SU-315-GPD-D-115

Reproducibility of CT Beam Width Measurements Using a Pencil Ionization Chamber

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2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Introduction

• Accurate characterization of the radiation beam width is essential for accurate dose reporting.

•Common techniques to measure CT radiation beam width include: radiographic and radiochromic films, computed-radiography (CR) imaging plates, and pencil-ionization chamber readings[2].

• Al-Senan et al. described a method that uses a **pencil ionization chamber** together with a radiopaque mask to determine the **beam width**[3].

• This method reported **high accuracy**: root-mean-square agreement of less than 0.5 mm against film and CR references across nominal beam widths from 1 to 40 mm.

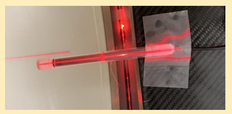
• This project **evaluates the reproducibility and precision** of CT beam width measurements using a pencil ionization chamber and radiopaque mask and to **assess the robustness of the technique against clinically realistic setup errors** in the superior-inferior (SI) and anterior-posterior (AP) directions.

Methods

Step 1: Align ionization chamber

Step 2: Scan with mask

Step 3: Scan without mask



Step 4: Calculate calibration factor (CF) and beam width (W_b)

$$CF = \frac{X_{unmasked} - X_{masked}}{L_{eff}}$$

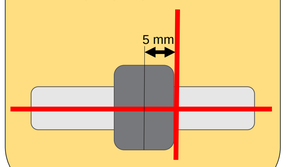
$$W_b = \frac{X_{coll}}{CF}$$

Setup Errors

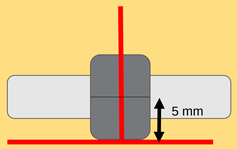
kV/mA Offsets
All combinations tested

Voltage (kV)	Currents (mA)
80	50
100	100
120	150

SI offsets
0, 1, 3, 5 mm



AP offsets
0, 5 mm



Results

Input Setup Errors

Summary of Beam width measurements across all kV and mA combinations.

Nominal Beam Width (mm)	Detector Configuration	Nominal Dose Efficiency (%)	Mean Beam Width (mm)	SD (mm)	CV (%)	F-Value
10	8 x 1.25 mm	79.93	13.04	0.07	0.57	0.12
15	4 x 3.75 mm	93.15	16.90	0.08	0.48	0.17
20	8 x 2.5 mm	98.93	20.60	0.05	0.25	0.08

Table 1. The small coefficient of variation indicates that the **kV and mA minimally affect the beam width**. F-values are from Levene's test for homogeneity of variance across kV/mA combinations within each nominal collimation; all p > 0.90.

Measured deviation from scanner-specific mean beam width as a function of tube potential for different nominal collimations.

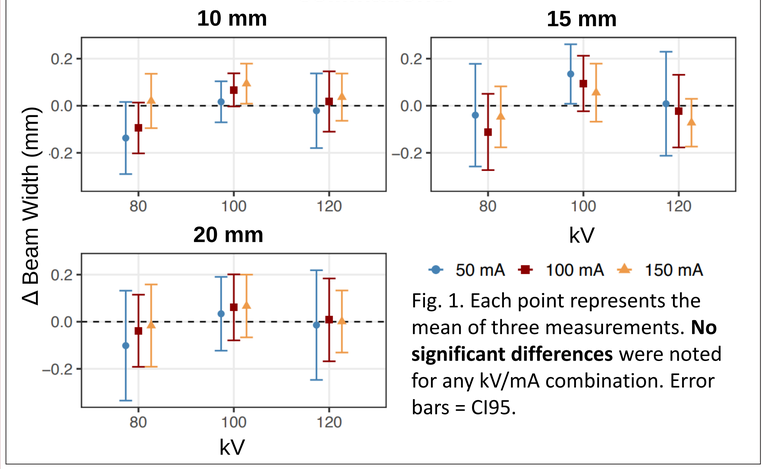


Fig. 1. Each point represents the mean of three measurements. **No significant differences** were noted for any kV/mA combination. Error bars = CI95.

Physical Setup Errors

Sensitivity of measured beam width to AP setup error at 120 kV/150 mA.

Nominal Beam Collimation (mm)	AP Offset (mm)	Mean Measured Beam Width (mm)	Δ beam width (mm)	CI95 for Δ beam width (mm)
10	0	12.75	0.09	[-0.06,0.24]
	5	12.66		
20	0	20.77	0.15	[-0.11,0.41]
	5	20.62		

Table 2. The **changes in beam width** between 0 and 5 mm offsets **are less than 0.2 mm** for both collimations. The change in beam width represents the difference between the 5 mm offset and baseline (0 mm) measurements.

Estimated sensitivity of measured beam width to SI setup error for each tube voltage and current combination at 20 mm collimation.

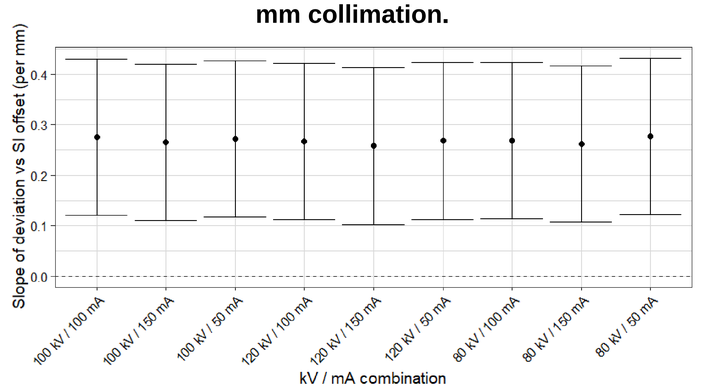


Fig. 2**. No significant differences** were reported across kV/mA combinations. Each point shows the estimated slope of beam width deviation versus SI offset per mm. Zero indicates no differences between SI offset. Error bars = CI95.

Conclusions and Future Work

The pencil ion-chamber and mask method produces **highly reproducible** CT beam-width measurements that are effectively **independent of tube potential and tube current** and are **robust to clinically realistic SI and AP setup errors**.

Future work

- Expand project to multiple CT scanners
- Construct holder to measure right-left and angular offsets

Acknowledgements

Financial support for this project is provided by:

- The Charles M. Smith endowment fund
- The Kenneth Hogstrom Superior Graduate Student Scholarship
- The LSU Graduate Student Association Travel Award

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