Neonatal X-ray optimization to reduce radiation dose

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Background:
X-ray imaging is necessary for diagnosis, but radiation dose should be low, particularly in preterm infants. To indicate a reference dose, Diagnostic Reference Levels (DRL) - using Dose Area Product (DAP) as dose quantity - have been published in several countries.

The **purpose** of our study is:
1. To benchmark DAP for 3 Neonatal Intensive Care Units (NICUs) in the Netherlands.
2. To compare these values to existing European DRLs.
3. To measure radiation dose reduction in a phantom study.

Methods:

Retrospective DAP evaluation:

2522 thorax x-ray images from three Dutch NICUs over a two year period were analyzed retrospectively. For each image, the Dose Area Product (DAP), kV and mAs was obtained and effective dose was calculated using this information with Monte Carlo software (PCXMC, Helsinki, Finland).

Between the three hospitals, with a similar population of infants, the regular clinical protocol differed: in Hospital A, the detector was positioned in the tray (Fig.1.) and in B+C the detector was positioned directly under the patient. This resulted in different choices for the imaging protocol for X-ray settings. Each hospital used different X-ray settings for different weight categories.

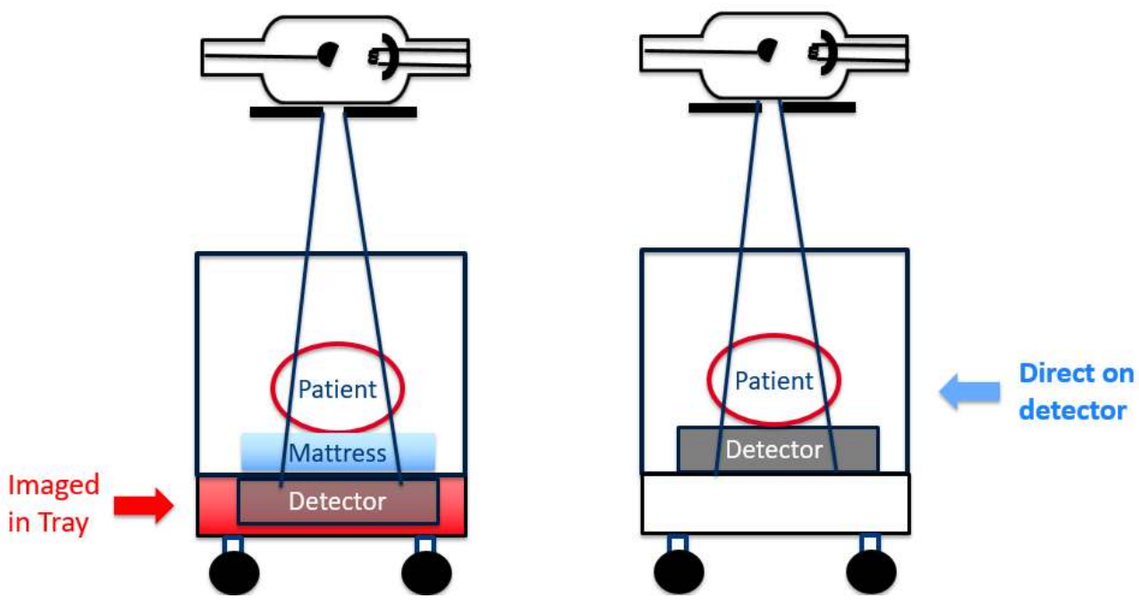
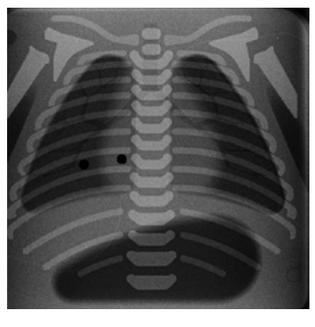


Figure 1. Imaging setup for different detector positions

Dose optimization:

A Gammex 610 Neonatal Chest Phantom was used to optimize X-ray settings for different detector positions. Starting from MMC protocol using detector in the tray, mAs was reduced for detector positioned under the mattress or directly under the patient while keeping the Exposure Index (measure for image quality) equal to the situation with detector in tray. For each optimal setting for the weight categories 1kg, 2kg and 3kg, effective dose was calculated using PCXMC.



Results:

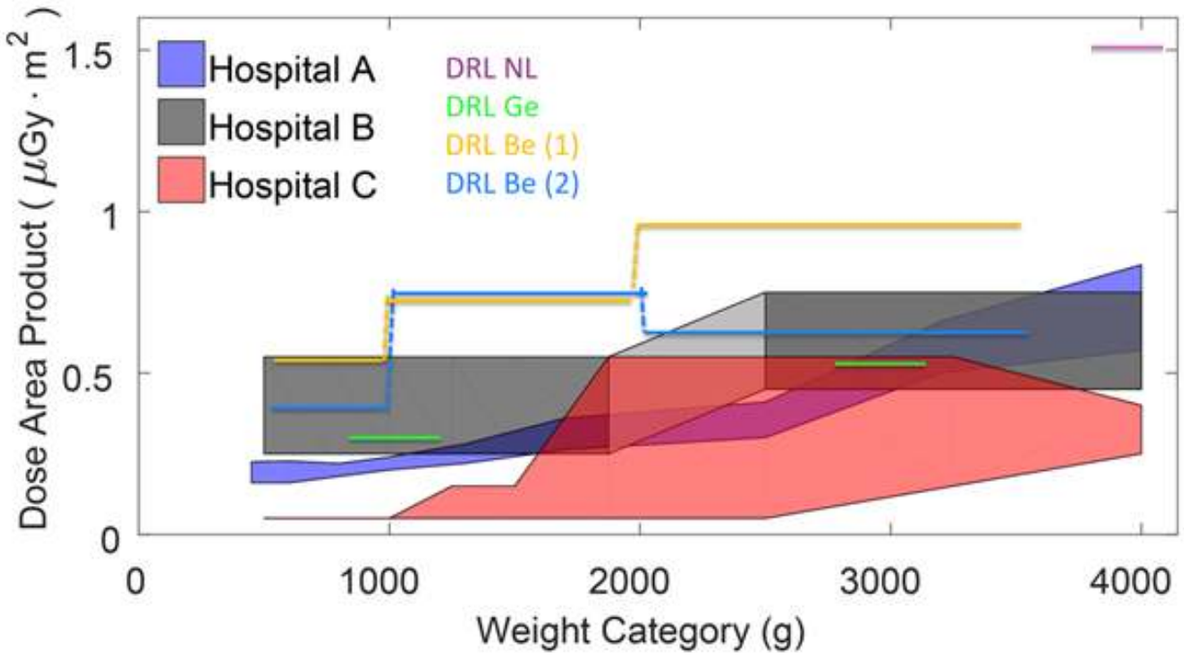


Figure 2. 25th and 75th percentile of DAP-values for thorax AP examinations. Hospital A places detector in the incubator tray, whereas B and C place detector directly under the patient.

Results retrospective DAP evaluation:

Median DAP ranged between 0.05 µGy m² - 0.69 µGy m² for different weight categories (Fig. 2), resulting in mean effective doses between (4±4) µSv and (20±8) µSv per examination. Substantial differences in protocols were observed between hospitals, partly due to differences in detector position (tray versus under patient).

Comparing with Diagnostic Reference Levels:

The lines in Fig. 2. indicate different Diagnostic Reference Levels of three European countries:

DRL Netherlands	DRL in the Netherlands, NCS reports. 2012.
DRL Germany -	Bundesamt für Strahlenschutz. 2010.
DRL Belgium (1)	Dabin, J et al. PREDOS study 2013.
DRL Belgium (2)	Dabin J, et al. Radiat Prot Dosimetry. 2014.

The DRLs differ per country and the hospitals are not all below the three DRLs for the different weight categories. In addition, it is clear that only a DRL for term newborns is not sufficient for NICU-practice.

Results for Dose optimization:

Phantom measurements showed that effective dose reduction of 30% could be achievable when placing the detector under the mattress and 50% if detector is placed directly under the patient for 1kg patients. For larger patients, less reduction was possible.

Conclusion: For preterm infants, DAP is lower than DRL but we conclude that a DRL specific for preterm infants should be determined. Radiation dose reduction is possible using the detector under the mattress or directly under the patient instead of in the incubator tray.