Acquisition parameters causing alignment misregistration in whole-spine imaging with flat panel detector radiography using an automatic image-pasting technique

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Purpose

Recently, radiography systems based on full-field, cesium iodine and amorphous silicon flat-panel detectors have become commercially available. These systems provide rapid access to the image for diagnosis, improved image quality (e.g. improved dynamic range and low-contrast resolution) relative to that of screen-film and storage phosphor systems, and possibilities for reduced radiation exposure. The flat panel detector (FPD) radiography system (Definium 8000; GE Healthcare, Chalfont St. Giles, UK) used has an image size of 41 cm × 41 cm and a pixel dimension of 0.2 mm × 0.2 mm. Furthermore, this system enables slot-scan radiography that has been introduced as a new scanning technology of digital radiography using an automatic image-pasting technique. This technique makes radiography of long anatomical objects possible in a digital environment, even when the formats of storage phosphor screens and image intensifiers are too small to accommodate imaging with a single exposure [1]. This technique has also recently been used for orthopedic imaging, although it was previously used primarily for chest imaging. In particular, this method is now often performed for the assessment of the whole spine and lower extremities in clinical settings [1, 2].

Whole spine radiography has generally been performed for assessing the severity of scoliosis by measuring the Cobb angle, and has traditionally used a screen-film system with a large cassette [1]. Currently, this assessment on both supine and upright positions can be easily performed on the anterior-posterior (AP) view of FPD whole-spine radiography using an automatic image-pasting technique. Specifically, this examination consists of a multiple (5 or less) image continuous scan of the whole spine, with the total scan time of 17 seconds or less. The images are then reconstructed into one composite image at a workstation. The total examination time is usually less than one minute from patient positioning to final image display. A major advantage of digital imaging is that all of the images have a consistent exposure along the entire length of the spine without under- or overexposed areas. In addition, the large and unwieldy full-size film used in the conventional method is also avoided [1]. In some rare cases, however, we have identified alignment misregistration in the whole-spine image increasing the difficulty of accurately measuring Cobb angle.

The purpose of the present study was to investigate acquisition parameters causing the misregistration and optimize the parameters for clinical use.

Methods and Materials
We obtained AP views of the whole spine radiographs of an anthropomorphic phantom (PBU-10, Kyoto Kagaku Co., Ltd., Kyoto, Japan) with an original measurement scale by a FPD radiography system (Definium 8000; GE Healthcare, Chalfont St. Giles, UK) using automatic image-pasting technique (Figure 1 on page 3). As previously stated, this system includes a cesium iodide scintillator and an amorphous silicon photodiode-transistor array; the detector has an image size of 41 cm × 41 cm and a pixel dimension of 0.2 mm × 0.2 mm. Each radiograph consisted of continuous 3-image scan with length of view ranging from 83 to 86 cm in the cranio-caudal direction (Figure 2 on page 4). We used an automatic exposure control technique and the following various acquisition parameters: constant tube current, 100 mA; tube voltage, 80-120 (80, 100, 110, and 120) kVp; speed, 800-1560 (800, 1000, 1250, and 1560); and a constant source-to-image distance, 180 cm. We performed 10 scans under each acquisition condition, and calculated the average dose of radiation exposure in each condition. We printed the acquired radiographs onto a film using a laser imager (Dry Pix 7000, Fuji Film Medical, Tokyo, Japan). We investigated the presence of alignment misregistration in those radiographs (Figure 3 on page 5). In addition, 10 readers visually graded image quality of those radiographs in the printed film with a magnification of 60 % using constant tube voltage of 80 kVp and various speeds of 200-800 (200, 400, 640, and 800) on a score from 1 (poor) to 5 (excellent), and determined the acceptable speed defined as an average score # 4.5. We measured the total radiation dose of the 3-image scan under each acquisition condition, and determined the dose reduction rate of the optimal speed compared to a speed of 200, which was default value and standard technique for this examination at our institution, using the following equation; Dose Reduction Rate (%) = (Dose at 200 speed - Dose at Optimal speed) / Dose at 200 speed x 100.

Images for this section:
**Fig. 1:** Figure 1 A photograph showing the imaging procedure of antero-posterior view of the whole spine radiograph using FPD automatic image-pasting technique.
Fig. 2: Figure 2 Three continuously acquired antero-posterior view images of an anthropomorphic phantom with an original measurement scale on whole spine FPD radiography in the cranio-caudal direction from a to c. a: the cervico-thoracic spine level, b: the thoraco-lumbar spine level, c: the pelvis level.
**Fig. 3:** Figure 3 Magnified antero-posterior view images of an anthropomorphic phantom with an original measurement scale at the pelvis level on whole spine FPD radiography with (a) and without (b) alignment misregistration. Note the mismatched scales suggest alignment misregistration in a (circle) compared with the matched scales in b (circle).
**Fig. 4:** Figure 4 Two antero-posterior view images of an anthropomorphic phantom with an original measurement scale on whole spine FPD radiography with the same speed of 1560 and 2 different tube voltages of 120 kVp (a) and 80 kVp (b). Note the mismatched scales suggesting alignment misregistration in a (circle) compared with the matched scales in b. Tube current-time product was 0.85 mAs for the cervico-thoracic spine level, 1.40 mAs for the thoraco-lumbar spine level, and 1.29 mAs for the pelvis level in a. Tube current-time product was 2.31 mAs for the cervico-thoracic spine level, 5.17 mAs for the thoraco-lumbar spine level, and 4.84 mAs for the pelvis level in b.
Fig. 5: Figure 5 Line graph showing the relationship between speed (x axis) and averaged visual grading score by 10 readers (y axis) regarding the image quality of an anthropomorphic phantom on FPD whole spine radiography using the automatic image-pasting technique. This grading score ranged from 1 (poor) to 5 (excellent), and that of 4.5 or more was defined as acceptable. The average visual score is improved as the speed decreases, and remains acceptable with a speed of 640 or less.
**Fig. 6:** Table 1 The presence of alignment misregistration and the average exposure dose of 10 scans at each level (a: the cervico-thoracic spine level, b: the thoraco-lumbar spine level, c: the pelvis level) with various tube voltages and speeds. The numerical values indicate the average exposure (µGy).
Results

We observed misregistration in the acquired images only with tube voltage of 110 kVp and a speed of 1560, and with a tube voltage of 120 kVp and speeds of 1000-1560 (Table 1 on page , Figure 4a on page ). For tube voltages of 80-100 kVp, those used in standard clinical practice, however, no misregistration was observed and we obtained image quality that enabled measurement of the Cobb angle (Table 1 on page , Figure 4b on page ). The average radiation dose was likely to be lower with increasing tube voltage and speed (Table 1 on page ).

The dose reduction rate by each speed (400, 640, and 800) compared to a speed of 200 was 49.6% for a speed of 400, 67.8% for a speed of 640, and 73.7% for a speed of 800 by using constant tube voltage of 80 kVp. The average visual score of image quality on FPD whole spine radiography was improved as speed decreased, and was acceptable with a speed of 640 or less (Figure 5 on page ). Thus, the use of speed of 640 can markedly reduce radiation dose by 67.8% using a tube voltage of 80 kVp without significantly degrading the image quality.

Conclusion

Extremely high tube voltage and speed may result in alignment misregistration on the AP view of FPD whole spine radiographs using an automatic image-pasting technique. Misregistration was shown not to occur for the techniques used in routine clinical practice. For tube voltages of 80-100 kVp, the use of high speed is useful for reducing radiation exposure to patients and obtaining image quality sufficient for accurate quantitative evaluation of scoliosis severity. Specifically, the combination of a tube voltage of 80 kVp and increased speed to 640 can reasonably and markedly reduce radiation dose by 67.8%. Further study is warranted to establish the clinical applicability of this phantom study.

References


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