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REGULAR ARTICLE

Association between the incidence of premature rupture of membranes in pregnant women and seismic intensity of the Noto Peninsula earthquake

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Abstract

Objectives The Noto Peninsula earthquake struck the coast of the Noto Peninsula, Japan on March 25, 2007, resulting in the death of one woman and injury to 356 people. A total of 684 houses were totally destroyed by this earthquake, and more than 2,500 people were forced to live at shelters. In this study, we have evaluated the association between the incidence of peripartum abnormalities and seismic intensity of the Noto Peninsula earthquake.

Methods Demographic data, births, seismic intensity of the earthquake and the incidence of peripartum abnormalities between June 25, 2007 and January 31, 2008 were surveyed. The dataset included 126 pregnant women who lived in the disaster area. The seismic intensity of the earthquake was expressed on the scale (0–7, with 7 being the strongest measure) used by the Japan Meteorological Agency. The subjects of the analysis included 19.7% of the pregnant women affected by the disaster.

Results Of the pregnant women included in this study, 7.9% had a premature rupture of membranes (PROM), with the percentage being significantly higher in the group that experienced a seismic intensity of 6 than in that experienced a seismic intensity of 5.

Conclusions Our epidemiologic study shows that the PROM among our study cohort was associated with seismic intensity, suggesting that the physical outcome was due to aftershocks of the earthquake at a seismic intensity $\geq$6. This outcome may result from the psychological stress caused by the earthquakes.

Keywords Earthquake · Peripartum abnormality · Pregnancy · Premature rupture of membranes · Seismic intensity

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Introduction

The Noto Peninsula earthquake struck the coast of the Noto Peninsula, Japan at 9:41 a.m. on March 25, 2007. According to the Japanese Meteorological Agency, the earthquake measured 6.9 on the Richter scale. About 500 aftershocks followed during a 3-month period. One woman died as a direct result of the earthquake, and 356 people were injured; a total of 684 houses were completely destroyed. More than 2,500 people were forced to live at shelters.

Pregnant women have been reported that they have experienced a range of peripartum abnormalities with the occurrence of the 2004 Sri Lanka earthquake (9.0 on the Richter scale), the 1999 Taiwan earthquake (7.3 on the Richter scale), and the 1995 Hanshin-Awaji earthquake (7.3 on the Richter scale), respectively [1–3]. More specifically, undernutrition and low body weight among pregnant women were reported to be effects of the 2004 Sri Lanka earthquake [1], an increase in low-birth-weight infants was reported as an effect of the 1999 Taiwan earthquake [2], and a low sex ratio was reported as an effect of the 1995 Hanshin-Awaji earthquake [3]. Schoenfeld et al. [4] reported that the unique physiology of pregnant woman may affect the outcome of crush injury in earthquakes. However, these studies and others [5–7] have made no mention of the influence of earthquakes on the premature rupture of the membranes (PROM) nor did they focus on the relationship between seismic intensity (i.e., the degree of shaking) and women experiencing peripartum abnormalities. The seismic intensity of an earthquake is given as a number on a scale of 0–7 (with 7 being the strongest) by the Japan Meteorological Agency. The scale number denotes the degree of shaking at a point on the ground. As a result, in most places, seismic intensity decreases with the distance from the earthquake center, although the seismic intensity as some locations is not proportional to the distance.

We have carried out an epidemiological study with the aim of evaluating the effects of the Noto Peninsula earthquake on the health of pregnant women in terms of the incidence of peripartum abnormalities and seismic intensity.

Materials and methods

Subjects

The study cohort consisted of 126 pregnant women who had suffered hardship in the disaster area when the earthquake occurred and who subsequently visited a maternity clinic in the disaster area for a health evaluation. Four of five maternity hospitals in the disaster area cooperated in this study, and the medical staffs in these hospitals obtained the informed consent from the participants, who were receiving regular prenatal examinations. In Japan, all pregnant women must record their pregnancy at official centers in their towns, cities or villages and subsequently receive regular prenatal examination in local or regional hospitals. Therefore, the medical histories of all pregnant women in this study are available at these hospitals.

In the disaster-stricken areas (Nanao and Wajima cities and Anamizu, Noto, and Shika towns), 927 infants were born between April 2006 and March 2007, was based on reports of a birth. During this period, 724 of these 927 infants (78.1%) were born at the four participating facilities. Because the percentage of pregnant women visiting a hospital is calculated as the number of annual births (252/365; 69%), the number of pregnant women visiting the four facilities at the time of the earthquake was estimated as 500 of 724 (69%). Consequently, the 126 participants in the study may represent 25.2% of 500 pregnancies at these four facilities and 19.7% of all 640 pregnancies in the entire disaster area (69% of 927 births).

Methods

The survey period of this cross-sectional study was from June 25, 2007, (3 months after the earthquake) through to

Table 1 Basic characteristics of study subjects

Demographic characteristics of study group	Seismic intensity 5	Seismic intensity 6	*p*
Age (years)	31.1 ± 5.2 (50)	30.3 ± 4.5 (72)	0.38†
Gestational age at the time of the earthquake disaster (weeks)	15.0 ± 7.9 (48)	16.5 ± 8.7 (70)	0.35†
Birth weight of infants (g)	3128.6 ± 413.2 (50)	3024.0 ± 352.2 (70)	0.14†
Gestational length (weeks)	39.3 ± 1.5 (50)	39.2 ± 1.4 (68)	0.59†
Duration of labor[a] (h)	8.3 ± 7.2 (42)	8.3 ± 5.3 (56)	0.43‡
Amount of blood loss during delivery (ml)	335.5 ± 325.2 (44)	412.4 ± 438.1 (61)	0.14‡
Parity	68.8% (48)	68.5% (73)	0.57¶
Cesarean delivery	16.0% (50)	15.7% (70)	0.58¶

Values are given as the mean ± standard deviation, with the exception of parity and cesarean delivery, for which they are given as a percentage. Values in parenthesis representing the number of subjects

† *P* values by student's *t* test

‡ *P* values by the Mann–Whitney *U* test

¶ *P* values by the chi-square test,

[a] Duration of labor except for subjects who delivered by cesarean delivery

Table 2 The incidence of peripartum abnormalities according to seismic intensity

Peripartum abnormalities	Variable	Seismic intensity [*n* (%)]		Sum	*p* value
		5	6		
Varicose veins	Yes	0 (0.0)	1 (1.4)	1	1.000
	No	50 (100.0)	71 (98.6)	121	
Pregnancy-induced hypertension	Yes	5 (10.0)	6 (8.3)	11	1.000
	No	45 (90.0)	66 (91.7)	111	
Premature rupture of membranes	Yes	1 (2.0)	9 (12.5)	10	0.046
	No	49 (98.0)	63 (87.5)	112	
Infection (candida, chlamydia, Bacterial vaginosis)	Yes	13 (26.0)	15 (20.8)	28	0.505
	No	37 (74.0)	57 (79.2)	94	
Infection (Group B streptococcus)	Yes	5 (10.0)	6 (8.3)	11	0.752
	No	45 (90.0)	66 (91.7)	111	
Chorioamnionitis	Yes	1 (2.0)	4 (5.6)	5	0.648
	No	49 (98.0)	68 (94.4)	117	
Placental insufficiency	Yes	1 (2.0)	3 (4.3)	4	0.640
	No	49 (98.0)	67 (95.7)	116	
Preterm birth	Yes	3 (6.0)	2 (2.9)	5	0.649
	No	47 (94.0)	66 (97.1)	113	
Birth weight of infants	$<$2,500 g	2 (4.0)	2 (2.9)	4	1.000
	$\geq$2,500 g	48 (96.0)	68 (97.1)	116	
Atonic bleeding	Yes	2 (4.0)	4 (94.3)	6	1.000
	No	48 (96.0)	66 (94.3)	114	
Mastitis	Yes	3 (6.0)	7 (10.0)	10	0.519
	No	47 (94.0)	63 (90.0)	110	
Uterine subinvolution	Yes	3 (6.0)	5 (7.1)	8	1.000
	No	47 (94.0)	65 (92.9)	112	

p Value by Chi-square test

January 31, 2008. A questionnaire survey was conducted in which the subjects were asked to personally fill out the form. The completed questionnaires were kept in a locked container or collected by mail. We surveyed demographic data and the seismic intensity of earthquake. We received the consent of the participants to review their medical charts for any peripartum abnormalities diagnosed after the earthquake and birth process. The presence of abnormalities in the gestational, intrapartum and postpartum periods were diagnosed by the doctor handling the pregnancy. For the gestational period, we investigated the presence of varicose veins, pregnancy-induced hypertension, PROM, infection (candida, chlamydia, bacterial vaginosis and Group B streptococcus), chorioamnionitis, and placental insufficiency. PROM was diagnosed clinically by the amnisure test at each facility. For the intrapartum period, we evaluated preterm birth and low-birth-weight infants. For the postpartum period, we investigated atonic bleeding, mastitis, uterine subinvolution. Age, address, and gestational age at the time of the earthquake were included as demographic data. The gestational age was divided into three trimesters, with the first trimester set as the period before 16 complete weeks of gestation, the second set at 16–27 complete weeks of gestation (from 16 weeks 0 days through to 27 weeks 6 days), and the third trimester set at $\geq$28 complete weeks of gestation. Gestational length, duration of labor, amount of blood loss during delivery, and birth weight recorded on the medical chart were investigated as the birth process. By cross-checking the addresses of the subjects at the time of earthquake and the seismic intensity table released by the Disaster Information Center of the Ministry of Land, Infrastructure, Transport and Tourism [8], we were able to estimate the seismic intensity experienced by each participant at the time of the earthquake in our study.

We received approval for this study from the ethical committee of Kanazawa University Graduate School of Medical Science (approval number 525), and the study was in accordance with the Declaration of Helsinki. All subjects provided informed consent before being included in the study.

Statistical analysis

Pearson or Spearman correlation coefficients were calculated to determine the association between two variables. The chi-square test was used for assessing two variables independently. The *t* test or Mann–Whitney test were used to assess the mean values between two groups, and the analysis of variance (ANOVA) or Kruskal–Wallis tests were used to assess the mean values among three groups. The Statistical Package for Social Sciences ver. 16.0 for Windows (SPSS, Chicago, IL) was used for the analysis, and $p < 0.05$ was regarded as being statistically significant in all tests.

Results

The mean age of the subjects was 30.6 [standard deviation (SD) 4.7, range 17–41] years, and the birth history of the subjects was primipara (38, 30.2%), multipara (83, 65.9%), and unknown (5, 3.9%). Modes of delivery were vaginal delivery (101, 80.1%), cesarean delivery (19, 15.1%), and unknown due to a change of clinic (6, 4.8%). In terms of the seismic intensity likely experienced by the subjects ($n = 126$), three (2.4%) of the pregnant women likely experienced a seismic intensity of 4; 13 (10.3%), a seismic intensity <5; 37 (29.4%), a seismic intensity >5; 18 (14.3%), a seismic intensity of <6; 55 (43.7%), a seismic intensity >6.

Three subjects experiencing a seismic intensity of 4 were excluded from the statistical analysis because of a scarcity of subjects. Consequently, data on 123 subjects were analyzed. Table 1 shows the basic characteristics of the women experiencing seismic intensities of 5 and 6, respectively. There was no difference in age, parity, cesarean delivery and birth process between these two groups of women.

Table 2 shows the characteristics of women with peripartum abnormalities who experienced the earthquake at a seismic intensity of 5 or 6. There is a significant difference ($p < 0.05$) between these two groups in terms of the percentage of pregnant women with PROM, with 12.5% of latter (scale 6 earthquake) and 2.0% of the former (scale 5 earthquake) having PROM. None of three subjects who experienced a seismic intensity of 4 had PROM. The map in Fig. 1 shows the geographic association between the presence of PROM and seismic intensities in the Noto Peninsula earthquake. Blue squares mean pregnant women with PROM and white squares mean pregnant women without PROM. All cases of PROM were in term patients.

Tables 3 and 4 show the incidence of peripartum abnormalities according the gestational trimester at the time of the earthquake disaster in the pregnant women who experienced a seismic intensity of 5 or 6. We did not observe any significant differences in the percentages of peripartum abnormalities according to the trimester at the time of the earthquake disaster.

Discussion

Undernutrition and low body weight were reported in pregnant women who had experienced the 2004 Sri Lanka earthquake (seismic intensity 9.0 on the Richter scale) [1], and an increase in low-birth-weight infants was as a consequence of the 1999 Taiwan earthquake (7.3 on the Richter scale) [2]. It is significant that these studies found an association between peripartum abnormalities and the occurrence of a catastrophic earthquake that directly affected the pregnant women.

A number of major earthquakes have occurred in Japan in recent years: the 2004 Niigata Chuetsu earthquake (6.8 on the Richter scale), the 2005 Fukuoka earthquake (7.0 on the Richter scale), the 2007 Noto Peninsula earthquake (6.9 on the Richter scale), the 2007 Niigata Chuetsu-oki earthquakes (6.8 on the Richter scale), and the 2008 Iwate-Miyagi Nairiku earthquake (7.2 on the Richter scale). Of all earthquakes with a Richter scale assessment of ≥6.0, 20.5% occur in Japan [9]. However, there have been few epidemiological studies on the effect of such earthquakes

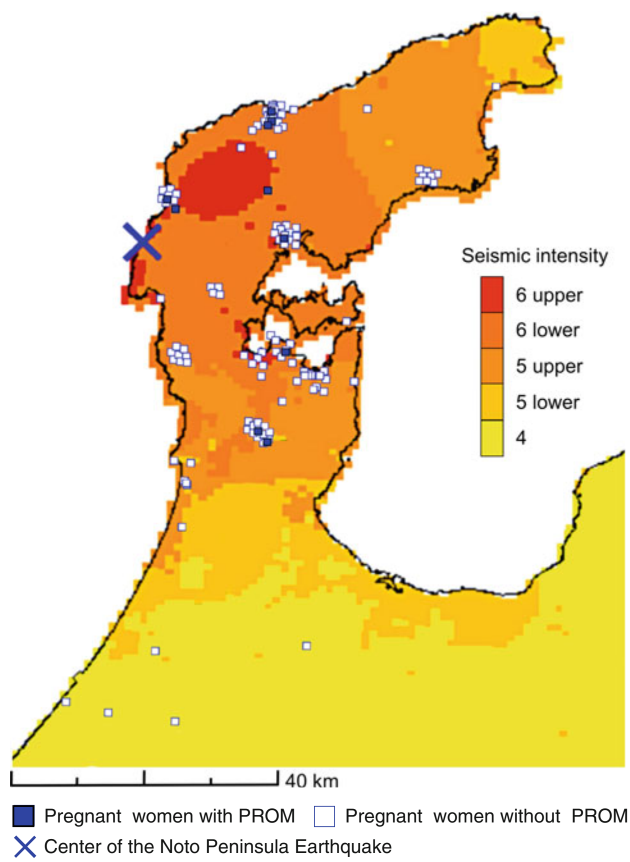

Fig. 1 The geographic association between the presence of premature rupture of membranes (*PROM*) and seismic intensities of the Noto Peninsula earthquake. *Blue squares* Pregnant women with PROM, *white squares* pregnant women without PROM, *large X* center of the Noto Peninsula earthquake (color figure online)

Table 3 Peripartum abnormalities in pregnant women at seismic intensity 5 according to gestational trimester at the time of the earthquake disaster

Peripartum abnormalities	Variable	The first trimester (<16 weeks of gestation) *n* (%)	The second trimester (16–27 weeks of gestation[a]) *n* (%)	The third trimester (≥28 weeks of gestation) *n* (%)	*p* value
Varicose veins	Yes	0 (0.0)	0 (0.0)	0 (0.0)	–
	No	28 (100.0)	17 (100.0)	3 (100.0)	
Pregnancy-induced hypertension	Yes	3 (10.7)	2 (11.8)	0 (0.0)	0.83
	No	25 (89.3)	15 (88.2)	3 (100.0)	
Premature rupture of membranes	Yes	1 (3.6)	0 (0.0)	0 (0.0)	0.69
	No	27 (96.4)	17 (100.0)	3 (100.0)	
Infection (candida, chlamydia, Bacterial vaginosis)	Yes	9 (32.1)	4 (23.5)	0 (0.0)	0.45
	No	19 (67.9)	13 (76.5)	3 (100.0)	
Infection (Group B Streptococcus)	Yes	2 (7.1)	2 (11.8)	0 (0.0)	0.75
	No	26 (92.9)	15 (88.2)	3 (100.0)	
Chorioamnionitis	Yes	0 (0.0)	1 (5.9)	0 (0.0)	0.39
	No	28 (100.0)	16 (94.1)	3 (100.0)	
Placental insufficiency	Yes	0 (0.0)	1 (5.9)	0 (0.0)	0.39
	No	28 (100.0)	16 (94.1)	3 (100.0)	
Preterm birth	Yes	2 (7.1)	1 (5.9)	0 (0.0)	0.89
	No	26 (92.9)	16 (94.1)	3 (100.0)	
Birth weight of infants	<2,500 g	2 (7.1)	0 (0.0)	0 (0.0)	0.48
	≥2,500 g	26 (92.9)	17 (100.0)	3 (100.0)	
Atonic bleeding	Yes	1 (3.6)	1 (5.9)	0 (0.0)	0.87
	No	27 (96.4)	16 (94.1)	3 (100.0)	
Mastitis	Yes	1 (3.6)	2 (11.89)	0 (0.0)	0.49
	No	27 (96.4)	15 (88.2)	3 (100.0)	
Uterine subinvolution	Yes	2 (7.1)	0 (0.0)	1 (33.3)	0.09
	No	26 (92.9)	17 (100.0)	2 (66.7)	

p Value by Chi-square test

[a] The interval covered 16 weeks 0 days through 27 weeks 6 days

on public health, especially on pregnancy [3], and no study has investigated the association between seismic intensity and health effects on pregnant women. One possible explanation for this is the difficulty in defining victims of a natural disaster, with direct trauma, as also suffering from the health effects of that natural disaster, such as an earthquake. Consequently, the impact of the natural disaster on health may be incorrectly calculated. Therefore, to evaluate the health effects of the Noto Peninsula earthquake on peripartum women, we compared peripartum abnormalities and seismic intensity using epidemiological cross-sectional methods. Our results (Table 2 and Fig. 1) show that the percentage of PROM was significantly higher in pregnant women experiencing a seismic intensity of 6 (12.5%) than in those experiencing a seismic intensity of 5 (2.0%), suggesting that earthquakes measuring 6.9 on the Richter scale produce PROM.

The diagnosis of PROM is usually established by the direct observation of amniotic fluid pooling in the vaginal vault. Duff [10] reported that PROM occurs in 5–10% of pregnancies, with approximately 60% of cases comprising term patients. Previous studies [11–13] reported that PROM at term is a complication in approximately 8% of term pregnancies. The percentage of PROM was 7.9% (n =126) in this study, and all cases of PROM were term patients. Therefore, the prevalence of PROM in this study reasonably approximates that reported in previous studies.

It has been reported that infection of the lower genital tract and/or amniotic cavity is one of the most important etiologies of PROM [10, 14]. The cause of PROM is almost certainly multifactorial [14]. Traditionally, PROM has been attributed to increasing physical stresses that weaken the membranes [14]. At the molecular level, PROM appears to result from diminished collagen synthesis,

Table 4 Peripartum abnormalities in pregnant women at seismic intensity 6 according to gestational trimester at the time of the earthquake disaster

Peripartum abnormalities	Variable	The first trimester (<16 weeks of gestation) *n* (%)	The second trimester (16–27 weeks of gestation[a]) *n* (%)	The third trimester (≥28 weeks of gestation) *n* (%)	*p* value
Varicose veins	Yes	1 (2.8)	0 (0.0)	0 (0.0)	0.62
	No	35 (97.2)	24 (100.0)	10 (100.0)	
Pregnancy-induced hypertension	Yes	4 (11.1)	0 (0.0)	1 (10.0)	0.24
	No	32 (88.9)	24 (100.0)	9 (90.0)	
Premature rupture of membranes	Yes	3 (8.3)	3 (12.5)	3 (30.0)	0.19
	No	33 (91.7)	21 (87.5)	7 (70.0)	
Infection (candida, chlamydia, Bacterial vaginosis)	Yes	7 (19.4)	7 (29.2)	0 (0.0)	0.15
	No	29 (80.6)	17 (70.8)	10 (100.0)	
Infection (Group B Streptococcus)	Yes	3 (8.3)	2 (8.3)	1 (10.0)	0.99
	No	33 (91.7)	22 (91.7)	9 (90.0)	
Chorioamnionitis	Yes	2 (5.6)	1 (4.2)	1 (10.0)	0.80
	No	34 (94.4)	23 (95.8)	9(90.0)	
Placental insufficiency	Yes	3 (8.8)	0 (0.0)	0 (0.0)	0.21
	No	31 (91.2)	24 (100.0)	10 (100.0)	
Preterm birth	Yes	1 (3.0)	1 (4.3)	0 (0.0)	0.81
	No	32 (77.0)	22 (95.7)	9 (100.0)	
Birth weight of infants	<2,500 g	2 (5.9)	0 (0.0)	0 (0.0)	0.36
	≥2,500 g	32 (94.1)	24 (100.0)	10 (100.0)	
Atonic bleeding	Yes	1 (2.9)	2 (8.3)	0 (0.0)	0.47
	No	33 (97.1)	22 (91.7)	10 (100.0)	
Mastitis	Yes	3 (8.8)	2 (8.3)	2 (20.0)	0.55
	No	31 (91.2)	22 (91.7)	8 (80.0)	
Uterine subinvolution	Yes	1 (2.9)	4 (16.7)	0 (0.0)	0.09
	No	33 (97.1)	20 (83.3)	10 (100.0)	

p Value by Chi-square test

[a] The interval covered 16 weeks 0 days through 27 weeks 6 days

altered collagen structure, and accelerated collagen degradation, possibly in association with concurrent cellular changes within the fetal membranes [14]. Women with a greater lifetime exposure to trauma have been found to have a higher rate of PROM and longer maternal hospital stays [15]. Many studies have also reported that stress affects pregnancy outcome [16–22]. In a search for an association between seismic intensity and stress, Maruyama et al. [23] reported that higher seismic intensity was associated with each severe life event and ill mental health among the victims of Hanshin-Awaji earthquake. Our results suggest that the development of PROM seems to be due to the psychological stress caused by the earthquake and the aftershocks at a seismic intensity ≥6.

This is the first epidemiological study that has shown an association between seismic intensity and PROM and which has focused on the degree of shaking at one point on the ground. Only seismic intensity—not Richter scale score—can determine the area actually affected by the earthquake.

A major limitation of this study is the small sample size. To clarify any further association between peripartum abnormalities and seismic intensity, data should be assessed using a larger population exposed to various seismic intensities. Since the factors for PROM are complex, the results of this study may not relate to a causal relationship between PROM and earthquakes. Nevertheless, our results do show an association between seismic intensity and PROM because the incidence of PROM was higher as the seismic intensity increased. It is necessary to take seismic intensities into account when caring for pregnant women.

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