Measurement of CT radiation profile width using CR imaging plates

Med Phys 2005; 32(9):2881-2887

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2007, April 18
Outline

- Introduction
- Materials and methods
- Results
- Discussion
- Conclusions
Introduction

Collimation of computed tomography (CT) radiation beams is crucial to both image quality and patient dose.

How do we measure the width of the beam?
--Full Width at Half Maximum, FWHM

tradition: film processing
today: imaging plate, IP
Materials

- CT: Light-Speed 16 multislice scanner (General Electric)
- IP system: Fuji Model 5000
- Film system: X-Omat V(XV) ready-pack film, X-Omat processor (Kodak)
- Array 2905 Laser Film Digitizer
Methods

1. Interpreting Fuji IP pixel
   --the pixel value $Q(E)$ resulting from exposure $E$, in mR

   $$Q(E) = \frac{1024}{L} \log_{10} (k \times S \times E) + 511$$

   $L$: latitude, 0.5\~4
   $S$: sensitivity, 2\~20000
   $k$: calibration constant, approximately 0.005
Methods

1. Interpreting Fuji IP pixel
   --a $S$ value of 200:
   - 1 mR exposure, 80 kVp, 1mm Cu
   - and 1 mm Al filtration
   --three Exposure Data Recognizer, EDR
   --automatic
   --semiautomatic
   --fixed
Exposure Data Recognizer

auto

low S

high L
Methods

2. Characterization of IP saturation
   --prior to each IP exposure, the free-in-air exposure was measured
   --80kVp, EDR mode with L=4, S=5,
   80kVp, EDR mode with L=4, S=50,
   mAs settings were varied between 2~40
Methods

CT radiation profile experiment
--using several collimation settings and detector configurations
--the image receptor was placed on a **Styrofoam spacer** on top of the table
--positioned at the isocenter of the CT gantry during exposure
Methods

CT radiation profile experiment
--for the film method:
Is the photographic calibration necessary??

![Graphs showing optical density vs relative exposure](image)
Methods

CT radiation profile experiment
--for the CR method:
--the IP was selected at random
--to evaluate the scattering and attenuation effects from the cassette: \textit{w/ cassette} & \textit{w/o cassette}
Results

Four experiments were set up
-- the effects of attenuation and scattering by the cassette
-- pixel value versus logarithm of CT exposure
-- CT radiation profile measured by film & IP
-- different CT radiation profile
Results

the effects of attenuation and scattering by the cassette

suggestion: using a IP exposed inside a cassette
Results

- PSP signal saturation for CT techniques greater than 20mAs at 80 kVp
- Pixel value = 869 for S = 50
- Pixel value = 613 for S = 5
Results

CT radiation profile measured by film & IP
Results

CT radiation profile measured by film & IP
Results

**CT radiation profile measured by film & IP**

<table>
<thead>
<tr>
<th>Detector</th>
<th>kVp</th>
<th>mAs</th>
<th>S</th>
<th>L</th>
<th>N&lt;sub&gt;ω&lt;/sub&gt;&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Nominal beam width (mm)</th>
<th>FWHM (mm)</th>
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<tbody>
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*Number of measurements per film/IP.

--discrepancies between the film and IP: < 3%
Results

Different CT radiation profile

--both PSP signal saturation and quantization limited profiles have flatter and wider plateaus
Discussion

Under the properly exposed and processed, IP is an adequate detector for measurements of CT radiation profiles

Why we need low S and high L number?
--S=5~50, L=4

\[ Q(E) = \left( \frac{1024}{L} \right) \log(k \times S \times E) + 511 \]
Discussion

- Different CT scanner, different exposure conditions
- Different manufacturers, different relationship between the logarithm of the exposure and pixel value
  -- for Agfa: \( \log E(E) = 1249.5 \times \log(S \times E/200) + 2774.5 \)
  -- for Kodak: \( EI(E) = 1000 \times \log(E) + Co \)
Conclusion

- The FWHM of CT radiation profiles can be accurately measured using CR imaging plates.
- Because of slight attenuation of the x-ray beam by the CR cassette, we recommend exposing the IP inside its cassette.
References

