藤田医科大学
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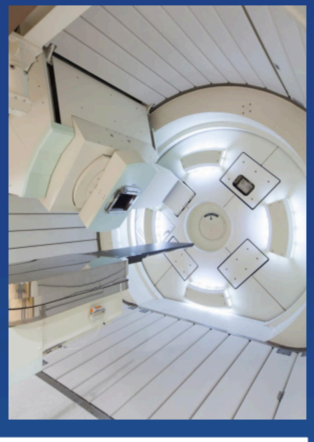
Nagoya Proton Therapy Center



Dosimetry of synchrotron-based FLASH irradiation using low-sensitivity radiochromic film

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INTRODUCTION / PURPOSE

In recent years, several studies have reported the effectiveness of ultra-high dose rate (FLASH) irradiation. Although there are still many unknowns about FLASH irradiation, many studies suggesting its efficacy have been conducted in cell experiments, and clinical cases were also reported [1, 2]. Synchrotrons are widely used for proton therapy because of their accelerator stability and variable energy, however, there are few reports on FLASH irradiation. At the Nagoya Proton Therapy Center, we have realized FLASH irradiation using a synchrotron (Fig. 1). In this study, we investigated the usefulness of low-sensitivity radiochromic film in synchrotron-based FLASH proton irradiation.

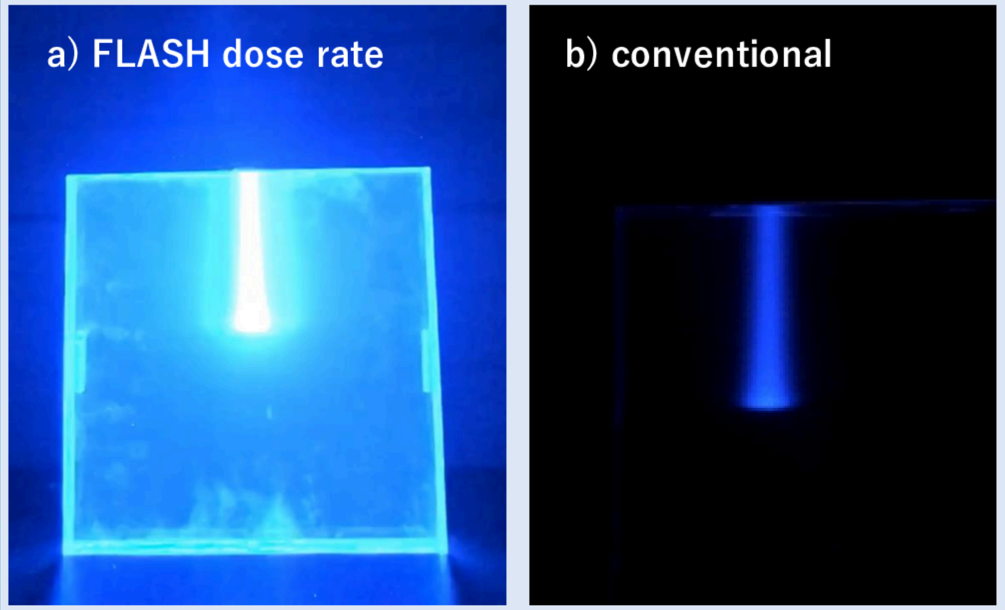

Fig.1 FLASH dose rate (a) vs. conventional dose rate (b). Luminescence is acquired using a plastic scintillator. The FLASH dose rate was approximately 600 Gy/sec at the peak depth during 50 msec and the energy was 139.3 MeV.

METHOD

For an experimental measurement, we used a new type of low-sensitivity radiochromic film (EBT-XD, Ashland) and plane-parallel ionization chamber (Advanced Markus, PTW).
The calibration curves of the EBT-XD were obtained by irradiation at a normal dose rate. The response characteristic of the EBT-XD due to the difference in linear energy transfer (LET) was also verified by obtaining the calibration curve at the plateau region and near the peak. A synchrotron-based scanning system (PROBEATⅢ, Hitachi Ltd.) used in clinical treatment at Nagoya Proton Therapy Center was used for FLASH irradiation. To form a small spread-out of Bragg peak, a small ridge filter made by a 3D printer was inserted into the beamline. The absolute dose and the dose distribution were measured using EBT-XD.

RESULTS

There was no difference between the calibration curve obtained by the two depths. The differences between absolute doses measured using the film and ionization chamber were 1.7% near the peak and 1.9% at the plateau. The doses were 24.0 Gy and 10.8 Gy, respectively, with dose rates of 480 Gy/s and 216 Gy/s. In the measurement of the depth dose distribution, the range agreed in all measurement conditions, but there was a difference in the dose distribution upstream of SOBP (Fig. 2). The lateral dose distribution was successfully obtained by EBT-XD (Fig. 3).

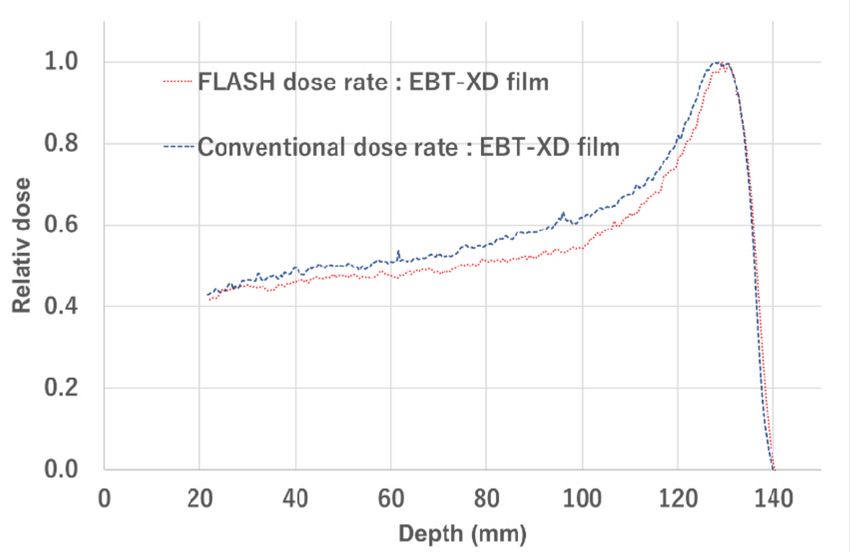

Fig. 2 Depth dose distribution measured using EBT-XD with FLASH condition and normal dose rate.

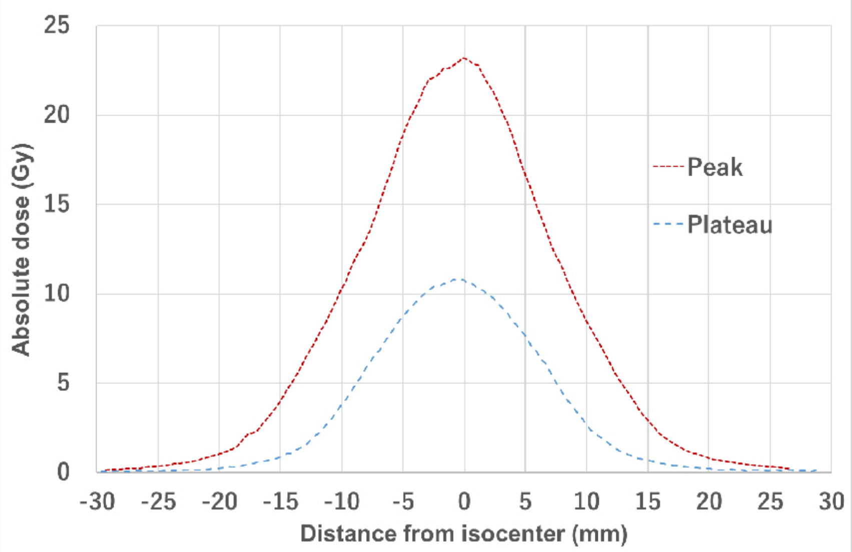

Fig. 3 Lateral dose profile at plateau and peak depth with FLASH condition.

CONCLUSIONS

Synchrotron-based FLASH proton beam irradiation was successfully performed. It was shown that the absolute dose could be measured with high accuracy by EBT-XD film. EBT-XD film is useful as a dose distribution measurement system for FLASH irradiation.
On the other hand, there are many issues that could not be clarified in this study; for example, the validity of the reference ionization chamber measurements, the range of dose rates that can be applied to FLASH irradiation, and effective treatment planning methods.
In addition, due to the characteristics of the accelerator, the synchrotron delivers beams intermittently. In this case, the biological FLASH effect needs to be verified.

ACKNOWLEDGEMENTS

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