

Ask EuroSafe Imaging

Tips & Tricks

CT Working Group

Optimisation of kilovoltage according to patient size and contrast enhancement

Mika Kortensniemi (HUS Medical Imaging Center, University of Helsinki, FI)

Dean Pekarovic (University Hospital Ljubljana, SI)

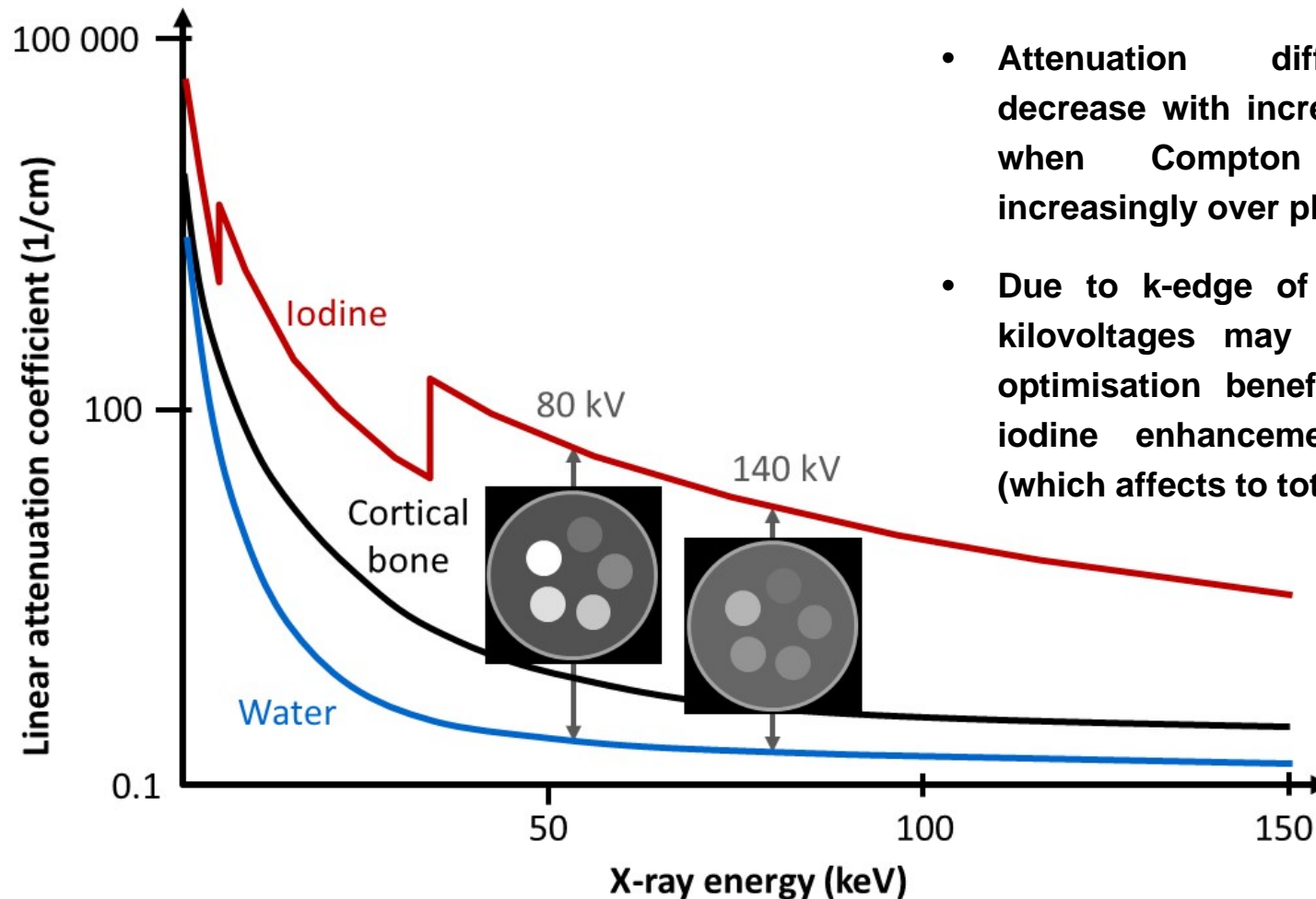
Key points – 1

- **X-ray spectrum optimisation by tube voltage reduction may provide 25% dose reduction with typical adult patients and even 50% dose reduction with paediatric patients in contrast enhanced CT scans.**
- **Suitability of voltage reduction depends on patient size and degree of contrast enhancement – which depends on exam indication and physiology factors.**
- **CT angiography scans of small patients are most suitable targets for low voltage settings. Thus, lower net attenuation and maximal benefit from the iodine k-edge absorption is simultaneously achieved.**
- **However, higher tube voltages are typically required when larger patients are scanned, especially without contrast enhancement.**

Key points – 2

- **Improvements in x-ray source technology may bring further improvements in the range of available tube voltages and more advanced automatic tube voltage selection tools in the new CT scanner models. Availability of lower tube voltages are also improved when higher tube currents (mA) can be implemented for required image noise level. This is especially important when using lower kilovoltages with shorter rotation times.**
- **In order to maintain image noise in constant level, tube voltage reduction is accompanied with mAs increase. However, typically the improved contrast with lower tube voltage scans enable moderate increase in noise to maintain contrast to noise ratio at the required diagnostic level.**

X-ray attenuation with different photon energies – effected by tube voltage



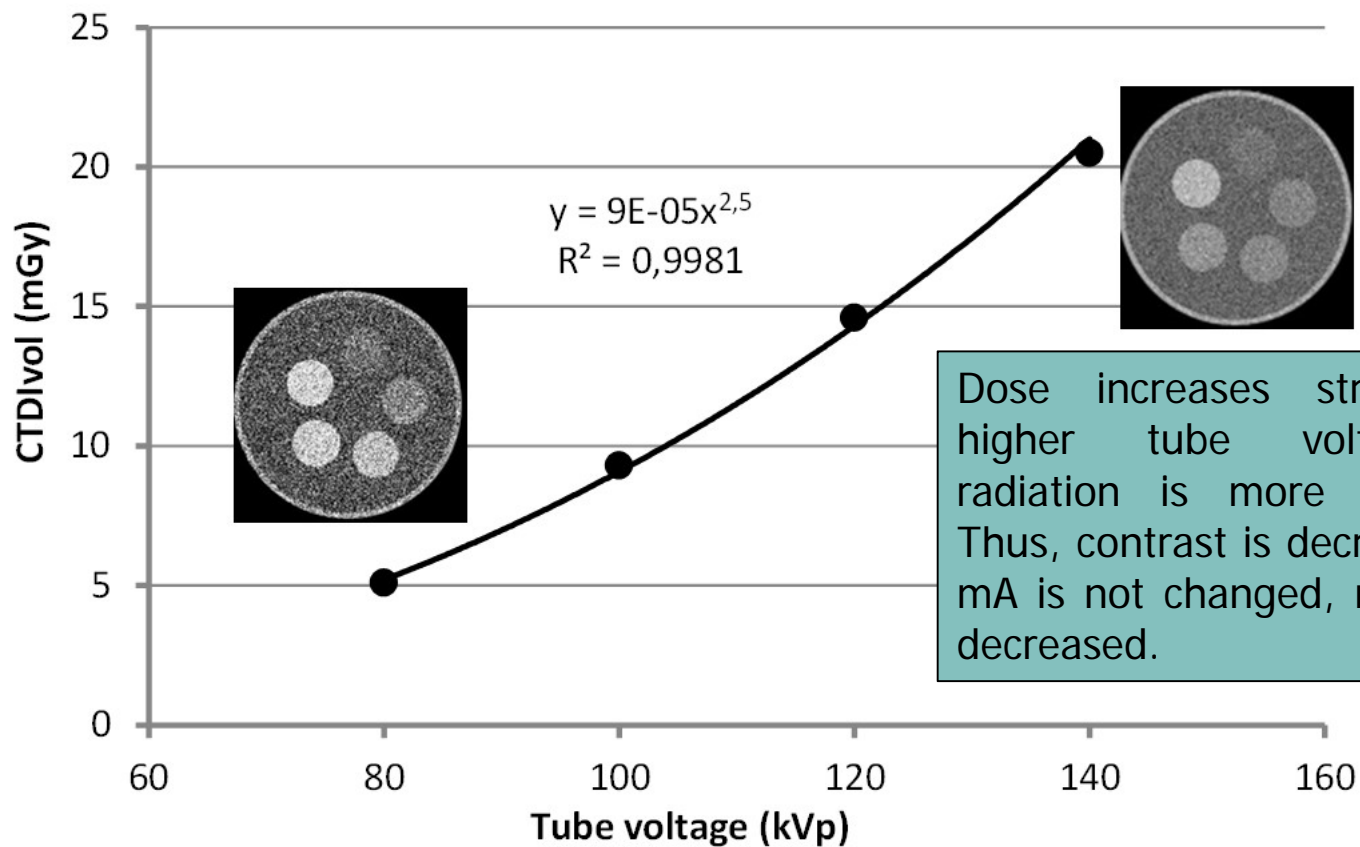
- Attenuation differences (contrast) decrease with increased photon energies when Compton effect dominates increasingly over photoelectric effect.
- Due to k-edge of iodine, use of lower kilovoltages may provide contrast and optimisation benefits, depending of the iodine enhancement and object size (which affects to total attenuation).

Voltage and dose

Dose \propto Voltage^{2.5}

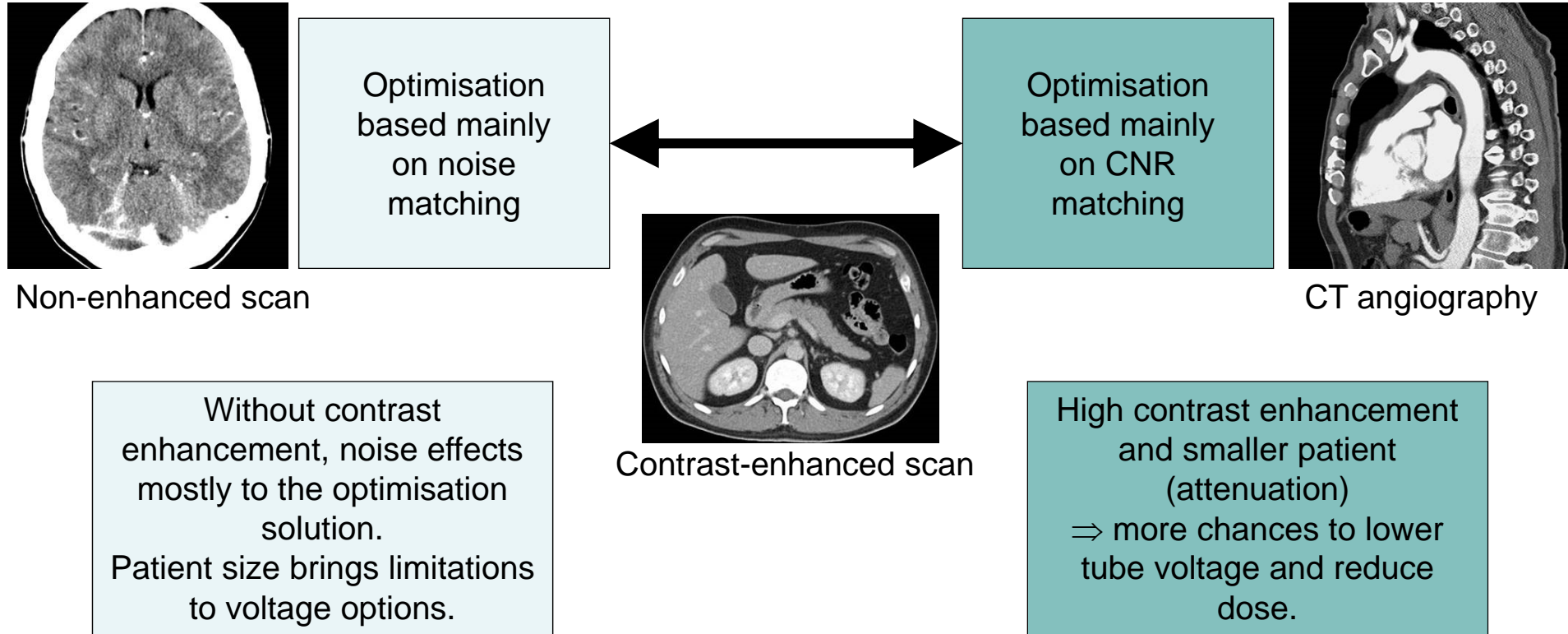
Dose ratio with different voltages

80 kVp	100 kVp	120 kVp	140 kVp
35 %	64 %	100 %	140 %



Dose increases strongly with higher tube voltage, and radiation is more penetrating. Thus, contrast is decreased but if mA is not changed, noise is also decreased.

Possibility to use lower tube voltages depends on varying level of contrast enhancement and patient size



Possibility to use lower tube voltages depends on varying level of contrast enhancement and patient size



Non-enhanced scan

Optimisation based mainly on noise matching



Optimisation based mainly on CNR matching



CT angiography

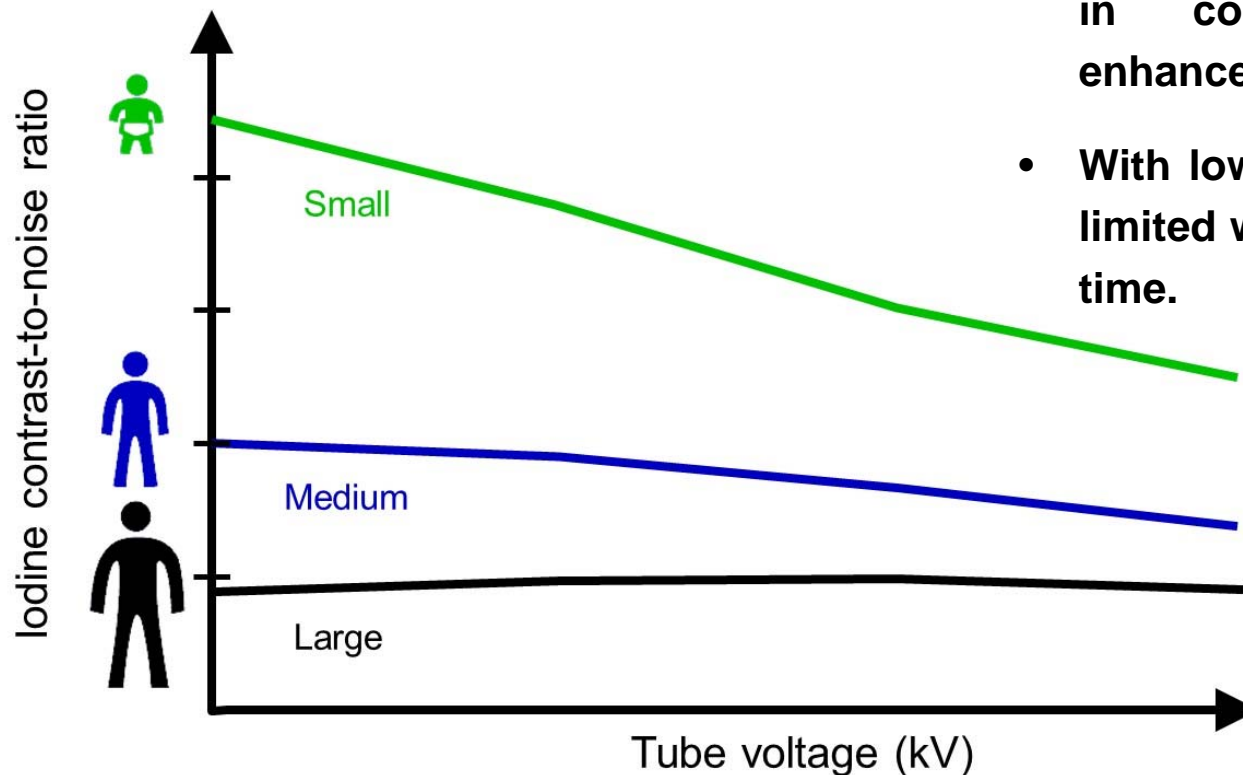


Contrast-enhanced scan

Without contrast enhancement, noise effects mostly to the optimisation solution.
Patient size brings limitations to voltage options.

High contrast enhancement and smaller patient (attenuation)
⇒ more chances to lower tube voltage and reduce dose.

Contrast-to-noise ratio (CNR) with different patient sizes vs tube voltage with constant dose



- CNR is a good optimisation criteria in contrast scans (adequate enhancement in examined organ).
- With lower kVp, tube output may be limited with higher pitch and rotation time.

References

- Yu L, Bruesewitz MR, Thomas KB, Fletcher JG, Kofler JM, McCollough CH. Optimal tube potential for radiation dose reduction in pediatric CT: principles, clinical implementations, and pitfalls. *Radiographics*. 2011 May-Jun;31(3):835-48.
- McCollough CH, Chen GH, Kalender W, Leng S, Samei E, Taguchi K, Wang G, Yu L, Pettigrew RI. Achieving routine submillisievert CT scanning: report from the summit on management of radiation dose in CT. *Radiology*. 2012 Aug;264(2):567-80.
- Yu L, Fletcher JG, Grant KL, Carter RE, Hough DM, Barlow JM, Vrtiska TJ, Williamson EE, Young PM, Goss BC, Shiung M, Leng S, Raupach R, Schmidt B, Flohr T, McCollough CH. Automatic selection of tube potential for radiation dose reduction in vascular and contrast-enhanced abdominopelvic CT. *AJR Am J Roentgenol*. 2013 Aug;201(2):W297-306.
- Yu L, Li H, Fletcher JG, McCollough CH. Automatic selection of tube potential for radiation dose reduction in CT: a general strategy. *Med Phys* 2010;37(1):234-243.
- Kalender WA, Deak P, Kellermeier M, van Straten M, Vollmar SV. Application- and patient size-dependent optimization of x-ray spectra for CT. *Med Phys* 2009;36(3):993-1007.
- Schindera ST, Nelson RC, Mukundan S Jr, et al. Hypervascular liver tumors: low tube voltage, high tube current multi-detector row CT for enhanced detection - phantom study. *Radiology* 2008;246(1):125–132.
- Funama Y, Awai K, Nakayama Y, et al. Radiation dose reduction without degradation of low-contrast detectability at abdominal multisection CT with a low-tube voltage technique: phantom study. *Radiology* 2005;237(3):905–910.

Understanding when low kV can be used and one still get appropriate image quality

120 kV
mAs 98
AEC on
2 mm Slice Thickness
CTDIvol 6,99 mGy
DLP 173 mGycm

100 kV
mAs 96
AEC on
2 mm Slice Thi.
CDIvol 4,13 mGy
DLP 102 mGycm

80 kV
mAs 95
AEC on
2 mm Slice Thi.
CTDIvol 47 mGy
DLP 47 mGycm

