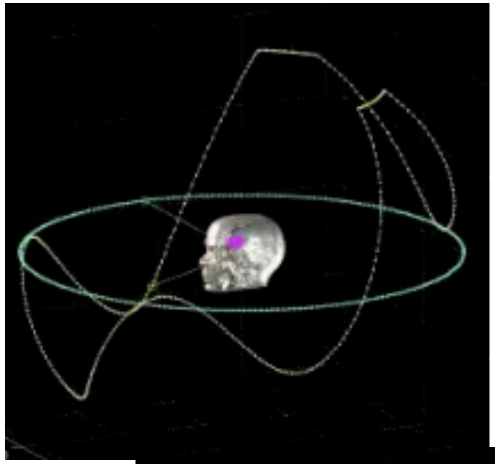
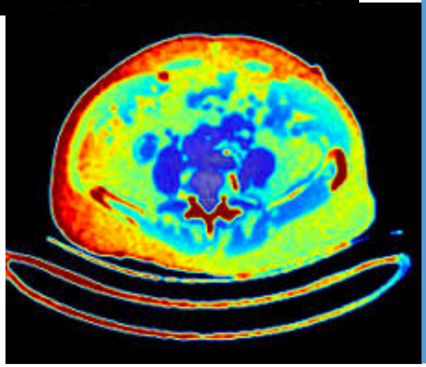




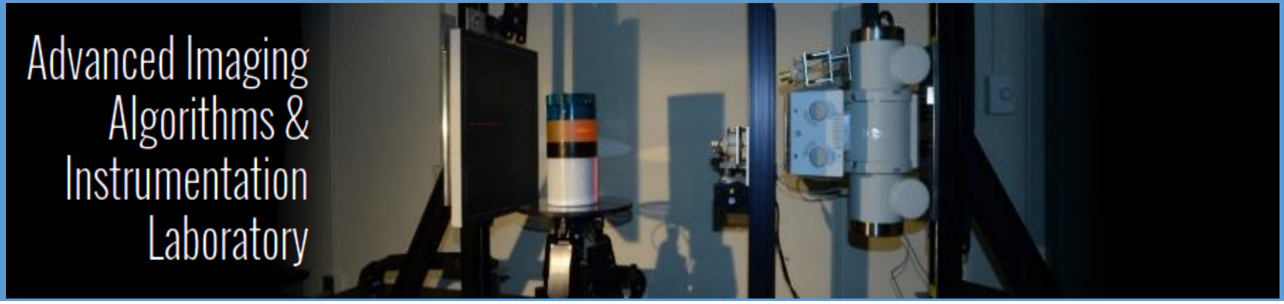
Seminar Presentation

Dynamic x-ray beam positioning for low-dose CT

Computer Integrated Surgery II

Andrew Mao

Mentor: J. Web Stayman Ph.D.



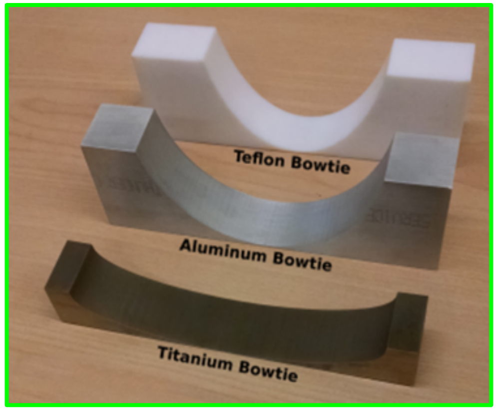
AIAI Lab

JOHNS HOPKINS
BIOMEDICAL ENGINEERING

JOHNS HOPKINS
MEDICINE

Project Overview

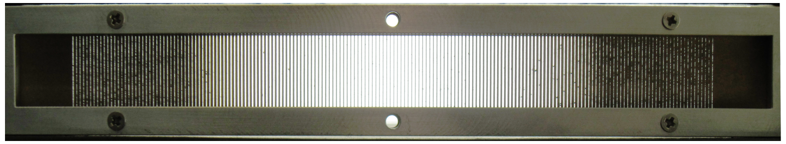
- Traditional CT systems have no control over the spatial profile of the x-ray beam
- Severe dose consequences when patient miscentering occurs in the emergency department
- Use fluence field modulation (FFM) strategies to reduce dose without losing image quality



Bowtie filters

Goal:

To achieve dynamic x-ray beam positioning in low-dose CT acquisitions and quantitative performance assessment for arbitrary patient positioning in emergency medicine applications



Multiple aperture device (MAD)

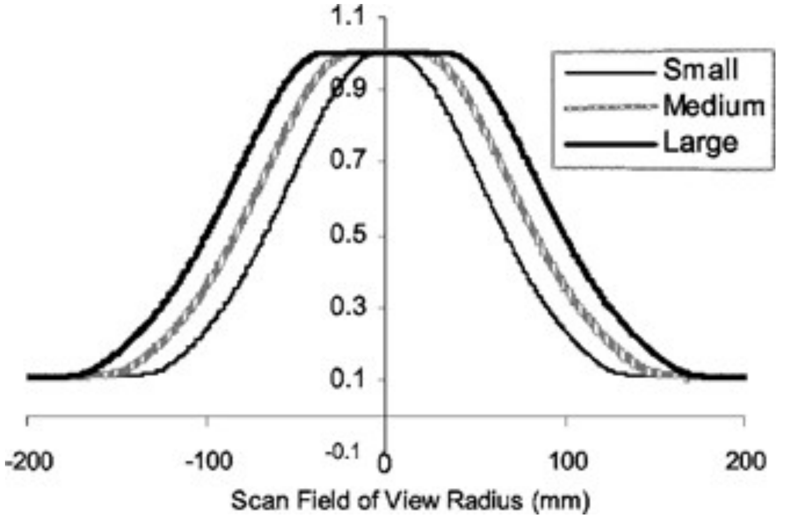
Paper Selection

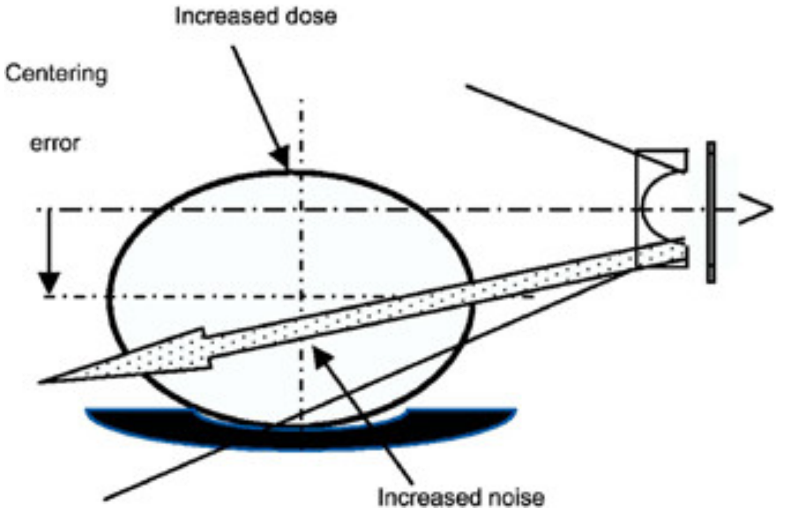
Toth, T., Ge, Z. and Daly, M. P. (2007), The influence of patient centering on CT dose and image noise. Med. Phys., 34: 3093–3101. doi:10.1118/1.2748113

- Study image noise, dose, and centering errors in phantoms and real clinical data
- Additionally modeled effect of patient size and beam filter size
- This paper contains a lot of the background information used to motivate our project
- Techniques to analyze effect of patient mis-centering can be applied to verify our system

I. Intro

- Image noise and dose important concepts in CT
- $Noise \propto 1/\sqrt{Dose}$
- CT scanners use automatic tube current modulation (TCM)
  - "automatic exposure control" for CT
  - Adjust overall intensity level of beam
- Bowtie filter modifies spatial beam profile
  - Clinical scanners come with several "sizes"
  - Selection related to patient anatomy & size, FOV
  - Poor understanding of clinical implications of dose/noise w.r.t. patient mis-centering
- Aim: Develop tools to estimate clinical effects of mis-centering





JOHNS HOPKINS BIOMEDICAL ENGINEERING

II. Methods: Dose/Noise Measurement

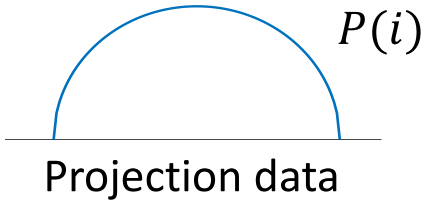
- Various size/shape/material phantoms
- GE Lightspeed VCT
- 3 bowtie sizes: large, medium, small
- 120 kV, 8x5mm axial collimation, 1s rotation
- Phantoms positioned 0, 3, 6cm below isocenter
- Scout scans (“SPR”) at AP and lateral views
- Axial dose using 10cm pencil ionization chamber
- Image noise in ROI of difference image: $\frac{1}{\sqrt{2}}\langle\Delta(x,y)\rangle$
  - ROI is circular region covering ~80% of phantom area

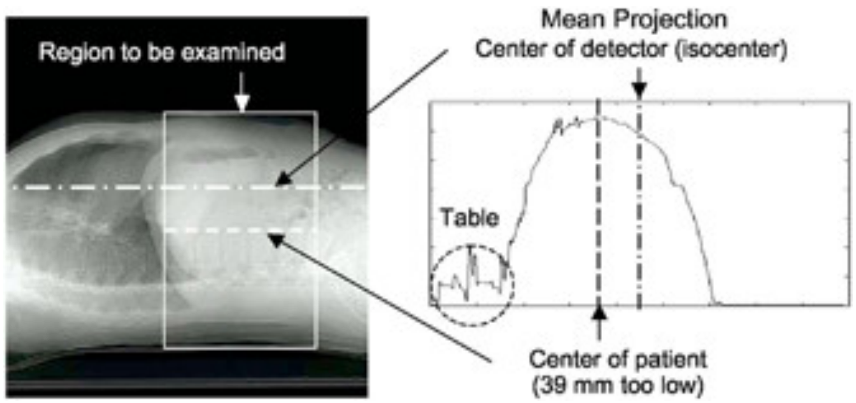
GE

FDA

II. Methods: Centering Calculation

- Object size using projection area (sqrtPA)
  - $sqrtPA = \sqrt{\sum P(i)}$
- Find centroid of pre-processed projection data
  - Subtract isocenter to obtain mis-centering
- "Table error" regression model to correct for error due to table contribution
  - Input: sqrtPA (patient size)
  - Output: error in centroid based mis-centering estimate w.r.t. true value (from table readout)
- Only lat view (no table in AP view)





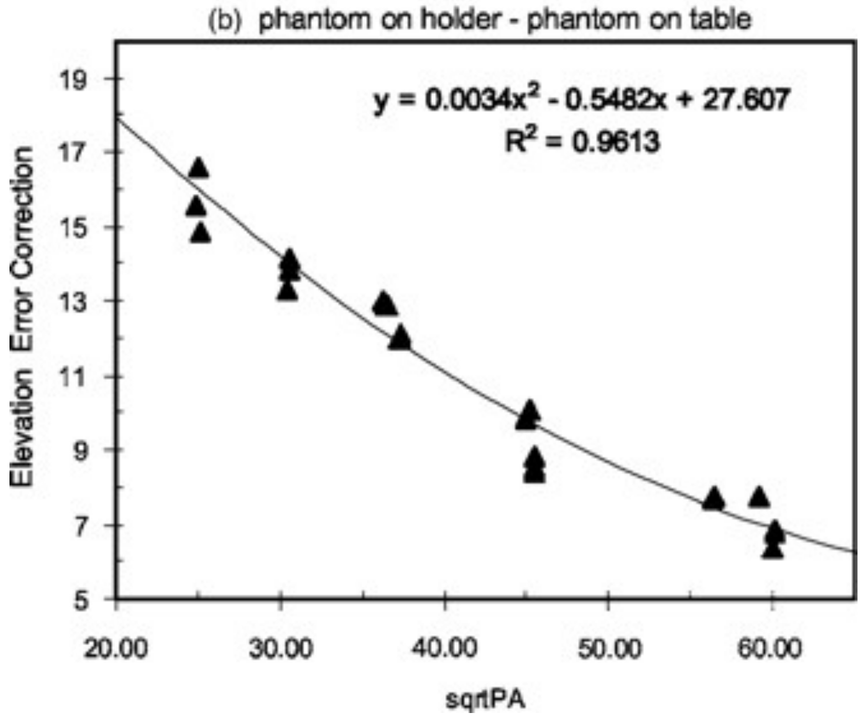
II. Methods: Clinical Implications

- Estimate noise/dose penalties in clinical imaging scenarios
- 549 AP & lat scout SPRs
  - 254 female, 295 male, 21-102 yo (with some peds)
  - Patients from previously concluded clinical studies
- Computer assisted parameter selection (CAPS) software in MATLAB

Projection data → sqrtPA Centroid → Table error model → Mis-centering → Regression model → Dose & noise increase

III. Results – Centering Error

	w12	w20	w25	w35	w46	P48
0	0.64	-0.33	0.46	-0.36	-1.17	0
-30	-0.14	-0.88	0.02	-0.53	-1.07	-3.78
-60	-1	-1.62	-0.43	-0.29	-7.98	-12.15



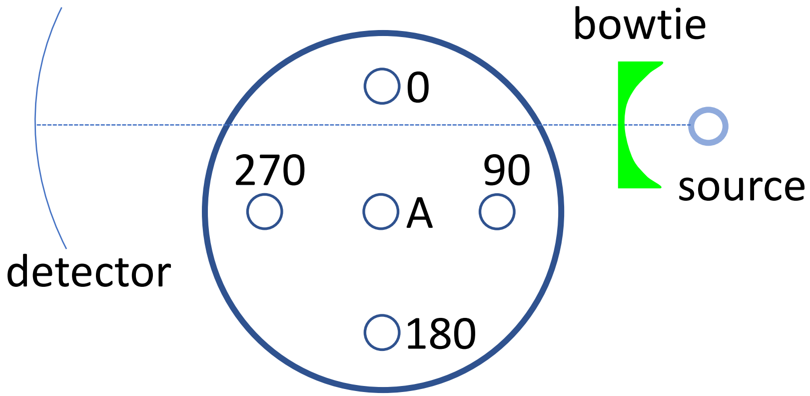
- Sub-mm accuracy (phantoms scanned in air)
- Large centering calculation errors when part of the object is out of the FOV

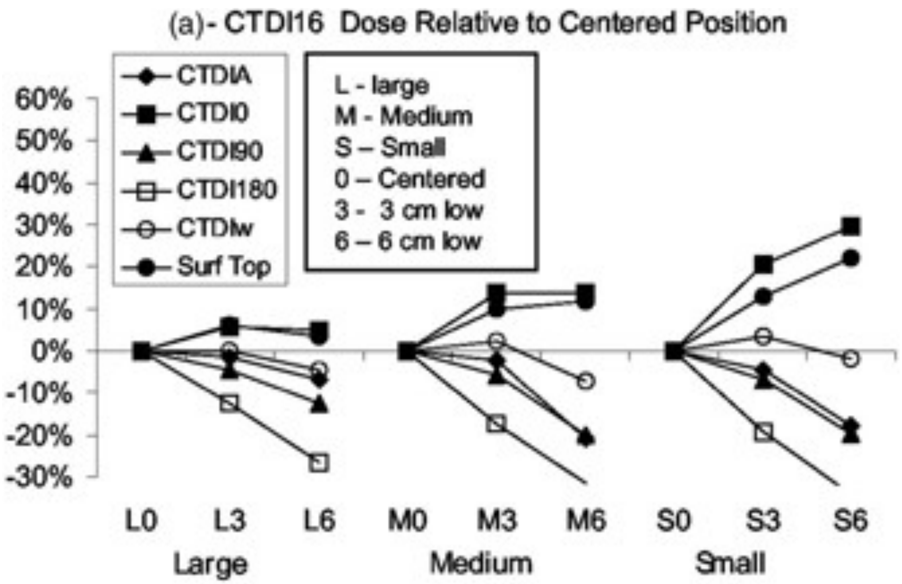
- Repeat measurements with phantoms on table to find regression model
- sqrtPA ∝ effective phantom diameter

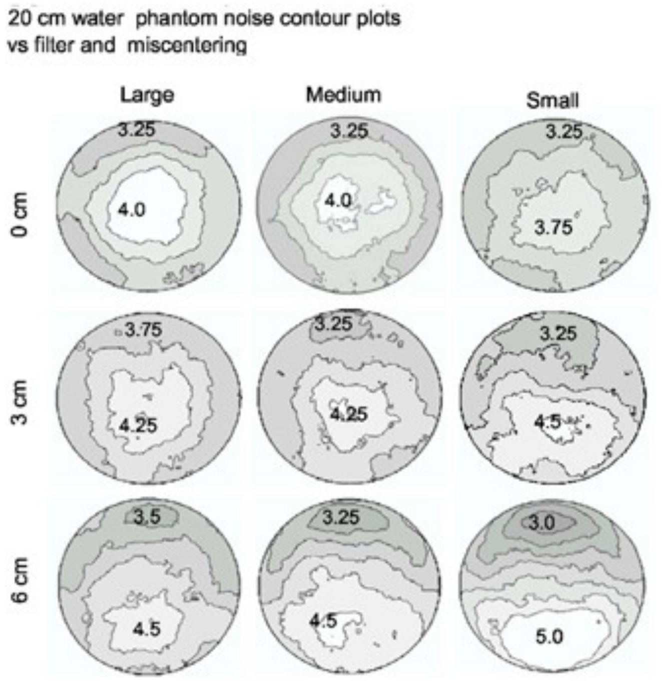
Johns Hopkins Biomedical Engineering

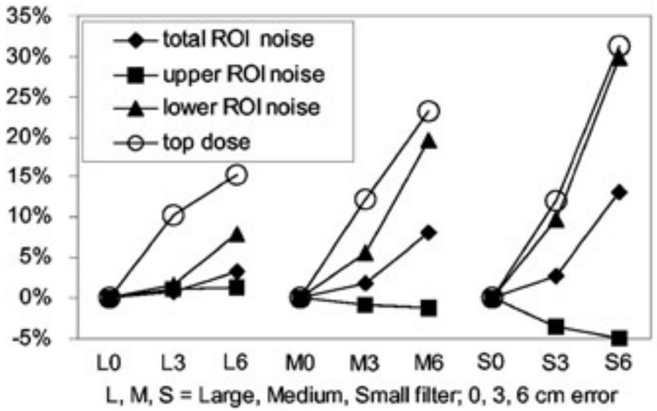
III. Results – Noise & Dose

- Mis-centering (lowering)
  - More dose at top, less at bottom
  - More noise at bottom, less at top



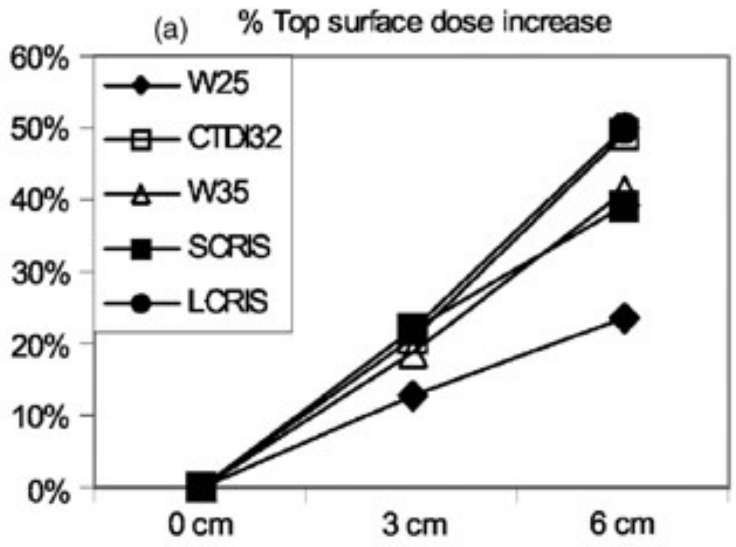


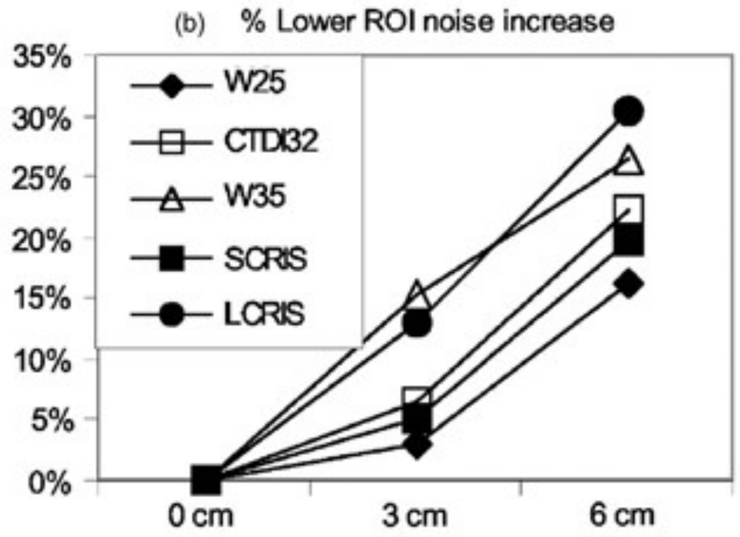




III. Results – Dose/Noise Regression

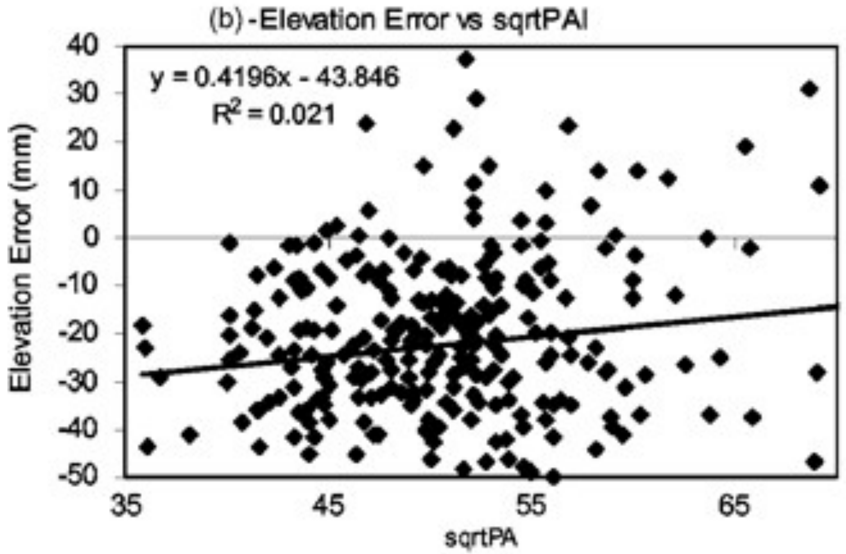
- Focus on top surface dose increase and lower ROI noise increase as a function of mis-centering and object size
- Data for large bowtie/abdomen size phantoms
- Did not show the actual quadratic regressions developed from this data and used later to study clinical implications
  - Only reported R^2 values



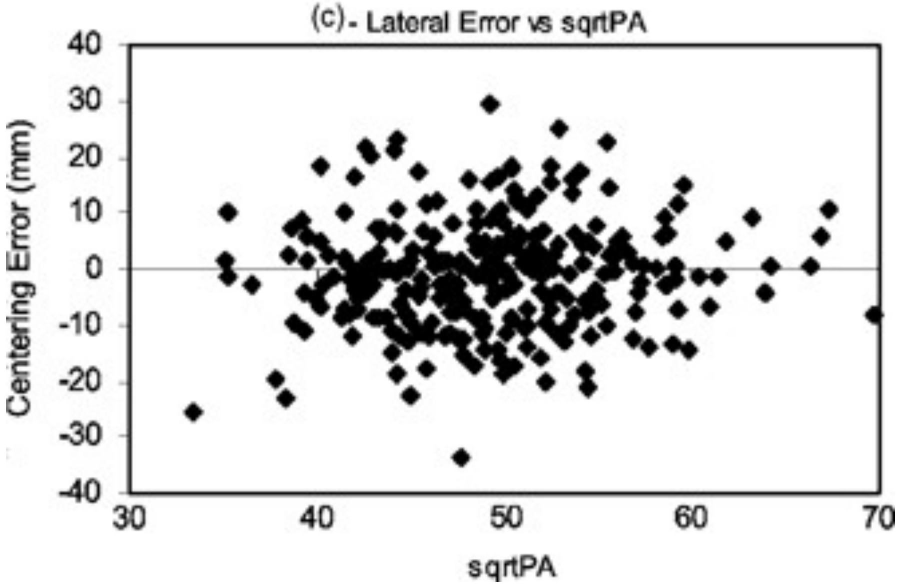


(c) Noise Adjusted Surface Dose Increase		
Phantom	3 cm	6 cm
W25	20%	67%
CTDI32	37%	123%
W35	58%	126%
SCRIS	35%	101%
LCRIS	56%	155%

III. Results – Clinical Centering Errors



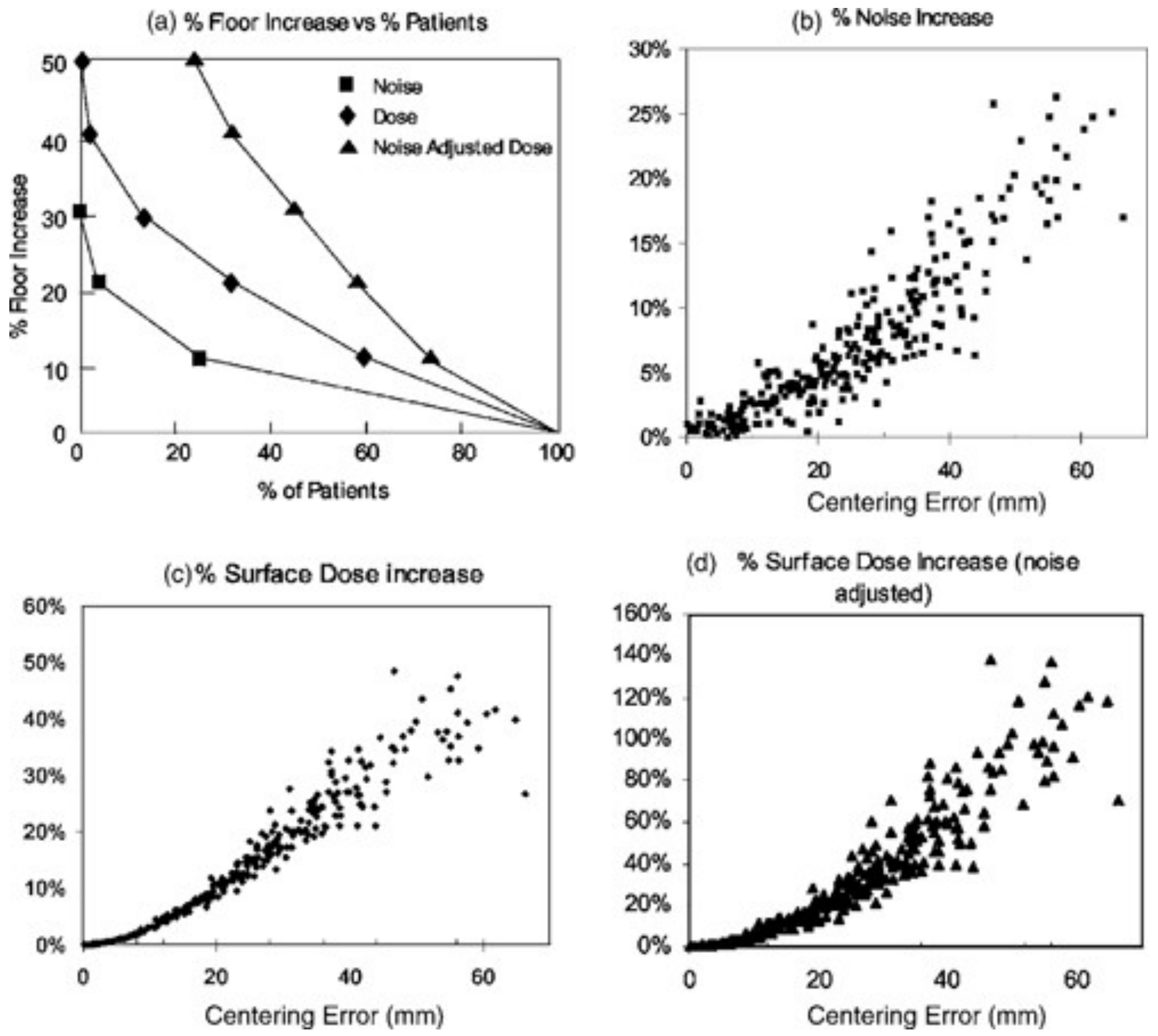
- Range: -6.6 to 3.4 cm
- Mean: -2.3 cm
- 74% mis-centered > 1cm
- 22% mis-centered > 3cm
- (slight) trend for smaller patients to be mis-centered lower than large patients



- Range: -2.9 cm to 3.3 cm
- Mean: 0.0 cm

III. Results – Clinical Dose/Noise

- Mean increase
  - Noise: 7%
  - Surface dose: 15%
  - Noise adjusted surface dose: 33%
- Minimum increase for 50% of patients
  - Noise: 5%
  - Surface dose: 15%
  - Noise adjusted surface dose: 25%
- Extra dose to anterior tissues (e.g. breast)
  - More for noise-adjusted



Paper Assessment

- Pros
  - Dose and noise measurements using a clinical CT scanner
  - Developed useful tools to assess patient size, mis-centering, and models for estimating dose or noise impacts based solely on scout scans
  - First paper to demonstrate a tendency for patient mis-centering in clinical scenarios and dose/image quality issues
- Cons
  - Absorbed dose in a phantom ≠ effective dose in real patient
  - Analysis is restrictive
    - only mis-centerings *below* isocenter
    - Dose/noise models for abdominal imaging – patterns may be different for head

Relevance & Takeaways

- Provides clinical context to the patient mis-centering problem
  - Real data that lends credence to our need statement
- Relative trends to expect in dose measurements
- Perform similar analysis to verify our system performance
  - Already done one set of CTDI measurements, but need should plot trends over multiple offset values
  - Spatial dependence of noise in difference images using homogenous water phantoms
  - Trends with/without our system on common axes