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Marginal internal radio-contamination in end-stage renal disease patients living in areas affected by the Fukushima Daiichi nuclear power plant disaster

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1	Title: Marginal internal radio-contamination in end-sta
2	renal disease patients living in areas affected by
3	Fukushima Daiichi nuclear power plant disaster
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Objective

To assess internal radio-contamination of end-stage renal disease (ESRD) patients who were regularly taking hemodialysis (HD) and living in areas affected by the crippled Fukushima Daiichi nuclear plant after the Great East Japan Earthquake on March 11, 2011.

40 <u>Methods</u>

Internal radio-contamination in 111 ESRD patients regularly taking HD at Jyoban Hospital in Iwaki city, Fukushima from July 2012 to November 2012 was assessed with a whole body counter (WBC). The maximum annual effective dose was calculated from the detected Cs-137 levels. Interviews concerning patient dietary preferences and outdoor activities were also conducted.

48 <u>Results</u>

Among the 111 patients tested, internal radio-contamination with Cs-137 was detected in 2 subjects, but the levels were marginal and just exceeded the detection limit (250 Bg/body). The tentatively calculated maximum annual effective dose ranged from 0.008 to 0.009 mSv/year, which is far below the 1 mSv/year limit set by the government of Japan. While the ESRD subjects had significantly more chance to consume locally grown produce which was not distributed to the market compared to non-ESRD subjects (p < 0.001), the percentage of ESRD subjects with detectable Cs (1.8%) was not statistically higher than that for non-ESRD subjects (0.6%)(p=0.16).

Conclusions

These findings suggest that internal radio-contamination levels and the calculated annual additional effective doses were negligible for ESRD patients taking HD in areas affected by the crippled Fukushima nuclear plant. Although hemodialysis is suggested to promote Cs-137 excretion,

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continuous inspection of locally grown produce together with WBC
screening for radio-contamination should be continued for ESRD patients
regularly taking HD.

69 Strenghts and limitations of this study

The present study is an unprecedented report to assess the internal radio-contamination for the chronic kidney disease patients on hemodialysis living in areas affected by the Fukushima Daiichi nuclear power plant disaster, and illustrates that contamination of Cs-137 was detected for two subjects even after 18 months after the incidence, but its levels were negligible, though hemodialysis is considered to more efficiently promote excretion of internal Cs than normal renal function.

The subject number is too small to extend present findings for the similar hemodialysis patients in the affected areas surrounding the crippled nuclear plant.

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97 INTRODUCTION

The aftermath of the Great East Japan Earthquake that occurred on March 11, 2011 brought diverse health threats and impaired medical care services for residents living in the affected areas during different periods.¹⁻³ Residents of the radio-contaminated areas surrounding the Fukushima Daiichi nuclear power plant that was crippled by the earthquake and tsunami were forced to consider possible health threats, mainly from radiation exposure.^{4,5} To reduce health threats and avoid undesirable radiation exposure, accurate assessment of radiation exposure of residents living in the radio-contaminated areas was necessary. Monitoring of the ambient air doses provided a basis for establishing safe residential regions in the affected areas.⁶ Moreover, inspection of produce grown in affected areas and whole body counter (WBC) measurement of internal radio-contamination of residents living in affected areas were performed to ensure that their annual effective dose from internal radiation exposure was below governmental limits.7

Our series of studies revealed that internal radiation exposure was marginal in the aftermath of the nuclear incident and that for nearly all examinees the doses from internal radiation exposure were far below the government-allowed limit (1 mSv/year).⁸⁻¹¹ However, a small percentage (1-2 %) of the examinees did show detectable internal Cs-137 radio-contamination within one year of the incident, and even beyond one year Cs-137 could still be detected in a few individuals.^{12,13} This radio-contamination could presumably be attributed to the intake of contaminated, locally grown produce that did not undergo radiation inspection. The findings from these studies clearly suggest that internal radiation exposure is manageable for residents living in radio-contaminated areas, but continuous WBC screening and food inspection is mandatory at the present time.

126 Although systematic WBC screening has been performed for voluntary 127 hospital visitors and schoolchildren younger than 16 years old, no specific 128 screening has been done for hospital patients. In this regard, end-stage

renal disease (ESRD) patients undergoing dialysis could represent a patient population among affected residents, since hemodialysis (HD) requires large amounts of tap water that could be contaminated with radionuclides that were reported to have been released from the crippled nuclear plant disaster^{14,15} immediately after the Measurement of internal radio-contamination in ESRD patients living in the affected areas is an unprecedented clinical opportunity to assess previous reports indicating that HD is more effective in eliminating radio-cesium in ESRD patients relative to non-ESRD patients.¹⁶⁻¹⁸ The present study was thus conducted to assess internal Cs contamination in ESRD patients from July 2012 to November 2012. Among the 111 examinees measured by WBC, very low levels of radio-cesium were detected in 2 patients, and after 18 months measureable radio-cesium persisted in these ESRD patients. These findings suggest that, while HD may promote radio-cesium excretion, ESRD patients face radio-contamination risks that are similar to those of healthy individuals living in areas affected by the nuclear accident.

146 METHODS

Patients

An internal radiation exposure-screening program was conducted between and December 31, 2014 to April 1, assess internal radio-contamination among all residents in affected areas that were south of the Fukushima nuclear plant. There were no costs to the residents to participate in the program.

153 Subjects of this study were ESRD patients undergoing HD who were 154 among voluntary visitors to Jyoban Hospital. The study subjects were 155 examined after obtaining informed consent to collect data on age, sex, and 156 results of the internal radiation exposure-screening program during the 157 study period.

159 Assessment of internal radiation exposure by WBC

160 Internal radio-contamination was assessed by WBC measurements at the

Jyoban Hospital between July, 2012 and November, 2012. The recorded major variables for the patients were age, sex, and the total body burden of radioactive Cs (Cs-134 and Cs-137). The patients changed into a hospital gown before WBC measurement to exclude any radio-contamination that may have been present on their clothing.

167 Measurement procedure

The WBC device used was a stereoscopic apparatus with two 3 x 5 x 16 inch NaI scintillation detectors (Fastscan Model 2251; Canberra, Inc., Meriden, CT, USA). The Cs detection limits in a two-minute scan were 220 and 250 Bq/body for Cs-134 and Cs-137, respectively.

173 Calculation of effective dose from detected Cs-137 internal 174 contamination

175 Calculation of annual effective doses based on observed levels of internal

176 Cs-137 contamination was performed using effective dose coefficients

177 derived from the International Commission on Radiological Protection,

178 Publication 67, wherein the amount of Cs activity detected by WBC

179 examinations is assumed to be in an equilibrium state between consecutive

180 ingestions and excretions over the course of one year.¹⁹ As there is no

181 available information to calculate the annual effective doses that reflect the

182 observed levels of internal Cs-137 contamination in patients with renal

183 disease, we tentatively calculated the annual effective doses of the present

184 subjects with respect to healthy subjects who had normal renal function.

Dietary counseling

In addition to the WBC measurements, the tested participants were
interviewed using unstructured forms. Study subjects were asked if they
frequently consumed locally grown produce that had not undergone
radiation inspection. Beginning on April 1, 2012, a maximum allowed limit
of 100 Bq/kg of Cs was set for general foods, thus commercially available
foods were considered to have been monitored regardless of their origins

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(i.e. Fukushima or non-Fukushima).²⁰ The patients were also asked about how much time they spent outdoors. **Ethics** All study participants provided written documentation for informed consent, and the protocol for assessing internal radio-contamination was approved by the Jyoban Hospital institutional review board. RESULTS A whole blood counter (WBC) radiation exposure screening of 111 end-stage renal disease (ESRD) patients regularly taking hemodialysis (HD) was conducted in Jyoban Hospital between July 2012 and November 2012. Among the 111 patients, 26 (23.4%) were women, and their ages ranged from 25-83 years, with a median age of 61 years. Internal radio-contamination with Cs was detected for 2 of the 111 subjects (Fig. 1). The number of voluntary hospital visitors who did not have kidney disease and underwent WBC screening during the same period is shown in Table. 1. The percentage of ESRD patients with detectable Cs (1.8%) was higher than that for non-ESRD subjects (0.6%), but this difference was not statistically significant (p = 0.16, determined by Fisher's Exact test). Moreover, among the putative radionuclides released from the crippled Fukushima nuclear plant, only Cs-137 was detected while Cs-134 levels were below the detection limit (220 Bq/body). The detected Cs-137 levels for the 2 patients were 257 (for a 75-year-old male) and 279 Bq/body (for a 73-year-old male), which were just over the detection limit (250 Bg/body). The annual effective radiation dose from Cs-137 could be virtually calculated for the two patients to be 0.008 and 0.009 mSv/year, respectively, which are both far below the dose limit for radiation exposure (1 mSv/year) that was set by the government. These findings suggest that the internal Cs contamination in ESRD patients living in areas affected by the nuclear incident was marginal and that programs to encourage avoiding intake of uninspected potentially

contaminated local foods were successful in preventing undesirableradio-contamination.

The nutrition interview results showed that some participants consumed locally grown rice (42 patients; 37.8%), and vegetables (31 patients; 27.9%) which was not distributed to the market, while meat, fish, mushrooms and milk were more likely to have been commercially obtained (Table 2). The ESRD examinees had significantly more chance to consume locally grown produce which was not distributed to the market compared to non-ESRD examinees. (p<0.001; determined by Pearson's Chi-squared test) Even though the tested patients spent less time outdoors, they were presumed to maintain, at least to a certain extent, a similar lifestyle after the incident in terms of harvesting and collection of food. While the nutrition interview result from 1 of the 2 detected participants was available, the participant regularly consumed undistributed locally grown rice and vegetables.

DISCUSSION

Two of the 111 (1.8%) patients in the study exhibited detectable but marginal levels of internal Cs-137 contamination, but not Cs-134. The committed effective doses for the 2 patients were calculated to be 0.008 to 0.009 mSv/year, which is far below the government-allowed limit of 1 mSv/year. Detection of internal radio-contamination levels ended during September 2012, or 18 months after the incident. The detection of Cs-137 radio-contamination so long after the incident supported results from other studies of areas affected by the nuclear plant accident that showed that even two years after the incident a very small number of study subjects had detectable levels of internal Cs-137 contamination.

We assume that the detected Cs-137 was derived from contaminated locally grown produce that in particular was consumed at early date after the accident, when the supplies of commercially available and uncontaminated food were severely compromised owing to the several month-long

evacuation of many employees of commercial food distribution companies located within a 50 km radius of the crippled nuclear plant. During this period, some residents within this 30-50 km radius were forced to consume locally grown produce that had not undergone inspections for radio-contamination. Alternatively, the detected internal Cs-137 contamination could have been derived from continuous intake of uninspected contaminated produce grown in the study subjects' gardens and fields as were suggested in the previous study. ¹² In fact, interviews that assessed the dietary preferences of study subjects (Table 2), and particularly one of two subjects who showed Cs-137 contamination, suggested that they did indeed consume locally grown produce, presumably from their own garden. In this regard, visitors to the hospital who were seeking medical care also require continuous assessment of internal Cs-137 radio-contamination in addition to the voluntary visitors who underwent WBC screenings.

Earlier reports showing that tap water was radio-contaminated with radioactive substances (I-131, Cs-134, Cs-137) immediately after the nuclear plant incident suggest that ESRD patients could have been radio-contaminated during HD that used contaminated tap water for the dialysates.¹⁴ However, dialysates can be successfully purified and decontaminated using reverse osmosis equipment such that radionuclides are present at undetectable levels. In our HD facility, all tap water used for the dialysates is purified by reverse osmosis and activated charcoal treatment according to standard procedures, which would reduce the likelihood that the radionuclides detected in the patients accumulated after HD treatment. This assumption is further supported by the present study wherein only a few ESRD patients showed internal radio-contamination. These findings imply again that the detected Cs-137 was likely derived from contaminated food.

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287 Previous reports of HD patients who experienced radio-contamination 288 from the Chernobyl incident showed that HD was two times more effective

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at eliminating whole body 137-Cs that remained in ESRD patients as compared to the healthy examinees, and even for those ESRD patients who had impaired renal-dependent radiocesium excretion.^{17,18} During HD, radiocesium, along with electrolytes and waste products, can be removed by diffusion through a membrane. Since ESRD patients generally need to undergo several hours of dialysis three times a week, presumably HD should function to excrete Cs-137 as well as or better than normal renal function. From the findings of this study, we assumed that most of the ESRD had undetectable of tested patients levels internal radio-contamination because they were regularly undergoing dialysis and the WBC screening was performed over 15 months after the incident.

More unexpectedly, the percentage of ESRD patients who had detectable levels of radio-contamination (2/111 = 1.8%) did not statistically differ from those seen for voluntary hospital visitors during the same period (15/2503 = 0.6%, Fig. 1). The reasons behind this similar detection rate between ESRD and healthy patients are unclear at this stage due to the small number of the subjects included in the study. However, from information gathered from interviewing study participants to determine their dietary preferences, the ESRD subjects had significantly more chance to consume locally grown produce which was not distributed to the market compared to non-ESRD subjects (p < 0.001). To reduce the long-term health risks of radiation in such patients, long-term measures, including continuous monitoring of internal contamination by WBCs, as well as of agricultural products, and public education are essential in the future.

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Contributors	publ
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HK and MT. JA, KA and SS conducted WBC screening, and RH	l as
technically supervised to establish the WBC screening. SK, MI and JA	10.11 Prot
data and drafted the manuscript. All of authors read and approved the final	36/bi ectec
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	Table.1	Kesul	ts of WBC screenings					
			non-ESRD examinees	5			ESRD examinees	
		n				n	n of CS-137	
		_	n of CS-137 detected		0/		detected	0/
	Month, Year		Individuais	10	%	47	Individuals	%
	Jul. 2012	1223		12	1.0	47	1	2.1
	Aug. 2012	541		2	0.4	49	0	0.0
	Sep. 2012	286		1	0.3	13	1	/./
	Oct. 2012	313		0	0.0	0	0	NA
	Nov. 2012	140		0	0.0	2	0	0.0
	Total	2503		15	0.6	111	2	1.8
425								
426								
					1 .			
					15			

8			Number of examinees who regularly eat locally grown produce							
9 10		Table.2	which was not distri	429						
11 12			non-ESRD examinees (n=2	2503)	ESRD examinees (n=111)	430			
13 14			n of Examinees		%	n of Examinees	\$ 31			
15 16		Rice	78	33	31.3	42	3 728			
17		Vegetables	12	29	5.2	31	217 39			
18 19		Mushrooms		28	1.1	5	44445			
20		Beans		39	1.6	5	4 4 55			
22		Fruits		30	1.2	2	4 368			
23 24		Milk	1	1	0.4	2	4 ₿.78			
25 26		Meat		8	0.3		4089			
20 27		Fish	1	L7	0.7	1	4099			
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45	441 442				16		440			
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	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
		(b) Provide in the abstract an informative and balanced summary of what was done
		and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		and free and
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment,
-		exposure, follow-up, and data collection
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of
		selection of participants. Describe methods of follow-up
		Case-control study—Give the eligibility criteria, and the sources and methods of
		case ascertainment and control selection. Give the rationale for the choice of cases
		and controls
		Cross-sectional study—Give the eligibility criteria, and the sources and methods of
		selection of participants
		(b) Cohort study-For matched studies, give matching criteria and number of
		exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of
		controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect
		modifiers. Give diagnostic criteria, if applicable
Data sources/	8*	For each variable of interest, give sources of data and details of methods of
measurement		assessment (measurement). Describe comparability of assessment methods if there
		is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,
		describe which groupings were chosen and why
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
		(b) Describe any methods used to examine subgroups and interactions
		(c) Explain how missing data were addressed
		(d) Cohort study-If applicable, explain how loss to follow-up was addressed
		Case-control study-If applicable, explain how matching of cases and controls was
		addressed
		Cross-sectional study-If applicable, describe analytical methods taking account of
		sampling strategy
		(<u>e</u>) Describe any sensitivity analyses
Continued on next page		

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Cohort study—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Cohort study—Report numbers of outcome events or summary measures over time
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their
		precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and
		why they were included
		(b) Report category boundaries when continuous variables were categorized
		(<i>c</i>) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity
5		analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision.
		Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity
		of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other informati	on	
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable,
-		for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Whole body counter assessment of internal radiocontamination in end-stage renal disease patients living in areas affected by the Fukushima Daiichi nuclear power plant disaster: a retrospective observational study

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7 8	2	radio-contamination in end-stage renal disease patients living
9	3	In areas affected by the Fukushima Dalichi nuclear power plant
10	4	disaster: a retrospective observational study
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47 ABSTRACT

Objective

To assess internal radio-contamination of end-stage renal disease (ESRD) patients who were regularly taking hemodialysis (HD) and living in areas affected by the crippled Fukushima Daiichi nuclear plant after the Great East Japan Earthquake on March 11, 2011.

54 <u>Methods</u>

Internal radio-contamination in 111 ESRD patients regularly taking HD at Jyoban Hospital in Iwaki city, Fukushima from July 2012 to November 2012 was assessed with a whole body counter (WBC). The maximum annual effective dose was calculated from the detected Cs-137 levels. Interviews concerning patient dietary preferences and outdoor activities were also conducted. BMJ Open: first published as 10.1136/bmjopen-2015-009745 on 7 December 2015. Downloaded from http://bmjopen.bmj.com/ on June 9, 2025 at Agence Bibliographique de Enseignement Superieur (ABES) .

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62 <u>Results</u>

Among the 111 patients tested, internal radio-contamination with Cs-137 was detected in 2 subjects, but the levels were marginal and just exceeded the detection limit (250 Bg/body). The tentatively calculated maximum annual effective dose ranged from 0.008 to 0.009 mSv/year, which is far below the 1 mSv/year limit set by the government of Japan. Relative to 238 non-ESRD subjects, ERSD patients had significantly more opportunities to consume locally grown produce that was not distributed to the market (p < p0.01). However, the percentage of ESRD patients with detectable Cs (1.8%) was lower than that for non-ESRD subjects (3.8%), although this difference was not significant (p=0.51).

74 Conclusions

These findings suggest that internal radio-contamination levels and the calculated annual additional effective doses were negligible for ESRD patients taking HD in areas affected by the crippled Fukushima nuclear plant. Although hemodialysis is suggested to promote Cs-137 excretion,

continuous inspection of locally grown produce together with WBC screening for radio-contamination should be continued for ESRD patients regularly taking HD.

Strengths and Limitations

Strengths of the present study include:

• An unprecedented observation of whole body counter (WBC) assessments of internal radio-contamination for end-stage renal disease patients on hemodialysis living in areas affected by the Fukushima Daiichi nuclear power plant disaster.

- Limitations of this study are:
- A small number of subjects, limiting the generalizability of these findings to patients in other affected areas around the crippled nuclear plant.
 - A delayed period between the disaster and beginning of this study (one year), due to a lack of systematic measurements during this time.

INTRODUCTION

The aftermath of the Great East Japan Earthquake that occurred on March 11, 2011 brought diverse health threats and impaired medical care services for residents living in the affected areas during different periods.¹⁴ Residents of the radio-contaminated areas surrounding the Fukushima Daiichi nuclear power plant that was crippled by the earthquake and tsunami were forced to consider possible health threats, mainly from radiation exposure.^{5 6} To reduce health threats and avoid undesirable radiation exposure, accurate assessment of radiation exposure of residents living in the radio-contaminated areas was necessary. Monitoring of the ambient air doses provided a basis for establishing safe residential regions in the affected areas.⁷ Moreover, inspection of produce grown in affected areas and whole body counter (WBC) measurement of internal radio-contamination of residents living in affected areas was performed to

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ensure that their annual effective dose from internal radiation exposure was
below governmental limits.⁸

Our series of studies revealed that internal radiation exposure was marginal in the aftermath of the nuclear incident and that for nearly all examinees the doses from internal radiation exposure were far below the government-allowed limit (1 mSv/year).9-12 However, a small percentage (1-2 %) of the examinees did show detectable internal radiocesium (Cs; Cs-134 and Cs-137) contamination within one year of the incident, and even beyond one year Cs-137 could still be detected in a few individuals.¹³ ¹⁴ This radio-contamination could presumably be attributed to the intake of contaminated, locally grown produce that did not undergo radiation inspection. The findings from these studies clearly suggest that internal radiation exposure is manageable for residents living in radio-contaminated areas, but continuous WBC screening and food inspection is mandatory at the present time.

Although systematic WBC screening has been performed for voluntary hospital visitors and schoolchildren younger than 16 years old, no specific screening has been done for hospital patients. In this regard, end-stage renal disease (ESRD) patients undergoing hemodialysis (HD) could represent a patient population among affected residents, since Cs tends to be eliminated via urine, and urine production may be compromised in ESRD patients due to severely impaired kidney function. In addition, HD requires large amounts of tap water that could have been contaminated with radionuclides dispersed from the crippled nuclear plant, including radioiodine (I-131) as well as Cs. However, this possibility seems unlikely except for the period immediately after the disaster, since the I-131 half-life is short (8 days) and Cs is presumably trapped during common water purification processes (e.g., coagulation-flocculation-sedimentation) used for drinking water in Japan.¹⁷

Measurement of internal radio-contamination in ESRD patients living in
the affected areas is an unprecedented clinical opportunity to assess
previous reports indicating that HD is more effective in eliminating Cs in

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146 METHODS

Patients

An internal radiation exposure-screening program was conducted between April 1, 2012 and December 31, 2014 to assess internal radio-contamination among all residents in affected areas that were south of the Fukushima nuclear plant. There were no costs to the residents to participate in the program.

Subjects of this study were ESRD patients undergoing HD who were among voluntary visitors to Jyoban Hospital. The study subjects were examined after obtaining informed consent to collect data on age, sex, and results of the internal radiation exposure-screening program during the study period.

159 Assessment of internal radiation exposure by WBC

Internal radio-contamination was assessed by WBC measurements at the Jyoban Hospital between July, 2012 and November, 2012. The recorded major variables for the patients were age, sex, and the total body burden of radioactive Cs (Cs-134 and Cs-137). The patients changed into a hospital gown before WBC measurement to exclude any radio-contamination that may have been present on their clothing. BMJ Open: first published as 10.1136/bmjopen-2015-009745 on 7 December 2015. Downloaded from http://bmjopen.bmj.com/ on June 9, 2025 at Agence Bibliographique de Enseignement Superieur (ABES)

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167 Measurement procedure

The WBC device used was a stereoscopic apparatus with two 3 x 5 x 16 inch NaI scintillation detectors (Fastscan Model 2251; Canberra, Inc., Meriden, CT, USA). The Cs detection limits in a two-minute scan were 220 and 250 Bq/body for Cs-134 and Cs-137, respectively.

173 Calculation of effective dose from detected Cs-137 internal 174 contamination

Calculation of annual effective doses based on observed levels of internal
 Cs-137 contamination was performed using effective dose coefficients
 derived from the International Commission on Radiological Protection,

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Publication 67, wherein the amount of Cs activity detected by WBC examinations is assumed to be in an equilibrium state between consecutive ingestions and excretions over the course of one year.²¹ As there is no available information to calculate the annual effective doses that reflect the observed levels of internal Cs-137 contamination in patients with renal disease, we tentatively calculated the annual effective doses of the present subjects with respect to healthy subjects who had normal renal function.

186 Questionnaire regarding dietary preference

In addition to the WBC measurements, a self-report exposure risk assessment questionnaire that was used in previous studies was administered to and completed by the screening participants. ¹² ¹³ ²² This questionnaire included items regarding food and water consumption. Questions concerning food asked whether the respondent selected certain produce based on the origin listed at the supermarket (Fukushima versus non-Fukushima), or was simply purchased from local farms. Beginning on April 1, 2012, a maximum allowed limit of 100 Bg/kg of Cs was set for general foods, thus commercially available foods were considered to have been monitored regardless of their origins (i.e. Fukushima or non-Fukushima).²³ Questions concerning water asked whether the respondents avoided drinking tap water. The patients were also asked about how much time they spent outdoors.

201 Ethics

All study participants provided written documentation for informed consent, and the protocol for assessing internal radio-contamination was approved by the Jyoban Hospital institutional review board.

206 Statistical analysis

All statistical analyses were conducted using R version 3.2.0.

RESULTS

A whole blood counter (WBC) radiation exposure screening of 111 end-stage renal disease (ESRD) patients regularly taking hemodialysis (HD) was conducted in Jyoban Hospital between July 2012 and November 2012. Among the 111 patients, 26 (23.4%) were women, and their ages ranged from 25-83 years, with a median age of 61 years.

Internal radio-contamination with Cs was detected for 2 of the 111 subjects (Fig. 1). Of a total of 2,503 voluntary hospital visitors who did not have kidney disease and underwent WBC screening during the same period, 238 individuals in the same age range as the study subjects (ESRD) patients) were selected as the control group, which is hereafter referred to as non-ESRD subjects with a median age 53.5 years and 45.0 % females (Table 1). The percentage of ESRD patients with detectable Cs (1.8%) was lower than that for non-ESRD subjects (3.8%), although this difference was not statistically significant (p = 0.51, determined by Fisher's Exact test). Moreover, among the putative radiocesium released from the crippled Fukushima nuclear plant, only Cs-137 was detected while Cs-134 levels were below the detection limit (220 Bq/body). The detected Cs-137 levels for the 2 patients were 257 (for a 75-year-old male) and 279 Bg/body (for a 73-year-old male), which were just over the detection limit (250 Bq/body). The annual effective radiation dose from Cs-137 could be virtually calculated for the two patients to be 0.008 and 0.009 mSv/year, respectively, which are both far below the dose limit for radiation exposure (1 mSv/year) that was set by the government.

The nutrition interview results showed that some participants consumed locally grown rice (42 patients; 37.8%), and vegetables (31 patients; 27.9%) that were not distributed to the market, while meat, fish, mushrooms and milk were more likely to have been commercially obtained (Table 2). Relative to non-ESRD subjects, the ESRD patients had significantly more opportunities to consume locally grown produce that was not distributed to the market (p < 0.01; determined by Pearson's Chi-squared test). Even though the ESRD patients spent less time outdoors,

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> they were presumed to maintain, at least to a certain extent, a similar lifestyle after the incident in terms of harvesting and collection of food. While the nutrition interview results from 1 of the 2 detected participants were available, this participant regularly consumed undistributed locally grown rice and vegetables.

DISCUSSION

Two of the 111 (1.8%) patients in the study exhibited detectable but marginal levels of internal Cs-137 contamination, but not Cs-134. The committed effective doses for the 2 patients were calculated to be 0.008 to 0.009 mSv/year, which is far below the government-allowed limit of 1 mSv/year. These findings suggest that the internal Cs contamination in ESRD patients living in areas affected by the nuclear incident was marginal and that programs to encourage avoiding intake of uninspected potentially contaminated local foods were successful in preventing undesirable radio-contamination. However, detection of internal radio-contamination levels ended during September 2012, or 18 months after the incident. The detection of Cs-137 radio-contamination long after the incident supported results from other studies of areas affected by the nuclear plant accident that showed that a very small number of study subjects had detectable levels of internal Cs-137 contamination even two years after the incident.

We assume that the detected Cs-137 was derived from contaminated locally grown produce that in particular was consumed soon after the accident, when the supplies of commercially available and uncontaminated food were severely compromised owing to the several month-long evacuations of employees of commercial food distribution companies located within a 50 km radius of the crippled nuclear plant. During this period, some residents within this 30-50 km radius were forced to consume locally grown produce that had not undergone inspections for radio-contamination. Alternatively, internal the detected Cs-137 contamination could have been derived from continuous intake of uninspected contaminated produce grown in the study subjects' gardens and fields, as was suggested in a previous study. ¹³ In fact, interviews that assessed the dietary preferences of study subjects (Table 2), and particularly one of two subjects who showed Cs-137 contamination, suggested that they did indeed consume locally grown produce, presumably from their own garden. In this regard, visitors to the hospital who were

seeking medical care also require continuous assessment of internal Cs-137
radio-contamination in addition to the voluntary visitors who underwent
WBC screenings.

Earlier reports showing that tap water was radio-contaminated with radioactive substances (I-131, Cs-134, and Cs-137) immediately after the nuclear plant incident suggest that ESRD patients could have been radio-contaminated during HD that used contaminated tap water for the dialysates.¹⁵ However, dialysates can be successfully purified and decontaminated using reverse osmosis equipment such that radionuclides are present at undetectable levels. Even immediately after the disaster, Cs appeared to be effectively trapped within muds in riverbeds and areas affected by the tsunami, and was generally undetectable in drinking water in the affected areas. However, monitoring of potential I-131 contamination of tap water immediately after the disaster was likely far more important than internal radiocontamination measurements in HD I-131 be patients since cannot removed by coagulation-flocculation-sedimentation purification processes, but instead must be removed by special purification measures, including activated charcoal treatment and separation with reverse osmosis membranes. In our HD facility, all tap water used for the dialysates is purified by reverse osmosis and activated charcoal treatment according to standard procedures, which would reduce the likelihood that the radionuclides detected in the patients accumulated after HD treatment. This assumption is further supported by the present study wherein only a few ESRD patients showed internal radio-contamination. These findings imply again that the detected Cs-137 was likely derived from contaminated food.

Previous reports of ESRD patients who experienced radio-contamination from the Chernobyl incident showed that HD was two times more effective at eliminating whole body 137-Cs that remained in ESRD patients as compared to the healthy examinees, and even for those ESRD patients who had impaired renal-dependent radiocesium excretion.^{19 20} During HD,

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radiocesium, along with electrolytes and waste products, can be removed by diffusion through a membrane. Since ESRD patients generally need to undergo several hours of dialysis three times a week, presumably HD should function to excrete Cs-137 as well as or better than normal renal function. From the findings of this study, we assumed that most of the **ESRD** patients had undetectable levels of tested internal radio-contamination because they were regularly undergoing dialysis and the WBC screening was performed over 15 months after the incident.

More unexpectedly, the percentage of ESRD patients who had detectable levels of radio-contamination (2/111 = 1.8%) did not statistically differ from those seen for voluntary hospital visitors during the same period (9/238 = 3.8%), Table 1). The reasons behind this similar detection rate between ESRD and healthy patients are unclear at this stage due to the small number of the subjects included in the study. However, from information gathered from interviewing study participants to determine their dietary preferences, relative to non-ESRD subjects, the ESRD patients had significantly more opportunities to consume locally grown produce that was not distributed to the market (p < 0.01). To reduce the long-term health risks of radiation for ESRD patients, long-term measures, including continuous monitoring of internal contamination by WBCs, in addition to assessment of agricultural product contamination and public education efforts, are essential to prevent radiocontamination in the future.

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338 Contributors

HS, JM and TT carried out clinical examinations that were supervised by
HK and MT. JA conducted WBC screening, and KA and SS technically
supervised to establish the WBC screening. MT SK, SN and JA prepared
the figures. HS designed the study, and MT, SN and SK analyzed the data.
MT and SK wrote the manuscript. All authors read and approved the final
manuscript.

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Competing interests

351 None declared.

353 Patient consent

354 Obtained.

356 Ethics approval

Written informed consent was obtained from the patients for publication of this report and the ethical review committee of the Jyoban Hospital approved the present study.

- **Provenance and peer review** Not commissioned;
- 362 Externally peer reviewed.

Data sharing statement

All data underlying the findings in our study will be made freely available researchers upon request; please contact other Η S to at shimmura@tokiwa.or.jp.

Figure legends

Figure 1: Levels of Cs-137 internal contamination among ESRD patients

evels of Cs-1.

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	non-ESRD examinees				ESRD examinees		
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		n of Cs-137 detect	ed			detected	
Month, Year		individuals		%		individuals	%
Jul. 2012	79		7	8.9	47	1	2.1
Aug. 2012	41		2	4.9	49	0	0.0
Sep. 2012	33		0	0.0	13	1	7.7
Oct. 2012	40		0	0.0	0	0	NA
Nov. 2012	45		0	0.0	2	0	0.0
Total	238		9	3.8	111	2	1.8
				19			

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$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$
n of Examinees % n of Examinees % Rice 50 21.0 42 34 Vegetables 37 15.6 31 24 Mushrooms 4 1.7 5 44 Beans 2 0.8 5 44 Fruits 4 1.7 2 44 Milk 0 0.0 2 44 Meat 1 0.4 1 44 Fish 3 1.7 1 44 Total 66 27.7 47 44
Rice 50 21.0 42 34 Vegetables 37 15.6 31 24 Mushrooms 4 1.7 5 44 Beans 2 0.8 5 44 Fruits 4 1.7 2 44 Milk 0 0.0 2 44 Meat 1 0.4 1 44 Fish 3 1.7 1 44 Total 66 27.7 47 44
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Fish 3 1.7 1 40 Total 66 27.7 47 42 4' 4' 4' 4'
Total 66 27.7 47 42
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	Corresponding Page Number	Item No	Recommendation
	p.1		(<i>a</i>) Indicate the study's design with a commonly used term in the title or the abstract
Title and abstract	p.3	1	(b) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	p.5,6	2	Explain the scientific background and rationale for the investigation being reported
Objectives	р.б	3	State specific objectives, including any prespecified hypotheses
Methods			
Study design	p. 7	4	Present key elements of study design early in the paper
Setting	p.7	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
	N.A.		(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
Particinants	N.A.	6	<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls
i articipants	N.A.	0	<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants
	p.7		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed
	N.A.		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case
Variables	p.7	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	p.7	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	p.7,8	9	Describe any efforts to address potential sources of bias
Study size	p. 7	10	Explain how the study size was arrived at
Quantitative variables	p.7.8	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
	p.8, p.9		(<i>a</i>) Describe all statistical methods, including those used to control for confounding
	N.A.		(b) Describe any methods used to examine subgroups and interactions
	N.A.		(c) Explain how missing data were addressed
Statistical methods	N.A.	12	(d) Cohort study—If applicable, explain how loss to follow-up was addressed
	N.A.		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed
	N.A.		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy
	N.A.		(<u>e</u>) Describe any sensitivity analyses
Results			

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Participants	р.9	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
F	р.9		(b) Give reasons for non-participation at each stage
	N.A.		(c) Consider use of a flow diagram
	р.9		(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Descriptive data	N.A.		(b) Indicate number of participants with missing data for each variable of interest
	N.A.		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
	N.A.		<i>Cohort study</i> —Report numbers of outcome events or summary measures over time
Outcome data	N.A.	15	<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure
	p.9		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures
	p.9.10		(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
Main results	N.A.	16	(b) Report category boundaries when continuous variables were categorized
	N.A.		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	p.9,10	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion	• · ·		
Key results	p.11	18	Summarise key results with reference to study objectives
Limitations	p.11,12,13	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	p.11,12,13	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	p.11,12,13	21	Discuss the generalisability (external validity) of the study results
Other information			
Funding	p.14	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

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