Sensitivity, Specificity, and Predictive Values of Diagnostic and Screening Tests

Objectives

- Review characteristics of suitable screening tests.
- Discuss the importance of sensitivity and specificity in screening tests.
- Examine how positive predictive values, negative predictive values, and disease prevalence affect the sensitivity and specificity of screening tests.

Key Terms

- Primary prevention
- Secondary prevention
- Sensitivity
- Specificity
- Cutoff point
- Positive predictive value
- Negative predictive value
- Prior probability

Prevention

- Primary Prevention
  - Reduction of risk (Behavior change, alteration of environmental risk, prophylaxis, etc.).
- Secondary Prevention:
  - Early detection of disease in the sub clinical stages (screening tests, periodic health exams, etc.).
- Tertiary Prevention
  - Treatment of clinically-apparent disease to reduce complications.

Screening

- Use of laboratory testing on asymptomatic persons to detect diseases whose morbidity and mortality can be reduced by early detection and treatment.
- Characteristics of diseases suitable for screening:
  - Common enough to justify the effort.
  - Significant morbidity if untreated.
  - Effective therapy is available.
  - Treatment in the asymptomatic phase provides benefits over treatment in early symptomatic phase.
- Characteristics of suitable screening tests:
  - Low-cost and low-risk.
  - Patient acceptability.
  - Should be abnormal in almost all patients who have disease (i.e. test should have good sensitivity).

Four Possible Test Outcomes

	Disease	No Disease
Test Positive	True Positives **(TP)**	False Positive **(FP)**
Test Negative	False Negatives **(FN)**	True Negatives **(TN)**

Sensitivity

- The probability that a test will be positive in a patient with disease.
  - True positive rate

$$\frac{TP}{TP + FN}$$

CA-125 Protein as a Marker for Ovarian Cancer

	Disease	No Disease
Test Positive	101	310
Test Negative	9	1540

CA-125 Protein as a Marker for Ovarian Cancer

$$\frac{TP}{TP + FN}$$

$$\frac{101}{101 + 9}$$

.92 = 92% sensitivity

Sensitivity

- A sensitive test is usually positive when disease is present (few false negatives).
- When many patients with disease have a negative test (false negatives) the sensitivity decreases. The test's utility as a screening test is diminished because the test fails to identify asymptomatic patients.

Specificity

- The probability that a test will be negative in a patient without disease.
  - True negative rate.

$$\frac{TN}{TN + FP}$$

CA-125 Protein as a Marker for Ovarian Cancer

	Disease	No Disease
Test Positive	101	310
Test Negative	9	1540

CA-125 Protein as a Marker for Ovarian Cancer

$$\frac{TN}{TN + FP}$$

$$\frac{1540}{1540 + 310}$$

.83 = 83% sensitivity

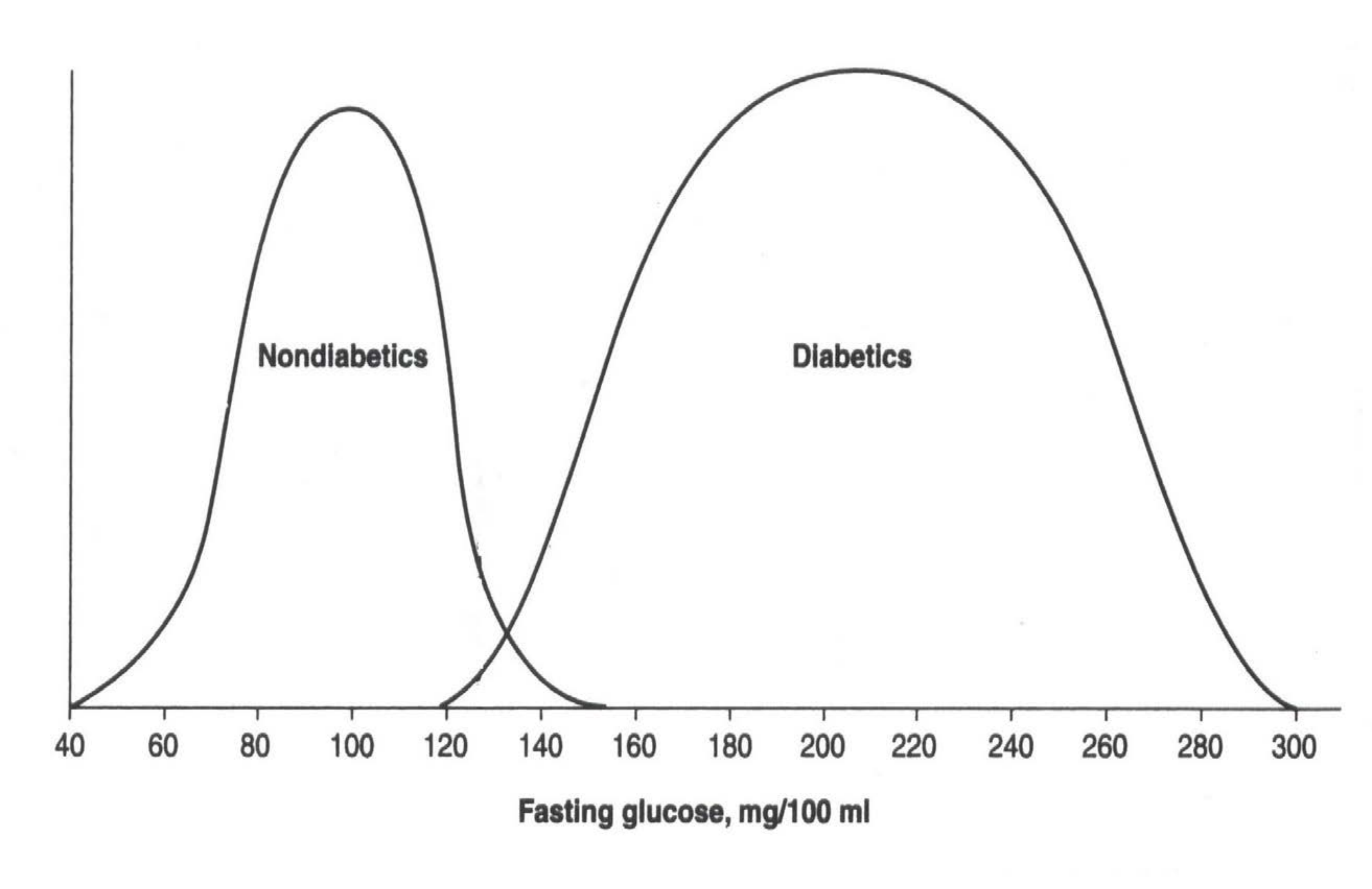
Specificity

- A specific test is usually negative in disease free patients (few false positives).
- When many disease free patients have a positive test (false positives), the specificity decreases.
  - Utility as a screening test may diminish because it results in too many needless work-ups.

Cutoff Points

1. How is the threshold for a positive test established?
   - Ideal test would have 100% sensitivity and 100% specificity (no false negatives and no false positives).
   - In such a situation the cutoff point (value above or below which a test is considered abnormal or positive) would be easily assigned.
   - However, there is usually some overlap between results in a population with disease and a population without disease and choosing a cutoff point is not always readily apparent.
2. Does this have an effect on the sensitivity and specificity of the test?

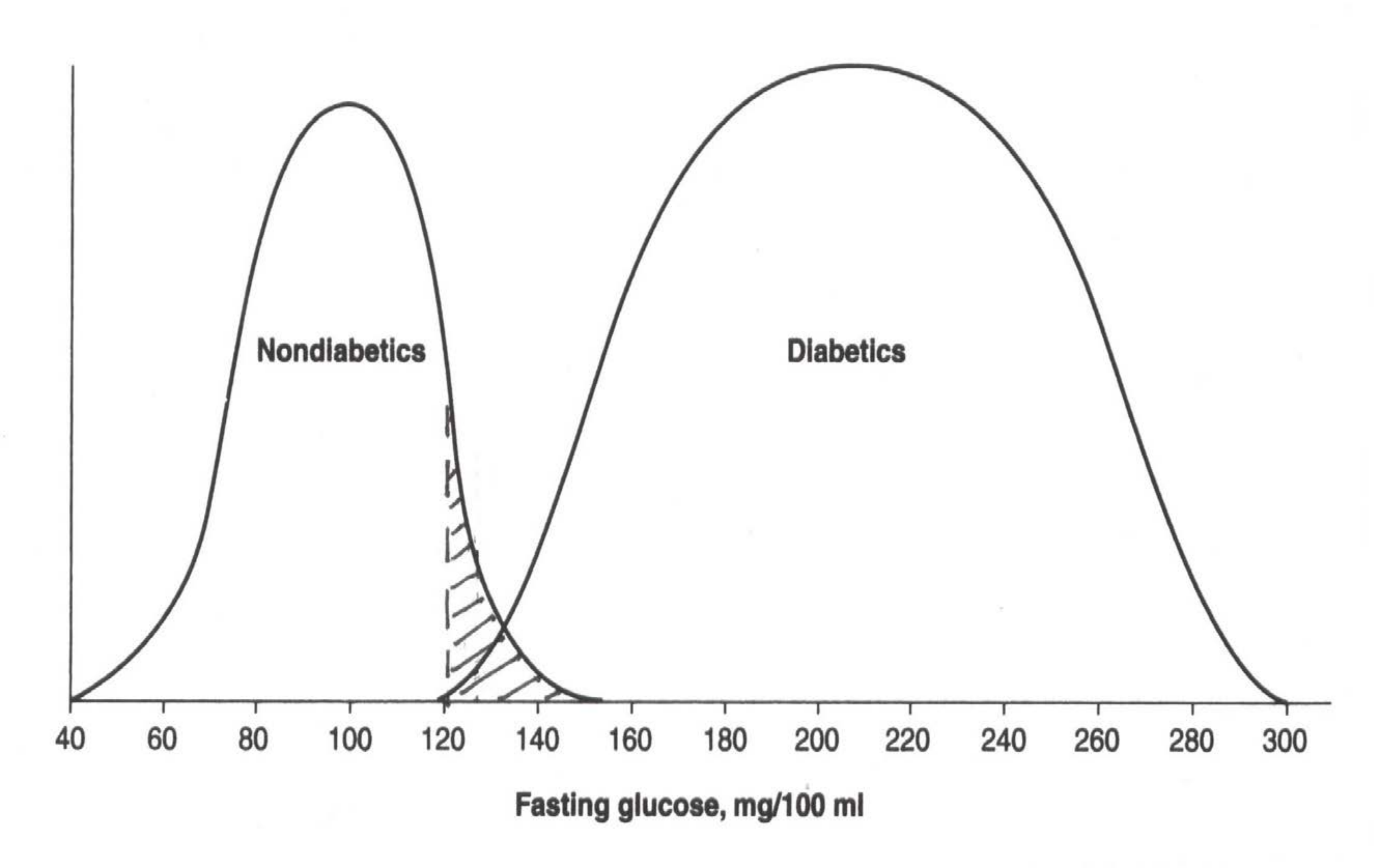
Cutoff Points



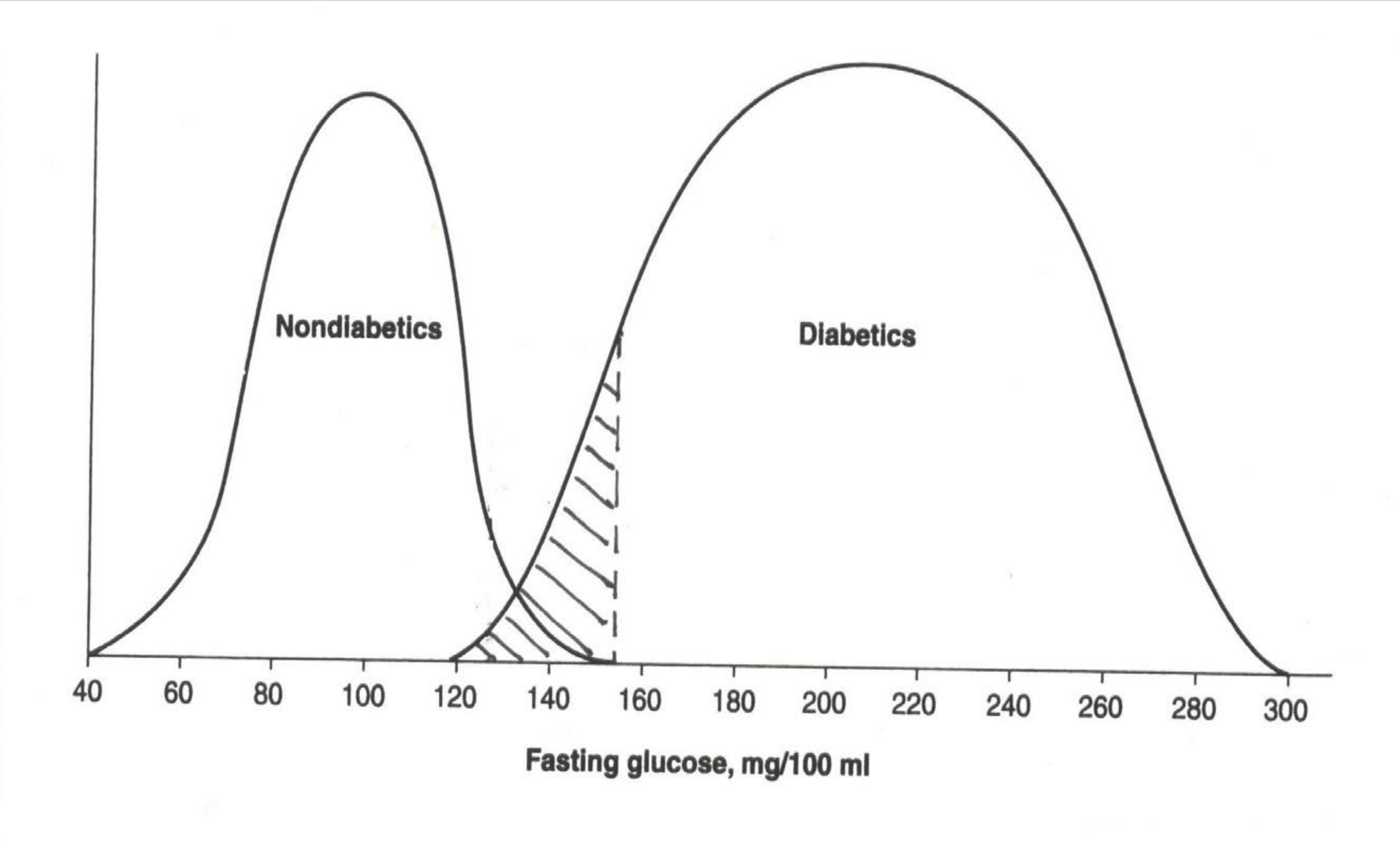
Cutoff Points

- In most cases the cutoff point is such that some patients with disease have a negative test (false negatives - sensitivity is compromised) and some patients without disease have a positive test (false positives - specificity is compromised).
- In general, raising the cutoff point to make a test more specific will reduce the sensitivity (increase the false negatives).
  - Lowering the cutoff point to make the test more sensitive will reduce specificity (increase the false positives).

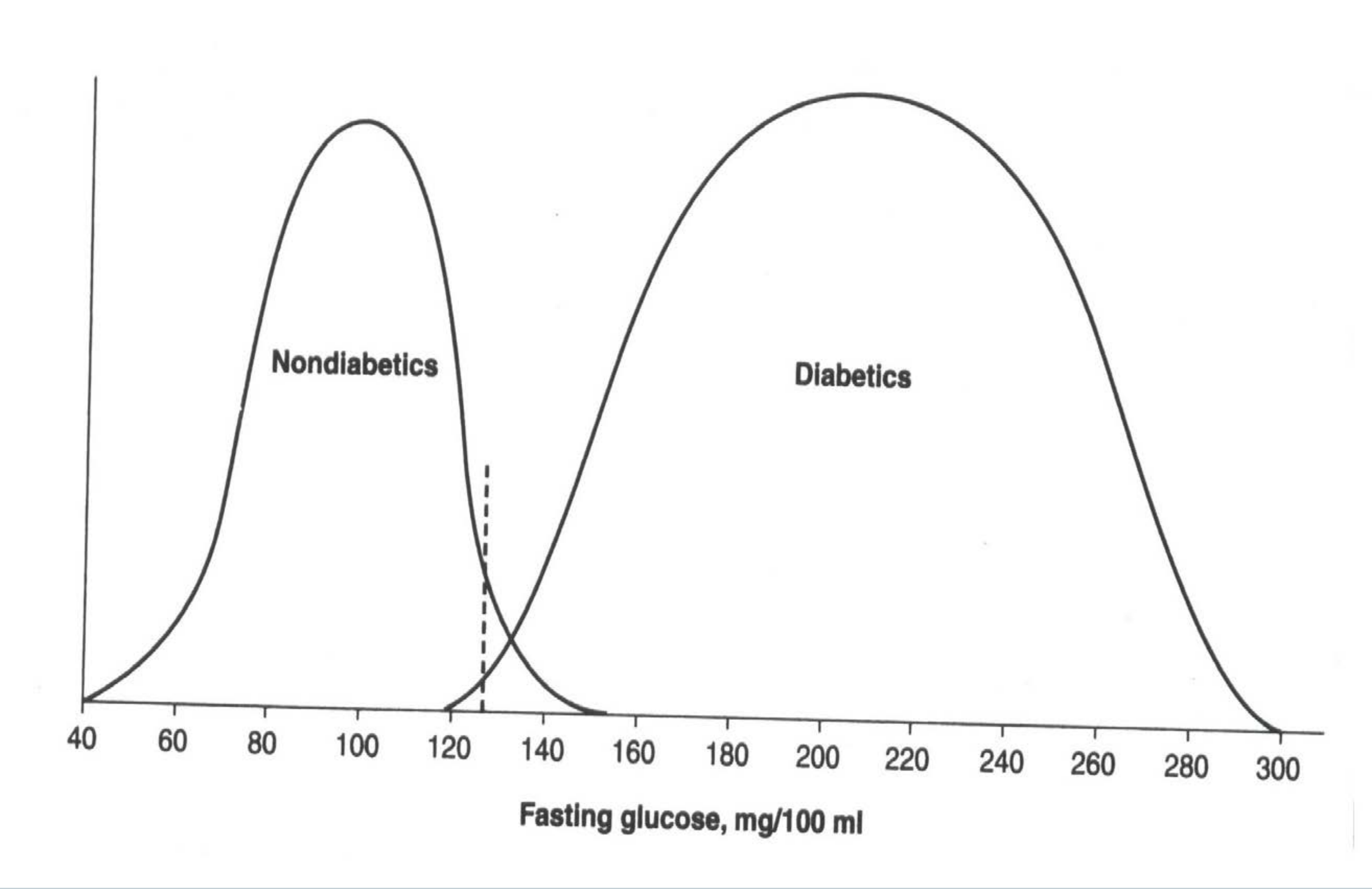
Cutoff Points – Effect on Sensitivity and Specificity



Cutoff Points – Effect on Sensitivity and Specificity



Choosing a Cutoff Point



Sensitivity and Specificity vs. Predictive Values

- Sensitivity and specificity are intrinsic characteristics of a test and do not change regardless of the patient or population being tested.
- Correct interpretation (predictive value) of a positive or negative test will vary depending on the particular patient or population being tested.
- Task of the clinician: determine the likelihood of disease given a positive test (positive predictive value), or the likelihood that disease is not present given a negative test (negative predictive value).
  - Must understand the concept of predictive values.

Positive Predictive Values (PPV)

- The probability that a patient with a positive test actually has disease.

$$\frac{\mathbf{TP}}{\mathbf{TP + FP}}$$

- A test with higher specificity (fewer false positives) will have a higher PPV in a given population.
- For any given test, as disease prevalence in the population being tested increases, the PPV of that test will also increase.

Positive Predictive Values (PPV)

Test with 90% Sensitivity and 90% Specificity in a Population with Disease Prevalence of 1% → PPV = .08 (8%)

	Disease	No Disease
Test Positive	9	99
Test Negative	1	891

Positive Predictive Values (PPV)

Test with 90% Sensitivity and 90% Specificity in a Population with Disease Prevalence of 10% → PPV = .5 (50%)

	Disease	No Disease
Test Positive	90	90
Test Negative	10	810

Negative Predictive Values (NPV)

$$\frac{TN}{TN + FN}$$

- A test with higher sensitivity (fewer false negatives) will have a higher NPV in a given population.
- For a given test, as disease prevalence in the population being tested decreases, the NPV of that test will increase.

Prior Probability

- Pre-test probability; Bayes Theorem
- A given test will have a higher positive predictive value in those patients with a higher prior probability of disease.

Positive Exercise Treadmill Test (ETT) As an Indicator of Coronary Heart Disease

	Disease	No Disease
Test Positive	90	245
Test Negative	31	982

Positive Exercise Treadmill Test (ETT) As an Indicator of Coronary Heart Disease

$$\frac{TP}{TP + FN}$$

$$\frac{90}{90 + 31}$$

.74 = 74% sensitivity

Positive Exercise Treadmill Test (ETT) As an Indicator of Coronary Heart Disease

	Disease	No Disease
Test Positive	90	245
Test Negative	31	982

Positive Exercise Treadmill Test (ETT) As an Indicator of Coronary Heart Disease

$$\frac{TN}{TN + FP}$$

$$\frac{982}{982 + 245}$$

.80 = 80% specificity

“Classic Findings”

Q: What is the classic history in a patient with the acute coronary syndrome?

A: Crushing, retrosternal chest pain that radiates to the jaw or shoulder, associated with nausea and diaphoresis.

- Q: What do we really mean by ‘classic’?
- A: In most cases, we mean specific, not sensitive.

Summary

- When sensitivity decreases, the test's utility as a screening test is diminished because the test fails to identify asymptomatic patients.
- When specificity decreases, the test's utility as a screening test may diminish because it results in too many needless work-ups.

IF	THEN
• Prevalence (prior probability) increases…	• PPV increases; NPV decreases
• Prevalence decreases…	• PPV decreases; NPV increases
• Specificity increases…	• PPV increases
• Sensitivity increases…	• NPV increases

Acknowledgements

- Richard DiCarlo, MD
- Rebecca Frey, PhD
- Stacey Holman, MD
- Richard Tejedor, MD
- Murtuza Ali, MD