Tohoku J. Exp. Med., 2002, **198**, 197-201

Stability of Electron-Beam Energy Monitor for Quality Assurance of the Electron-Beam Energy from Radiotherapy Accelerators

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Chida, K., Saito, H., Takai, Y., Zuguchi, M., Mitsuya, M., Sakakida, H., Kohzuki, M. and Yamada, S. *Stability of Electron-Beam Energy Monitor for Quality Assurance of the Electron-Beam Energy from Radiotherapy Accelerators.* Tohoku J. Exp. Med., 2002, **198** (3), 197-201 —— Information on electron energy is important in planning radiation therapy using electrons. The Geske 3405 electron beam energy monitor (Geske monitor, PTW Nuclear Associates, Carle Place, NY, USA) is a device containing nine ionization chambers for checking the energy of the electron beams produced by radiotherapy accelerators. We wondered whether this might increase the likelihood of ionization chamber trouble. In spite of the importance of the stability of such a quality assurance (QA) device, there are no reports on the stability of values measured with a Geske monitor. The purpose of this paper was therefore to describe the stability of a Geske monitor. It was found that the largest coefficient of variation (CV) of the Geske monitor measurements was approximately 0.96% over a 21-week period. In conclusion, the stability of Geske monitor measurements of the energy of electron beams from a linear accelerator was excellent. ———— electron-beam energy monitoring; electron therapy; Quality Assurance; radiation therapy
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The radiation dose distribution of an electron beam, particularly in the steeply falling region, depends strongly on electron energy. Information on electron energy is important in radiation therapy planning using electrons, and quality assurance (QA) of the electron energy from radiotherapy accelerators is very important. The standard procedure according to the American Association of Physicists in Medicine (AAPM) protocol uses a water phantom; how-

Received September 5, 2002; revision accepted for publication November 25, 2002.
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ever, this is time consuming, and is unsuitable for daily QA of electron beam energy (American Association of Physicists in Medicine [Task Group 21] 1983).

Recently, simple methods and devices have been developed to monitor electron beam energy (Ramsay et al. 1991; Aoyama et al. 1995). A commercially available Geske 3405 electron beam energy monitor (Geske monitor, PTW Nuclear Associates) is such a device; it is designed for checking the energy of the electron beams produced by radiotherapy accelerators in the range between 5 and 25 MeV (Ramsay et al. 1991). Although Geske monitors have come into wide use, to the best of our knowledge no reports have described the stability of Geske monitors. The purpose of this paper was to describe the stability of Geske monitors in measuring the energy of electron beams from a linear accelerator (Chida et al. 2001).

MATERIALS AND METHODS

Geske monitor

A Geske monitor is a device that measures the total ionization quantity of an electron beam, which consists of nine flat parallel plate ionization chambers, arranged one behind the other with an aluminum absorber disk between successive chambers. Each radiation accelerator has its own electron energy spectrum, and the values of the Geske monitor measurements vary with the structure of the electron energy spectrum. Therefore, the Geske monitor must be calibrated for each radiotherapy accelerator.

Linear accelerator

A Clinac 2100c linear accelerator (Varian, Palo Alto, CA, USA) was used. The irradiation from the linear accelerator was measured with a LINACHECK dosimeter (PTW Nuclear Associates) to check the stability of the electron dose. The largest coefficient of variation (CV) of the irradiation dose was 0.27% for 6 MeV electron beams: the stability of the irradiation dose of this linear accelerator was excellent. Therefore the Clinac 2100c is a stable machine.

The mean energy (E0) of an electron beam from the linear accelerator was estimated from a depth-dose curve using the depth of the 50% dose level (d50) measured by an ion chamber in a water phantom. The E0 used in this paper was determined as follows:

$$E0 = 2.33 \times d50 \ [\mathrm{MeV}],$$

where d50 is given in cm, and 2.33 MeV/cm is the value from the AAPM protocol (American Association of Physicists in Medicine [Task Group 21] 1983).

Geske monitor measurement

A Geske monitor was irradiated by an electron beam (nominal energies: 6, 9, 12, 16, and 20 MeV) from a Clinac 2100c linear accelerator. The Geske monitor was irradiated for 200 monitor units (radiation dose rate: 5 Gy/min) at an SSD of 100 cm with a 10×10 cm electron cone. The irradiation striking the Geske monitor was measured with a UNIDOS dosimeter (PTW Nuclear Associates, polarization voltage: 300 V). Atmospheric pressure and the air temperature were corrected for. Just before each measurement, the Geske monitor was irradiated with 5 Gy to stabilize the potentials on the isolators. Thirty-nine Geske monitor measurements, assessed in five consecutive measurements, were performed over a 21-week period (approximately 2 days per week). Evaluation of the stability of Geske monitors in measuring the energy of electron beams were based on CV of thirty-nine Geske monitor measurements.

A calibration curve was plotted using the relationship between E0 and the values of the Geske monitor measurements.

RESULTS

Fig. 1 shows the depth-dose curve. The mean energies of the electron beam were calculated using d50. Fig. 2 shows the Geske monitor calibration curve. There was a very precise

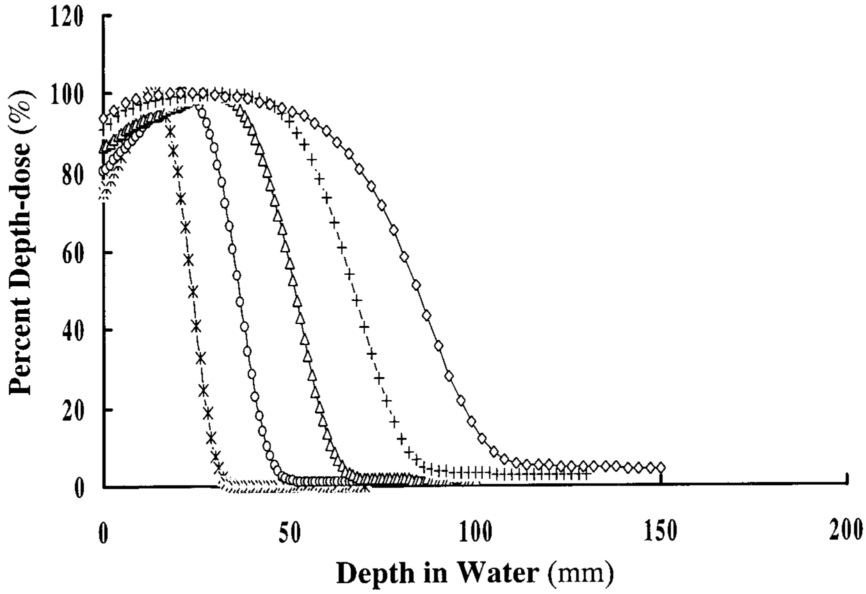

Fig. 1. Depth-dose curves measured for the clinac 2100C accelerator (nominal electron energy: 6, 9, 12, 16 and 20 MeV) by standard method using an ion chamber and water phantom (AAPM protocol).
Nominal electron energy, — * —, 6 MeV; — ○ —, 9 MeV; — △ —, 12 MeV; — + —, 16 MeV; — ◇ —, 20 MeV.

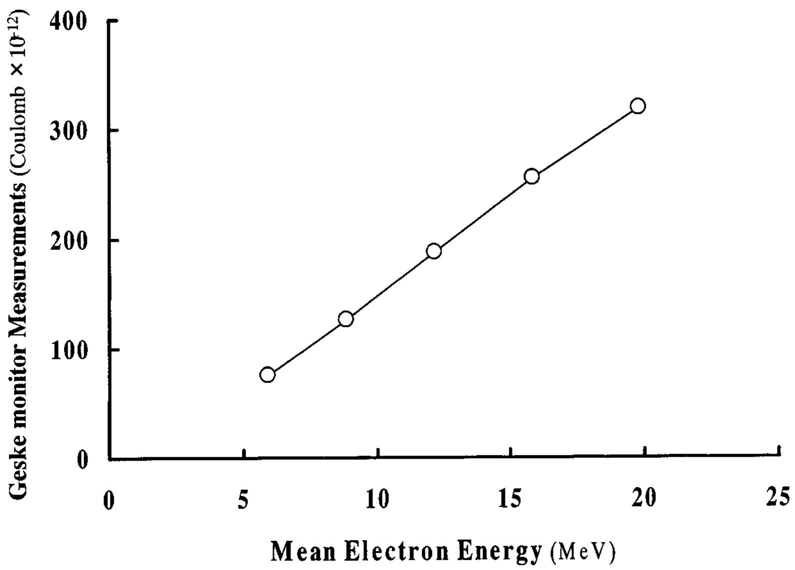

Fig. 2. Response of Geske monitor to electron energies available the clinac 2100C accelerator. The mean electron energies were estimated from depth-dose measurements in water phantom using the depth of 50% of the maximum dose.

linear response between the Geske monitor measurements and the mean energies of the electron beam from the radiotherapy accelerator. Fig. 3 shows the stability of the Geske monitor over the 21 weeks. The largest CV for the values of the Geske monitor measurements was 0.96% for 12 MeV electron beams.

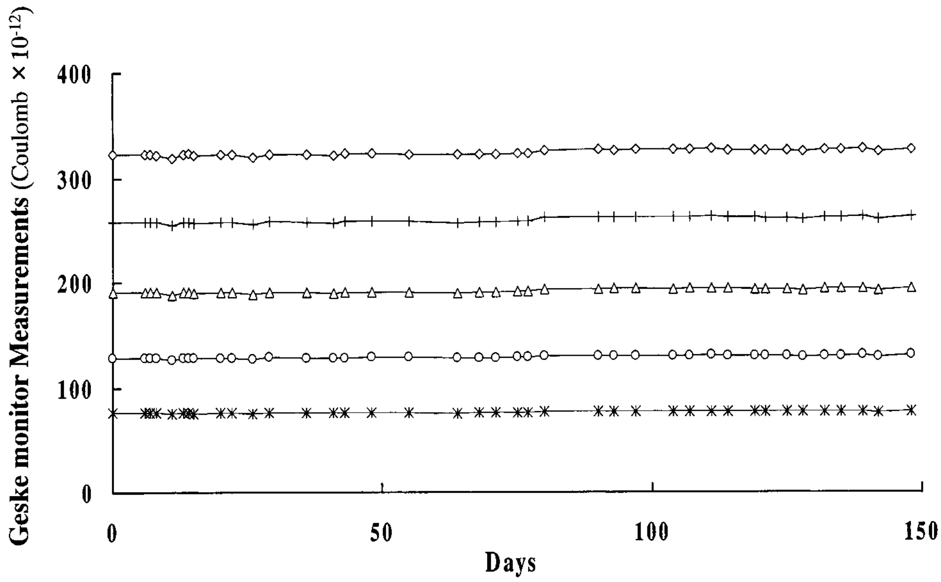

Fig. 3. Thirty-nine Geske monitor measurements (over the 21 weeks). The stability of Geske monitor measurements of the energy of electron beams from a linear accelerator was excellent. Nominal electron energy, ( ), coefficient of variation (CV) of thirty-nine Geske monitor measurements. — * —, 6 MeV (0.85%); —○—, 9 MeV (0.80%); —△—, 12 MeV (0.96%); — + —, 16 MeV (0.91%); —◇—, 20 MeV (0.76%).

DISCUSSION

In radiation therapy, further improvements in cure rate can be expected with refinements in patient day radiotherapy machines and with greater precision in their use (Yamada et al. 1994; Guden et al. 2002).

The Geske monitor had excellent stability. The largest CV of the values of the Geske monitor measurements was approximately 0.96% over 21 weeks. Geske monitors have become a quality assessment device that is routinely used in electron beam therapy, but in spite of the importance of its stability as a QA device, there are no reports describing the stability of Geske monitor measurements. The Geske monitor consists of nine chambers and it was considered that this degree of complexity might increase the likelihood of problems. However, our results clearly indicate that the Geske monitor has excellent stability. Therefore, Geske monitors are a very useful QA device for daily or weekly test that can be used routinely in electron beam therapy.

Measurements made with a Geske monitor are easy to perform. The depth-dose curve of an electron beam falls more steeply than that of x-rays, and the dose distribution of the beam depends strongly upon electron energy. There is therefore a need to verify the electron energy to assure the quality of the electron beam from radiotherapy accelerators. However, the standard AAPM protocol procedure, using a water phantom, is very time consuming, and is unsuitable for daily QA of electron beam-energy constancy (American Association of Physicists in Medicine [Task Group 21] 1983). Our results clearly show that Geske monitor measurements are consistent with results obtained following the standard AAPM procedure. Hence the Geske monitor would be used widely as a routine means of electron energy checking for QA purposes for electron beam therapy. It is important that the Geske monitor is assessed under the same conditions as used to calibrate the irradiation dose.

It is concluded that the stability of Geske monitor measurements of the energy of electron beams from a linear accelerator was excellent.

Acknowledgments

We acknowledge Mr. Shigeyoshi Saito, Ms. Emi Ohsawa, Ms. Kohko Kudo, Ms. Izumi Fujita, Mr. Kazutoshi Shirotori, Mr. Shinsaku Kumagai, Ms. Hiromi Nakayama and Ms. Kana Matsubara, College of Medical Sciences, Tohoku University, Japan, for their invaluable assistance.

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