An Attempt for Low-dose Myelo-tomosynthesis

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Is it possible to reduce whole-body radiation exposure in pediatric full spine X-ray examination?

Background

Insufficient dose → Unexpected low dose
↓
Reduction of radiation exposure → Intended low dose

(A) Use of small focal point → Sharpened edges
(B) Improvement in parameter processing methods
   Flexible Noise Control (FNC) processing
      (1) It improves image quality in the area of X-ray images where noise is obtrusive.
      (2) It brings out good-quality images from low-dose radiographs.
      (3) It reduces noise in images taken for measuring purposes to delineate edges of structures.
(C) Maintenance of high imaging voltage
   → Reduced quantization noise in image signals
↓
Clinical application of low-dose imaging, 1/20 the exposure dose in conventional CR

(Speakers, the 39th Annual meeting of the Japanese Scoliosis Society)
Objectives

Tomosynthesis

(Combination of digital image processing and conventional tomography techniques)

↓

We have been attempting to reduce patient exposure to radiation in tomosynthesis-based myelography, myelo-tomosynthesis (MTS), by means of the image processing techniques used for our low-dose whole-spine imaging, to take images at exposure doses lower than those for conventional myelography (MG), and to replace MG by MTS.

This report introduces our attempts and the results of efficacy evaluation of our new techniques.
Methods:

The surface doses (SDs) were compared between frontal and lateral plain X-ray examination and MTS of the cervical, thoracic, and lumbar vertebrae at our hospital.

Surface dose (SD): Calculated by a simple conversion equation of entrance dose on patient skin surface "Numerical Dose Determination (NDD) method"*

The usefulness of MTS was also compared to that of MG, CT-myelogram (CTM), and MRI.

The conditions of MTS imaging and image processing used at our hospital are shown below;

#Diagnostic imaging apparatus: SHIMADZU Sonial, vision safire 17
#Cu filter for total filtration during imaging: 0.1 mm
#Operative angle of X-ray tube: 30°
#Method of reconstruction in tomosynthesis: Filtered Back Projection (FBP) method
#Reconstruction filter: Thickness++, Metal 6
#Image processing of reconstructed images: FUJI Multi-objective Frequency Processing, which enhances specific signal components to make images easy to see even at low doses and adjusts the contrast and density to optimize the images

The surface doses (SDs) at our hospital (mGy)

<table>
<thead>
<tr>
<th></th>
<th>X-ray</th>
<th>MTS*</th>
<th>IAEA** guidance level</th>
<th>JART guideline***</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cervical spine</strong></td>
<td></td>
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<tr>
<td>AP</td>
<td>0.51</td>
<td>1.18</td>
<td>–</td>
<td>0.9</td>
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<tr>
<td>LAT</td>
<td>0.51</td>
<td>1.18</td>
<td>–</td>
<td>0.9</td>
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<tr>
<td><strong>Thoracic spine</strong></td>
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<tr>
<td>AP</td>
<td>2.19</td>
<td>2.15</td>
<td>7</td>
<td>4</td>
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<tr>
<td>LAT</td>
<td>2.73</td>
<td>3.07</td>
<td>20</td>
<td>8</td>
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<tr>
<td><strong>Lumbar spine</strong></td>
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<tr>
<td>AP</td>
<td>2.37</td>
<td>2.73</td>
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<tr>
<td>LAT</td>
<td>4.75</td>
<td>3.90</td>
<td>30</td>
<td>15</td>
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</tbody>
</table>

*MTS: myelo-tomosynthesis  
**IAEA: International Atomic Energy Agency  
***JART guideline: the targeted depreciation values with plain X-ray specified in the Japan Association of Radiological Technologists (JART) Guideline for Medical Exposure.
CASE 1  76y/o Female

conventional myelography (MG)

myelo-tomosynthesis (MTS)

↑: Myelo-tomosynthesis (MTS) provides a well-defined image of the nerve root, which cannot be delineated with conventional myelography (MG) due to transverse connecter and pedicle screws.
CASE 2  64y/o Male

The patient had pain in the left lower limb in a sitting position with leftward bending (+). Myelo-tomosynthesis (MTS) was performed in a sitting position with rightward and leftward bending. Lt. L5 root is not visualized with leftward bending, while it is visualized with rightward bending. Subsequent Lt. L5 nerve root block resulted in pain relief. Foraminotomy and spinal fusion improved the symptoms. MTS is also expected to be useful in diagnosing foraminal stenosis.
Discussion

ICRP Recommendations for radiological protection

There is no restriction on patient exposure to medical radiation.

Justification of the medical procedures

Optimization of radiological protection

Every effort should be made to reduce exposure doses!

An insufficient dose compromises image quality.

- Decrease in Signal Noise Ratio \(\rightarrow\) Decrease in image quality

- Dose increase by 4 times \(\rightarrow\) Noise decrease by half

- Dose decrease by half \(\rightarrow\) Noise increase by 4 times

Low-dose imaging \(\rightarrow\) Increase in random noise (quantum noise)

It is a key to reduce random noise to perform low-dose imaging without impairing image quality.
The keypoint of Flexible Noise Control (FNC) processing

**line signals+noise**

Line-structure extraction processing

The edge directions for individual pixels are determined and smoothing performed in those edge directions. Signals that do not run along those edges are suppressed, enabling signals that run along the edges to be extracted as line structures.

**dot signals+noise**

Dot-structure extraction processing

Processing is performed that leaves high-contrast signals as they are and suppresses low-contrast signals. As a result, signals with high contrast can be extracted as dot structures.
Flow of image processing

Reconstructed image  Pre-optimization image  Final image
In general, radiation exposure levels in tomosynthesis are comparable to the IAEA guidance levels for plain X-ray imaging and approximately 1/5 those in CT (approximately twice the reduction target with plain X-ray specified in the Japan Association of Radiological Technologists [JART] Guideline for Medical Exposure and approximately 1/10 the exposure in CT).

↓

Our MTS techniques reduced the SDs in imaging of the thoracic and lumbar vertebrae to approximately 1/8 to 1/4 the IAEA guidance level for plain X-ray imaging (approximately 1/4 to 1/2 the JART's reduction target with plain X-ray)!!
(The exposure in MTS of the cervical vertebra was similar to the JART's reduction target with plain X-ray)

Our MTS method has achieved low-dose imaging, which can replace MG!!

The advantages of MTS

(1) it enables tomography in supine, sitting, or standing position and even under dynamic stress from forward or backward bending, rightward or leftward bending, and rotation among others, and thereby provides more detailed information
(2) it is more useful than MG in delineating lesions such as deformed joints, destroyed bones, and foraminal stenoses
(3) it is less subject to metal artifacts than CT and MRI
(4) it requires a shorter imaging time and is less distressing to the patient than CT and MRI
(5) it involves digital image processing other than that for M-G, CT, or MRI and extensively and clearly provides previously unavailable image information.

Aiming at further expansion of low-dose MTS imaging, we will establish a physician-radiological technologist alliance, and improve imaging techniques and image processing capacity.
Conclusions

- The surface doses (SDs) in frontal and lateral myelo-tomosynthesis (MTS) of the cervical, thoracic, and lumbar vertebrae were compared to those in plain X-ray examination.

- The SDs in front and lateral plain X-ray, respectively, were 0.51 and 0.51 mGy for the cervical vertebra, 2.19 and 2.73 mGy for the thoracic vertebra, and 2.37 and 4.75 mGy for the lumbar vertebra.

- The SDs in front and lateral MTS, respectively, were 1.18 and 1.18 mGy for the cervical vertebra, 2.15 and 3.07 mGy for the thoracic vertebra, and 2.37 and 3.90 mGy for the lumbar vertebra.

- The SDs in our MTS imaging of the thoracic and lumbar vertebrae were approximately 1/8 to 1/4 the IAEA guidance level with plain X-ray.

- Our MTS has sufficiently achieved a reduction of patient exposure and can be an alternative to conventional myelography.

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Disclosure: None

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