

Daily patient dose from kilovoltage cone beam CT: a comparison between Elekta Synergy® XVI and Varian OBI

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Purpose: To make a comprehensive set of absolute dose measurements from Elekta Synergy® XVI X-ray volumetric imager and the Varian OBI® on-board imager on cylindrical phantoms using a calibrated ion chamber.



Accuracy study



Daily patient dose from kilovoltage cone beam CT: a comparison between Elekta Synergy® XVI and OBI

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Method and materials

Two cylindrical (acrylic) phantoms with diameters of 18cm (head phantom) and 30cm (body phantom) were used for all measurements.

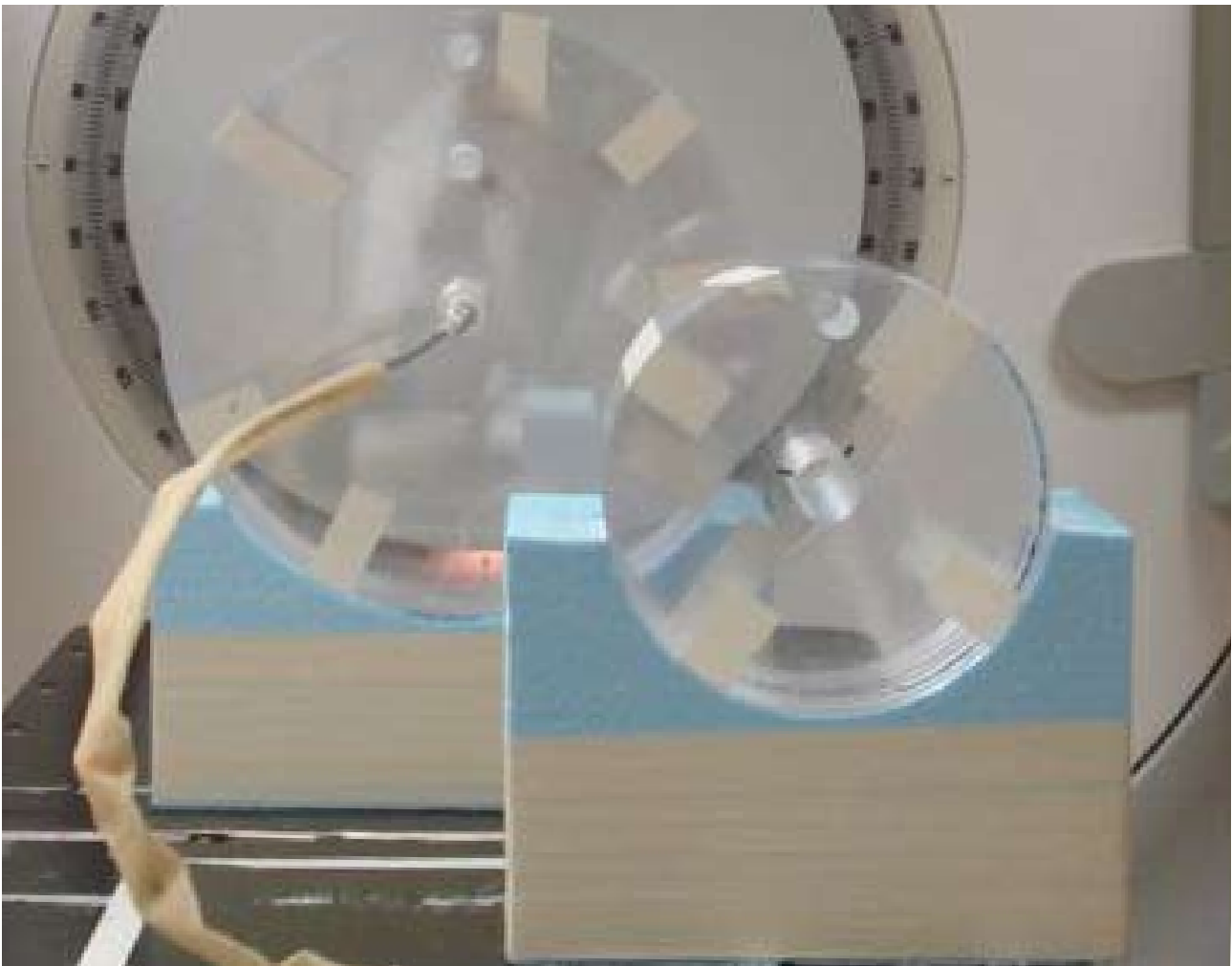


Figure 1: acrylic phantoms

Each phantom has a hole in the center and 2cm below the phantom surface. For the XVI unit, the four manufacturer-supplied protocols were measured, namely, head-and-neck, prostate, pelvis, and pelvis-large. The total mAs settings were also varied for each protocol to verify the dose linearity. For the OBI unit, full bow tie, half bow tie, and no bow tie filters were used in combination with the two scanning modes, namely, full fan and half fan.

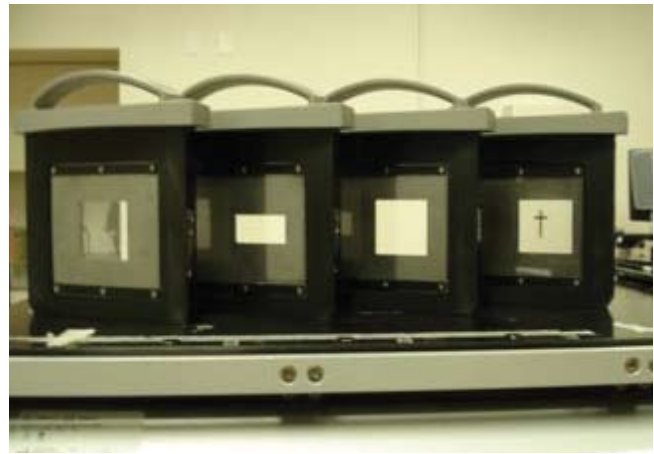


Figure 2: Elekta Synergy® at University of Florida

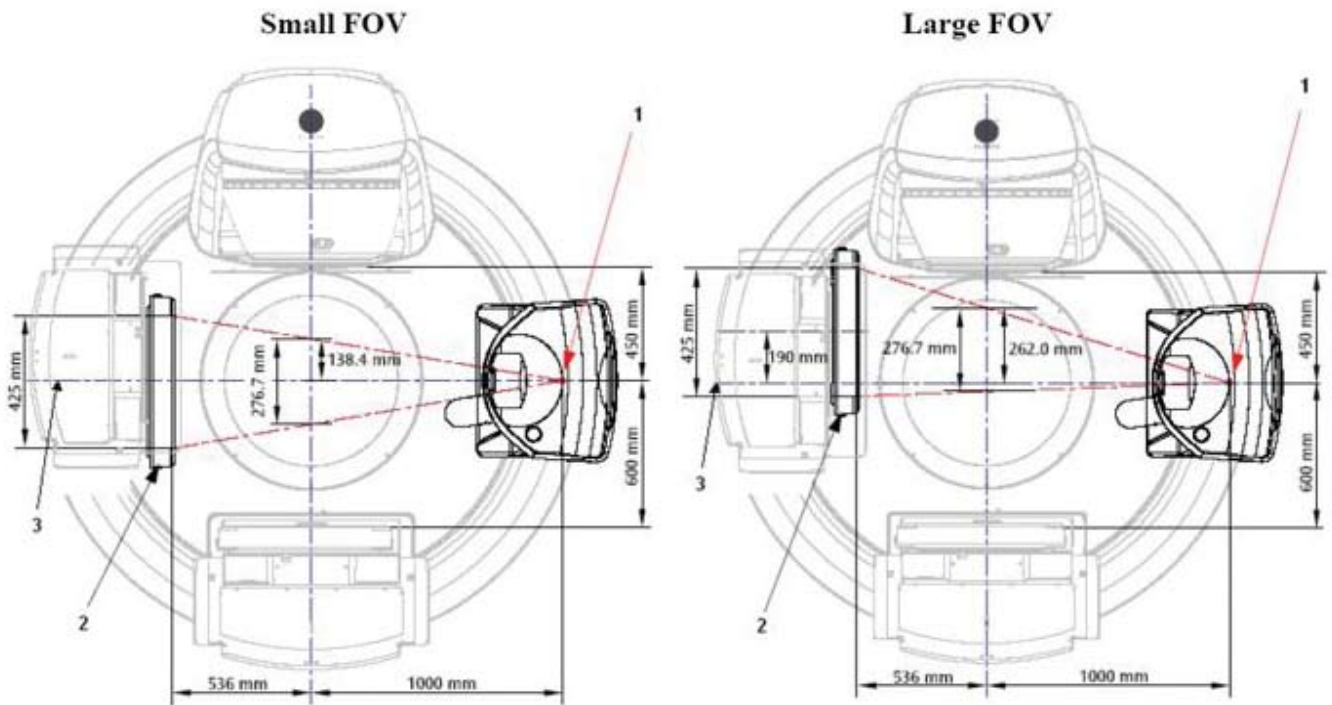


Figure 3: XVI

Protocol	Head-and-neck*	Prostate	Pelvis	Chest
Phantom size (cm)	18	30	30	30
kV collimator	S20	M10	M20	L20
kVp	100	120	120	120
mA	10	40	25	25
ms/frame	10	40	40	40
#frames	361	643	643	643
Total mAs	36.1	1028.8	643	643
Acquisition angle**	350° to 190°cw	273 to 269°cw	273° to 269°cw	273° to 269°cw

* for the head-and-neck protocol the total acquisition angle is <math><360^\circ</math> ($\approx 200^\circ$)

** not the gantry angle but the angle at which the kV source is positioned

Table 1: XVI protocols at University of Florida

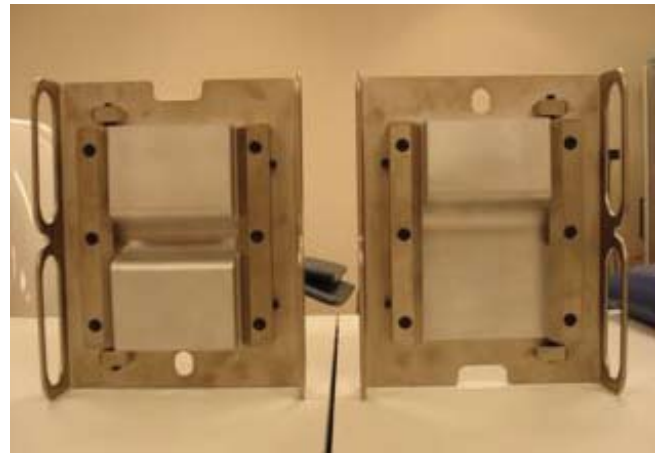


Figure 4: Varian Trilogy at University of Florida

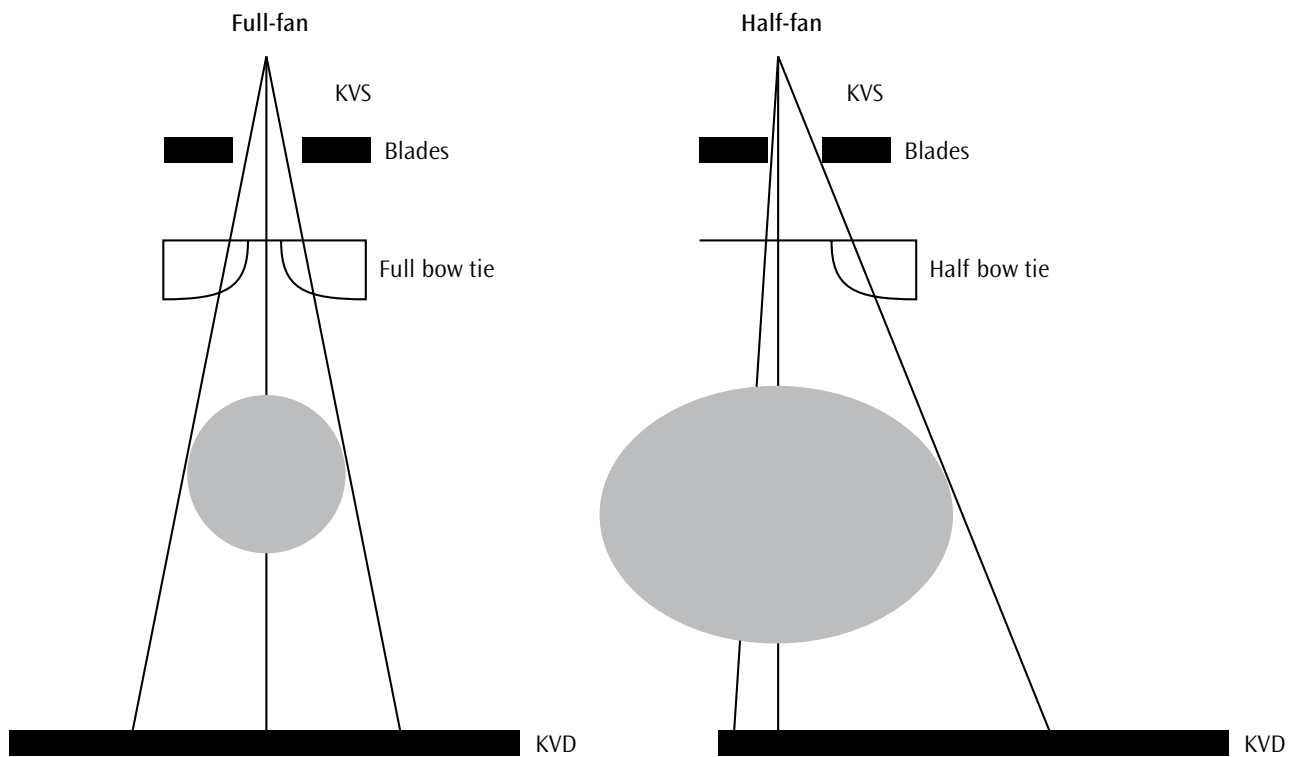


Figure 5: OBI®

Protocol	150cm FSD with bow tie		150cm FSD low dose		150cm FSD no bow tie	
Phantom size (cm)	18	30	18	30	18	30
Filter	Full bow tie	Half bow tie	Full bow tie	Half bow tie	Full bow tie	Half bow tie
Scan mode	Full fan	Half fan	Full fan	Half fan	Full fan	Half fan
kVp	125		125		125	
mA	80	80	40	40	40	40
ms/frame	25	25	10	10	10	10
#frames	630		630		630	
Total mAs	1260	1260	252	252	252	252
Acquisition angle*	85.5° to 92.5° or 94.5° to 87.5°		85.5° to 92.5° or 94.5° to 87.5°		85.5° to 92.5° or 94.5° to 87.5°	

* not the gantry angle but the angle at which the kV source is positioned – all acquisition angles are $\approx 360^\circ$.

Table 2: OBI® protocols at University of Florida

Results

For the XVI unit, the (isocenter) doses range between 0.1 and 2.2cGy for the head-and-neck and prostate protocol, respectively, and agree well with the nominal scan dose supplied by the manufacturer. The measured doses were highly linear with the total mAs settings. For the OBI unit, the (isocenter) doses range between 0.9 and 8.5cGy. In the full bow tie with full fan mode, the head phantom central dose was 8.5cGy. This is significantly larger than a similar protocol scan measured with the XVI unit (head-and-neck).

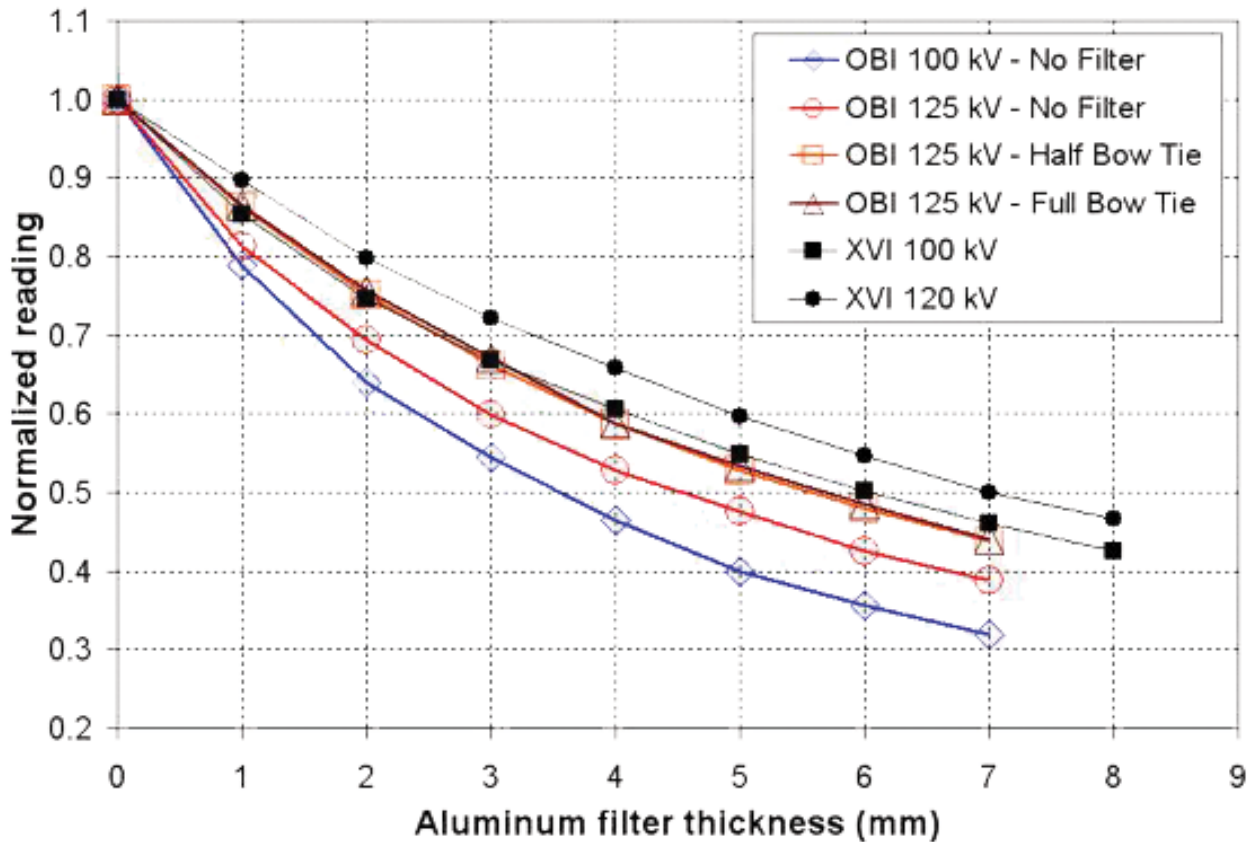


Figure 6: HVL in broad beam geometry

Machine	XVI		OBI			
	100kVp	120kVp	100kVp*		125kVp	
Filter	No filter		No filter	No filter	Half bow tie	Full bow tie
HVL (mm-Al)	6.0	7.0	3.5	4.6	5.7	5.7

* not used clinically

Table 3: HVL in broad beam gantry.

Half value layers were between 4.6 to 7.0-mm-Al for the two X-ray units. The OBI offers a higher kVp and XVI has harder beams. All results show good agreement with the literature.

Protocol	Head-and-neck	Prostate	Pelvis	Chest
Phantom size (cm)	18	30	30	30
kV collimator	S20	M10	M20	L20
kVp	100	120	120	120
mA	10	40	25	25
ms/frame	10	40	40	40
# frames	361	643	643	643
Total mAs	36.1	1028.8	643	643
Acquisition angle	350° to 190°cw	273° to 269°cw	273° to 269°cw	273° to 269°cw
Dose (cGy)				
D central	0.10 ± 0.01	2.2 ± 0.04	1.6 ± 0.04	1.1 ± 0.03
Edge 0°	0.13 ± 0.01	4.3 ± 0.05	2.8 ± 0.03	2.2 ± 0.01
Edge 90°	0.22 ± 0.01	4.1 ± 0.01	2.7 ± 0.01	2.1 ± 0.03
Edge 180°	0.13 ± 0.01	3.7 ± 0.03	2.5 ± 0.01	2.0 ± 0.03
Edge 270°	0.22 ± 0.01	4.6 ± 0.01	3.1 ± 0.01	2.4 ± 0.01
D peripheral	0.14 ± 0.06	4.2 ± 0.39	2.8 ± 0.24	2.2 ± 0.17
CBCTDI w	0.1	3.5	2.4	1.8

Table 4: XVI

For the head-and-neck scan, the kVp and acquisition angles are reduced this results in very low dose, in the region of 0.1cGy. For body scans, dose is in the region of 1.8 to 3.5cGy. In general, the peripheral doses are greater than the central axis doses by a magnitude of 1.5 to 2 with the largest found consistently at 270° periphery.

Protocol	150cm FSD with bow tie		150cm FSD low dose		150cm FSD no bow tie	
	18	30	18	30	18	30
Filter	Full bow tie	Half bow tie	Full bow tie	Half bow tie	Full bow tie	Half bow tie
Scan mode	Full fan	Half fan	Full fan	Half fan	Full fan	Half fan
kVp	125		125		125	
mA	80	80	40	40	40	40
ms/frame	25	25	10	10	10	10
# frames	630		630		630	
Total mAs	1260	1260	252	252	252	252
Acquisition angle	85.5° to 92.5° or 94.5° to 87.5°ccw		85.5° to 92.5° or 94.5° to 87.5°ccw		85.5° to 92.5° or 94.5° to 87.5°ccw	
Dose (cGy)						
D central	8.5 ± 0.12	4.1 ± 0.09	1.8 ± 0.02	0.9 ± 0.01	2.5 ± 0.05	1.1 ± 0.03
Edge 0°	8.7 ± 0.33	6.3 ± 0.04	1.8 ± 0.07	1.3 ± 0.02	3.5 ± 0.06	2.5 ± 0.02
Edge 90°	8.1 ± 0.17	7.5 ± 0.35	1.6 ± 0.03	1.6 ± 0.06	3.1 ± 0.02	2.7 ± 0.10
Edge 180°	7.5 ± 0.01	4.8 ± 0.27	1.5 ± 0.01	1.0 ± 0.05	2.8 ± 0.01	2.0 ± 0.04
Edge 270°	8.1 ± 0.04	5.7 ± 0.02	1.7 ± 0.01	1.2 ± 0.01	3.0 ± 0.01	2.1 ± 0.02
D peripheral	8.1 ± 0.52	6.1 ± 1.13	1.7 ± 0.13	1.3 ± 0.25	3.1 ± 0.29	2.3 ± 0.34
CBCTDI w	8.3	5.4	1.7	1.1	2.9	1.9

Table 5: OBI

OBI scans generally result in greater dose than XVI scans with full fan scans greater than half fan scans. A full fan scan results in a dose of 8.3cGy for head-and-neck region studies, compared to the head-and-neck protocol in XVI which delivers a dose of 0.1cGy. The largest dose was found consistently at 90° periphery.

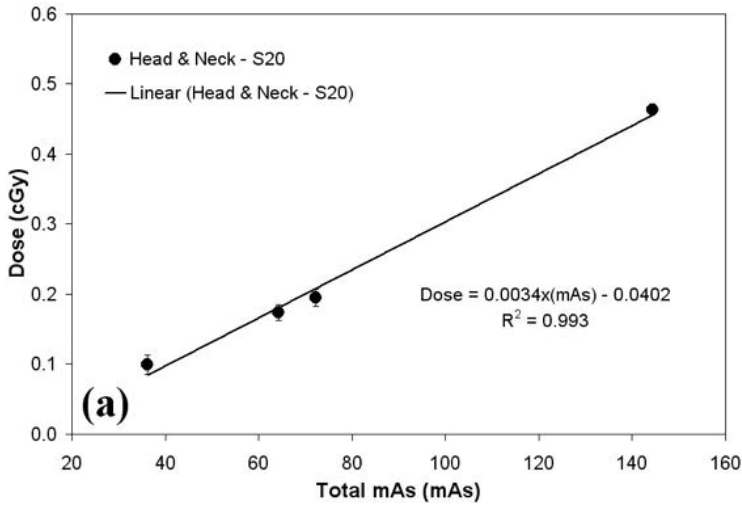


Figure 7: table – XVI (central axis dose)

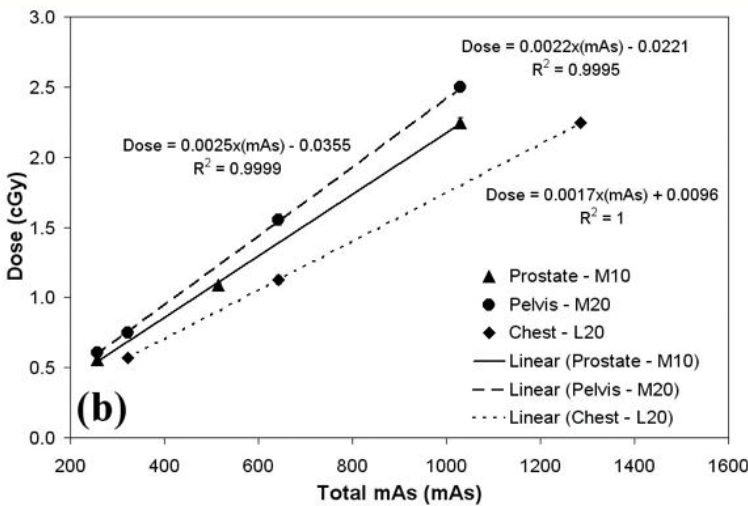


Figure 8: XVI (central axis dose) in all cases, $R^2 > 0.99$ – for XVI, the slopes are:

- head-and-neck: 3.4×10^{-3} cGy/mAs (largest)
- prostate: 2.2×10^{-3} cGy/mAs
- pelvis: 2.5×10^{-3} cGy/mAs
- chest: 1.7×10^{-3} cGy/mAs

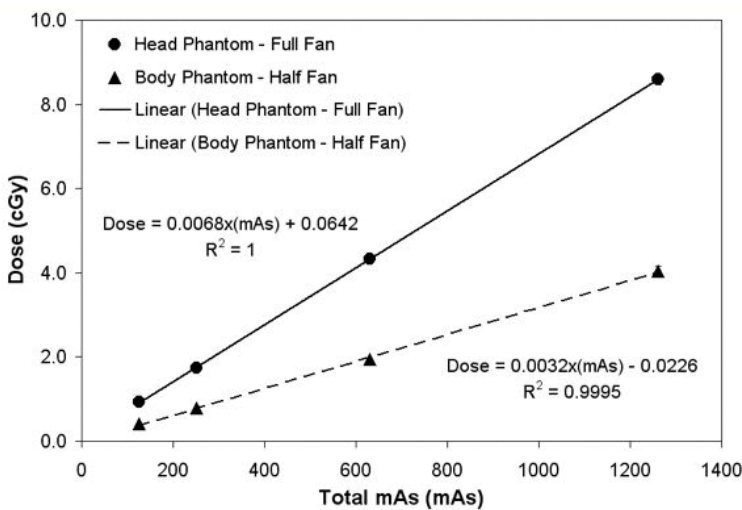


Figure 9: for OBI, the slopes are:

- full fan: 6.8×10^{-3} cGy/mAs (largest)
- half fan: 3.2×10^{-3} cGy/mAs
- generally, the slopes are OBI > XVI

Conclusion

A comprehensive series of dose measurements were made on the XVI and OBI CBCT imagers. It was observed that the OBI unit generally results in higher dose with up to 8.5cGy measured with the head phantom. More studies are required to determine the increase in image quality expected from the increase in patient dose from the OBI unit.

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