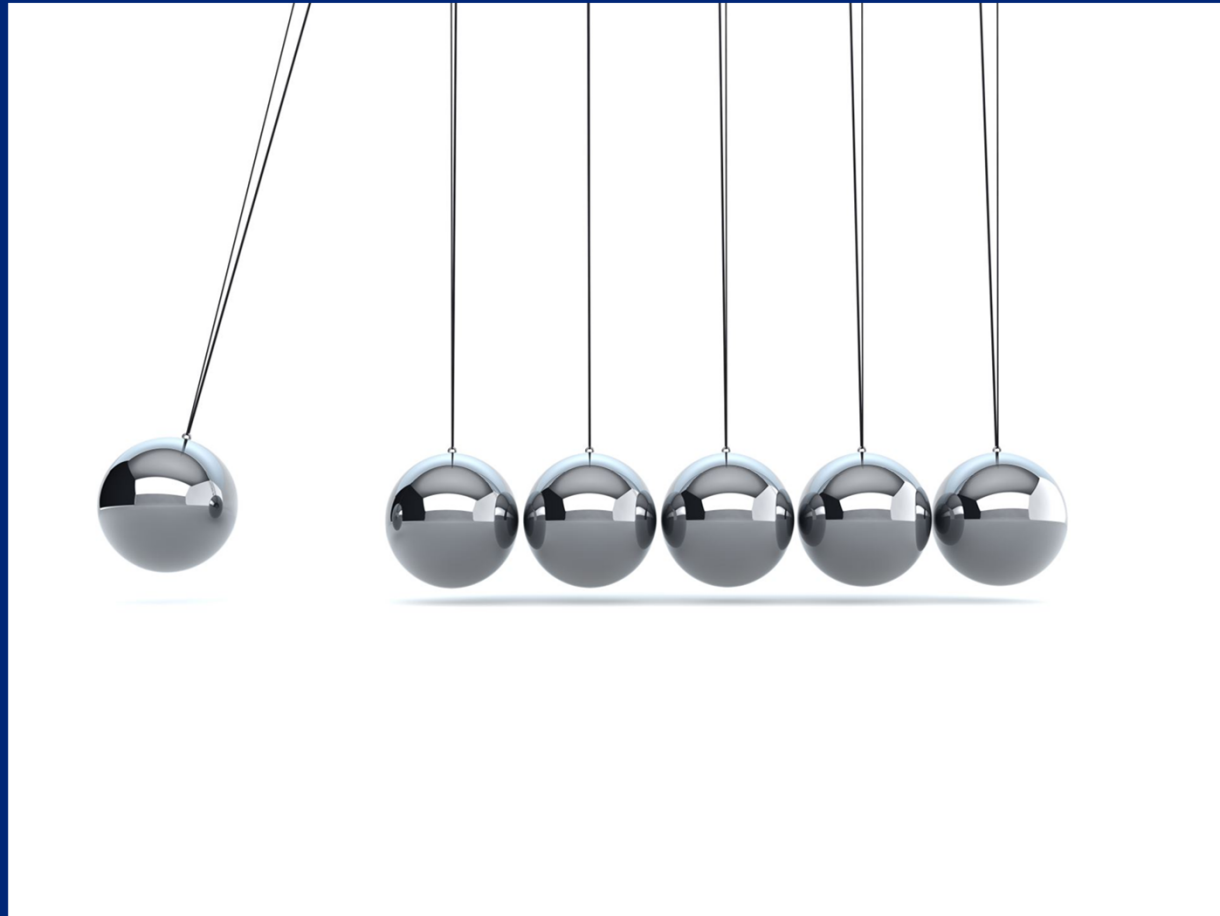
Mild to moderate, uncomplicated DKA may be managed in observation status or on a medical-surgical ward if the patient is alert, hemodynamically stable, able to tolerate oral intake, and can be safely treated with subcutaneous insulin protocols and frequent monitoring.^{[1][3-8]} This approach is supported by recent studies demonstrating comparable safety and outcomes for select patients managed outside the ICU.

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Ask a follow-up question...



Ethics



Different ethical theories provide distinct frameworks for determining what is **morally right** or **wrong**. These theories may be drawn upon when ethical decisions need to be made in a **variety of different contexts**, guiding what a potential '**right**' course of action should look like based on contexts such as **people, community values, principles** and potential **consequences**.

Deontological

- Immanuel Kant

Deontological ethics focuses on the nature of **actions** rather than their **consequences**. The philosophy emphasises the importance of individuals following their established **moral rules, duties** or **principles**, regardless of the **outcomes**.

For example,

Utilitarian

- Jeremy Bentham & John Stuart Mill

Utilitarian ethics examines the **morality of actions** based on their **potential consequences**. It focuses on **maximising happiness** or **minimising suffering** for all parties involved.

For example, If **lying** in a **specific situation** would result

Virtue

- Aristotle

A **virtue** is a **positive trait** or **characteristic** that is considered **morally good** in an individual. Virtue ethics focuses on the **moral character of individuals**. The theory emphasises the development of these **traits** and **values** as a means to determine the right and wrong courses of action.

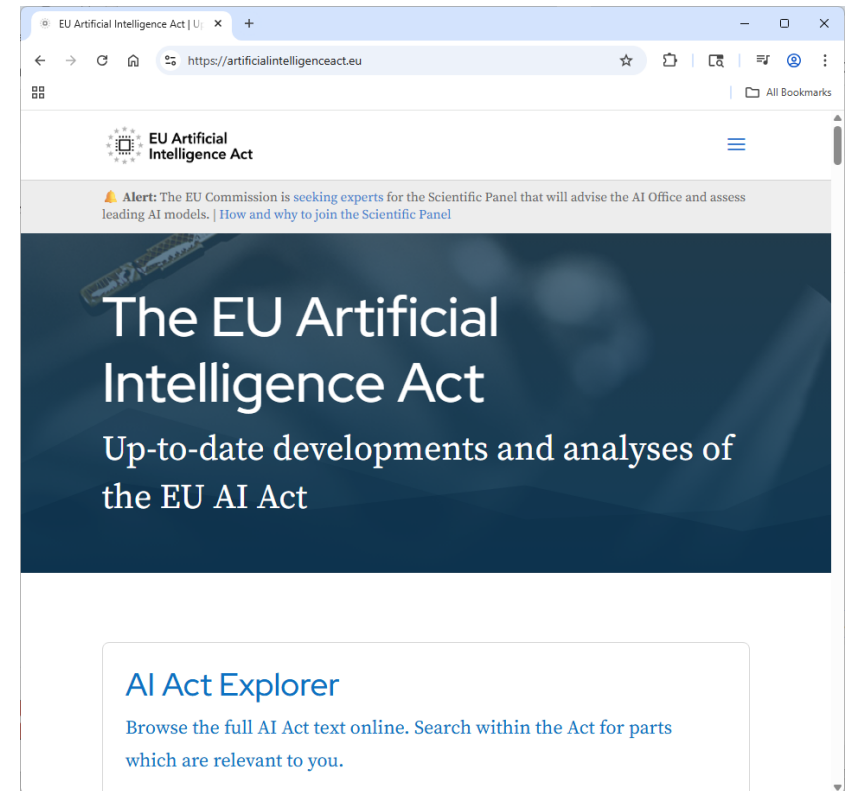
Ethical Foundation: Principlism in AI

- Autonomy → Transparent AI systems with informed consent and explainability
- Beneficence → AI that enhances clinical outcomes and supports decision-making
- Non-maleficence → Rigorous testing and post-market surveillance to prevent harm
- Justice → Bias mitigation and equitable access to AI-driven healthcare



EU AI Act: A Global Benchmark

- World's first comprehensive AI legislation (2024)
- High-risk AI systems must meet strict requirements:
 - Transparency and explainability
 - Human oversight
 - Bias detection and mitigation
 - Data governance and privacy
 - Fundamental rights impact assessments
- Prohibited practices include:
 - Social scoring
 - Biometric categorization based on sensitive traits
 - Emotion recognition in sensitive contexts





Bias Prevention & Sensitive Group Protection

- Demographics drive health outcomes
- AI can amplify existing disparities
- Medicine is heterogeneous
- Variance matters
- Unaddressed bias will lead to real-world harm





Human Oversight & Clear Regulatory Guidance

- AI mimics human intelligence—but inherits human flaws
- Imagine medicine without human oversight
- Humans must stay in the loop
 - Auditing and review of critical decisions
 - Predefined oversight mechanisms and checkpoints
- Oversight and regulation must be designed a priori, not retrofitted





Transparency & Explainability

- Ability to **check the reasoning process** builds trust
- **Explainability = Trust**
- Neural networks are **flexible but opaque** → often a “black box”
- **Noise vs. Information**
 - Humans must perform **sanity checks** to ensure noise is filtered and conclusions make sense
- **Testing must be transparent**
 - Processes should be **repeatable, auditable, and explainable**



Conclusion: The Dawn of a New Era

- **The Age of AI is here**
 - Like past revolutions: agriculture, industry, electricity, computation, internet
- **You don't need to code to understand AI**
 - Just as you don't need anatomy biochemistry to understand humans
- **AI is your new coworker and assistant**
- **Our responsibility:**
 - Understand its underpinnings, **strengths**, and **weaknesses**.
 - Understand the **philosophy** and **ethics** of this new creation
- **Shape this tool for the good of our communities**

