RADIATION DOSES AND RISKS TO NEONATES UNDERGOING COMMON RADIOGRAPHIC EXAMINATIONS IN THE NEONATAL INTENSIVE CARE UNIT

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INTRODUCTION

Neonates in the Neonatal Intensive Care Unit (NICU) can receive large numbers of radiographs owing to the clinical conditions they may present [1]. More neonatal radiation dosimetry data are required for three fundamental reasons: (1) to aid in the establishment of reference dose levels for interinstitutional comparisons; (2) to improve childhood cancer risk estimates following neonatal exposure; and (3) to indicate appropriate directions for dose reduction.

This paper describes an investigation of two different NICU radiological techniques with significantly different neonate doses. While patient-matched images taken with both techniques were assessed in a blind review, this component of the study is beyond the scope of this paper and is not discussed here.

The development of neonatal reference dose levels also requires establishing a mechanism of relating neonate size and dose. We have further investigated the variation of neonate ESD and EI with the equivalent patient diameter, d, given by [2,3],

$$d = 2\sqrt{\frac{W}{\pi L}} \qquad [1]$$

where d is in cm, W is the neonate weight in g and L is the neonate length in cm. The ESD and EI data for both techniques were fit by exponential functions in d,

$$ESD = ESD_o \exp(m_{ESD}\, d) \qquad [2a]$$
$$EI = EI_o \exp(m_{EI}\, d) \qquad [2b]$$

METHODS AND MATERIALS

The two techniques reviewed in this study were a "conventional" technique, used at this institution for a number of years, with the kVp variable between 50 and 60 kVp for a fixed 0.8 mAs, and a "low-dose" technique with the kVp increased to between 62 and 70 kVp and the mAs reduced to either 0.4 or 0.5 mAs. This latter technique is similar to that recommended by the CEC [4]. Patient dosimetry was evaluated from the technique used and previously measured dosimetric quantities. Patient dose data evaluated were the entrance skin dose (ESD), the dose-area product (DAP), the energy imparted (EI) and the mean dose (D), estimated by the ratio of the EI to the neonate weight.

All images were acquired with a General Electric AMX-4 mobile unit and a 400-speed Kodak T-Mat G/Lanex Regular film-screen combination. While others have judged such a speed class to yield less suitable images than slower speeds [5], we have found it to be clinically adequate.

The normalized in-air collision kerma ($K_{C,AIR}$/mAs) was measured for all kVp values used in the study using a 15cc thin window ionization chamber and electrometer (Keithley 96035 and 35050A), both with NIST-traceable calibrations. The ESD was determined using these measured $K_{C,AIR}$/mAs values and the technique recorded by the technologist. Backscatter and attenuation through the incubator Perspex were accounted for and the mass energy absorption coefficient ratio averaged over the energy spectrum was evaluated for ICRU muscle and used to convert to dose. The DAP was approximated by the product of the ESD and the cross-sectional area of the imaged anatomy determined retrospectively from the film. The EI was calculated from the DAP and conversion factors evaluated by Chapple et al [6].

RESULTS

A total of 363 radiographs were acquired for 77 neonates. Of these, 262 films were acquired for the "conventional" technique (160 chest, 63 abdomen and 39 chest/abdomen combined); 101 films were obtained for the "low-dose" technique (72 chest, 13 abdomen and 16 chest/abdomen). The mean number of radiographs per neonate was 4.7, with a range of 1 to 41. Table I presents a summary of the dose quantities measured, the percentage reductions achieved by switching techniques and the levels of statistical significance in these reductions. Table II presents the log dose gradients, m_{ESD} and m_{EI}, determined by taking natural logarithms of both sides of Equations (2a) and (2b) and performing linear regression.

The major risk of concern for the irradiated neonate is childhood cancer. By using fetal risk factors to estimate the neonatal risk, the excess risk of cancer mortality during the first 15 years of life determined from the Oxford Survey of Childhood Cancers [7] is 0.0288 mGy^{-1} (95% confidence limits, 0.0171 mGy^{-1}: 0.0436 mGy^{-1}). A "worst case" estimate using the upper 95% confidence limit would put the risk per radiograph in the conventional technique to be about 1 in 5210, 1 in 4250 and 1 in 3370 for chest, abdomen and combined chest/abdominal films, respectively. The corresponding risks for the low dose technique are 1 in 6550, 1 in 5460 and 1 in 3530. Most neonates receive multiple films: switching techniques for our "worst case" baby who received 41 chest films would reduce the excess relative risk of childhood cancer death from 1 in 127 to 1 in 164.

CONCLUSIONS

A switch to a neonate radiological technique using a 400-speed film/screen combination and kVp's in the range of 62 to 70 kVp and 0.4 mAs results in considerably reduced doses. Although not discussed here, an independent and blind comparison of clinical images taken with both techniques by three radiologists showed no statistically significant difference in image quality.

REFERENCES

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TABLE I: MEASURED NEONATE DOSES

Quantity	Site Chest	 Abdomen	 Chest/Abdomen
Mean ESD			
Conv Tech	20.0 ± 3.2 μGy	20.0 ± 4.2 μGy	19.0 ± 2.7 μGy
Low Dose Tech	16.4 ± 3.6 μGy	14.5 ± 1.5 μGy	17.6 ± 4.4 μGy
% Change in Means	-18.0%	-27.5%	-7.4%
Significance	$p < 0.0005$	$p < 0.0005$	$p < 0.085$
Mean EI			
Conv Tech	7.9 ± 3.2 μGy	9.2 ± 4.9 μGy	11.5 ± 5.7 μGy
Low Dose Tech	7.1 ± 3.5 μGy	7.1 ± 3.9 μGy	11.9 ± 9.3 μGy
% Change in means	-10.1%	-22.8%	+3.5%
Significance	$p < 0.017$	$p < 0.013$	*
Mean Dose			
Conv Tech	4.4 ± 1.7 μGy	5.4 ± 1.3 μGy	6.8 ± 1.5 μGy
Low Dose Tech	3.5 ± 2.9 μGy	4.2 ± 2.5 μGy	6.5 ± 4.6 μGy
% Change in Means	-20.1%	-22.3%	-3/6%
Significance	$p < 0.0028$	$p < 0.0042$	*

* consistent with no change between the two techniques
- E ~ ros are 1 standard deviation

TABLE II: DOSE GRADIENTS

	Site Chest	 Abdomen	 Chest/Abdomen
m_{ESD} (cm^{-1})			
Conv Tech	0.068 (0.051 - 0.084)	0.130 (0.105 - 0.155)	0.079 (0.50 - 0.108)
Low dose Tech	0.095 (0.054 - 0.136)	0.044 (-0.027 - 0.114)	0.090 (0.005 - 0.175)
m_{EI} (cm^{-1})			
Conv Tech	0.249 (0.233 - 0.265)	0.349 (0.308 - 0.389)	0.326 (0.255 - 0.398)
Low Dose Tech	0.244 (0.174 - 0.315)	0.178 (0.061 - 0.295)	0.310 (0.068 - 0.552)

Quantities in brackets are 95% confidence limits