Clinical Decision Making and Decision Analysis

CBB 7400

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What is Decision Making?

What do you need to make a decision

- World Model:
  - What will happen if I do X?
- Outcome Model:
  - How much value does that branch lead to?

Disciplines of Analyzing Decision Making

- Causal Inference
  - Concerned with:
    - what is the change in an outcome of interested for two different treatments or exposures
- Reinforcement Learning
  - What policy (method of selecting actions) creates optimal value?
- Game Theory
  - In situations where an individual's decisions can impact the decision of others, what strategies emerge and are optimal?

Decision Making In Medicine

What does she have—A, B, or C?

What test do I order?

What treatment should I choose?

Should I admit to hospital or manage at home?

Challenge 1: Uncertainties

- Cannot agree on what constitutes a disease.
  - Fever = Temp ≥ X?
  - Sinusitis = mucosal thickening on CT ≥ Y
- Even with clear criteria, disagree about interpretation of findings
  - Truth of patient's statement?
  - Hearing acuity affects what is heard thru stethoscope
- Testing has false positive and false negative results
- Therapy has failure rate
- No certainty about outcome of an intervention
- May disagree about desirability of an outcome

Cognitive Decision Systems

Type 1

Type 2

Cognitive Decision Systems

Type 1: The Intuitive/Reflexive System involves automatic decision making based on pattern recognition. It's fast and requires little effort.

Type 2: The Analytical/Problem-Solving System is more critical and logical. It involves stepping back and thinking more carefully about the patient's presentation. It involves estimating pretest probabilities, continuous self-questioning, and considering alternative diagnoses.

Cognitive Decision Systems

Type 1

Type 1

Raw pattern recognition

Heuristics

Raw Pattern Recognition

Chest pain and unilateral leg swelling

Representativeness

When confronted with a new experience and a need to make a judgment or decision, our brains automatically rely on past experiences and mental representations seemingly similar to this new situation

Representativeness is about reliance on stereotypes.

Use of Heuristics

Experience-based techniques that help in problem solving, learning and discovery

Used to come to a solution rapidly that is hoped to be close to the best possible answer

Examples

- Trial and error
- If you are having difficulty understanding a problem, try drawing a picture.

Sources of Error — Type 1 Thinking

- **Anchoring bias** – locking on to a diagnosis early in the assessment and failing to adjust to new information
- **Diagnosis momentum** – accepting a previous diagnosis without considering the differential diagnosis adequately
- **Confirmation bias** – looking for evidence to support a pre-conceived opinion, rather than looking for dis-confirming information
- **Premature closure** – once you have found one diagnosis (eg: a fracture on a set of x-rays) you stop to searching for others (eg: the second fracture on the same set of x-rays)

More Cognitive Biases

- **Availability Bias**: overestimate rare events because of recency
- **Representativeness Bias**: overestimate rare events because of pattern matching
- **Value Bias:** distort probability because of the perceived value

Cognitive Decision Systems

Type 2

Probabilities
Bayesian Thinking and Probability Revision
Threshold approach to Decision Making
Formal Decision Analysis

Probabilistic Decision Making

- Wordle is a great example of sequential probabilistic decision making
  - Prior probabilities
  - Sequential decisions

- Wordle is restricted to two letter words with A,B,C,D
  - P(AB)=0.5, P(CB)=0.3, P(DB)=0.19, P(CD) = 0.01
  - First guess: AB
    - 0.5 chance immediate win
    - Second guess, best has 0.6:
    - total expectation = 0.5+0.5*0.6 = 0.8 in two steps
  - First Guess: CD
    - 0.01 chance immediate win
    - Second guess 100%
    - Total expectation = 0.01+0.99*1 = 1.0

Fundamentals of Probabilities

- **Summation** - the sum of all possible outcomes of a chance event = 1.0
- **Joint probability** - concomitant occurrence of any number of events; p[E and F]
- **Product rule** - p[E and F] = p[E] x p[F] when they are independent
- **Conditional probability** - probability that E occurs given that F is known to occur

  p[E | F] = p[E and F] / p[F]
- **Independence** - when p[E | F] = p[E]

Bayes' Formula

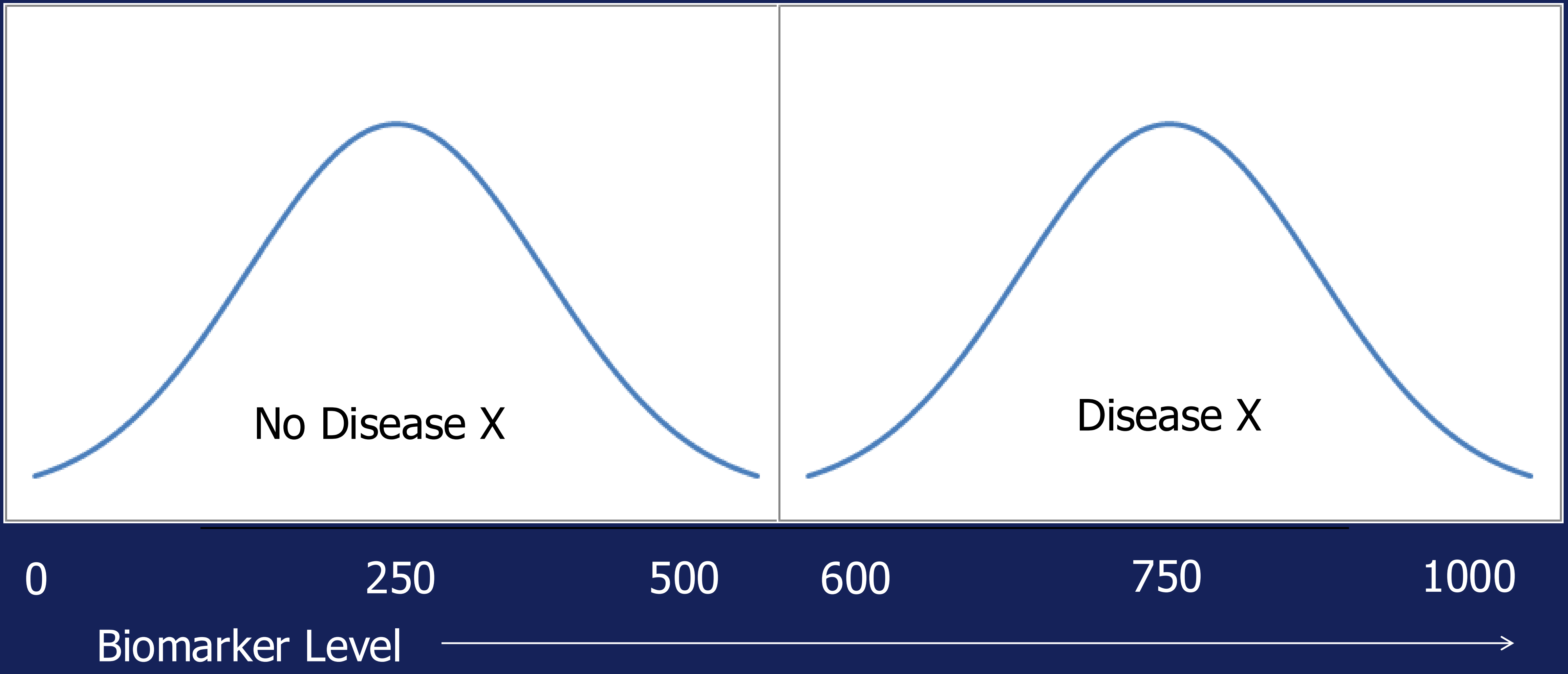
$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

- Probability revision in view of new information
- What is the p(D+|T+) i.e., the post test probability of disease
- **This requires knowing the pre-test probability (prevalence) of the disease: p(D+)**

Testing Truths

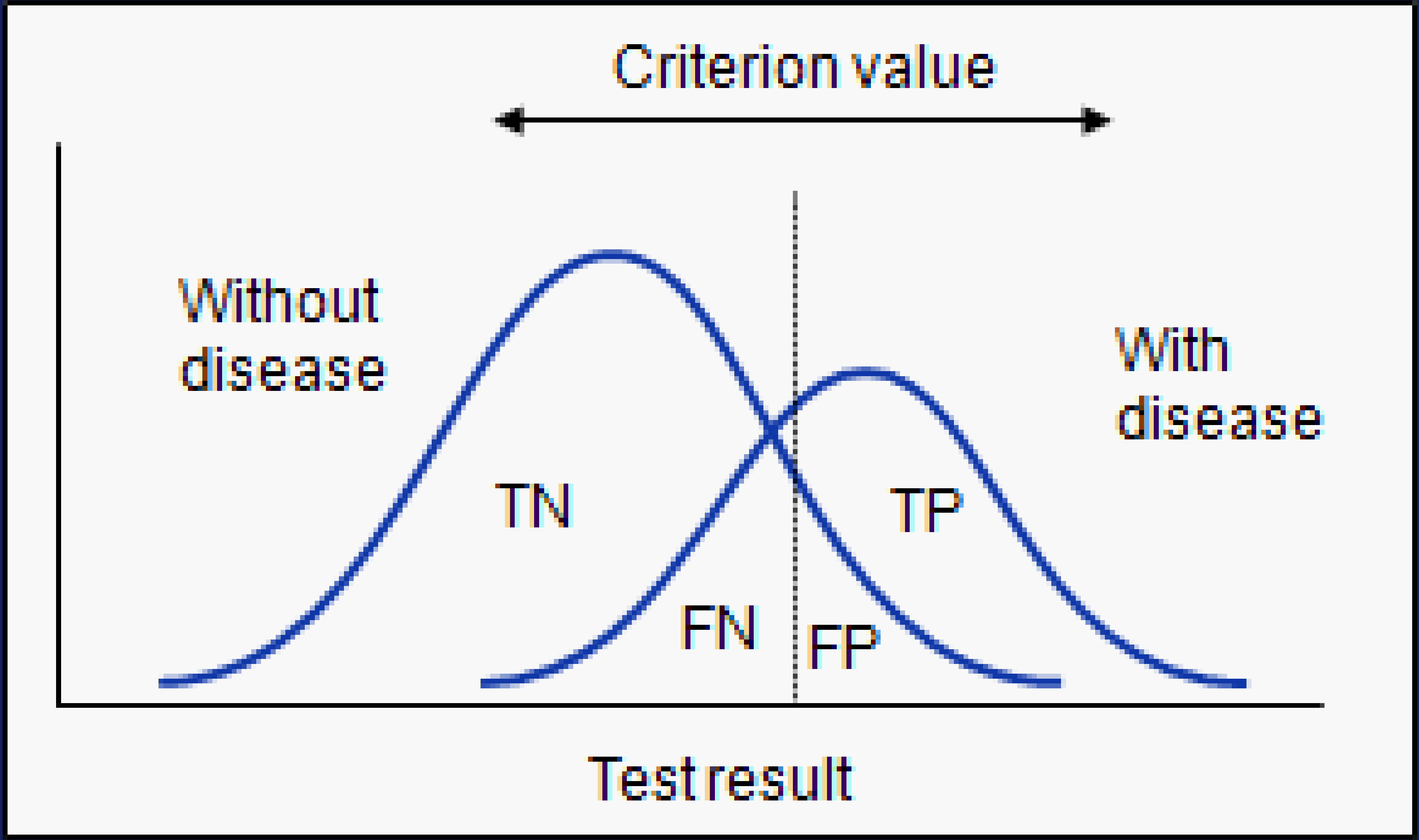
- Tests rarely reveal *with certainty* a patient's true state (true positive and true negative)
- False positive results and false negative results must be considered
- **Sensitivity** = **probability** of the test being positive when the patients has the disease $p(T+|D+)$
- **Specificity** = **probability** of the test being negative when the patient doesn't have the disease $p(T^-|D^-)$

Two Populations

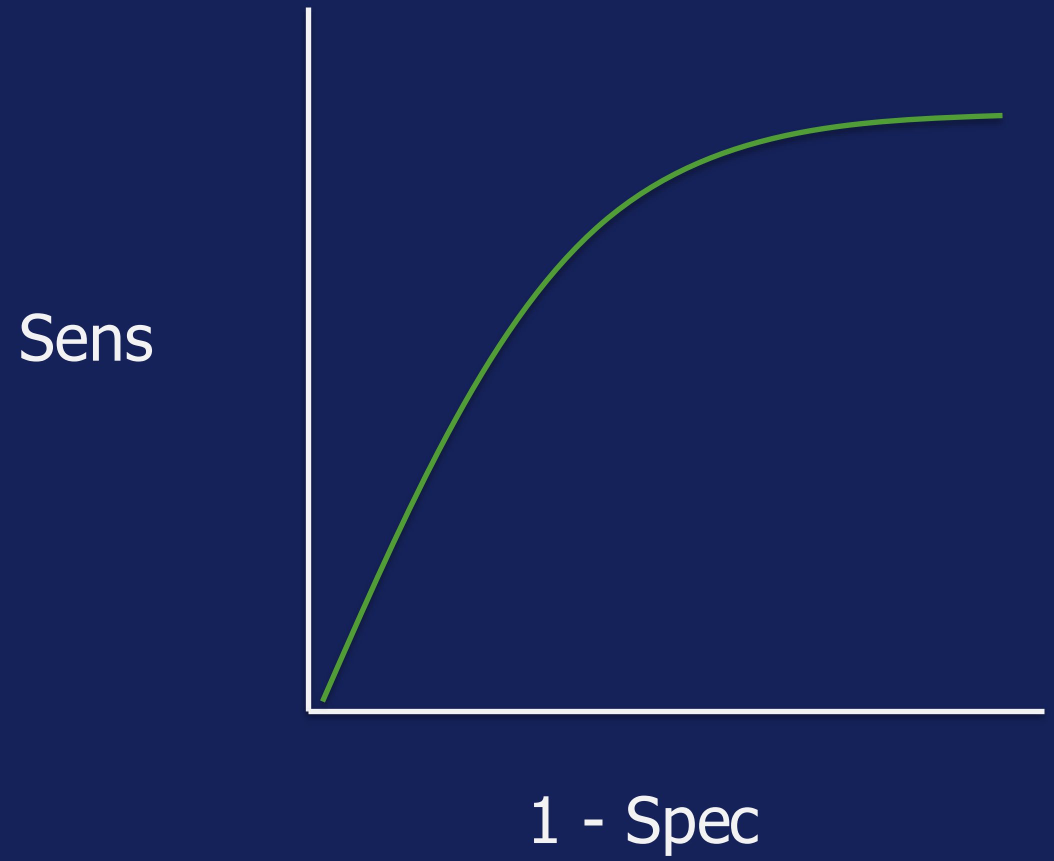


High Sensitivity
Many False Positives

High Specificity
Many False Negatives



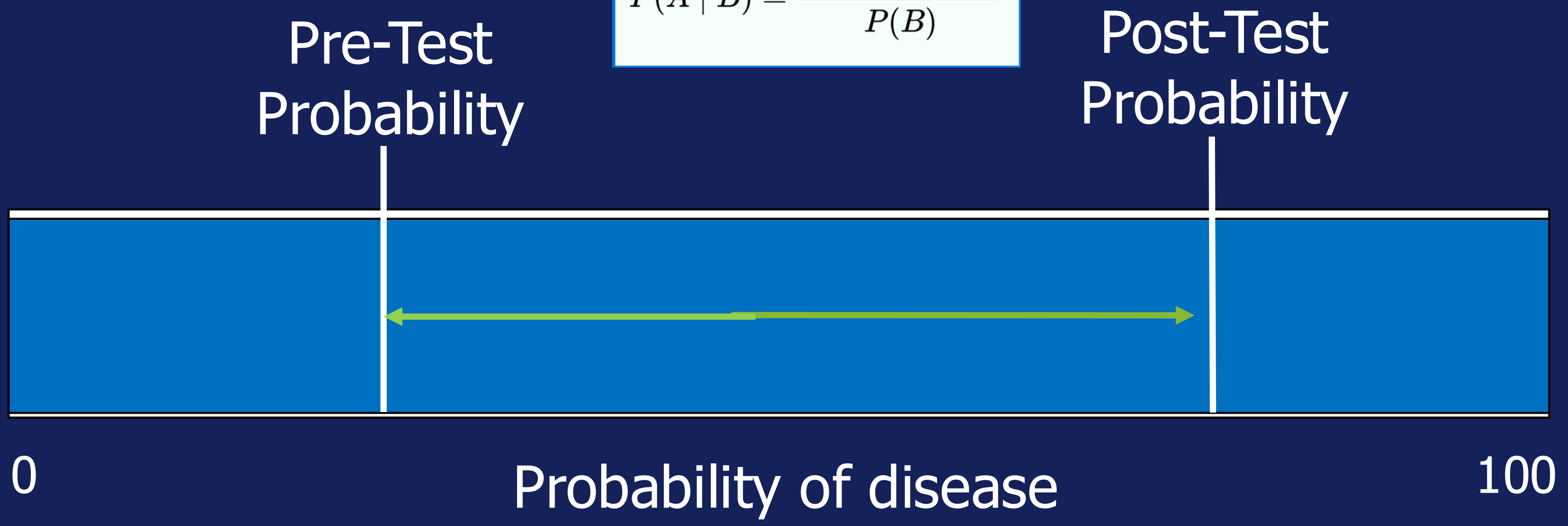
ROC Curve



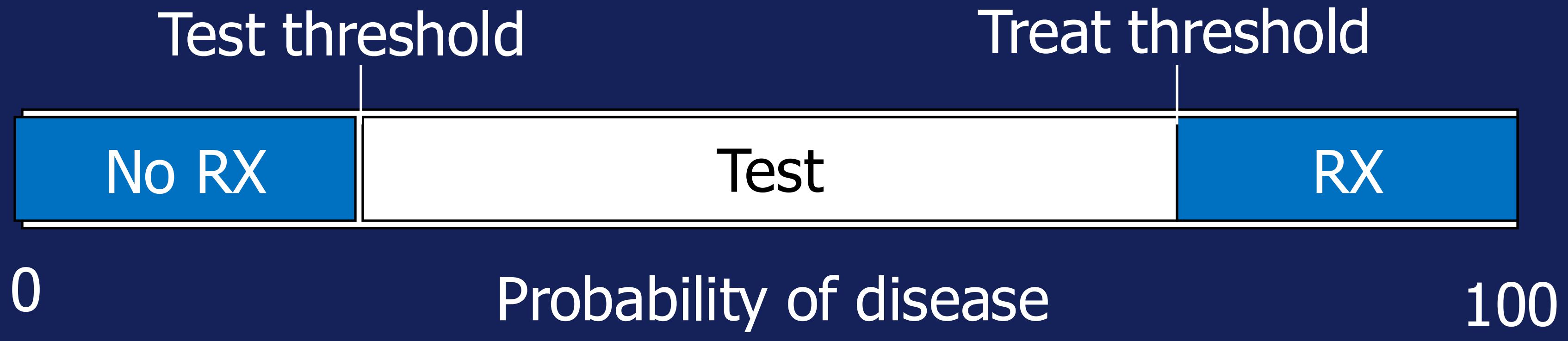
- Graphic representation of tradeoff between sensitivity and 1-specificity (FPR)
- Shoulder (inflection point can help determine optimal threshold for a test
- Area under the curve helps compare different tests. Higher AUC is better

Testing Is Probability Revision

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$



Threshold Approach to Testing and Treating

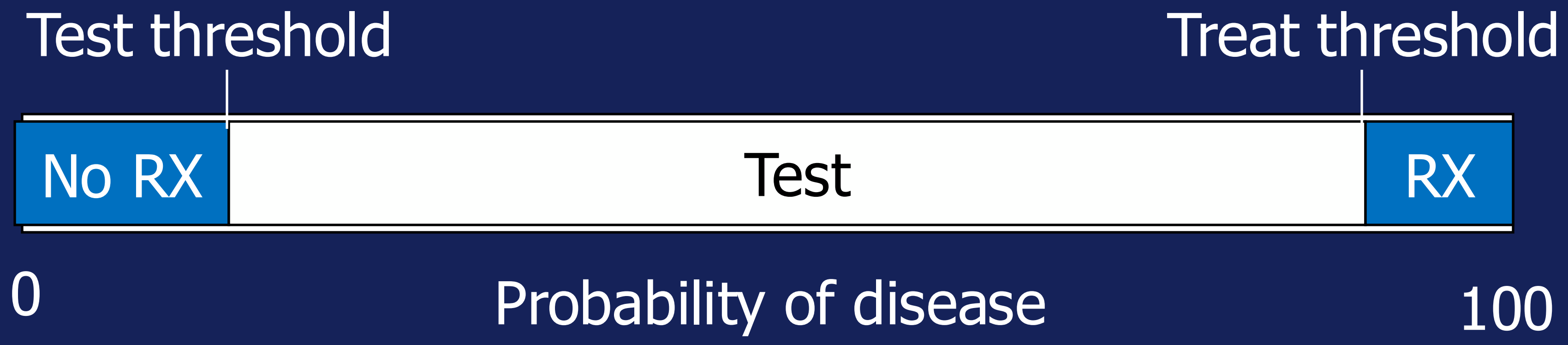


Selection of a test depends on:

- the probability of disease at which testing becomes reasonable
- the probability of disease at which we are willing to start treatment despite being unsure of a patient's true state

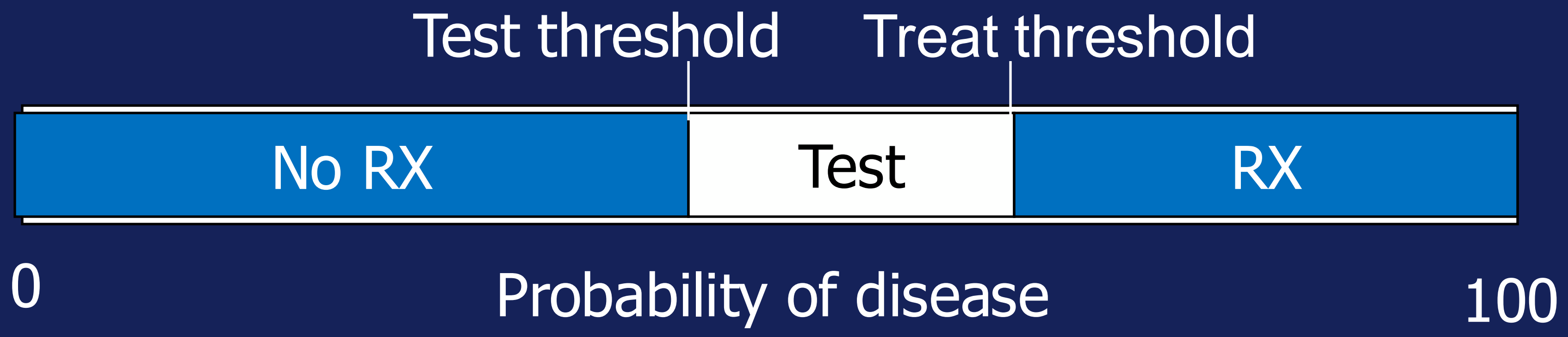
Pauker/Kassirer. NEJM 1980

Threshold Approach to Testing and Treating



Test with greater accuracy and lower risk

Threshold Approach to Testing and Treating



Test with lower accuracy or greater risk

Pauker/Kassirer. NEJM 1980

Probabilistic Thinking & Health Informatics

- Clinical Decision Support
- Available Tests
- Thresholds
- Information Sources

SEGMENT 3 SUMMARY

FORMAL DECISION ANALYSIS

Premises for Decision Analysis

- A decision must be made!
- Consequences of action are uncertain
- Objectives conflict
- For cost-effectiveness analysis
  - Resources are constrained
- Decision analysis is **decision-oriented**, not **truth-oriented**

Expected Value Decision Making

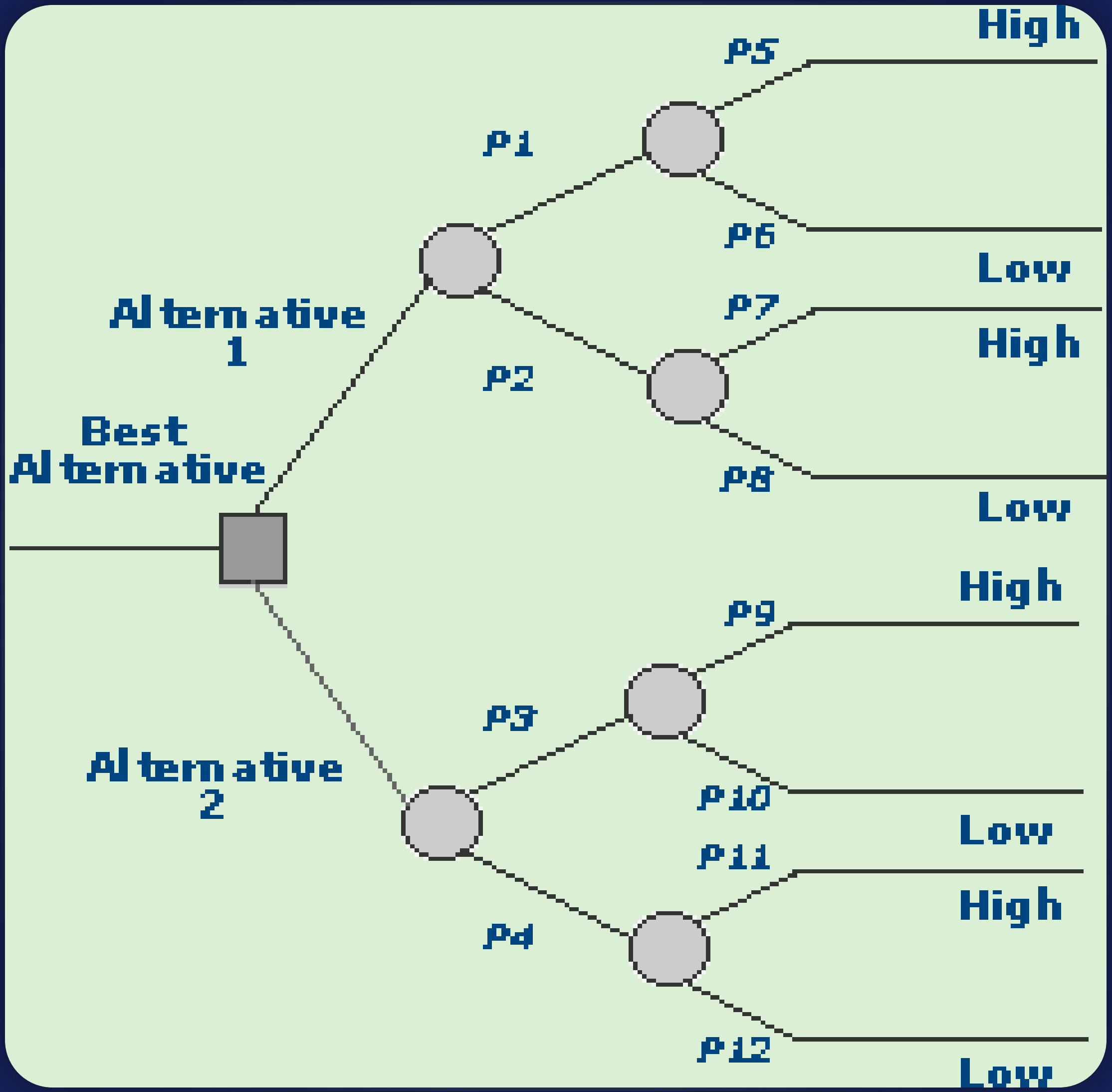
EV = result expected "on average"

Calculate expected value of each decision alternative

Choose strategy with maximum EV (or minimal expected cost)

4 Steps in Decision Analysis

1. Create a decision tree
2. Calculate EV for each decision alternative
3. Choose alternative with highest EV
4. ***<u>Use sensitivity analysis to test the conclusions of the analysis</u>***

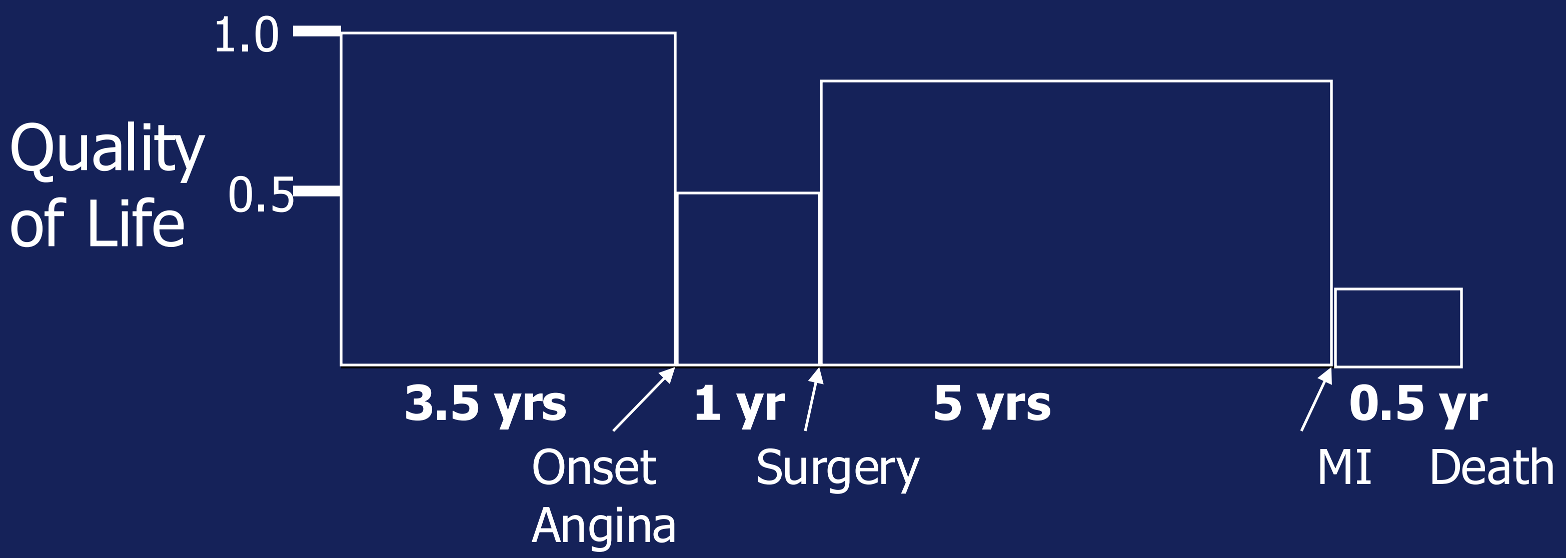


Defining Values of Outcomes: Categorical Scale

Death	AK Amputation	BK Amputation	Cure
0			100

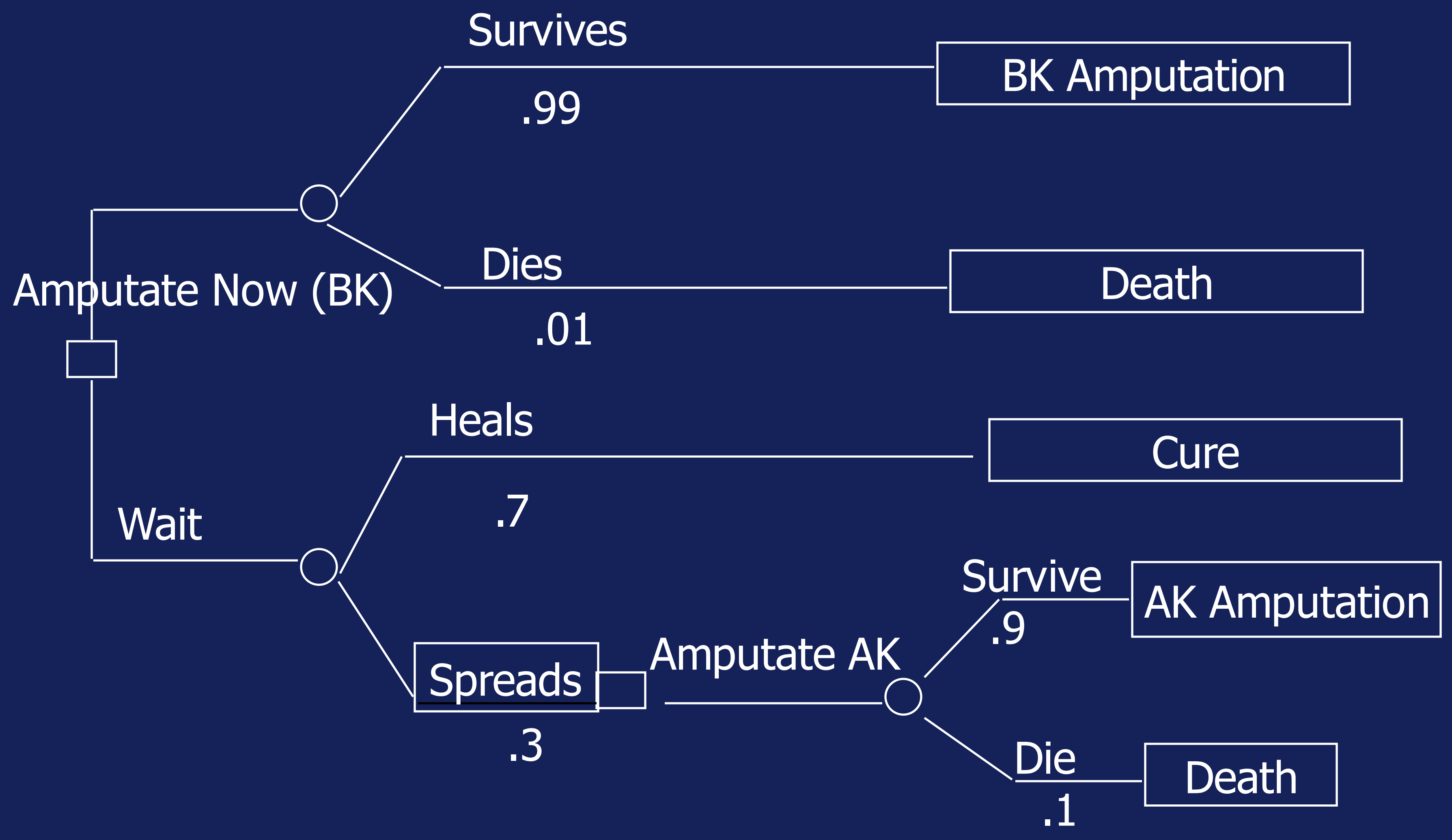
People tend to assign lower values to the intermediate states.

Quality Adjusted Life Years



- Intervals with varying health states x weights
- QALYs = 3.5(1) + 1(0.5) + 5(0.9) + 0.5(0.2)
- 8.6

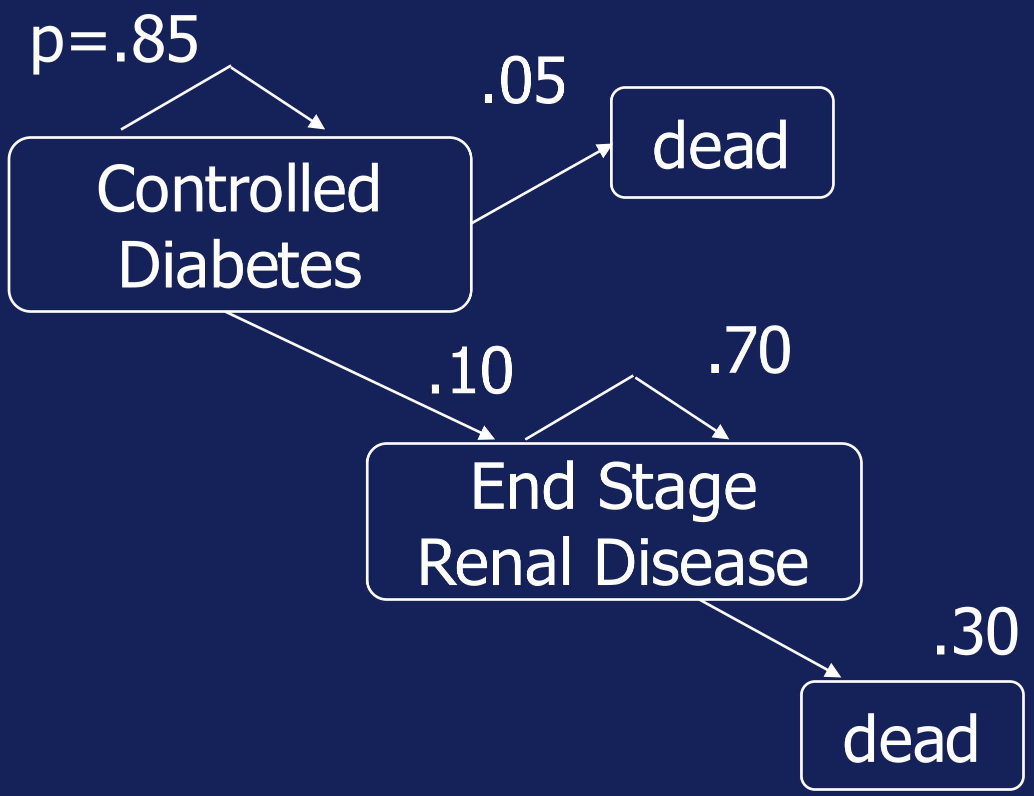
Vascular Insufficiency



Markov Model

represents a changing set of health states over time, where there is a known rate of transition from one health state to another

Probabilities



Utilities

Diabetes .95

ESRD .30

Death 0

http://araw.mede.uic.edu/cgi-bin/markov.cgi
araw.mede.uic.edu/~alansz/tools/markov.html

Cost-Effectiveness Analysis

- Compares the cost of an intervention to its effectiveness
- **CEA** results are presented in a ratio ($\Delta C/\Delta E$), which expresses cost per health outcome (e.g., $50,000 per year of life gained)
- **CEA** is generally used to either:
  - –compare alternative programs with a common health outcome, or
  - –assess the consequences of expanding an existing program
- Resources are scarce; therefore, they must be allocated judiciously

Sensitivity Analysis

Method for evaluating uncertainty in decision analysis parameters

Sensitivity Analysis

Variable	Point Value	Range
Sensitivity of CT	0.84	0.77-0.93
Brain Cancer	0.3 QALY	0.1 – 0.7

Expected Value = XX - XX

Summary

- Uncertainties in clinical medicine
- Probability
- Probability revision when there is new information: Bayes' Rule
- Testing
- Expected Value Decision Making
- Building a decision tree

SEGMENT 4 SUMMARY