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Technical notes

Investigating in-field and out-of-field neutron contamination in high-energy medical linear accelerators based on the treatment factors of field size, depth, beam modifiers, and beam type

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ABSTRACT

Purpose: We analysed the effects of field size, depth, beam modifier and beam type on the amount of in-field and out-of-field neutron contamination for medical linear accelerators (linacs).

Methods: Measurements were carried out for three high-energy medical linacs of Elekta Synergy Platform, Varian Clinac DHX High Performance and Philips SL25 using bubble detectors. The photo-neutron measurements were taken in the first two linacs with 18 MV nominal energy, whereas the electro-neutrons were measured in the three linacs with 9 MeV, 10 MeV, 15 MeV and 18 MeV.

Results: The central neutron doses increased with larger field sizes as a dramatic drop off was observed in peripheral areas. Comparing with the jaws-shaped open-field of 10 × 10 cm, the motorised and physical wedges contributed to neutron contamination at central axis by 60% and 18%, respectively. The similar dose increment was observed in MLC-shaped fields. The contributions of MLCs were in the range of 55–59% and 19–22% in Elekta and Varian linacs comparing with 10 × 10 and 20 × 20 cm open fields shaped by the jaws, respectively. The neutron doses at shallow depths were found to be higher than the doses found at deeper regions. The electro-neutron dose at the 18 MeV energy was higher than the doses at the electron energies of 15 MeV and 9 MeV by a factor of 3 and 50, respectively.

Conclusion: The photo- and electro-neutron dose should be taken into consideration in the radiation treatment with high photon and electron energies.

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PURPOSE

We analysed the effects of **field size, depth, beam modifier** and **beam type** on the amount of **in-field** and **out-of-field neutron contamination**

for medical linear accelerators

MATERIALS AND METHODS

Table 1
The methodology for photo- and electro-neutron contamination measurements.

Photo-neutron measurements	
Linacs	Varian Clinac DHX, Elekta Synergy Platform
Energy	18 MV
Stage I: Field Size	
SDD (cm)	100
Field Size (cm)	10 × 10, 20 × 20 and 30 × 30
Distance from axis (cm)	0, 10, 20, 50 and 80
Stage II: Wedge Filter	
Modes	No wedge, with physical and motorized wedge
SDD (cm)	100
Field Size (cm)	10 × 10
Distance from axis (cm)	0, 10, 20, 50 and 80
Stage III: MLC	
SDD (cm)	100
Jaws (cm)	40 × 40
MLC (cm)	10 × 10 and 20 × 20
Distance from axis (cm)	0, 10, 20, 50 and 80
Stage IV: Depth	
SSD (cm)	100
Field Size (cm)	10 × 10
Depths (cm)	1, 5 and 10
Distance from axis (cm)	0, 10, 20, 50 and 80
Electro-neutron Measurements	
Linacs	Varian Clinac DHX, Elekta Synergy Platform, Philips SL 25/75
Energy (MeV)	9, 10, 15 and 18 (avaliable energies)
Field Size (cm)	10 × 10 electron cone
Distance from axis (cm)	0 and 10

RESULTS

- **Photo-neutron dose at central axis increases with enhancement of field size.**

- **We observed a dramatic drop-off in neutron doses at the distance of 10 cm from the central axis in both Linacs.**

RESULTS

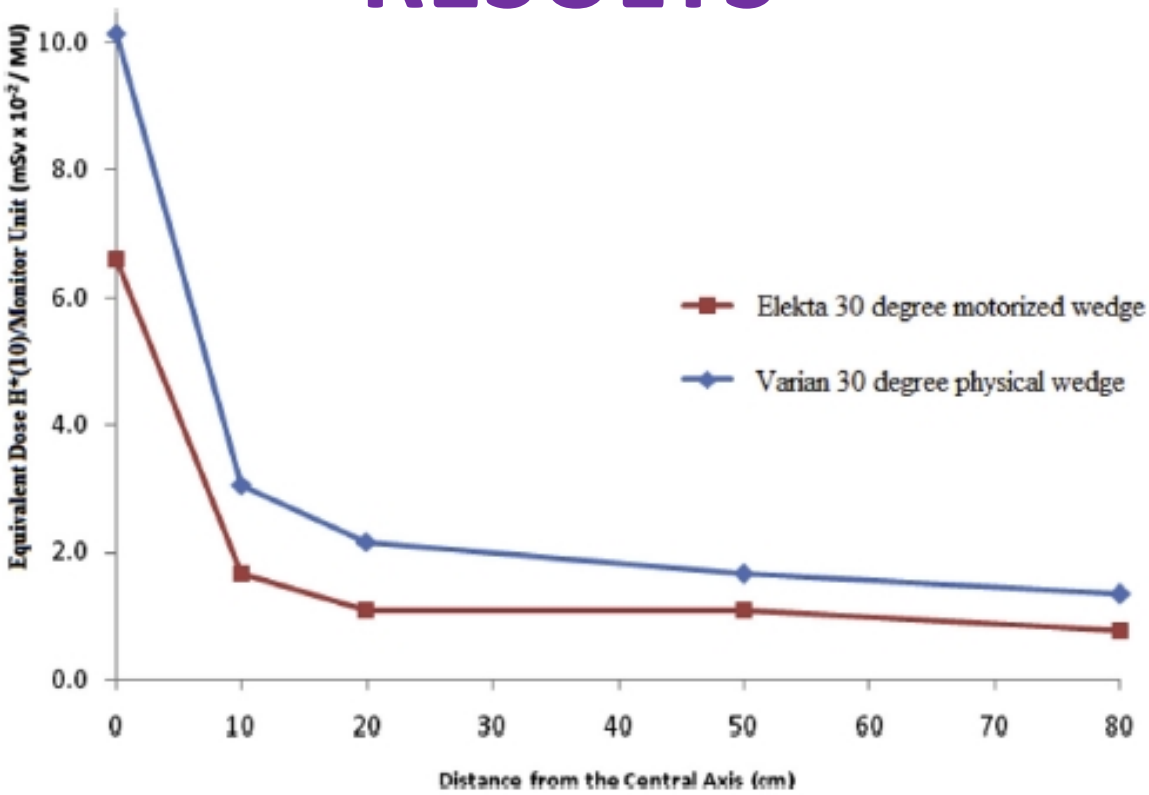

Figure 2. Equivalent dose H*(10) measured in 10 × 10 cm 30 degree wedged field produced by 18 MV Elekta Synergy Platform and Varian Clinac DHX High Performance linacs.

- **30° physical wedge contribute to the contamination at central axis by 18%.**
- **30° motorized wedge contribute to the neutron dose at central axis by 60%.**

RESULTS

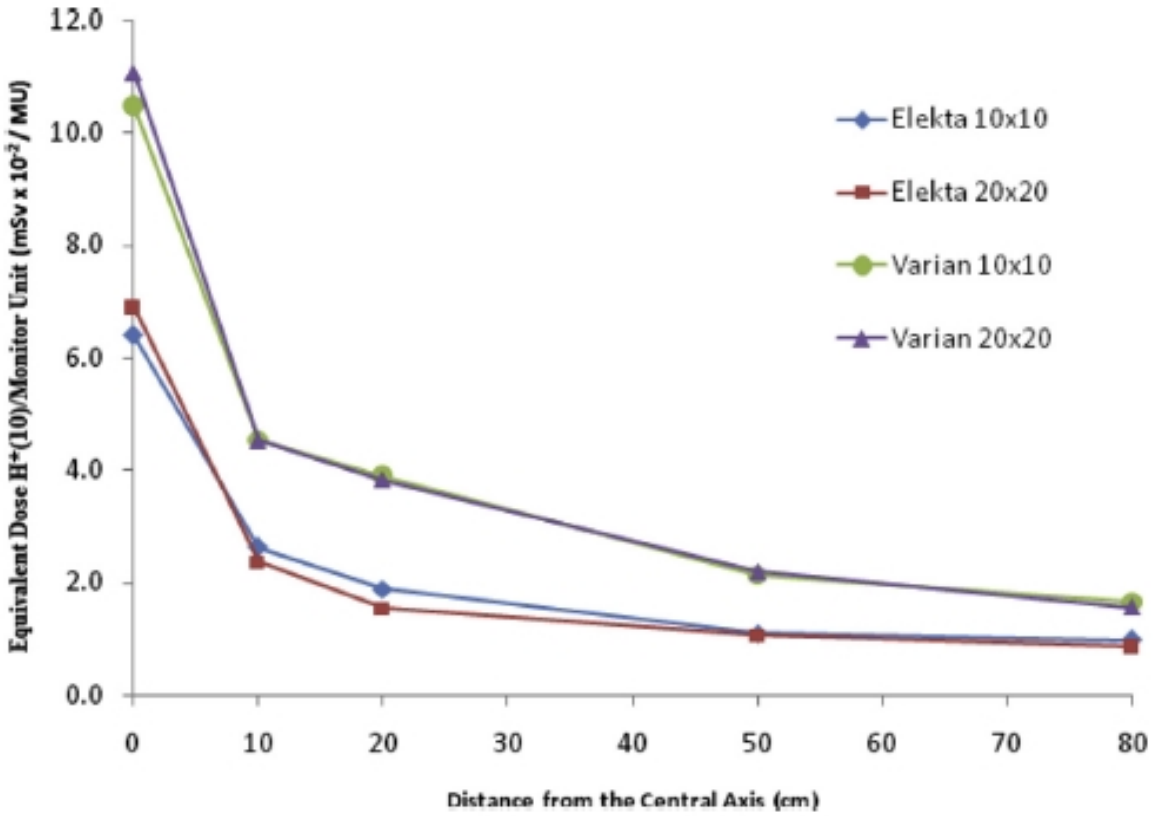

Figure 3. Equivalent dose H*(10) measured in 10 × 10 cm and 20 × 20 cm equivalent square field size shaped with MLC in 18 MV Elekta Synergy Platform and Varian Clinac DHX High Performance linacs.

- **Contributions of MLCs on neutron dose were about 55% in Elekta and 20% in Varian.**

RESULTS

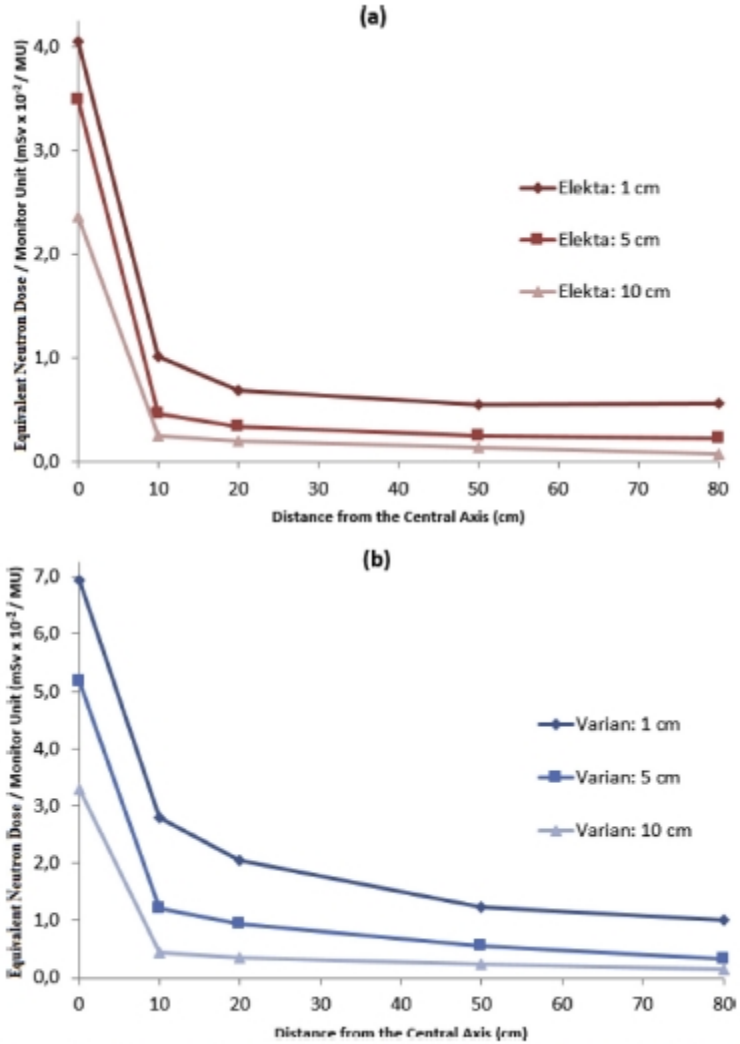

Figure 4. Equivalent neutron dose measured at different depths in 18 MV Elekta Synergy Platform (a) and Varian Clinac DHX High Performance (b) linacs.

- **The central doses at the shallow depths were higher than the deep central doses as expected.**

- **For Elekta Linac, the central dose readings at 10 cm depth were 58% of the reading at 1 cm depth and 68% of the reading at 5 cm depth, respectively.**

- **Varian Linac had similarly lower dose at 10 cm depth than shallow doses by the factors of 0.48 and 0.64.**

RESULTS

Table 2
Electro-neutron contamination for different electron energies.

Electron Energy	Elekta Synergy (mSv × 10^{-2}/MU)	Varian Clinac DHX (mSv × 10^{-2}/MU)	Philips SL25 (mSv × 10^{-2}/MU)
9 MeV		0.026 ± 0.004	
10 MeV	0.038 ± 0.003		0.016 ± 0.003
15 MeV	0.473 ± 0.023	0.460 ± 0.0230	0.276 ± 0.025
15 MeV (10 cm)	0.091 ± 0.008	0.044 ± 0.008	0.057 ± 0.005
18 MeV		1.330 ± 0.048	
18 MeV (10 cm)		0.157 ± 0.013	

- **Electroneutron dose should be considered in electron energies higher than 18 MeV.**

CONCLUSION

- The photo-neutron contamination generated in high energy medical Linacs has evident dependency on treatment field size, beam modifiers, and tissue depth.
- The measurements indicated an increase in photo-neutrons with larger treatment fields, while the inverse relationship was observed between depth in tissue and the neutron dose.
- Beam modifiers, i.e. MLCs, physical and motorised wedges, contributed to the contamination. A sudden drop-off was observed in peripheral region compared with the dose at the central axis.
- The electro-neutron dose should also be taken into consideration during the treatment with high electron energies.