Signal intensity measurement of hydrophone to position change of Bragg-peak using iono-acoustic wave in hospital-based cyclotron

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Purpose: Proton range can be measured using an iono-acoustic wave generated in the Bragg-peak when a proton beam is irradiated on an object. Research on proton range measurement using iono-acoustic wave continues in research cyclotrons, but studies in hospital-based cyclotrons are insufficient. Hospital-based cyclotrons are difficult to measure iono-acoustic waves due to the low beam current and long pulse width. We confirmed the possibility of measurement through the last simulation study, and based on this, we intend to measure the intensity of hydrophone to position change of Bragg-peak using the iono-acoustic wave in the cyclotron proton beam of Samsung Medical Center (SMC).

Materials and Methods: The proton beam energy was 230 MeV and beam current was 11 nA. The irradiation time was set at a 200 msec cycle and 20 msec irradiation, 180 msec rest. The water phantom made of polyethylene has dimensions of 420 mm x 220 mm x 250 mm, the wall thickness is 10 mm, and the wall thickness in the direction of beam incidence is 2 mm. The Bragg-peak position of 230 MeV proton beam in water phantom is 32 cm and was adjusted to 24 cm using a solid phantom made of water equivalent material. The position of the hydrophone was set from 5 cm to the right of the entrance of the beam to 32 cm (A point), 28 cm (B point), and 24 cm (C point) in the direction of the beam. We compared the signal intensity of the hydrophones located at the same distance from the two Bragg peak positions (32 cm and 24 cm). The signal intensity of A point at 32 cm and the C point at 24 cm, the C point at 32 cm and the A point at 24 cm, and the B point at two Bragg-peak positions were compared. The hydrophone used for the measurement was TC4032, the preamplifier was VP2000, and RESON's equipment was used. The signal acquisition equipment was used by Keysight's DSOX2014A oscilloscope, and the signal analysis was performed using MATLAB (MathWorks, MA, USA). Using the trigger signal indicating the irradiation of the beam from the cyclotron, the signal was acquired for 5 msec starting from the trigger signal. To reduce noise, a high-resolution mode was used in the oscilloscope and 2000 signals were summed and compared.

Results: At the Bragg-peak position of 32 cm, the intensity was 3521 V, 2324 V, 2181 V at A, B, C point, respectively. At the Bragg-peak position of 24 cm, the intensity was 318 V, 508 V, 3083 V at A, B, C point, respectively. The difference of the signal intensity was 438 V for A point at 32 cm and the C point at 24 cm. The difference of the signal intensity for the C point at 32 cm and the A point at 24 cm, and the B point of two Bragg-peak positions was 1863 V and 1816 V, respectively. The reason is that the greater the distance between the proton Bragg-peak position and the hydrophone, the greater the effect of noise. Also, this is thought to be the effect of the incoming signal reflected by the limited phantom size.

Conclusions: The intensity of the beams was compared with the hydrophone located at the same distance from the two Bragg-peak positions. In this study, the correlation of the signal intensity could not be found at the same distance between the proton Bragg-peak position and the hydrophone. If the influences of the reflected signal and noise are evaluated and corrected, it is thought that good results will be obtained.

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Keywords: Proton therapy, iono-acoustic wave, range verification, hospital-based cyclotron