Radiation Exposure Reduction by Use of Kevlar Cassettes in the Neonatal Nursery

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A study was performed to determine whether the use of Kevlar cassettes in the neonatal intensive care nursery would reduce radiation exposure to patients. The radiation dose to the neonates was measured by using thermoluminescent dosimeters. In addition, the attenuation of the Kevlar cassettes and the sensitivity of the film-screen combination were compared with the previously used system. The greatest radiation reduction using a mobile X-ray unit was 27%; based on sensitivity measurements, the theoretical reduction averaged 38%. The reduction in radiation exposure resulted from reduced attenuation by the Kevlar cassette.

Most premature neonates, especially those with birth weights less than 1500 g, have severe respiratory problems and, therefore, undergo many radiographic examinations, usually performed with mobile radiographic equipment in the neonatal nursery. Radiographic examinations are more frequent during periods of rapid clinical change. With the increasing survival of small neonates, there is an increasing population that have received significant radiation doses early in life. Because the clinical situation dictates the number of examinations, methods must be found to reduce the level of exposure per examination.

Recently, a new X-ray film cassette has become available; the front face is made of Kevlar, a fabric manufactured by Du Pont (Wilmington, DE). Because this cassette was designed for use in the 50–70 kVp range, ideal for neonatal chest examinations, we evaluated the radiation exposure to infants when this cassette is used. We also used a different film-screen combination than normally used in our department, and compared it with our previous film-screen-cassette system and techniques. The purpose of the test was to determine the effect of the Kevlar cassette on the radiation exposure of the neonates.

Methods

All radiographs were taken in our neonatal intensive care unit with the infants in their isolettes. The neonates were divided into three groups based on weight: group 1, 500–1200 g; group 2, 1200–2000 g; group 3, >2000 g (see Table 1). The two X-ray film-screen combinations compared in this study were (1) old system; Radelin T2 cassette (Wolf X-ray, West Hempstead, NY), par speed screen ($CaWO_4$), Cronex 4 film; and (2): new system: Cronex Kevlar cassette, Cronex Quanta Detail screen ($YTaO_4$), Cronex Quanta 7 film. The old combination has been used for many years in this department for neonatal intensive care radiography. All films were obtained by using the same battery-powered mobile X-ray unit (AMX-III, General Electric, Milwaukee, WI) at a source-image distance of 28 in. (71.1 cm), and all were developed in one of two 90-sec processors. Each processor is checked daily by sensitometry as part of our quality-assurance program. Results show that the processors are almost identical. The radiographic techniques selected for each weight group for the two film-screen combinations (see Table 1) were those that gave the appropriate visual density for the lung fields and penetration of the mediastinum desired by the pediatric radiologist. The radiation exposure of the neonates was measured by using a packet of three thermolu-

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TABLE 1: Radiation Reduction and Radiographic Techniques Used

Neonate Group (weight in g)	FSC[a]	No. of Films	Mean kVp	Radiation Exposure (mR)	Exposure Reduction (%)
1	New	16	54	8.9 ± 0.22	19.4
(500–1200)	Old	14	64	11.0 ± 0.03	
2	New	27	58	10.6 ± 0.15	27.4
(1200–2000)	Old	11	68	14.6 ± 0.41	
3	New	14	60	12.4 ± 0.33	20.5
(>2000)	Old	10	72	15.6 ± 0.61	

Note.—Data include full backscatter. Amperage = 1 mAs for all groups.
[a] FSC = film-screen cassette. Old FSC system included Radelin T2 cassette, par speed screen ($CaWO_4$), and Cronex 4 film. New FSC system included Cronex Kevlar cassette, Cronex Quanta Detail screen ($YTaO_4$), and Cronex Quanta 7 film. 1 mR = 2.58×10^{-7} C/kg.

TABLE 2: Cassette-Front X-Ray Transmission (%)

kVp	Kevlar	Radelin T2
	Without attenuation	
50	87	50
60	88	56
70	89	58
80	89	62
90	90	65
100	91	66
	With 3.8-mm lucite attenuation	
50	88	58
60	90	63
70	90	65
80	91	69
90	92	70
100	92	75

TABLE 3: Theoretical Radiation Reduction Based on Film Speed

kVp	Radiation Reduction (%)
50	30.8
56	39.7
60	44.5
66	36.1
70	36.9

minescent dosimeter (TLD, lithium-100) chips placed on the neonate's chest by the technologist at the time of the examination. The technologist recorded the radiographic technique used. Each packet was used for more than one patient in the same weight-cassette group. Because of the large number of radiographs taken for these neonates, some patients were radiographed at different times with both systems. The TLD chips were calibrated as described by Morgan et al. [1]. The variation of the response of the chips was less than 2% between 50 and 70 kVp.

To compare the attenuation of the two cassettes, the X-ray transmission of the front face of each cassette (without the screen) was measured for X-ray energies between 50 and 100 kVp with an MDH model 1015 X-ray monitor (MDH Industries, Monrovia, CA). A single cassette of each type was selected at random from those available. This measurement was performed with and without a 3.8-cm block of lucite in the beam. The X-ray beam had a half-value layer of 3 mm of aluminum at 100 kVp.

The speed of a film-screen combination is defined as the reciprocal of the exposure in roentgens required to produce a density of 1.0 above base plus fog [2]. Since the exposure per unit mAs is a constant for a given kilovoltage, the speed can also be defined in terms of the amperage required to produce a unit density. The two systems were exposed to X-rays between 50 and 70 kVp with a 3.8-cm acrylic phantom placed on the cassette, after the amperage necessary to obtain a film density of 1 was determined.

Results

Although X-ray exposure was reduced by the new system for all three weight groups, the greatest reduction was measured for group 2, 1200–2000 g (see Table 1). Measurement of X-ray transmission showed that, on average, the transmission through the Kevlar cassette is approximately 1.5 times greater than through the Radelin T2 cassette for the unhardened beam and 1.35 times greater for the hardened beam (see Table 2). The error associated with this measurement is estimated to be within 5%. From the determined speed of the two systems, the theoretical reduction of X-ray exposures obtainable were calculated (see Table 3). The phantom studies show that if the kilovoltage remains constant and the amperage is reduced to obtain the desired film density, the patient exposure can be reduced by an average of 38% over the kilovoltage range for which the Kevlar cassette was designed.

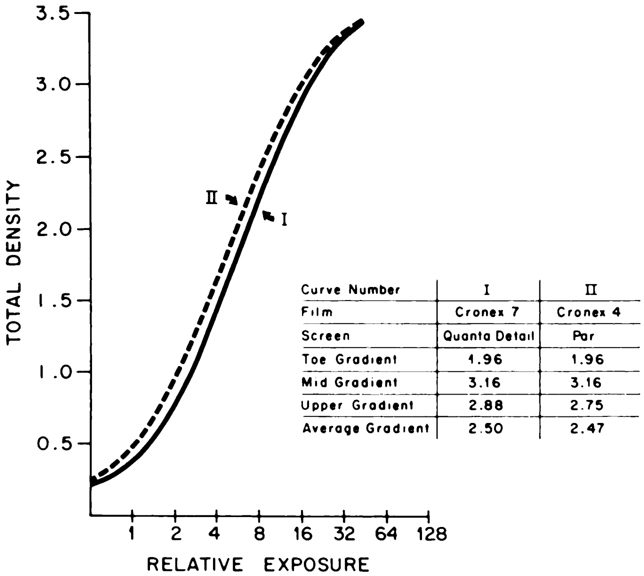
Discussion

One of the problems in taking radiographs in the neonatal intensive care units is the large amount of equipment that surrounds the isolettes. Most of the isolettes have heaters above the infant compartments, and in some models the heater cannot be moved. In our institution we have many different models and different brands. To avoid varying the X-ray techniques for each type of isolette, we measured the shortest source-image distance necessary—28 in.—to allow filming under the worst-case situation and adopted this measurement for all filming in the unit. Although the shortened source-image distance increases the radiation exposure of the neonates, standardizing this measurement reduced the probability of errors (and, thus, repeated examinations) in adjusting distances for all the models of isolettes in use.

In addition, the shortened source-image distance requires a low amperage, which presents a problem with our mobile X-ray unit. The available amperage stations are not low enough for the use of fast screens and films, such as Cronex High Plus screens and Cronex 4 film (the types generally used in our department), when used in a standard cassette. For this reason we had adopted the Radelin T2 cassette and par speed screens with Cronex 4 film for radiography in the neonatal nursery. In choosing the film-screen combination for use with the Kevlar cassettes, we needed to find a slower system because the par speed–Cronex 4 system was too fast. We chose the Cronex Quanta Detail–Cronex Quanta 7 combination for use with the Kevlar cassette because it

allowed us to obtain radiographs under the conditions in the neonatal intensive care unit at 1 mAs for the kilovoltage range desired. Du Pont rates the par screen–Cronex 4 combination at a speed of 100, while the Cronex Quanta Detail–Cronex Quanta 7 film is rated at a speed of 64 (Cronex Quanta Detail Rare Earth Intensifying screen data sheet, Du Pont, Wilmington, DE). We found that the use of the Kevlar cassette–Quanta Detail screen–Quanta 7 film combination reduces the radiation exposure of neonates when compared with our older system. The next step was to determine the source of the exposure reduction.

Figure 1 shows characteristic curves of the film obtained from the manufacturer for the two film-screen systems at 70 kVp. It also shows that the Cronex Detail screen–Cronex 7 film is the slower system. Our measurements show that for the kilovoltages tested the Kevlar system is the faster of the two, even though the film-screen combination is slower than the par speed–Cronex 4 system. The nonlinearity of the measured results seen between 56 and 66 kVp is due to k-edge absorption by yttrium, a component of the Quanta Detail screen. The k edge occurs at 17.03 keV [3]. At the k edge there is greater absorption of the X-rays in the screen with increased light output. The difference in the speed of the two film-screen systems would change with varying kVp because of the k-edge effect. However, the H & D curve shows that the gamma of the two systems is approximately the same. The response of the two systems to increased exposure is the same.



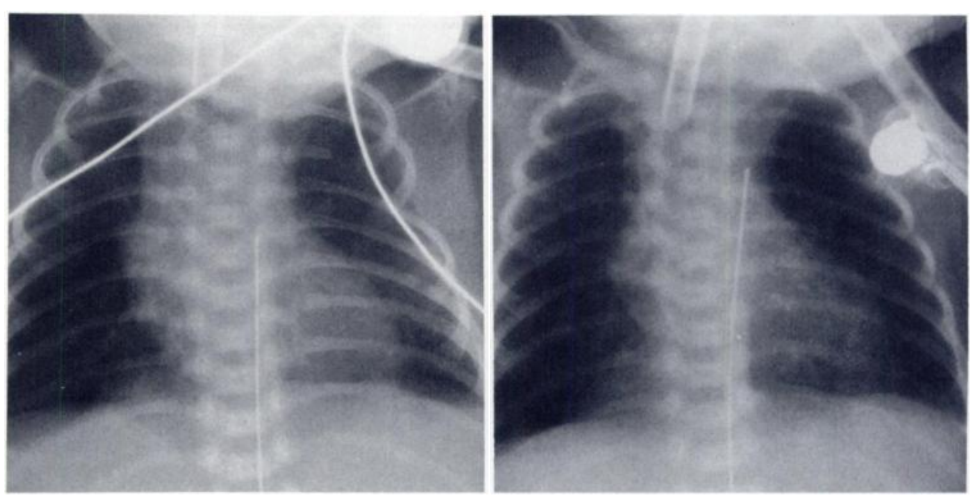
Curve Number	I	II
Film	Cronex 7	Cronex 4
Screen	Quanta Detail	Par
Toe Gradient	1.96	1.96
Mid Gradient	3.16	3.16
Upper Gradient	2.88	2.75
Average Gradient	2.50	2.47

Fig. 1.—Characteristic curves of film-screen combinations. Curve I: Cronex Quanta Detail screen, Cronex 7 film. Curve 2: par speed screen, Cronex 4 film.

Our measurements of radiation exposure for the older system are similar to those reported by Wesenberg et al. [4] for chest filming of neonates with mobile equipment: a 24-in. (61-cm) source-image distance, par speed screens with RP film (Eastman Kodak, Rochester, NY). Type of cassette was not reported. One must then conclude that the reduction in X-ray exposure resulted primarily from reduction in the attenuation by the Kevlar cassette. The effect of the reduced attenuation becomes more apparent when one considers that the Cronex Detail screen–Cronex 7 film combination has a 1/3 lower speed than the par speed–Cronex 4 combination. With the mobile X-ray equipment used in this study, the full-exposure reduction capability can not be realized because of the limitations of available low-amperage stations. It is for this reason that the kilovoltage values for the two systems were different while the amperage was held constant.

The pediatric radiologist reported that the films taken with the newer system were sharper. However, the information content of radiographs taken with both systems appears the same. Figure 2 shows radiographs of the same patient with both systems, revealing that the quality of the images is virtually the same.

Wesenberg et al. [5] reported using a Kevlar cassette system for routine pediatric radiology and found a dose



A B

Fig. 2.—Radiographs of same patient obtained with the two systems.

***A*, Kevlar cassette system. Technique: 58 kVp, 1 mAs, 28-in. (71.1-cm) source-film distance.**

***B*, Radelin cassette system. Technique: 68 kVp, 1 mAs, 28-in. source-film distance.**

reduction between 30% and 37%. This reduction is similar to our findings based on the speed studies. Our study clearly shows that the use of the new Cronex Kevlar cassette can significantly reduce the radiation dose to premature neonates. The theoretical exposure reduction we found and that reported by Wesenberg et al. [5] were not obtained because of the limitations imposed by the mobile radiographic equipment and the conditions under which the radiographs had to be obtained. The further reduction in radiation exposure possible if lower amperage values are available may justify installation of a standard three-phase X-ray generator with an overhead rail-mounted tube in the neonatal intensive care unit.

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REFERENCES

1. Morgan TJ, Bencomo JA, Marsh I, Finn D. A technique for routine calibration of thermoluminescent dosimeters in the diagnostic energy range. *Med Phys* **1986**;13(3):365–367
2. Curry TS III, Dowdey JE, Murray RC Jr. *Christensen's introduction to the physics of diagnostic radiology*, 3rd ed. Philadelphia: Lea & Febiger, **1984**
3. Fine S, Hendee CF. X-ray critical absorption and emission energies in keV. *Radiological health handbook*. Rockville, MD: U.S. Department of Health, Education and Welfare, **1970**
4. Wesenberg RL, Rossi RP, Hendee WR. Radiation exposure in radiographic examinations of the newborn. *Radiology* **1977**;122:499–504
5. Wesenberg RL, Amundson GM, Mueller DL. Kevlar cassettes: further reduction in radiation exposure during routine pediatric radiography. Presented at the annual meeting of the Society of Pediatric Radiology, Washington, DC, **April 1986**