



Earthquake and hypertension—from acute to chronic phase after the Great East Japan Earthquake

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On 11 March 2011, the Great East Japan Earthquake hit the northeast part of Japan (the Tohoku region) with a magnitude of 9.0 on the Richter scale, which was one of the largest ocean-trench earthquakes ever recorded in Japan. The Earthquake caused huge damage, including 9,512 dead and 1,581 missing persons and 400,851 destroyed houses (as of 20 October 2016). It also forced many people (~400,000) to be evacuated to the temporary accommodations, such as public halls, gymnastic halls and scholastic institutions in disaster-stricken area. Especially in the seacoast area, the damage was significantly amplified by the Tsunami (The report on damage from the East Japan Earthquake. In: Fire and Disaster Management Agency; 2016). Furthermore, the Fukushima Daiichi Nuclear Power Plant struck by the Tsunami got out of order, and hydrogen explosion occurred subsequently. Consequently, many residents living around the nuclear power plant were also forced to evacuate from their houses to the temporary accommodations, such as public halls, gymnastic halls and scholastic institutions in the Great East Japan Earthquake disaster.

Earthquake and hypertension

In a report entitled “Evacuation and Risk of Hypertension after the Great East Japan Earthquake”, Ohira *et al.* examined blood pressure among people living around the Fukushima Daiichi Nuclear Power Plant before and after the disaster. They evaluated the effects of the disaster on blood pressure, demonstrating that systolic/diastolic blood pressure significantly increased not only in evacuees but

also in non-evacuees after the disaster, with greater changes in blood pressure noted in the former than in the latter (+5.8/3.4 vs. 4.6/2.1 mmHg, both of $P < 0.01$) (1).

Hypertension is a well-known major risk factor for occurrence and/or worsening of cardiovascular diseases. We reported that the occurrences of heart failure (HF), acute coronary syndrome (ACS), stroke, and cardiopulmonary arrest (CPA) were all significantly increased after the Great East Japan Earthquake in the Miyagi prefecture next to the Fukushima prefecture (*Figure 1*) (2). In situations after severe disaster, where people are exposed to extreme physical and mental stresses associated with sympathetic nervous system activation and transient increase in blood viscosity increase the occurrences of ACS, stroke and CPA. Furthermore, the discontinued logistics distribution struck by the earthquake resulted in insufficient delivery of regular medications (e.g., antihypertensive drugs and antithrombotic drugs), which can also increase cardiovascular events. Moreover, these situations forced people to take preserved foods with high salt but less fresh food, which also can elevate blood pressure. It has been reported that high salt intake under mental stress elevates blood pressure to a greater extent than normal conditions (3). The report from our institute also demonstrated that self-monitoring blood pressure was significantly elevated just after the earthquake (4). Activated sympathetic nervous system in the Great East Japan Earthquake should have elevated blood pressure and heart rate, as previously reported after large earthquakes (5). In fact, it was previously demonstrated that sympathetic nervous system is activated as evaluated by

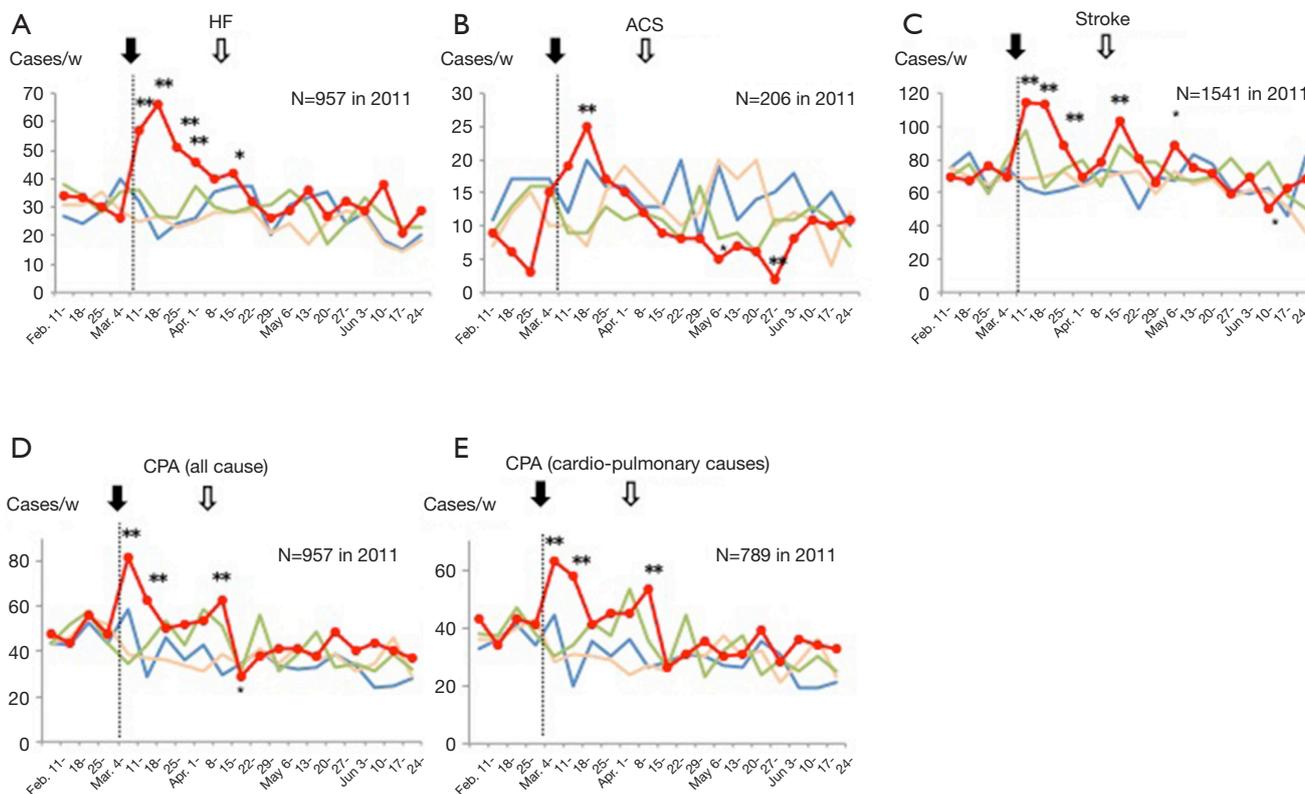


Figure 1 Time-course of weekly occurrences of cardiovascular diseases and pneumonia. (A-E) Weekly occurrences of heart failure (HF), acute coronary syndrome (ACS), stroke, cardiopulmonary arrest (CPA) and pneumonia were all significantly increased after the Earthquake. *, $P < 0.05$; **, $P < 0.01$. The number in the panels indicates the total number of the patients in 2011. Black arrows indicate the occurrence of the Great East Japan Earthquake (magnitude of 9.0, March 11, 2011), and white arrows indicate the largest aftershock (magnitude of 7.0, April 7, 2011).

heart rate variability in a 24-hour Holter recording before and after an earthquake (6). We also reported the increases in ventricular tachyarrhythmia after the Great East Japan Earthquake, which may be related to sympathetic nervous activation (7). Taken together, in the early phase after an earthquake, discontinuation of drugs, increased salt intake, activated sympathetic nervous system associated with extreme physical and mental stresses may cause blood pressure elevation (Figure 2).

In contrast, the mechanisms of prolonged elevation of blood pressure in the chronic phase after an earthquake remained to be elucidated. In the report by Ohira *et al.*, blood pressure of those living around the Fukushima Daiichi Nuclear Power Plant was significantly elevated in the 2 years after the Earthquake, and evacuation was an independent risk factor of hypertension among men (1). A recent study demonstrated that excess intake of salt

with β -adrenergic stimulation increases blood pressure via glucocorticoid receptors and WNK4, a regulator of sodium reabsorption (8). Increased levels of catecholamine and glucocorticoid by physical and mental stresses may lead to increased salt sensitivity under prolonged stressful environment, such as evacuation, and subsequently induce elevated blood pressure in the chronic phase (Figure 2). The authors reported that evacuation was significantly associated with increased incidence of diabetes and elevated low-density cholesterol level (9). Thus, evacuation forced evacuees to change their life-style, leading to increased risk of occurrence and/or worsening of life-style-related diseases in the chronic phase (Figure 2).

Earthquake and post-traumatic disease (PTSD)

PTSD is an important mental health disorder and is

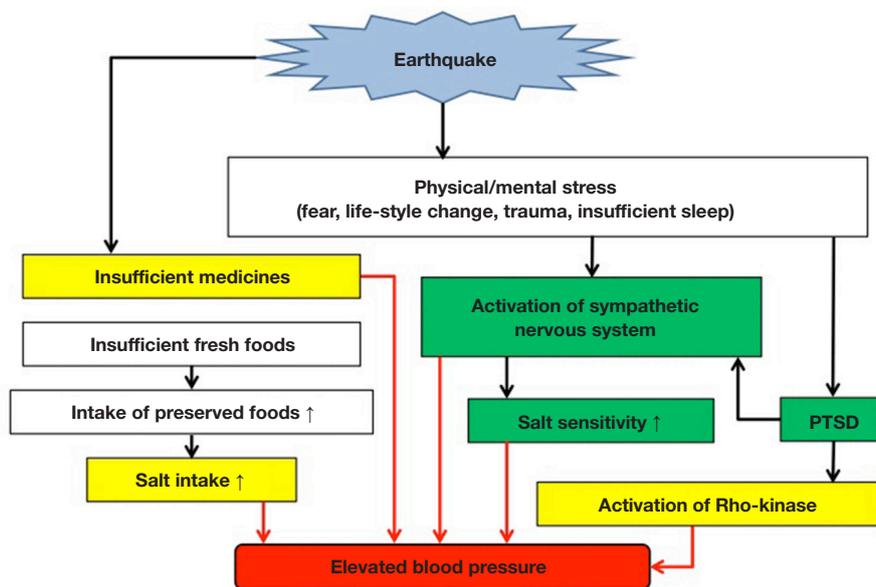


Figure 2 Possible relationship between hypertension and disaster-related risk factors. Several factors induced by the earthquake are considered to play important roles to develop hypertension. Factors in yellow may influence blood pressure in the acute phase and those in green may do so from the acute to chronic phase. PTSD indicates post-traumatic stress disorder. PTSD, post-traumatic disease.

noted in those exposed to extreme physical/mental stress. We have recently reported that the occurrence of PTSD was increased in 6 months after the Great East Japan Earthquake among the patient cohort in our prospective observational study, the Chronic Heart Failure Analysis and Registry in the Tohoku District-2 (CHART-2) (10). The occurrence around the Fukushima Daiichi Nuclear Power Plant was comparable to that in the tsunami stricken-area, and was significantly higher compared with other areas, suggesting that living around the Nuclear Power Plant after the Earthquake or evacuation from the plant area was associated with strong mental stress. Importantly, the occurrence of PTSD was significantly associated with increased incidence in cardiovascular events (10). A previous study elucidated that PTSD was independently associated with elevated blood pressure among military veterans with combat exposure (11). Although the association between PTSD and hypertension was not examined in the report by Ohira *et al.*, we consider that PTSD induced by the Earthquake may have an impact on elevated blood pressure in the chronic phase (Figure 2). Moreover, we reported transient activation of Rho-kinase, which is a molecular switch for vascular smooth muscle contraction, in association with PTSD after the Earthquake, which may contribute to the elevated blood pressure (12).

Although the influence of the radiation around the Fukushima Daiichi Nuclear Power Plant remains to be elucidated, it has been reported that change of life-style by evacuation resulted in substantial adverse effects in elderly people (13). In the Fukushima prefecture, a number of disaster-related death, indirectly caused by the earthquake and tsunami, accounted for more than half of the all disaster-related deaths in the prefecture (13). These results suggest that the resident in the Fukushima prefecture has been exposed to greater stress, compared with those living other areas, and the life-style change and various stresses induced by evacuation may cause blood pressure elevation. Thus, careful observation and long-term interventions for the evacuees' life-style, the life-style-related diseases and mental stress disorders including PTSD are required in order to reduce the risk of hypertension and the occurrence of cardiovascular diseases.

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