Pediatric thoracic spine radiographs: Comparison of two scintillators

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Abstract
Purpose. To compare image quality and radiation exposure from pediatric thoracic spine radiographs from two systems, one using a granular structure scintillator and another using a needle structure scintillator with 40% reduction of exposure.

Patients and methods. Randomized prospective study of 296 patients divided into 2 groups of 5 weight categories from 4 to 60 kg. Standard technique parameters are used for granular structure scintillators with dose reduction of 40% applied for needle structure scintillators based on results from a phantom study. Image quality based on detectability of 8 anatomical structures for both types of scintillators was assessed by 6 blinded radiologists. Exposure was expressed by DLP. Results underwent statistical analysis.

Results. Overall, image quality was superior with corresponding dose reduction between 33-46% according to weight with needle structure scintillators. For the 4 lower weight categories, image quality was identical.

Conclusion. With image quality at least equal, new needle structure scintillator units allow a dose reduction of about 40%.


The advantages of digital storage phosphor systems (DSPS) have been clearly established. Even if conventional radiography provides better spatial resolution, numerous studies have shown that image quality and diagnostic value are at least equal in DSPS (2-5). The latter have a larger exposure range, are more sensitive, dynamic and have better low contrast resolution. Digital storage phosphor systems offer other advantages which become essential with the development of picture archiving and communication systems (PACS): direct visualization of images on a monitor that can be saved and transferred via a computer network (6, 7). However, until now, a significant dose reduction was not possible with storage phosphor radiography in chest radiographs in pediatric practice (8-11). A new storage phosphor system has become available on the market in the last few months. This includes a scintillator with a crystalline structure in the form of long needles, the DXS (Agfa, Rueil Malmaison, France). A preliminary study on a phantom was performed in our unit to compare the DXS DSPS to the ADC DSPS High Resolution device (ADC) (Agfa, Paris M, Bourlière B, Devred P, Petit P. Radiographies thoraciques pédiatiques : comparaison de deux détecteurs à mémoire (full text in English on www.em-consulte.com/produit/jradio). J Radiol 2009;90:485-91.

Résumé
Radiographies thoraciques pédiatiques: comparaison de deux détecteurs à mémoire
J Radiol 2009;90:485-91

Objectifs. Comparer la qualité et la dosimétrie des radiographies thoraciques pédiatrices numériques réalisées avec un détecteur à structure granulaire à celles d’un détecteur à aiguilles sur lequel une réduction de 40 % de charge est appliquée.

Patients et méthodes. Il s’agit d’une étude prospective randomisée comparative de 296 patients, répartis en deux groupes de cinq catégories de poids de 4 à 60 kg. Des constantes standard sont appliquées au groupe « détecteur à structure granulaire », réduites de 40 % dans le groupe « détecteur à aiguilles », d’après les conclusions d’une étude préalable sur fantôme. La qualité des clichés estimée par la visualisation de huit structures anatomiques est évaluée en aveugle sur les deux types de détecteurs utilisés par six radiologues. La dose est exprimée en produit dose surface. Les résultats ont fait l’objet d’une analyse statistique.

Résultats. Sur l’ensemble de la population, une qualité d’image supérieure est obtenue avec une réduction de dose variant de 33 % à 46 % selon la catégorie de poids avec le détecteur à aiguilles. Pour les quatre catégories de poids les plus faibles, cette qualité est identique.

Conclusion. À qualité d’image au moins égale, le nouveau détecteur à aiguilles permet une réduction de dose d’environ 40 %.


The regular arrival of new radiographic imaging devices on the market makes it difficult to understand their advantages compared to others and to know how to choose. Two of the parameters that help make this decision are image quality and radiation exposure doses. The notion of optimising techniques recommended by the European Directive 97/43 (1) makes it necessary to compare the different radiographic devices.

The advantages of digital storage phosphor systems (DSPS) have been clearly established. Even if conventional radiography provides better spatial resolution, numerous studies have shown that image quality and diagnostic value are at least equal in DSPS (2-5). The latter have a larger exposure range, are more sensitive, dynamic and have better low contrast resolution. Digital storage phosphor systems offer other advantages which become essential with the development of picture archiving and communication systems (PACS): direct visualization of images on a monitor that can be saved and transferred via a computer network (6, 7). However, until now, a significant dose reduction was not possible with storage phosphor radiography in chest radiographs in pediatric practice (8-11). A new storage phosphor system has become available on the market in the last few months. This includes a scintillator with a crystalline structure in the form of long needles, the DXS (Agfa, Rueil Malmaison, France). A preliminary study on a phantom was performed in our unit to compare the DXS DSPS to the ADC DSPS High Resolution device (ADC) (Agfa, Paris M, Bourlière B, Devred P, Petit P. Radiographies thoraciques pédiatiques: comparaison de deux détecteurs à mémoire (full text in English on www.em-consulte.com/produit/jradio). J Radiol 2009;90:485-91.

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Abreviations
ED Entrance dose
PD Flat panel detector
DQE Detective quantum efficiency
DSPS Digital storage phosphor system
DAP Dose area product

Rueil-Malmaison, France) which has a granular structure scintillator. Our results showed that a dose reduction of 46% was possible with the DXS detector, with no loss in low contrast resolution and no loss in spatial resolution. The aim of this study was to evaluate the application of the results of our phantom study in chest radiography in pediatric practice.

Patients and methods
This prospective randomized study was performed in our pediatric radiology unit from May to July 2007.

Patients
Two hundred and ninety seven children who were prescribed a chest X-ray were included in this study. They were divided according to weight into 5 groups (group 1: 4-9.9kg; group 2 10-19.9kg; group 3: 20-29.9kg; group 4: 30-39.9kg ; group 5: 40-59.9kg).

The anteroposterior chest diameter was measured for each child.

Image acquisition
Radiographs were performed in a room used for chest radiographs according to a standardized protocol. An anterior view was obtained either anterior to posterior with the patient lying down or anterior or posterior to anterior with the patient standing depending on the age of the child and how cooperative the child was. Centering with a light beam diaphragm was standardized for each patient from the cervical trachea to the twelfth rib and laterally to the rims of the chest. Radiographic exposure conditions, except for the dose reduction for DXS, were the same for each unit.

Image interpretation
Chest radiographs were all interpreted on the same display station (Agfa DS1000, 3.5 million pixel screen) by 6 senior pediatric radiologists. Radiologists were blinded to the type of unit used. It was impossible to tell where the images have come from on the display station. Radiologists could modify contrast, luminosity, and zoom on the image at will.

Image quality parameters
The radiologist was asked to rate chest radiograph image quality according to criteria corresponding to the visualisation of 8 anatomical thoracic structures: (a) retrocardiac lung (b) visually sharp contours of the mediastinal lines (c) image of the spine seen through the heart (d) visually sharp contours of the principal bronchi (e) visually sharp contours of the vascular structures in the central half of the lungs (f) visually sharp contours of the vascular structures in the central 2/3 of the lungs (g) visually sharp image of the peripheral vascular structures in the lungs (h) visually sharp image of the diaphragm and the costo-phrenic angles.

The radiologist had to check “yes” or “no” in response to whether there were sharp images of these structures. The visualisation of each anatomical structure and the number of structures present on each film (global score) were compared between the two systems for the entire population and then by weight group. X-rays which were judged to be uninterpretable because of specific patient parameters (insufficient inspiration, no anterior view, severe scoliosis) were not included.

Data collection
The administered dose was expressed as the Dose Area Product (average dose absorbed in the air in the section of the beam multiplied by the surface of that section). This dose, expressed in micro Gy.m², was obtained with the same dosimetric system; an ionisation chamber (Diamentor C2 of PTW) placed at the exit point of the radiogenic tube.

The dose was entered into a notebook with two sheets of paper by the X-ray operator. The operator included the date of the X-ray on the first sheet as well as the child’s name, weight, anteroposterior chest diameter, the type of system used and the dose registered on the Diamentor. The second sheet was given to the radiologist and it included the child’s identity with the table for qualitative parameters, as well as the clinical indications for X-ray.

Statistical analysis
Comparative univariate analysis was performed between the two study groups (the ADC versus the DXS group) for all clinical and physical data (student’s T-test or non-parametric test for quantitative variables, Chi² tests or Fischers Exact
Results

Demographics

Fifty percent of the 296 children included in this study were examined with a DXS unit and 50% with an ADC unit. The distribution by weight is presented in Table III. There was no statistical difference between the two groups for weight or anteroposterior chest diameter.

Image quality

There was no statistically significant difference between the two systems for visualizing any of the anatomical elements of the thoracic radiographs for the entire population, all weight categories combined (fig. 1). Visualisation of the anatomical elements of the chest was not different between the systems for any of the weight categories, except one: visualisation of peripheral vascular structures was better in children weighing more than 40 kg with DXS (84.6% with the DXS compared to 53.8% with the ADC, p<0.05) (fig. 2 et 3). A global score of 100%, which signifies that 8 anatomical structures were visualized on the same radiograph, was reached in 50.7% of cases with DXS and 35.8% with ADC (significant difference of p=0.01) for all films. The global score of 100% for each system by weight group is shown in Figure 4. The difference was only statistically significant for the group that weighed more than 40 kg (p=0.01) (fig. 2 et 3).

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Discussion

Because of increased sensitivity to radiation in children and the long term risk of developing cancer (12), radiation doses in children is a major concern for pediatric radiologists. For this reason, one of the challenges for manufacturer’s of radiological equipment is to reduce radiation while maintaining or improving image quality (13). Our results show that it is now possible to reduce radiation doses by between 33% and 46% in pediatric chest X-rays, with a new needle structured scintillator storage phosphor system (DXS) with an image quality that is at least as good as with granular structured scintillators (ADC). The quality of the images is similar in children weighing between 4 and 39.9 kg (fig. 4) and better in children weighing more than 40 kg (fig. 5) especially for the detection of peripheral vessels of the lung (indicating better spatial resolution).

These results are closely linked to the physical characteristics of the DXS (14). Its Detective quantum efficiency (DQE) is twice as high as that of a granular scintillator, whose DQE is close to that of conventional plain films (QDE – 20 to 25% for granular structure scintillators, 20 to 30% for screen-films and 50% for the DXS). This parameter provides a good evaluation of digital systems because it integrates the absorption of X-ray photons, sensitivity, noise and resolution. The DQE expresses how efficiently X-rays are used. A detector with a high DQE...
requires lower doses of radiation than one with a low DQE, to obtain an image of the same quality.

The intrinsic physical structure of the DXS explains this improvement in dosimetric results. The chemical substance for detection, which is different from granular structure scintillator storage phosphor systems (barium bromide crystals), is a thin layer of cesium iodide crystals, which are more sensitive to radiation. The light crystals of granular structure screens are replaced by needle shaped crystals arranged in tight rows, without any binding material, which should help improve spatial resolution, contrast resolution and reduce scatter. Moreover, the system for reading this new technology increases spatial resolution (pixels can reach 50 microns in the 800 speed class) and reading time (line by line reading rather than point by point).

We did not find any pediatric study in the literature comparing two storage phosphor systems. Two German publications by the same author studied a needle scintillator for adults in clinical practice (15, 16). The first study (15) evaluated bedside chest X-rays performed in 24 adults in the intensive care unit. This study compared image quality of chest X-rays obtained with a granular scintillator (ADS) to those obtained with a needle scintillator (DXS). It showed that a dose reduction of 50% in the DXS did not affect image quality. The second published study (16) performed in a phantom, showed improved detection of low contrast details with the DXS needle scintillator versus the granular scintillator unit, without any dose reduction. This same conclusion was recently reached by a Spanish group in a phantom study (17). Thus, the diagnostic results of the DXS may be better, but this needs to be evaluated in daily clinical practice.

When comparing image quality and dose in each scintillator it is important to study homogeneous populations. However, pediatric populations have the particularity of being heterogeneous. This population includes small, low-weight newborns, and large adolescents. Differences in weight and height may be marked at different ages, which may create great differences in radiation dose, especially in older children. This is why we chose to study our pediatric population according to weight rather than age which we associated with the anteroposterior chest diameter so that the dose delivered to each group would be

![Fig. 2: Thoracic radiographs in 2 patients in the 4 to 9.9 kg group consulting for fever.](image)

6 month old child. ADC System. Constants: 77 Kv, 1.6 mAs.

9 month old child. DXS System. Constants: 77 Kv, 1 mAs.

![Fig. 3: Thoracic radiographs in two patients in the 40-60kg weight category consulting for an evaluation of tumor extension.](image)

12 year old child. ADC System. Constants: 85 Kv, 2.5 mAs.

16 year old child. DXS System. Constants: 85 Kv, 1.5 mAs.

![Fig. 4: Histogram showing the percentage of radiographs obtained with a global score of 100% (8 visible anatomical structures) for each unit, by weight group.](image)
since the percentage of dose reduction
between the percentage of dose reduction
in our study (19). Although the relationship
between the percentage of dose reduction
applied and the dose reduction at the exit
of the tube was not strictly linear in our
pilot study, which was performed at a
constant voltage and surface radiation.
these two values remained very similar.
Based on these results and for greater
security, we chose to reduce the dose in our
clinical study by 40%. In terms of delievered
dose, our results were a 41% dose
reduction in the total population which var-
ed between 33.4% and 46.3% depending
on the weight group. The intergroup dif-
fences can be explained by variations in
factors that influence the DAP, in particu-
lar mAs, Kv, and surface exposure.
We chose to evaluate dose by DAP becau-
sing this value can be measured at the exit
of the x-ray tube and is thus easily available.
It now corresponds to the measurement
found on the report filled out for each ra-
diographic examination and this dose in-
formation is now obligatory according to
European Directives (1). There is a poten-
tial bias in the measurement of DAP because
of the risk of variations in surface exposure
linked to the operator-dependent position-
ing of the diaphragm of the patient,
which is a parameter which directly influ-
ences DAP. We limited this risk by
using the same radiology room and by
centering with a standardized light beam
diaphragm.
The eight anatomical criteria chosen to
evaluate our images do not correspond to
the quality criteria published by the Eu-
ropean Commission for pediatric practice
(1). There are fewer of the latter and they
are less precise, which explains our low
number of 100% scores. The European
quality criteria differ according to the age
of the child. The anatomical characteristics,
the density of corporal structures (bone
versus cartilage, amount of water in the
lung parenchyma...), and the coopera-
tion of a child changes depending on his/
her stage of development. According to
European recommendations, vascular
structures should be visualised in half of
the lungs in newborns and in two thirds
of the lungs in other children, because of
the small sized vessels at these ages. Indeed,
an improvement in our global scores can
be noted when the criteria “visually sharp
image of peripheral pulmonary vessels”
were excluded. Moreover, the degree of
visualisation of anatomical structures in
our study was stricter than that recom-
bended by the European Commission.
For example in our study the mediastinal
lines, the principal bronchi and the vascu-
lar structures needed to be visualised and
the contours had to be clear as well. It is
surprising to note that radiologists felt
that the principal bronchi and the spine
were less clearly visualised than the vas-
cular structures in 2/3 of the lungs with
both uniyd. The senior radiologists parti-
cipating in this study probably only ac-
cepted a perfectly clear image of the enti-
re structure and not segments. Our binary
choice response (yes/no) which is the same
as that used by the European Commission
could explain these categorical results,
which are far from the 100% optimal re-
results, even though visualisation of the
structures was better. A more flexible ra-
ting system with a larger scale based on
confidence level (rated from 0 to 4, for
example) might have improved the global
score.
It should be remembered that in daily prac-
tice, the quality of the image is adapted to

Fig. 5: Histogram showing the percentage of radiographs obtained with a global score of
100% (7 visible structures = excluding the criteria “sharp image of peripheral ves-
sels”) for each unit by weight group.

Table IV

<table>
<thead>
<tr>
<th>Weight Category</th>
<th>ADC Average Dose (microGy.m²)</th>
<th>DXS Average Dose (microGy.m²)</th>
<th>Dose Reduction (%)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Standard deviation ()</td>
<td>Standard Deviation ()</td>
<td></td>
</tr>
<tr>
<td>4-9.9 kg (n=296)</td>
<td>2.7 (2.2)</td>
<td>1.6 (1.2)</td>
<td>41</td>
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<tr>
<td>4-9.9 kg</td>
<td>0.9 (0.2)</td>
<td>0.6 (0.3)</td>
<td>33.4</td>
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<td>10-19.9 kg</td>
<td>1.7 (0.6)</td>
<td>1.0 (0.7)</td>
<td>41</td>
</tr>
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<td>20-29.9 kg</td>
<td>2.6 (0.7)</td>
<td>1.5 (0.7)</td>
<td>42.3</td>
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<td>30-39.9 kg</td>
<td>3.5 (0.9)</td>
<td>2.2 (0.7)</td>
<td>37.2</td>
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<td>40-59.9 kg</td>
<td>6.7 (1.7)</td>
<td>3.6 (0.5)</td>
<td>46.3</td>
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</table>
the clinical situation. The best radiation dose-quality compromise is looked for to obtain the necessary diagnostic information for medical management. In this respect, the delivered dose is optimised according to the “ALARA” principle, or “the weakest reasonably possible dose”. Certain diseases on these chest radiographs could have affected the visualisation of anatomical structures: for example the visualisation of peripheral vessels in the presence of cardiopathies associated with an increase in pulmonary vasculisation or the visualisation of bronchi in the presence of bronchial syndromes. This was a randomised prospective study, thus making this bias theoretically impossible. Even though dosimetric study by weight group has been validated (18), the European recommendations and different studies present dosimetric results by age group (8, 20, 21).

In order to compare our results with those in the literature, we had to consider that children between 1 month and 12 months weighed between 4 and 9.9 kg, that children between 1 and 5 years old weighed between 10 and 19.9 kg, that children between 5 and 10 years old weighed between 20 and 29.9 kg, and that children between 10 and 15 years old weighed between 30 and 60 kg. The dosimetric results obtained with the ADC unit correspond to those in the literature (8, 20, 21) (Table V), which are different from the European dosimetric threshold for the 5 year old age group. The actual recommended doses (diagnostic reference level, decree February 12, 2004) are at present noted as the Entrance Surface Dose for two age groups (0–1 year olds: 0.08 mGy and 5 year olds: 0.1 mGy). To compare our results to dose recommendations we would have had to provide an Entrance Surface Dose based on our DAP and the average entrance surface. However, the latter was not calculated or gathered during the study. With the new generation of digital detectors, pediatric dose recommendations will probably be lowered.

We did not study newborns in our study, a population which is most vulnerable to the effects of radiation. Certain children, in particular premature babies, must undergo repeated X-rays in intensive care and neonatal intensive care (22, 23). The potential benefits of radiation dose reduction with the DXS unit must be studied in this population.

There have been several studies comparing Digital flat panel detectors (DFP) and granular scintillator storage phosphor systems (24-27). In chest X-rays in newborns, dose reductions of more than 75% are possible with a portable digital flat panel detector compared to granular scintillator storage phosphor systems without affecting the quality of the image (25). A dose reduction of 75% in a lumbar spine X-ray and 50% in a pelvic X-ray have been published (26, 27). A dose reduction of approximately 40% in standard examinations has been described in pediatric radiology (28). However, the very high cost of Digital flat panels and their fragility limit the number of devices that have been installed. DXS with its cassette system has the advantage of being able to be used on existing radiographic tables and portable radiographic systems. To our knowledge, there is no existing clinical study comparing flat panel detectors and needle structure storage phosphor systems. However, recent results of a phantom study have shown that DXS provides a better quality image than flat panel detectors, with an entry dose on the phantom of 0.2 mg (17).

### Conclusion

In our study of pediatric thoracic radiographs a dose reduction of approximately 40% was possible with a needle structure scintillator with an image quality that is at least as good as that with a granular structure scintillator.

### References

10. Nickoloff EL, Berdon WE, Lu ZF et al. Pediatric high KVfiltered airway radiographs: comparison of CR and

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**Table V**

Pediatric thoracic radiographies with a granular structure scintillator: comparison of DAP values (microGy.m2) in relation to weight (or age) in our study and in 3 other pediatric studies: Hufton et al. (8), Kiljunen, et al (18), Mooney et al. (19).

<table>
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<tr>
<th>Age Group</th>
<th>Our Study DAP (microGy.m2)</th>
<th>Hufton DAP (microGy.m2)</th>
<th>Kiljunen DAP (microGy.m2)</th>
<th>Mooney DAP (microGy.m2)</th>
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<td>1-12 months</td>
<td>0.9</td>
<td>1.7</td>
<td>1.3</td>
<td>3.5</td>
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<tr>
<td>(4-9.9 kg)</td>
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<td></td>
</tr>
<tr>
<td>1-5 years</td>
<td>1.7</td>
<td>1.57</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>(10-19.9 kg)</td>
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<tr>
<td>5-10 years</td>
<td>2.6</td>
<td>2.1</td>
<td>2.3</td>
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<tr>
<td>(20-29.9 kg)</td>
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<tr>
<td>10-15 years</td>
<td>3.5</td>
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<td>2.7</td>
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<tr>
<td>30-39.9 kg</td>
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<tr>
<td>40-60 kg</td>
<td>6.7</td>
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C Desvignes et al.


