Preventive Medicine 82 (2016) 77–82

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Post-nuclear disaster evacuation and survival amongst elderly people in Fukushima: A comparative analysis between evacuees and non-evacuees

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ARTICLE INFO

Available online 22 November 2015

Keywords:
Fukushima nuclear incident
Evacuation
Elderly people
Mortality

ABSTRACT

Background. Considering the health impacts of evacuation is fundamental to disaster planning especially for vulnerable elderly populations; however, evacuation-related mortality risks have not been well-investigated. We conducted an analysis to compare survival of evacuated and non-evacuated residents of elderly care facilities, following the Great East Japan Earthquake and subsequent Fukushima Dai-ichi nuclear power plant incident on 11th March 2011.

Objective. To assess associations between evacuation and mortality after the Fukushima nuclear incident; and to present discussion points on disaster planning, with reference to vulnerable elderly populations.

Methods. The study population comprised 1,215 residents admitted to seven elderly care facilities located 20–40 km from the nuclear plant in the five years before the incident. Demographic and clinical characteristics were obtained from medical records. Evacuation histories were tracked until mid 2013. Main outcome measures are hazard ratios in evacuees versus non-evacuees using random-effects Cox proportional hazards models, and pre- and post-disaster survival probabilities and relative mortality incidence.

Results. Experiencing the disasters did not have a significant influence on mortality (hazard ratio 1.10, 95% confidence interval: 0.84–1.43). Evacuation was associated with 1.82 times higher mortality (95% confidence interval: 1.22–2.70) after adjusting for confounders, with the initial evacuation from the original facility associated with 3.37 times higher mortality risk (95% confidence interval: 1.66–6.81) than non evacuation.

Conclusions. The government should consider updating its requirements for emergency planning for elderly facilities and ensure that, in a disaster setting, these facilities have the capacity and support to shelter in place for at least sufficient time to adequately prepare initial evacuation.

Introduction

Safe evacuation is of paramount importance in disaster settings. In the case of the 2005 Hurricanes Katrina and Rita and 2008 Hurricane Gustav in the United States the evacuation of elderly care home residents resulted in increased morbidity and mortality (Dosa et al., 2007, 2012; Brown et al., 2012; Thomas et al., 2012). The analysis of data on elderly evacuees following Japan's Fukushima Daiichi Nuclear Plant incident precipitated by the Great East Japan Earthquake on March 11, 2011 also suggested that evacuation was associated with increased mortality (NAIIC, 2012; Ishikawa, 2013; Kiura, 2013). On the day following this incident (March 12, 2011), the Japanese government issued a mandatory evacuation order for those living within a 20 km radius of the nuclear plant, and on March 15, 2011, an indoor shelter instruction was given to residents in the 20 to 30 km zone. A total of 1770 elderly evacuees from 34 care homes within the 20 km zone experienced approximately 2.4 times higher mortality risk when compared to mortality data from the previous year (Yasumura et al., 2013). In retrospect this significant increase in mortality can be contrasted with the likely limited acute radiation damage (Tsubokura et al., 2012, 2013a, 2013b,2013c; Hayano et al., 2013).

Rigorous comparative analyses before and after the evacuation were performed by Nomura et al. (2013). The authors evaluated mortality risks amongst residents of five of eight care homes in Minamisoma city located 20 to 30 km from the nuclear plant, outside the mandatory evacuation zone but within the indoor sheltering zone, and which were evacuated after the incident due to shortages of care staff and essential

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http://dx.doi.org/10.1016/j.ypmed.2015.11.014
0091-7435/

medical supplies (Nomura et al., 2013). The authors reported that compared to the period before the disasters, the overall relative mortality incidence after the disasters was 2.68 (95% CI: 2.04–3.49), with a substantial variation across the facilities.

This previous analysis was restricted to data from residents who evacuated, but because there was no control group (i.e., non-evacuees) it was not possible to investigate whether the observed increased mortality was associated with stress from the disasters, facility-specific evacuation processes, or care quality at evacuation sites. In this extended study we employed additional data from non-evacuees from elderly care facilities in the neighbouring Soma city. The inclusion of data on non-evacuees enabled an estimation of the impact on mortality risk of experiencing the disasters versus evacuation. This is the first comparative assessment between evacuees and non-evacuees after the Fukushima Daiichi nuclear incident.

The research objectives of the present study are two-fold: to assess the association between evacuation and mortality risk amongst elderly people after the Fukushima Daiichi nuclear incident; and to present discussion points on disaster planning for the elderly population.

Material and methods

Design, settings, and participants

We used data collected for the previous survival analysis conducted by Nomura et al. (2013), which was obtained from five of the eight care homes in Minamisoma, representing 62% of all care home residents in the city at the time of the disasters. To provide additional information on non-evacuees, we collected data from the two facilities in Soma city, neither of which conducted evacuation. All elderly residents who had been admitted to one of these seven facilities in Minamisoma/Soma between March 11, 2006 and March 11, 2011 were included in this analysis. The locations of Soma and Minamisoma, relative to the Fukushima Daiichi nuclear power plant, are shown in Fig. 1. Note that there are two main types of care homes in Japan: intensive care homes and rehabilitation facilities. Four facilities in Minamisoma are intensive care homes, which provide general rehabilitation and end of life care with those who have difficulty rehabilitating at home. One facility in Minamisoma and two in Soma are rehabilitation facilities for the elderly, which make efforts to enable residents to rehabilitate at home. Both facility types admit residents regardless of their care levels and health conditions.

Data on residents' demographic and clinical characteristics, and entry records (age and sex at death, withdrawal or end of study), was obtained from their medical records. These data included care level on a scale of 1 to 5, measuring severity of care needs based on the Japanese Category of Condition of Need for Long-Term Care (Ministry of Health, Labour and Welfare, 2012). This scale is an indicator of severity of disability and does not necessarily reflect health condition (Beland and Zunzunegui, 1999). In order to support clinical and policy interpretations, we defined residents with care level of 1 to 4 as requiring low/moderate care and those with care level of 5 as requiring high care, as with the definition in Nomura et al. (2013). No reliable records of the cause of death were able to be obtained.

Residents in the facilities in Minamisoma experienced multiple evacuations, with evacuation histories tracked until between August 31, 2011 and February 2, 2012, depending on the facility. They comprised date and site of the evacuations. The additional data from Soma followed residents until September 25, 2013 (Facility 6) and September 3, 2013 (Facility 7). These facilities in Soma did not conduct evacuation, except for one self-evacuee (n = 1, 0.5%). Evacuation distances were calculated using the Google Maps API with R software version 2.15.0. We measured the distance between the care facility (or previous evacuation site for subsequent evacuations) to the evacuation sites as the shortest distance on a public road. Finally, we conducted interviews with the care home presidents and/or care-givers in order to understand the emergency situation in each care home at the time of the disaster.

Statistical analysis

Hazard ratio

To assess the evacuation-related mortality risk, we employed a Cox proportional hazards regression model. We conducted two separate Cox multiple regression analyses:

1) To evaluate the mortality risk of the evacuation itself, we undertook a comparative analysis of survival between non-evacuees and evacuees. To adjust for the potential effect on mortality of experiencing the disasters, we used both pre- and post-disaster data. Data of those who survived beyond the date of disasters (i.e., March 11, 2011) were divided into pre- and post-disaster periods, indicating non-disaster-exposed data, and disaster-exposed data, respectively.
2) To evaluate the mortality risk of the initial evacuation from the original facility versus subsequent evacuations we investigated the post-disaster data amongst evacuees.

All covariates identified in our previous study, such as care level, and basic variables known to be associated with mortality, such as age and sex, as well as covariates of primary interest, such as evacuation type and experience of disaster, were entered into the models regardless of their significance as long as stable models were obtained. For both analyses, selection of variables were based on the backward-stepwise method with p-to-remove of >0.05 (McCuen, 2003). Backward-stepwise regression starts with all the candidate

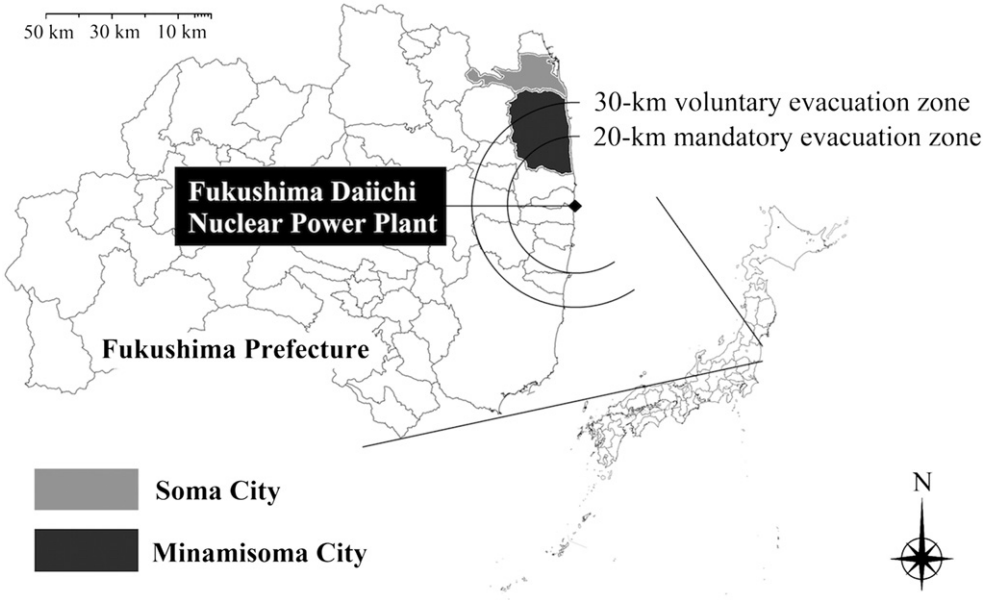

Fig. 1. Geographical location of Minamisoma city and Soma city.