

Scan Protocol Optimization for Soft and Adipose Tissue Separability

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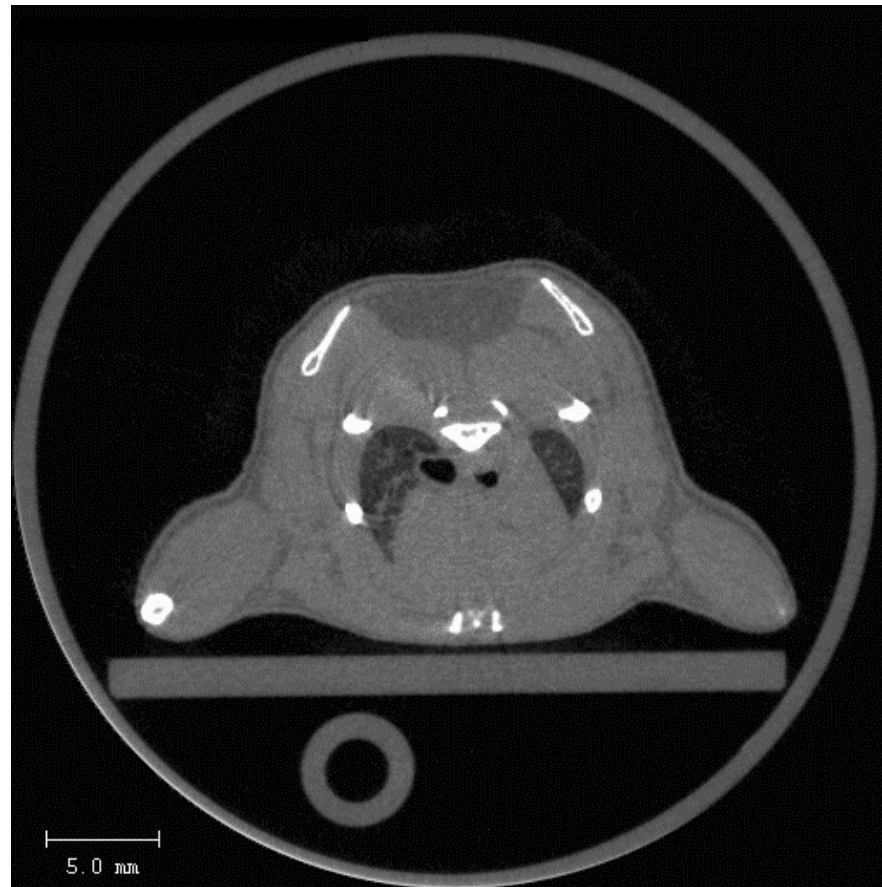
Content

- Goal
- Introduction Contrast
- Contrast and Noise
- Separability
- Adipose and Soft Tissue Separability
- Conclusion
- Outlook



Goal

- Determine optimal scan parameters to separate (segment) adipose and soft tissue



Introduction Contrast



Introduction Contrast

- Difference in signals or intensities

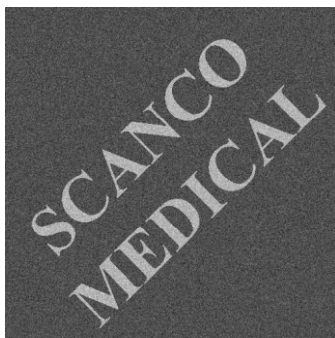
$$C = |q_2 - q_1|$$

- Various other definitions

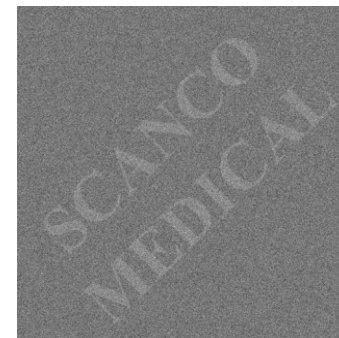
$$C_1 = \frac{|q_2 - q_1|}{q_1}$$

$$C_2 = \frac{|q_2 - q_1|}{q_1 + q_2}$$

$$C_3 = 2 \frac{|q_2 - q_1|}{q_1 + q_2}$$



Grayscale values



$$C = |180 - 80| = 100$$

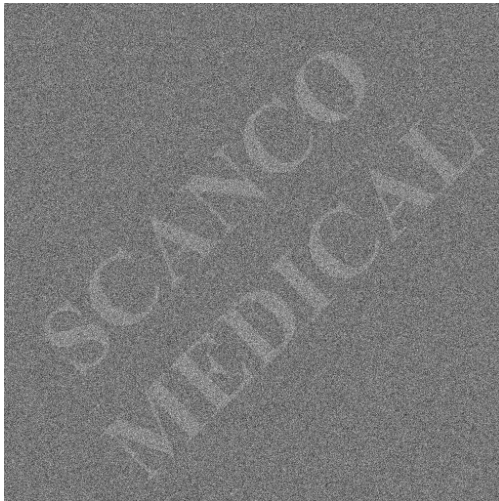
$$C = |140 - 120| = 20$$



Contrast of CT Images

- Definition contrast?

$$C = |\mu_2 - \mu_1|?$$



$$C = |140 - 120| = 20$$

$$\sigma = 20$$



$$C = |140 - 120| = 20$$

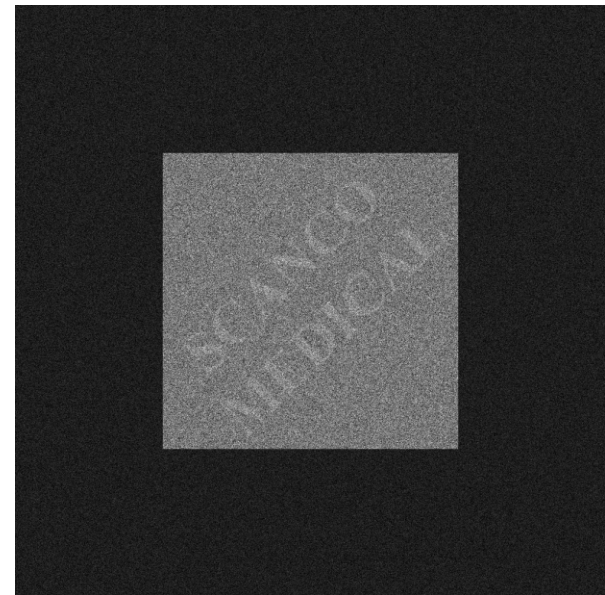
$$\sigma = 40$$



Contrast to noise ratio (CNR)

- Contrast to noise ratio (CNR)

$$CNR = \frac{|\mu_2 - \mu_1|}{\sigma_{Background}}$$

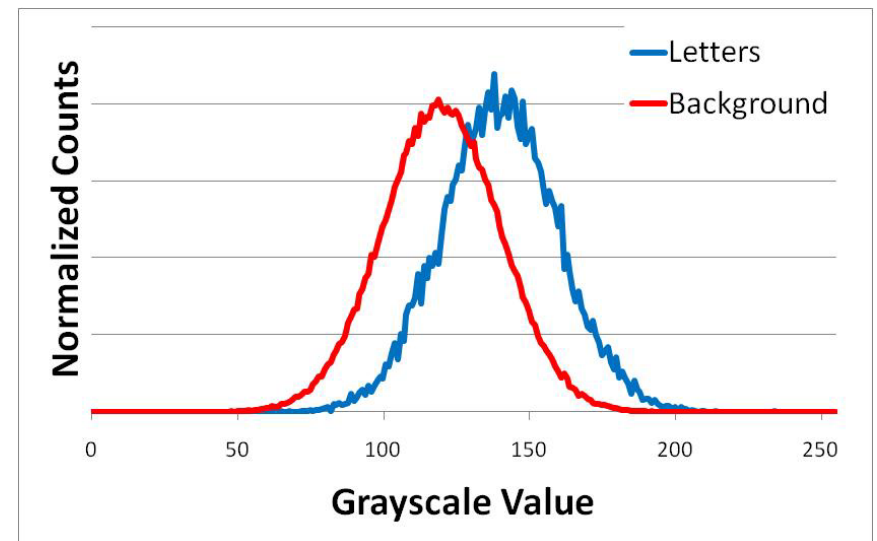
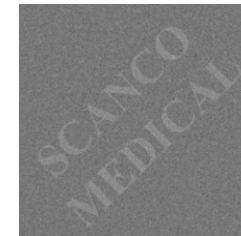
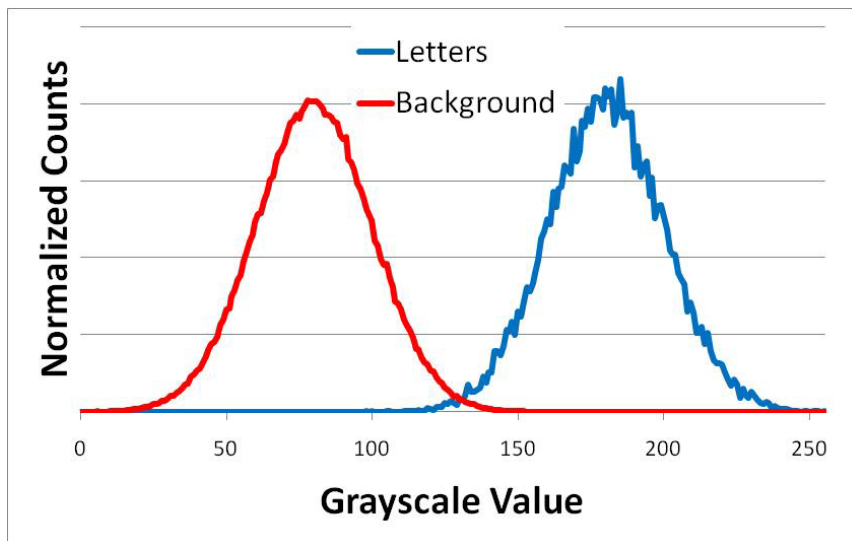
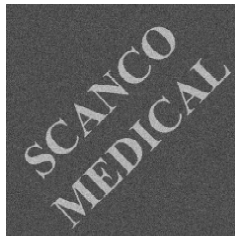


- CNR does not account for noise in the objects



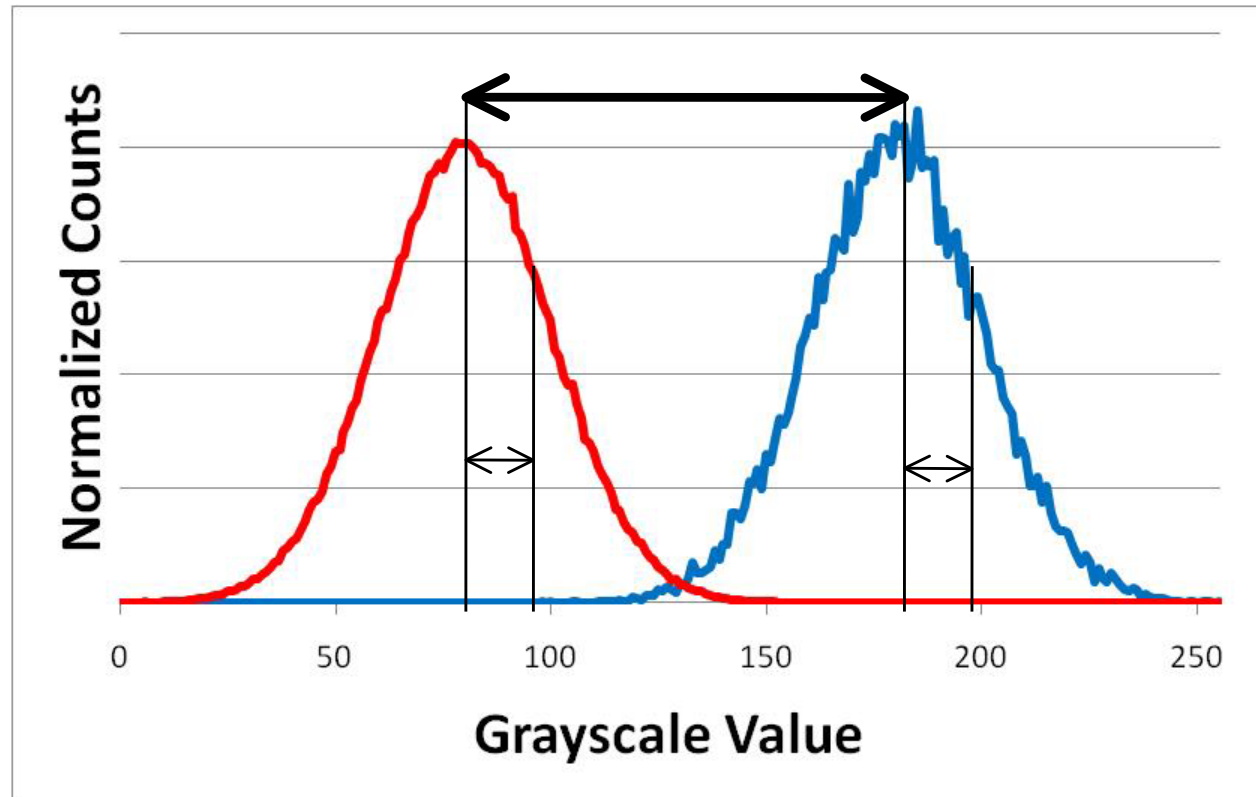
Separability

- Histograms



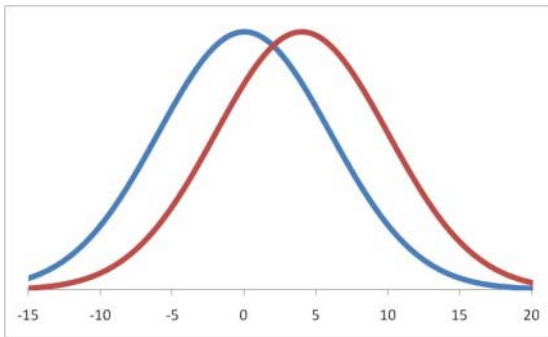
Separability - Definition

- Separability: $S = \frac{|\mu_2 - \mu_1|}{\sigma_1 + \sigma_2}$

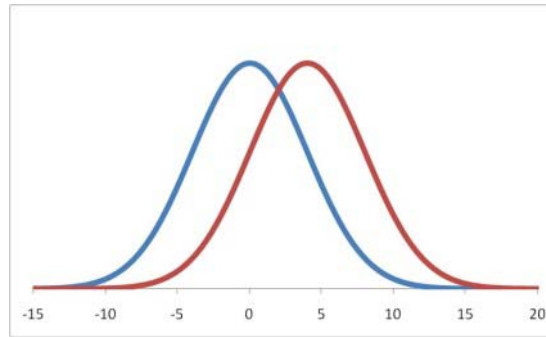


Separability - Examples

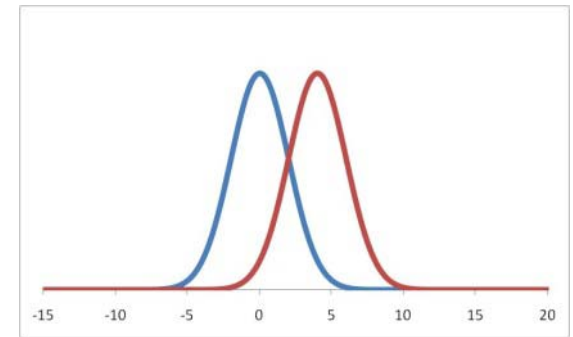
$$S = \frac{1}{3}$$



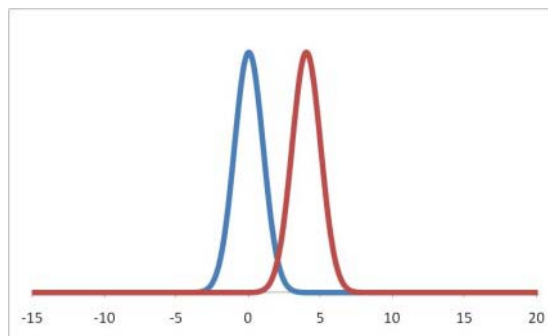
$$S = 0.5$$



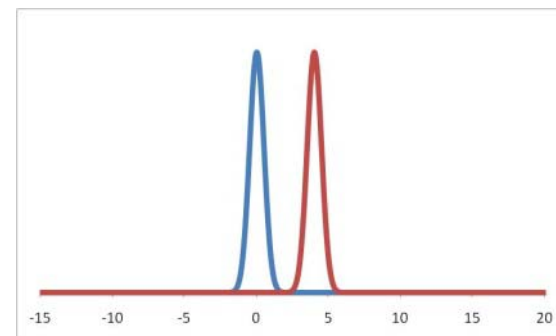
$$S = 1$$



$$S = 2$$



$$S = 4$$



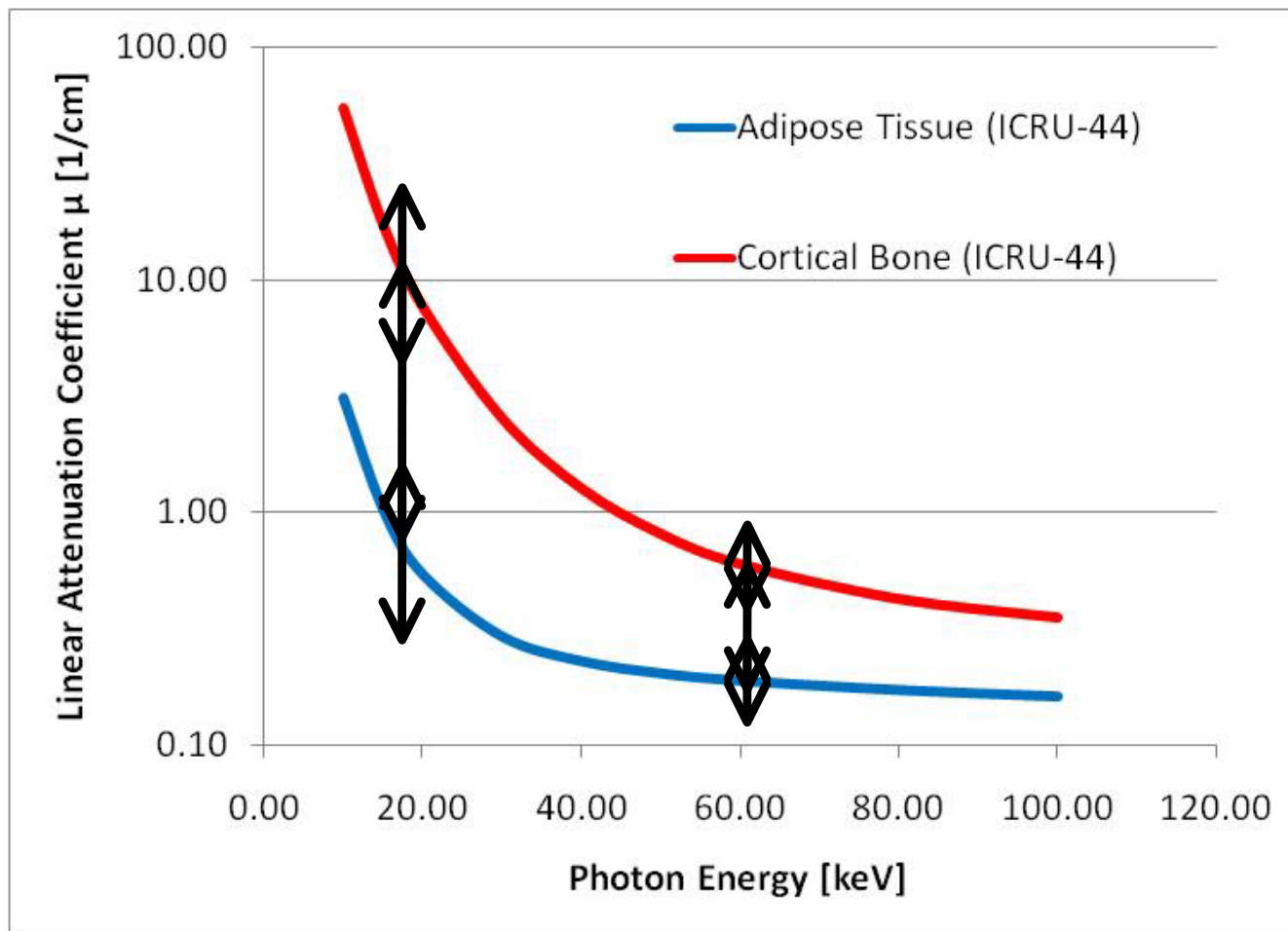
Separability in CT images

- Mean values correspond to linear attenuation coefficients μ
- Noise arises (amongst others) from the statistical character of x-ray emission and absorption (Poisson statistics $\sigma = \sqrt{N}$)
 - ✓ „More signal $\rightarrow$ less noise“

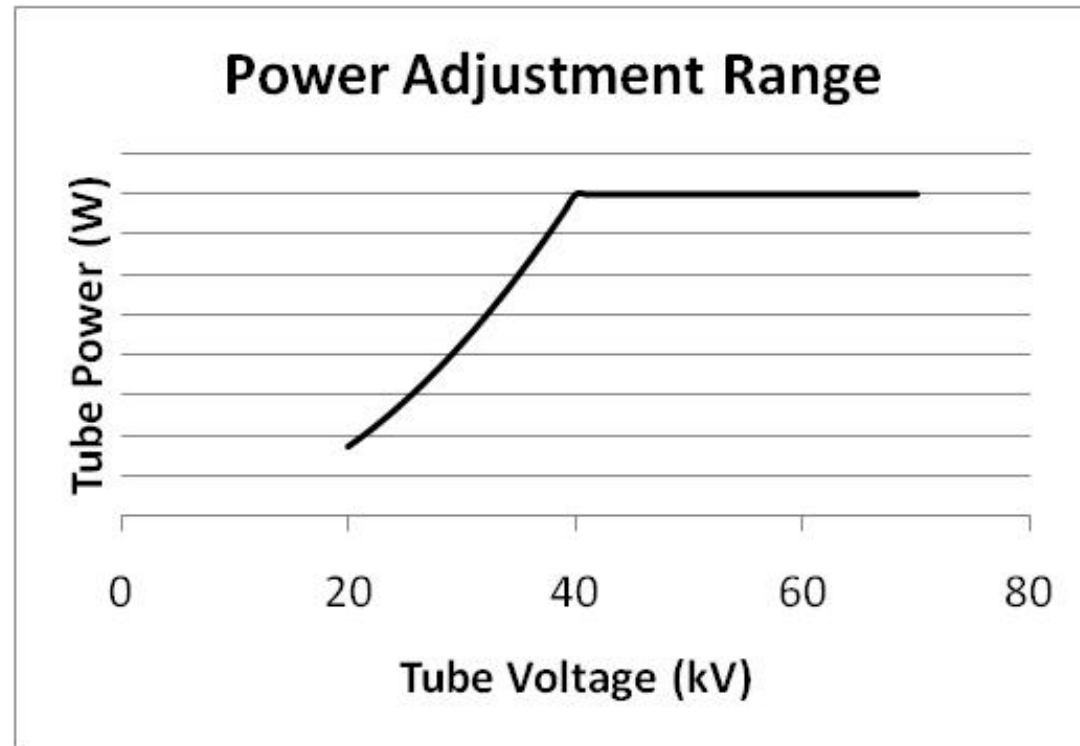


Separability in CT images

- μ vs. Photon Energy (Intensity const.)



Tube Voltage and Intensity



- Intensity (energy flux density): $\Psi \sim IU^2 = P * U$
- “Higher intensity → more signal → less noise”



Separability - Summary

- Low tube voltage
 - ✓ higher μ values
 - ✓ lower x-ray beam intensity
 - ✓ larger difference in μ values

} less signal $\rightarrow$ more noise
- High tube voltage
 - ✓ lower μ values
 - ✓ higher x-ray beam intensity
 - ✓ smaller difference in μ values

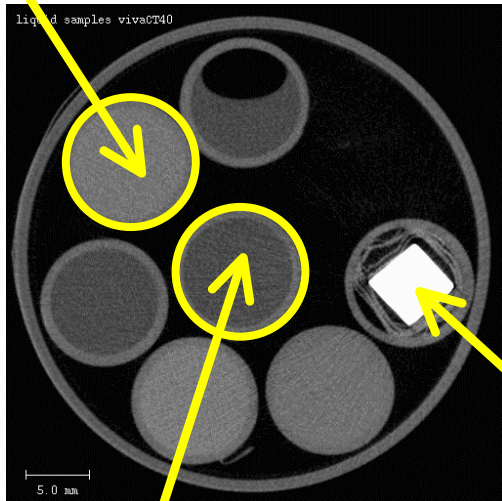
} more signal $\rightarrow$ less noise
- What is the optimal x-ray tube voltage for adipose and soft tissue separability?



Measurement - Sample

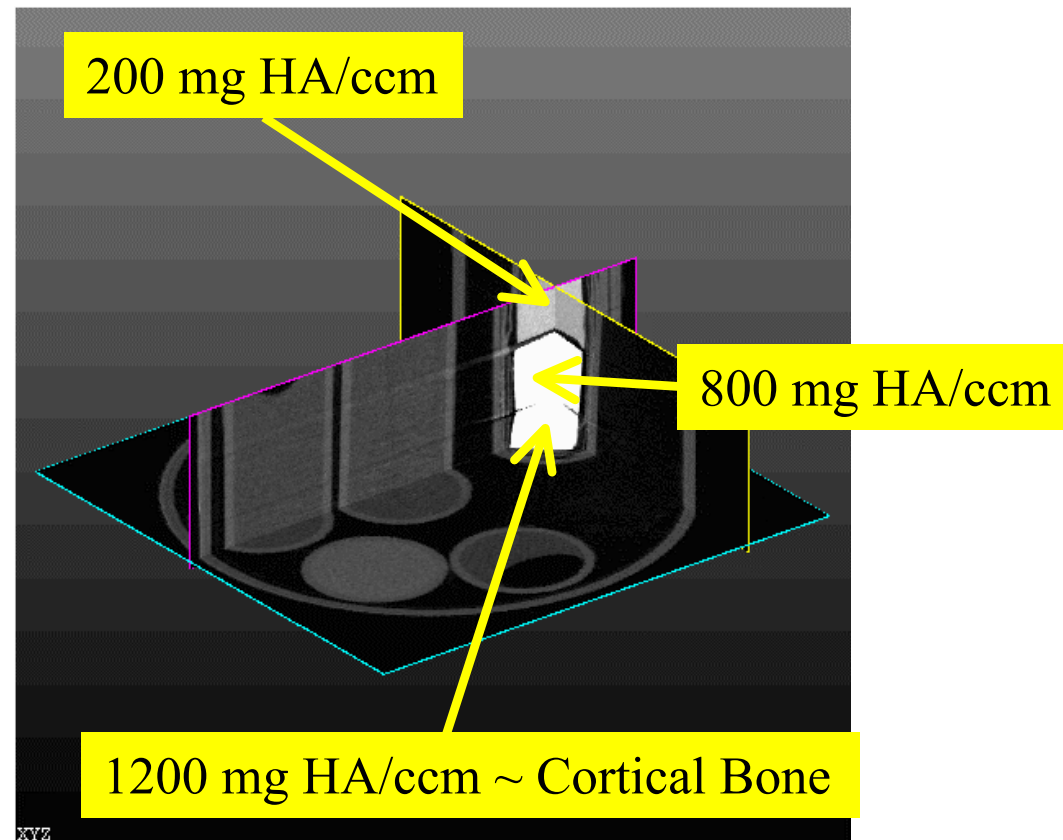
- ✓ Cube ($5 \times 5 \times 5 \text{ mm}^3$) with given mg HA/ccm density
- ✓ Liquid samples

Saline (0.9%)



Clarified butter

Cube



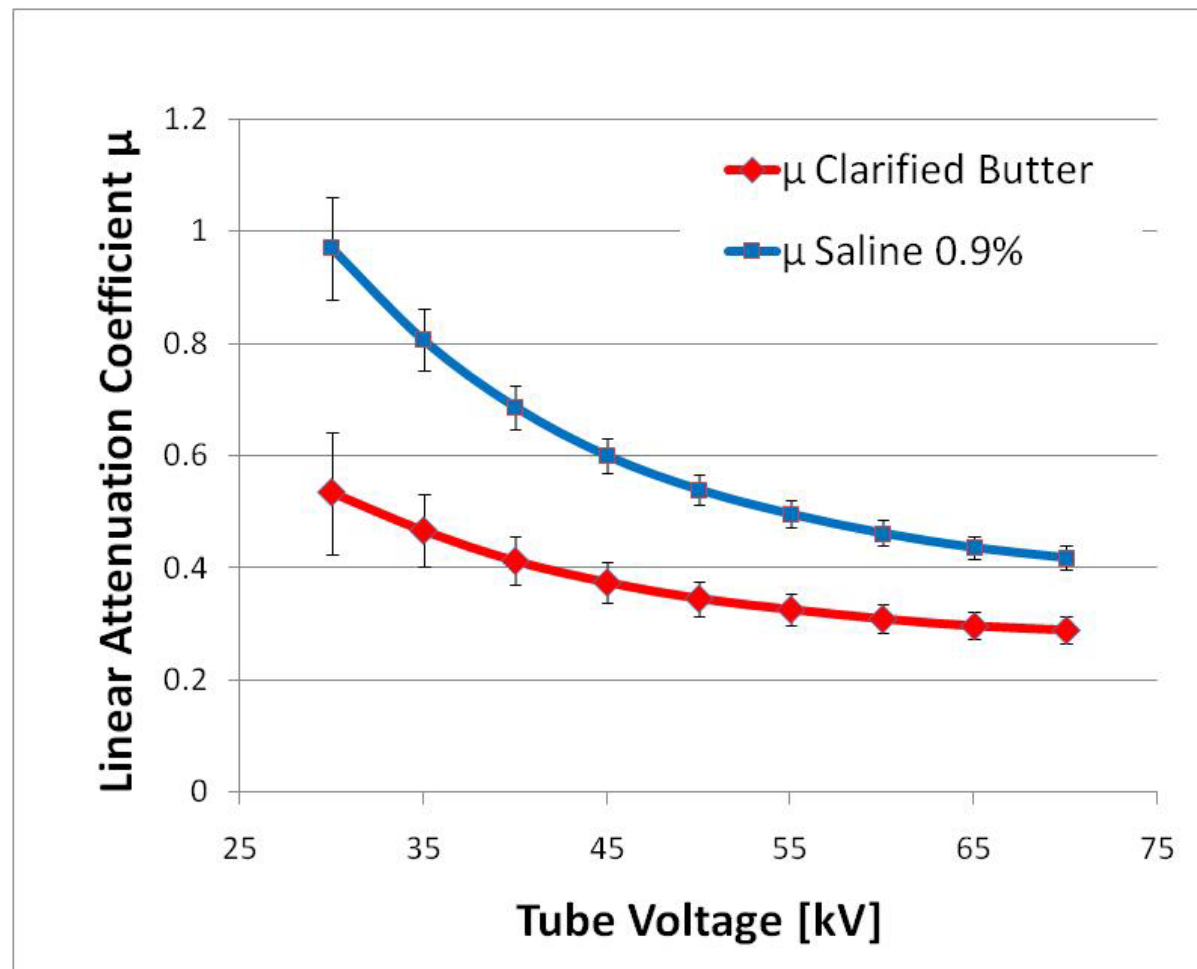
Measurement Parameters

- Scan distance (diameter): ~40 mm
 - In plane matrix size: 512 x 512 pixels
 - Voxel size: 76 μ m
 - Maximal tube power
 - Variable tube voltage
-
- Evaluation of mean values and standard deviations of clarified butter and saline

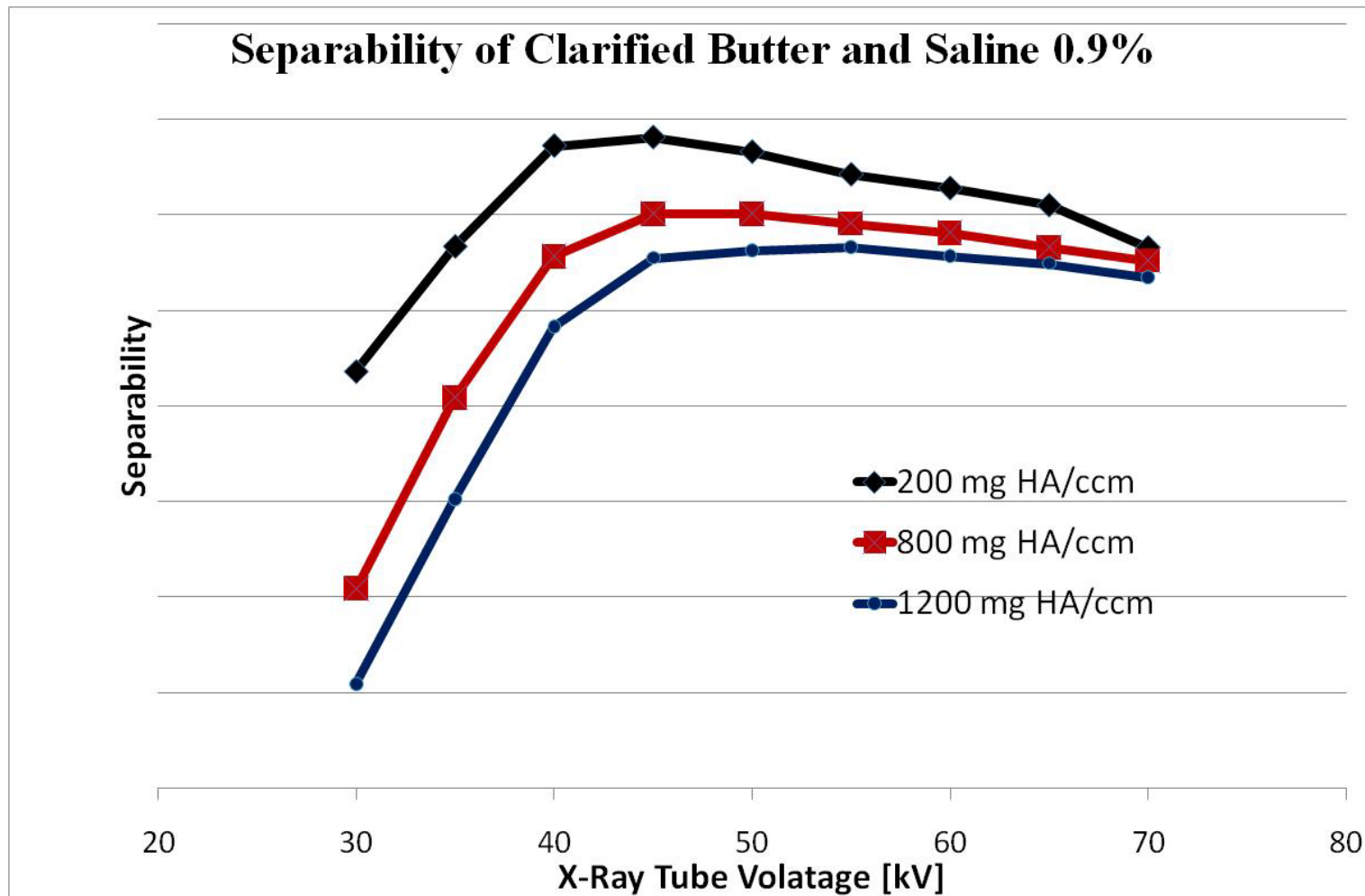


Results – Mean Values

- With 200 mg HA/ccm in plane

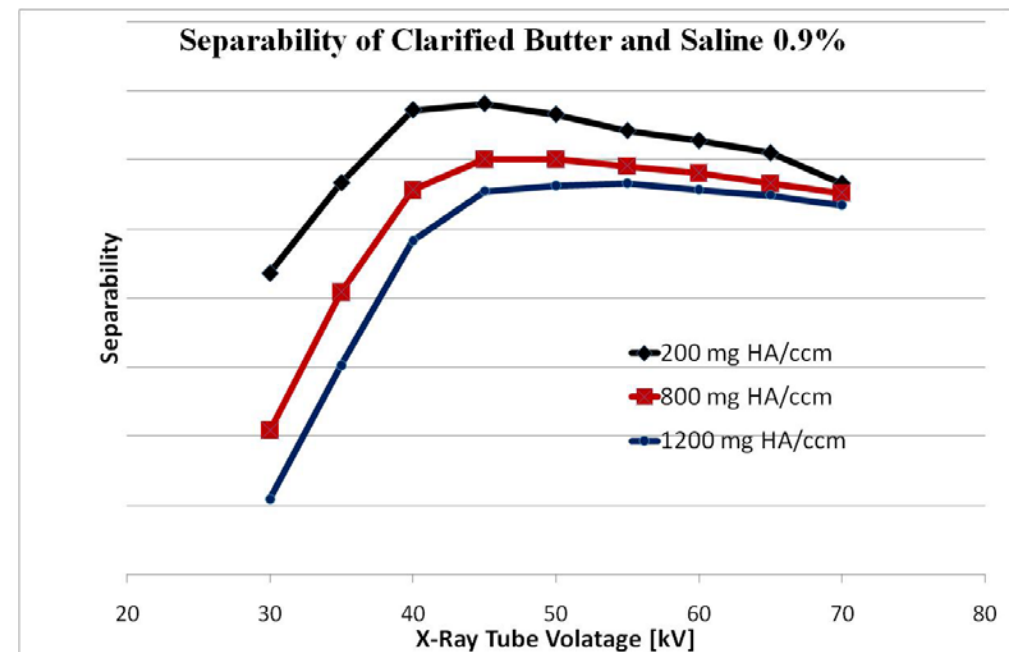


Results - Separability



Separability and Dose

- @maximum power(40 – 70 kV)
- Same integration time



- Increasing tube voltage:
 - ✓ increases dose
 - ✓ decreases separability



Conclusion

- Use 45 kV tube setting for adipose and soft tissue separability
- Use low resolution
 - ✓ Averaging reduces noise
 - ✓ Double the pixel size results in an increased separability by a factor $\sqrt{8}$
- Use high tube current (!Dose)
- Use a lot of projections (!Dose)
- Use long integration time (!Dose)



Outlook

- Noise – a Problem
- Different data filters (Gaussian, median, etc.) (!resolution)
- Different reconstruction kernel filters (!resolution)



END

- Thank you for your attention!

