The effect of anchoring of MR scanners to prevent earthquake hazards – an analysis of the damages to the 602 MR scanners in Great East Japan Earthquake

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Introduction

The Great East Japan Earthquake (GEJE, magnitude 9.0), the largest one in the modern Japanese record, attacked east Japan at 14:16 (JST), on March 11, 2011. The Kobe earthquake in 1995 (magnitude 7.3) was the first large one after MR scanners became popular in medical facilities. Since the Kobe earthquake, anchoring of the radiological facilities has been the main concern to prevent earthquake disasters. Not only earthquake-proof structures but also seismic vibration control and base isolation of the building have been employed for new medical facilities in this decade. In order to evaluate the potential risk to MR scanners and consider patient safety under large earthquakes, we have performed a survey study to investigate damages in MR scanners caused by GEJE. The effectiveness of anchoring of MR scanners and seismic strengthened building structures for damage prevention were also investigated.

Material and Methods

Questionnaires were mailed to the 984 facilities installed with MR scanners in the seven prefectures of east Japan including areas that severely devastated by the earthquake (Iwate, Miyagi, Fukushima, and Ibaragi) and neighboring areas (Chiba, Saitama, and Tokyo). The followings were inquired, 1) basic information of the facility, MR scanners installed and the magnitude of the earthquake experienced, 2) the details of damages to the MR scanners, 3) anchoring for each MR scanner, and 4) building structure of MR room. Chi-square (χ^2 test) test was used to examine the relationship between the damages in MR scanners and seismic intensities. Binominal logistic regression analysis was performed to evaluate the effectiveness of anchoring and building structures for damage prevention.

Results

Responses were obtained from 456 facilities (collecting rate 46 %) installed with 602 MR scanners (≤0.5 T: 144 units, 1 T: 31, 1.5 T: 371, ≥3 T: 54, and higher than 4 T: 2). The number of superconducting magnet was 472, permanent magnet 129 and 1 were unknown type. Base isolation structure was employed in 8.2 % of the buildings and conventional earthquake-proof structure was 68.0 %. Anchoring of the MR scanner was performed in 396 (65.8 %) scanners.

Significant differences were observed in the ratio of damages between seismic scale (SS) 5 (SS5- and SS5+) and SS over 6 (SS6 and SS7) (χ^2 test, $p<0.05$ or $p<0.001$). Since the SS over 4 was reported from 94.7 % of the facilities in these 7 prefectures, it was not possible to estimate the difference between the risk of damages by common earthquake (SS under 5) and that by this large earthquake. Frequencies of the typical damages were displacement of magnets (ratio to the total 251 facilities experienced SS5: 7.2 % / ratio to the 150 facilities experienced SS over 6: 25.2 %, $p<0.001$), failure of chiller or air-conditioning (25.8 % / 74.2 %, $p<0.001$), and rapid decrease of liquid helium (40.7 % / 59.3 %, $p<0.05$).

Logistic regression analysis suggested that anchoring for MR facilities reduced the occurrence of quake-induced damages (odds ratio (OR), 0.26; 95 % confidence interval (CI) 0.17 to 0.40; $p<0.001$, Fig.1). And this damage preventive effect was observed in both SS5 (OR, 0.31; 95 % CI 0.15 to 0.63; $p<0.001$) and SS over 6 (OR, 0.26; 95% CI 0.14 to 0.49; $p<0.001$).

Then, effectiveness of seismic strengthened building structures (1) earthquake-proof structures (N=408) or 2) base isolation (including seismic vibration control, N=58)) against quake-induced damages in MR scanners were examined. Significant decrease in quake-induced damages was observed in base isolation group (OR, 0.26; 95% CI 0.09 to 0.73; $p<0.05$) compared with earthquake-proof structures.

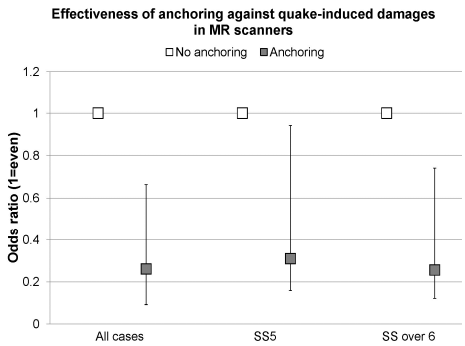

Fig. 1 The odds ratio of the occurrence of quake-induced damages in MR scanner.

Discussion and Conclusion

The characteristics of GEJE were disasters by Tsunami and failure of basic infrastructure (electricity, water, communication) in very wide area. However, quake-induced damages were still observed generally in this earthquake. Indeed, it was confirmed that the extent of damage was significantly different between SS5 and SS over 6. Then, relationships between damages and anchoring were investigated to examine effectiveness of its safeguarding against quake-induced damages. As shown in Fig. 1, anchoring for MR facilities reduced the quake-induced damages and it was demonstrated that anchoring is an efficient way for quakes. Recently, in Japan, any fixation methods have been implemented for almost of all newly installed MR scanners but types of fixation are different among facilities. Next challenge is to define the feature of each fixation against quake-induced damages in MR scanners. And it was also confirmed that nobody was severely injured in MR scanners. Odds ratio revealed that base isolation was very useful to prevent damages in MR scanner.

As the future direction, training for evacuation, establishing standard protocol of emergency shut down of MR scanners and onsite checking of MR scanners by MR operators, and equipment of emergency power plant to cover the chiller of MR scanners will further ensure the MR safety under earthquake.

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