TITLE:

Energy subtraction computed tomography measured by current-mode detector

AUTHOR(S):

Kanno, Ikuo; Imamura, R.; Mikami, K.; Hashimoto, M.; Ohtaka, M.; Ara, K.; Nomiya, S.; Onabe, H.

CITATION:

Kanno, Ikuo ...[et al]. Energy subtraction computed tomography measured by current-mode detector. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 2009, 610(1): 325-327

ISSUE DATE:

2009-10-21

URL:

<http://hdl.handle.net/2433/93444>

RIGHT:

© 2009 Elsevier Science. All rights reserved; この論文は出版社版でありません。引用の際には出版社版をご確認ご利用ください。; This is not the published version. Please cite only the published version.

Energy Subtraction Computed Tomography Measured by Current-mode Detector

I. Kanno,^{a,*} R. Imamura,^a K. Mikami,^a M. Hashimoto,^b M. Ohtaka,^b K. Ara,^b
S. Nomiya,^c H. Onabe^c

^aKyoto University, Sakyo, Kyoto 606-8501, Japan

^bJapan Atomic Energy Agency, O-arai, Ibaraki 311-1393, Japan

^cRaytech Corporation, Yoto, Utsunomiya 321-0904, Japan

Elsevier use only: Received date here; revised date here; accepted date here

Abstract

For the reduction of exposure dose in contrast media detection with x-ray transmission measurements, the energy measurement of x-rays and the energy subtraction (ES) method have been shown to be effective. To make the ES method applicable, a novel detector for unfolding the x-ray energy distribution was proposed by the authors. As an application of this novel detector, a CT image was reconstructed with ES data and compared with the image reconstructed using electric current data. © 2001 Elsevier Science. All rights reserved

Keywords: diagnostic x-rays, unfolding, energy subtraction method, contrast media, filtered X-ray, CT

PACS: 87.57.Q-;78.70.Dm;29.40.Mc

1. Introduction

For the reduction of exposure dose in x-ray diagnosis, the authors have proposed the energy measurements of x-rays; in conventional x-ray diagnosis, x-rays have been measured as electric currents. In the case of detecting contrast media such as iodine, which concentrates in cancers, the x-ray events in the energy ranges lower and higher than the

energy of the K-edge of iodine are utilized. Using an additional filter made of materials for which the atomic numbers are slightly higher than that of iodine, unnecessary x-rays, which do not give information on the contrast media, are reduced. This method is termed the filtered x-ray energy subtraction (FIX-ES) method. Using the FIX-ES method, the exposure dose could be reduced to 30% of that when a filter is not employed. [1] Furthermore, the FIX-ES method was shown to be twice as sensitive to iodine as the current measurement method. [2]

Although energy measurement in x-ray diagnosis has some advantages over the current measurement method, it is not applicable to practical x-ray diagnosis, as the energy measurement of x-rays takes a longer time than the current measurement does. During the time required for the accumulation of x-ray events to produce an energy spectrum, the subject, and the internal organs, would change their positions.

For a quick acquisition of energy information of incident x-rays, the authors invented a novel detector called the transXend detector, which consists of several current detectors arrayed along the line of x-ray incidence. The energy distribution of incident x-rays is determined from the measured currents. The transXend detector was shown to be useful in estimating the thickness of iodine in an acryl phantom. [3]

In this paper, the transXend detector is briefly described and then used in a CT measurement.

2. TransXend detector

A schematic drawing of the transXend detector is shown in Fig. 1. The detector consists of several current detectors, which are aligned along the line of x-ray incidence. Low energy x-rays are absorbed by the forward segment detectors and never reach the back segment detectors. On the other hand, parts of high energy x-rays are absorbed by the back segment detectors. With the currents measured by the segment detectors, the energy distribution of incident x-rays is obtained using the unfolding technique.

In the unfolding process, the response function of each segment detector is required. The response function could be estimated using a simulation code,

Fig. 1 Schematic drawing of a transXend detector.

such as EGS5 [4], in the case of the energy deposition by x-rays being directly reflected by the measured current. If the energy deposition and charge creation are not directly related, as is the case for scintillators, the response function can be estimated using experimental data as reference points [3]. After obtaining the response function, the energy distribution of incident x-rays is estimated using unfolding code, SAND II. [5] The iodine thickness results for the example of a 30 mm thick acryl phantom are shown in Fig. 2. [3]

Fig. 2 Example of the results of iodine thickness estimation in an acryl phantom. X-ray tube voltages are shown in the figure. [3]

3. CT measurement

The experimental setup is shown in Fig. 3. The employed x-ray tube was a TRIX-150S (Toreck, Co. Ltd., Japan). As additional filters, 2 mm thick Al and 100 μm thick La were used. As the transXend detector, a CsI(Tl) scintillator array (S5668-11, Hamamatsu Photonics K. K., Japan) was used. The CsI(Tl) scintillator array comprised 16 CsI(Tl) scintillators with photodiodes. The dimensions of each CsI(Tl) scintillator were a thickness of 1.175 mm, a width of 2 mm and a height of 5 mm. The space between neighbouring CsI(Tl) scintillators was 0.4 mm and was packed with TiO_2 . The CsI(Tl)

surface was also covered with TiO_2 . In the experiments, the first two scintillators were connected together and behaved as segment detector No. 1. In the same way, 12 scintillators out of 16 were employed in total, providing a 6-channel transXend detector.

A cylindrical acryl phantom with a diameter of 40 mm was placed between the x-ray tube and transXend detector. In the center of the phantom, a hole of 10 mm diameter was bored for iodine tinker thinned by water, i.e., 10 μm iodine thickness in 10 mm water thickness. The acryl phantom was placed on a x - θ precision stage.

Fig. 3 Schematic drawing of the experimental setup.

The currents from the transXend detector were amplified by a 6-channel current preamplifier (IPA-6, Raytech Corp., Japan) and read simultaneously by timer-counters with voltage-frequency converters (VFCT-8S4, Laboratory Equipments Corp., Japan). A computer with LabVIEW software controlled the precision stage and the timer-counters.

The CT image was reconstructed from the summed current of segment detectors 1–6 at each measurement point and is shown in Fig. 4 (a).

To produce energy subtraction (ES) CT data, energy distributions of incident x-rays at each measurement point were unfolded. As the first step, response functions of each segment detector were prepared; in this unfolding process, the response functions for the acryl phantom thickness of 30 mm, which we obtained earlier in proving the capability of the transXend detector [3], were employed. As initial guess spectra, x-ray energy spectra were calculated for the cases of water thickness of 0 to 80 mm with steps of 1 mm and iodine thickness of 0 to 20 μm with steps of 1 μm . By employing the spectrum surveillance method in the unfolding process using

SAND II code, the x-ray energy distribution giving the minimum σ we reported earlier [3] was found for each measurement point. For x-ray events in the energy ranges 28–33 keV and 34–39 keV, ϕ_1 and ϕ_2 and thus the ES data ϕ_1/ϕ_2 were obtained. The CT image reconstructed by the ES method is shown in Fig. 4 (b). The CT profiles at the center of the phantom are shown based on the current and ES CT

Fig. 4 CT images reconstructed using (a) current and (b) energy subtraction data.

images in Fig. 5.

In the current measurement, a difference in CT values in the iodine and acryl regions is barely seen. On the other hand, the CT value in the iodine region differs clearly from the one in the acryl region in the ES measurement. The CT value for the ES method has been shown to be proportional to the iodine thickness [6]. An iodine thickness of 1 μm could be detected with the ES method because the CT value

differences between the center and fringe of the iodine region is nearly 0.02 using the ES method whereas it is 0.002 using the current method.

Fig. 5 CT values for current and energy subtraction (ϕ_1/ϕ_2) measurement methods using the transXend detector.

4. Conclusion

The ES method has been shown to have an advantage over the conventional current measurement method in an x-ray transmission measurement and x-ray CT measurement. The energy measurement, however, takes too long in

practice. With the proposal of the transXend detector, which measures x-rays as current and gives an energy distribution of incident x-rays, the ES method can be employed in practical use. CT values determined by the ES method were found to be more than ten times as sensitive as values determined by the electric current method. Reductions in exposure dose and the quantity of iodine contrast media are expected.

Acknowledgement

The authors are grateful to Prof. T. Shoji and Dr. K. Hitomi of the Tohoku Institute of Technology for allowing us to use their CT image reconstruction code. This study was supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science.

References

- [1] I. Kanno, S. Maetaki, H. Aoki, S. Nomiya, H. Onabe, J. Nucl. Sci. Technol., **40** (2003) 457.
- [2] I. Kanno, A. Uesaka, S. Nomiya, and H. Onabe, Nucl. Instrum. and Meth. in Phys. Res. **A580**, 534 (2007).
- [3] I. Kanno, R. Imamura, K. Mikami, M. Hashimoto, M. Ohtaka, S. Nomiya, and H. Onabe, submitted to J. Nucl. Sci. Technol.
- [4] H. Hirayama, Y. Namito, A.F. Bielajew, S.J. Wilderman and W.R. Nelson, SLAC-R-730 (2005).
- [5] W. McElroy, S. Berg, T. Crocket, G. Hawkins, AFWL-TR-67-41 (1967).
- [6] I. Kanno, A. Uesaka, S. Nomiya, and H. Onabe, J. Nucl. Sci. Technol., **45**, 15 (2008).