Evaluation of CBCT Image Quality of the KOALA Dual-Robot Radiotherapy System

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INTRODUCTION

Modern cone-beam CT (CBCT) images are conventionally acquired using a linac gantry. The fixed c-arm nature of the gantry requires minor 2D positional corrections for reconstruction. While dual-arm CBCT systems exist, these systems face the challenge of requiring a 3D positional correction for the two independent robotic arms to achieve adequate image quality [1].

AIM

To evaluate image quality for the Kilovoltage Optimized AcceLerator Adaptive radiotherapy (KOALA) system, a dual-robot CBCT imaging and radiotherapy device.

MATERIALS & METHODS

The dual-robot KOALA CBCT system (Figure 1a) [2], comprises of two ABB robot arms, one with a 225kVp x-ray tube and the other with an a-Si flat panel detector, a custom carbon fibre curved couch, and 2mm of Al as filtration.

- A **CATPHAN504 phantom** was scanned on KOALA and a TrueBeam CBCT system.
- A **lamb head** (Figure 1b) was scanned on KOALA, the TrueBeam CBCT system, and a GE Optima CT580 clinical CT scanner.
- All scans were reconstructed using proprietary Orimtech, Varian, and GE Healthcare reconstruction algorithms for the KOALA, TrueBeam, and clinical CT scans, respectively.

Table 1: Imaging acquisition parameters.

Object	Scanner	Rotation	kVp	mAs
CATPHAN504	KOALA	half	100	153
CATPHAN504	TrueBeam	half	100	580
Lamb head	KOALA	half	100	153
Lamb head	TrueBeam	half	100	250
Lamb head	Clinical CT	full	100	428

- **Geometric accuracy, modulation transfer function (MTF), contrast-to-noise ratio (CNR), and HU accuracy** were evaluated on the CATPHAN504 (Figure 2).
- A calibration curve was created for KOALA CBCT CT number accuracy (Figure 4).

RESULTS

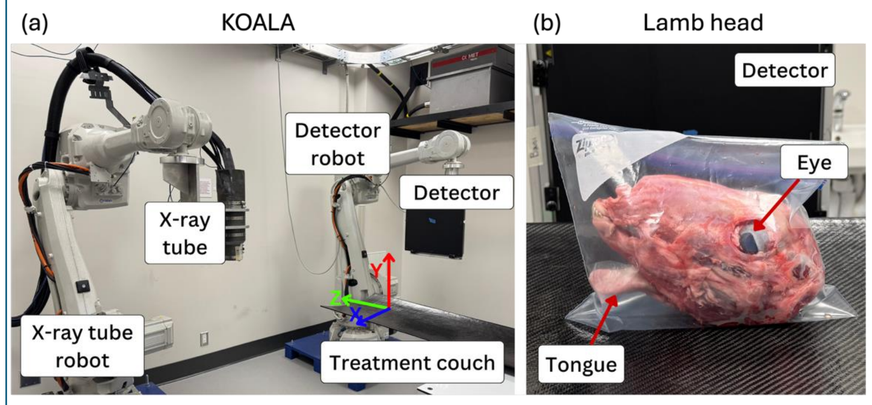

Figure 1: Images of the (a) KOALA dual-robot system and (b) the lamb head biological sample used to evaluate image quality.

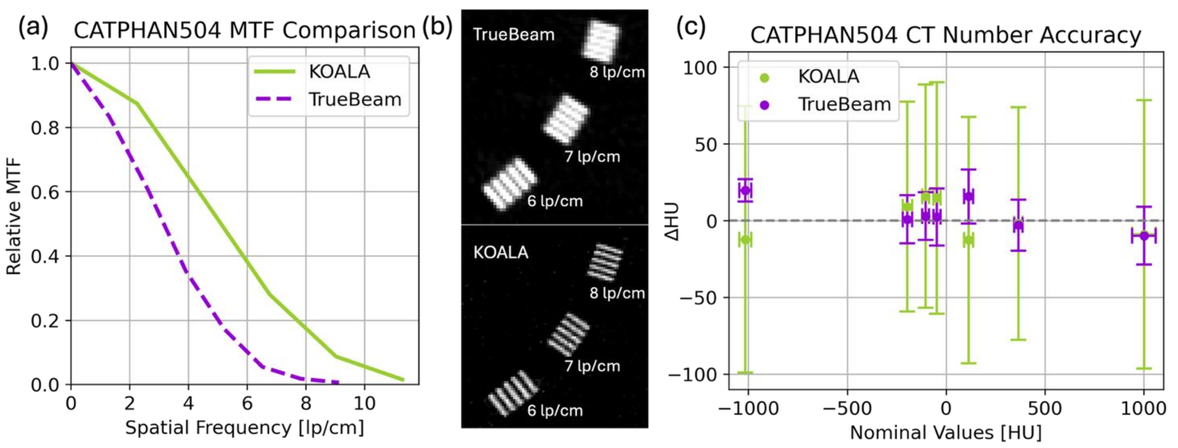

Figure 2: (a) & (b) Spatial resolution and (c) CT # accuracy comparisons for KOALA and TrueBeam CBCT. Both CBCT scans were acquired using 100kVp and with 152.7mAs for KOALA and 580mAs for TrueBeam.

Table 2: Spatial resolution results.

Scanner	Visual SR	10% MTF
KOALA	13 lp/cm	8.9 lp/cm
TrueBeam	7 lp/cm	6.0 lp/cm

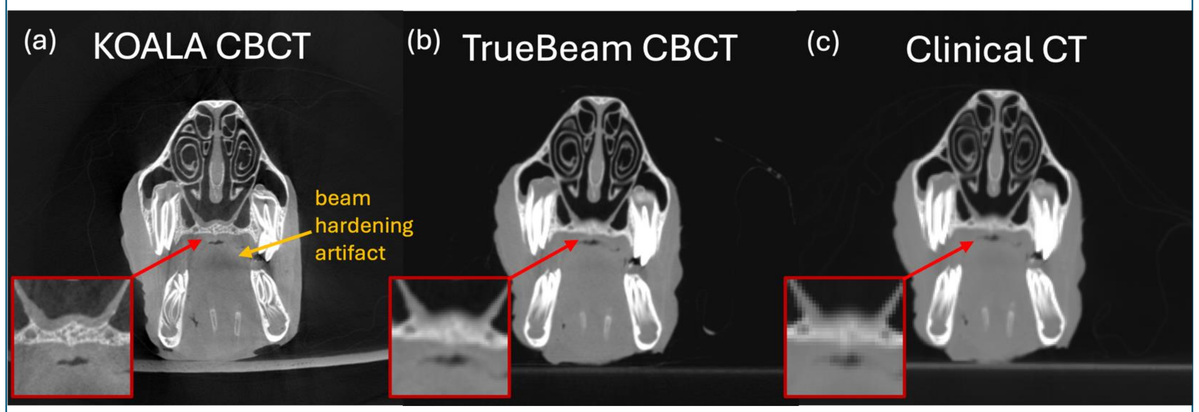

Figure 3: (a) KOALA CBCT, (b) TrueBeam CBCT, and (c) clinical CT scans of a lamb head biological sample. Scans were acquired using 100kVp and 152.7mAs for KOALA, 250mAs for TrueBeam, and 428.3mAs for the clinical CT. Same W/L for all. The red insets showcase KOALA's ability to resolve the porous trabecular bone structure compared to clinical imaging systems. The yellow arrow indicates a beam hardening artifact present in the KOALA CBCT image.

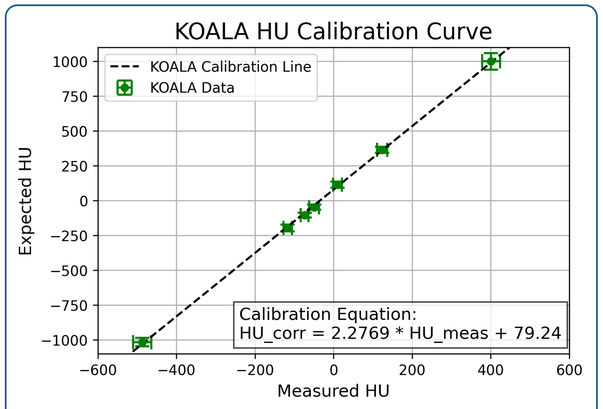

Figure 4: CT Number Calibration curve for KOALA.

Table 3: CATPHAN504 analysis results.

Measurement	KOALA	TrueBeam
Geometric measurement (50mm)	49.5 mm	49.9 mm
Teflon CNR	11	53
HU mean abs. error	11 HU	8 HU
Mean noise	78 HU	15 HU

CONCLUSIONS

- KOALA images had a **superior spatial resolution** compared to TrueBeam and clinical CT using QA phantoms and biological samples
- KOALA **maintained clinical geometric accuracy**
- A CT number **calibration curve was required** and proved successful.
- KOALA CT number measurements and high noise resulted in a **reduced CNR**.
- KOALA resulted in more artifacts, particularly **beam hardening artifacts**.
- Potential improvements to image quality could be made by designing a **custom bowtie filter.**

ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr Tainang Huang and Linden Bioscience Technologies for their support. The authors would also like to acknowledge funding from the NSERC Canada Graduate Research Scholarship program, NSERC Discovery Grants, and the Canada Research Chairs program.

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