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Evaluating differences in attempted and confirmed follow-up from Poison Centers following the Fukushima nuclear accident, 2012-2017.

By

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Master of Public Health

Epidemiology

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Committee Chair

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By

Sydney Shuk

B.S., University of Michigan, 2017

Faculty Thesis Advisor: Allison Chamberlain, PhD

An abstract of

A thesis submitted to the Faculty of the
Rollins Schools of Public Health of Emory University

In partial fulfillment of the requirements for the degree of
Master of Public Health
In Epidemiology

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Abstract

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By Sydney Shuk

The 55 poison centers across the United States receive regular calls regarding exposures to potentially toxic materials, such as ionizing radiation. Staff persons receiving these calls are also responsible for following up with callers to determine the medical outcomes of such exposures. After the Fukushima nuclear plant accident in Japan in March 2011, reports of above average readings of radioactive materials along the western coast of the United States have been reported even in early 2019. Between January 1, 2012 to December 31, 2017, 586 calls were evaluated to assess whether factors like caller age, gender, and location impacted the likelihood of medical follow-up from a poison center staff member. Between 2012 and 2017, men were more likely to receive attempted (PR=1.23) and confirmed (PR=1.68) follow-up compared to women, and calls made from health care providers were also more likely to receive attempted (PR=1.45) and confirmed (PR=2.28) follow-up compared to calls made by the general public. Calls received from west coast states (those presumably more affected by the Fukushima accident than others) were 36% less likely to have had attempted follow-up (PR=0.64) and 65% less likely (PR= 0.35) to have had confirmed follow-up compared to calls from other states. These findings signal a need to further understand this discrepancy and explore whether there is a need for enhanced follow-up, especially for regions impacted or potentially impacted by large-scale events with long lasting health impacts like the Fukushima meltdown. If data from poison centers are to be used for surveillance of ionizing radiation exposures across the United States, there may be a need to routinize follow up with callers to realize the true public health impacts of such hazards.

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Background and Literature Review

On March 11, 2011, a tsunami immediately following a 9.0 scale earthquake caused the Fukushima Daiichi nuclear plant active reactors to shut down. The emergency reactors and the plant's reactor cooling mechanisms were also disabled, resulting in three meltdowns leading to release of radioactive materials including Iodine-131 and Cesium-137, the classic markers of a nuclear power plant accident, over the span of three days (March 12-15, 2011) (1). Some of the radioactive materials eventually reached the west coast of the United States via a radioactive plume traveling in and above the Pacific Ocean. (2). Due to the long half-lives of Cesium-137 (30.17 years ± 0.03 years) and the other leaked radioactive materials (e.g. Cesium-134), above average concentrations of radioactive materials are still being detected in west coast (Washington, Oregon, and California) and pacific island (Alaska and Hawaii) states (3). While the disaster in Japan did not pose an immediate health danger to individuals in the U.S., the higher than normal presence of radioactive materials along the west coast prompted a need for radiation specialists to be involved the public health response (4). It became apparent in the aftermath of this event that U.S. public health system lacks adequate surveillance systems for monitoring human radiologic exposures and contamination following large-scale radiological and nuclear events (5).

The National Poison Data System (NPDS) is a surveillance system that cooperates with the U.S. Centers for Disease Control and Prevention (CDC) to routinely monitor multiple hazardous and potentially hazardous substances across the U.S. It receives de-identified data from 55 poison centers located in all 50 U.S. states and 5 territories. Individuals concerned about hazardous exposures or health care providers caring for potentially exposed individuals can call their state poison control center to report exposures. (6). After an initial call, the poison center staff member handling the case either confirms the case as a non-exposure, after which no further action is taken, or the staff person follows up with the caller (or their health care provider) to see if there are any notable medical outcomes potentially correlated with the exposure (7).

Starting in 2000, the CDC and the American Association of Poison Control Centers (AAPCC) teamed up to focus on the use of poison center data as a surveillance tool to monitor exposures to and effects of a wide variety of chemicals and other toxic substances (8). In June 2011, after over 400 calls were made to poison centers relating to potential exposures to radioactive materials released by the Fukushima nuclear accident, the CDC and AAPCC decided to re-code calls for exposures to radiation (9). Instead of using only the broad categories of ionizing and non-ionizing radiation, the expanded rubric allowed poison staff to capture specific suspected radionuclides if callers were aware of the exact source and substance.

To date, analyses of NPDS data has shown that poison center call data can serve as a near real time surveillance system for a multitude of exposures, but data is limited on the subsequent medical outcomes from such exposures (8). Even less is known about whether and how NPDS data can be used to garner information on radiation exposures and related health outcomes. Using NPDS data collected from January 2012- December 2017, the objective of this study is to characterize all calls made to U.S. poison control centers following the Fukushima Daiichi nuclear power plant accident and examine factors such as caller age, gender, source, and location that may have been associated with receipt of a medical follow-up call. By examining the likelihood of medical follow-up based on certain characteristics (caller gender, region, type of poison staff handling the report), we can determine whether one's geographic proximity to a major public health incident in the years following the disaster impacts the likelihood for follow-up, but it also aims to uncover a potential gap in the use of poison center call data as a national public health surveillance tool.

Methods

Data were obtained from the National Poison Data System (NPDS), a repository of all calls made to the 55 poison centers across the United States, and the territories of Puerto Rico, the U.S. Virgin Islands, American Samoa, Micronesia, and Guam. Only data on confirmed ionizing radiation exposure calls made to poison centers from January 1, 2012- December 31, 2017 were initially collected. Confirmed non-exposure calls such as training exercise calls, information calls, and calls regarding exposures that occurred outside of the United States were excluded from the study. The study also excluded calls for exposures to radon, smoke detectors, X-rays and other radiation based medical therapies. For exposures listed as “ionizing radiation, type unknown”, a sensitivity analysis was conducted to compare effect estimates including and excluding unknown ionizing radiation in the analyses.

Follow-up calls to individuals reporting non-pharmaceutical ionizing radiation or unknown ionizing radiation were assessed in two ways; first, whether or not there was an attempt at following up with a caller (1=attempt made, 0=no attempt made), and secondly, whether or not there was medical outcome data collected from a follow up call (1=medical outcome data present, 0=medical outcome data missing). Those with medical outcome data have health outcomes categorized as “no effect,” “minor effect,” “moderate effect,” “major effect,” or death. Those listed as “not followed” or “unable to follow” were considered to have this medical outcome data missing. Calls with documented follow-up attempts include those that have medical outcomes listed as above or who were listed as “unable to follow”. The coding “unable to follow” can be interpreted as the poison center staff trying to follow up with the caller, but for reasons such as death from competing causes or lack of response, data could not be collected for the medical outcome of the exposure.

The primary exposure of interest was the region from which the call originated, with the hypothesis that calls made from states along the west coast would have a greater likelihood of having attempted or confirmed follow-up. To that end, this region variable was dichotomized as "west coast" vs. "non-west coast" with calls made from Alaska, Hawaii, Washington, Oregon, and California being considered as "west coast." Year (2012-2017), sex (1=male, 0=female), call source (1=call from a health care provider, 0=call from the public), and age (<20, 20-39, 40-59, 60-+) were considered as possible effect modifiers and confounders of the association between whether or not a caller was from the west coast and attempted or confirmed follow-up. Call source was dichotomized into calls originating from health care providers and the general public because calls made on behalf of a patient from a health care provider are often considered serious exposures. Statistical significance for a variable was set at an alpha of 0.05 for the interaction assessment. To assess confounding of the relationship between caller location (West Coast vs. non-West Coast) and follow-up, unadjusted model estimates were compared to adjusted estimates containing the covariate of interest. A difference of over 10% was deemed a meaningful difference.

SAS version 9.4 and Microsoft Excel for Mac 2011 were used to conduct analyses and visualize NPDS data. The analysis was approved by the Centers for Disease Control and Prevention (CDC) and the American Association for Poison Control Centers (AAPCC).

Results

Between January 1, 2012 – December 31, 2017, a total of 1,091 calls regarding on ionizing radiation exposure were available in the National Poison Data System (NPDS). Nine (0.8%) calls were excluded for being training exercise calls, information calls or calls regarding exposures that occurred outside of the United States, and 496 (45.5%) were excluded for resulting from radon, smoke detectors, X-rays and other radiation based medical therapies. The final analytic sample contained 586 calls regarding ionizing radiation exposure.

The distribution and characteristics of calls by year can be found in Table 4. Three-hundred twenty six (55.6%) were made by men, 290 (49.5%) were regarding individuals aged 20 – 59, and 175 (29.9%) were received from a healthcare provider. [Table 1] While the distribution of calls did not differ meaningfully between West Coast and non-West Coast on sex or age, significantly more calls from the West Coast were made by health care providers than from other areas of the country (39.9% vs. 28.8%; p = 0.045).

There were no meaningful trends in the proportions of either attempted or confirmed follow by region between 2012 and 2017 [Figure 1, Figure 2]. Overall, the South had a higher proportion of attempted follow-ups (46.4%) compared to the Northeast (20.5%), Midwest (29,6%) and West (27.7%) [Figure 1]. However, the Northeast had a lower proportion of confirmed follow-up on average between 2012 and 2017 (33.96%) compared to the South (57.7%), Midwest (51.2%), and West (53.6%) [Figure 2].

Compared to calls initiated by women, calls from men were more likely to have had attempted follow-up (58.3% vs. 47.2%; PR=1.23) and confirmed follow-up (41.1% vs. 24.5%; PR=1.68).[Table 3] Calls received from a health care provider were also more likely to have had attempted (68.0% vs. 47.0%; PR=1.45) and confirmed (55.4% vs. 24.3%; PR=2.28) follow-up compared to calls from the general public. [Table 3]. There were no meaningful differences in either attempted or confirmed follow-up across age categories. [Table 3]. The crude association between location and follow-up shows West Coast callers were less likely to have attempted (PR=0.66) or confirmed (PR=0.37) follow-up compared to the rest of the United States.

In fully adjusted models to explore the combined relationships of all co-variates with each of the two outcomes of interest, backwards elimination showed no statistically significant effect modification by any of the four variables for both attempted and confirmed follow-up outcomes ($p>0.05$). In the model exploring factors associated with attempted follow-up, there was no meaningful difference in the model after adjusting for sex (PR 0.492 vs. aPR 0.505), but there were meaningful differences after controlling for call source (PR 0.492 vs. aPR 0.433), and age (PR 0.492 vs. aPR 0.441). Age and call source were kept in the final adjusted model evaluating the difference in attempted follow-up West Coast and non-West Coast callers.

For confirmed follow-up, there was no meaningful difference in the model after adjusting for sex (PR 0.266 vs. aPR 0.265), but there were meaningful differences when controlling for call source (PR 0.266 vs. aPR 0.185) and age (PR 0.266 vs. aPR 0.223). Age and call source were kept in the model evaluating the difference in confirmed follow-up between those directly affected by Fukushima and those not directly affected by Fukushima.

When examining follow-up status between calls initiated from the West Coast versus the rest of the country after adjusting for age and call source, calls from the West Coast were 36% less likely (PR=0.64) to have received an attempted follow-up. Similarly, compared to the rest of the United States, calls initiated from the West Coast were 65% less likely (PR= 0.35) to have had confirmed follow-up after adjusting for age and call source.

Discussion

Beginning to more seriously consider using the NPDS for national surveillance of exposures to ionizing radiation necessitates examining how the system has performed thus far in response to large-scale nuclear threats. Fortunately, there have been very few of these types of events; the most salient event to have occurred since the expansion of the system's coding convention for ionizing radiation was the 2011 Fukushima Daiichi nuclear plant meltdown. While this event did not happen in the continental U.S., its reach was large and could have affected the U.S., thus providing one of the only opportunities to examine the subsequent NPDS data for important trends or characteristics useful for improving the system for future public health emergencies.

While we did not find any strong associations between caller characteristics like age or census region and either attempted or successful follow-up on behalf of poison center staff, we did find that gender and call source were meaningfully associated with attempted and confirmed follow-up. Calls reporting exposures to males were more likely to have received calls back than those about women, and calls made by health care providers were more likely to receive calls backs. These findings perhaps suggest that calls made by men and health care providers may be prioritized. For the gender disparity, one hypothesis is that men are less likely to initiate a call for more minor exposures or illnesses than women (10). For the increased likelihood for calls from health care providers to have attempted or confirmed follow-up, this aligns with study findings from other arenas indicating that queries or calls from health care providers suggest a more hazardous exposure that warranted seeking medical care (11). Both findings do however signal that in the event of an emergency, NPDS leadership may need to reiterate the importance of returning calls made by all individuals since exposures could be very legitimate and more widespread that typically observed.

Supposing a heightened level of risk to residents of west coast states following Fukushima even years after the initial meltdown, as well as greater media attention to these potential risks (12) we hypothesized that poison control center calls originating from the west coast would have higher rates of follow-up from poison control staff. Our analyses did not support this hypothesis, and were in fact contrary to this theory. Calls initiated from the west coast were meaningfully less likely to have had attempted or confirmed follow up. This implies that not only were exposures potentially linked to the Fukushima nuclear disaster not followed up with, but there may be a lack of standardization between poison centers serving the west coast and the rest of the country. If there was a universal protocol for follow up to calls regarding ionizing radiation for all 55 poison centers, we would either have expected to see equal proportions of follow up for all regions of the United States or higher proportions from the western states most likely to have been affected. This analysis reveals that there may be a need to either revisit protocols for response to calls regarding ionizing radiation, and if no such protocols exist, to perhaps establish a set of standard steps that call center staff across the country could be trained on.

Strengths and Limitations:

The major strength of this study is that NPDS datasets have all calls made to poison centers across the United States and it’s territories. Having all ionizing radiation exposure calls made in the United States between 2012 and 2017 allows us to observe the true characteristics of all calls that come in and to explore certain relationships of interest like that between region and call outcome.

The nature of NPDS data and its coding system have a few important limitations. First, there is no way to ascertain why a call was not followed in the data. Persons with no follow-up data are coded as either "Not Followed" or "Unable to Follow (potentially toxic exposure)" without any additional details. There is however a code for confirmed non-exposures, and these were excluded from our analysis. This poses challenges; for instance, we do not know whether calls coded as "Not Followed" have non-toxic exposures that do not warrant follow-up, or if the poison center staff member simply did not follow up with that specific call. In the absence of a standard protocol for determining whether or not a call should be followed, the NPDS follow-up data is plagued by a certain amount of subjectivity; while poison center staff have some clinical background, each call center staff member uses their own discretion to assess whether or not an exposure is toxic, meaning that different thresholds for what constitutes a toxic exposure will vary between poison center staff. A call that would have warranted follow-up from one staff member may be viewed as a non-hazard by another.

Another limitation is that ionizing radiation coding in NPDS was expanded in June 2011, three months after the Fukushima nuclear incident. Prior to the code expansion, there was no reliable way to find specific non-pharmaceutical ionizing radiation exposures, so 2011 had to be excluded from the analysis. Having 2011 data from NPDS could have significantly altered these results since most Fukushima related calls likely occurred in the days or weeks immediately after the incident. It is possible that calls from this period may have revealed an equal or higher proportion of attempted and confirmed follow-up compared to the rest of the country.

And lastly, it is impossible to tell whether a call was truly attributed to an exposure related to Fukushima. The NPDS data only code for type of substance within ionizing radiation and where the exposure occurred, not suspected source. Many of the calls from the West Coast received between 2012 and 2017 likely had no relation to the Fukushima, so not being able to discern the probable source of radiation exposure may have impacted the results of the analysis.

Future Directions:

These results will be presented to the Centers for Disease Control's Radiation Studies Branch. The hope is that this study will start a dialogue about the use of NPDS data as a tool for surveillance. As previously determined by the CDC, NPDS data can identify incidents based on abnormal spikes in regional calls, but the lack of follow-up data from poison centers makes it difficult to see the public health impacts of such events. Moving forward, if these data are to be used as a more comprehensive public health surveillance system for ionizing radiation exposures, we should investigate possible improvements or standardizations to implement to have a more comprehensive and universal approach to follow-up.

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Table 1. Characteristics of U.S. Calls Made for Exposures to Ionizing Radiation to Poison Centers[a], by geographic location, 2012-2017

	All U.S. Calls (n=566)		West Coast[b] Calls (n=118)		Non- West Coast Calls (n=448)	
	No.	%	No.	%	No.	%
Sex						
Male	326	57.6	61	51.7	265	59.2
Female	229	40.5	57	48.3	172	38.4
Unknown	11	1.9	0	0.0	11	2.5
Age, In years						
<20	77	13.7	17	14.4	60	13.4
20-39	162	28.6	38	32.2	124	27.7
40-59	128	22.6	34	28.8	94	21.0
60+	51	9.0	12	10.2	39	8.7
Unknown	148	26.2	17	14.4	131	29.2
Caller Site						
Health Care Facility	175	30.9	46	39.0	129	28.8
Public Call[c]	383	67.7	72	61.0	311	69.4
Unknown	8	1.4	0	0.0	8	1.8
Year						
2012	61	10.8	16	13.6	45	10.0
2013	111	19.6	17	14.4	94	21.0
2014	107	18.9	26	22.0	81	18.1
2015	95	16.8	18	15.3	77	17.2
2016	88	15.6	17	14.4	71	15.9
2017	104	18.4	24	20.3	80	17.9

[a]Only calls for exposures to specific non-pharmaceutical ionizing radiation or unknown ionizing radiation included

[b]West Coast includes Alaska, Hawaii, Washington, Oregon, and California

[c]Public calls are any calls not made on behalf of a health care provider

[d]p-values based on Chi-Square test for difference in distributions between West Coast and Non-West Coast

Table 2. Characteristics of U.S. Calls Made for Exposures to Ionizing Radiation to Poison Centers[a], by recorded follow up status, 2012-2017

	Attempted[b] Calls (n=304)		Confirmed[b] Calls (n=191)	
	No.	%	No.	%
Sex				
Male	190	62.5	134	70.2
Female	108	35.5	56	29.3
Unknown	6	2.0	1	0.5
Age, In years				
<20	31	10.3	16	8.3
20-39	105	34.5	83	43.5
40-59	58	19.1	32	16.8
60+	25	8.3	16	8.3
Unknown	85	28.0	44	23.0
US Census Region				
Northeast	30	9.9	13	6.8
Midwest	69	22.7	44	23.0
South	100	32.9	79	41.4
West	105	34.5	55	28.8
Caller Site				
Health Care Facility	119	39.1	97	50.8
Public Call[c]	180	59.2	93	48.7
Unknown	5	1.6	1	0.5

[a]Only calls for exposures to specific nonpharmecutical ionizing radiation or unknown ionizing radiation included

[b]Followed-up means that there is recorded data in NPDS for the medical outcome of the exposure

[c]Public calls are any calls not made on behalf of a health care provider

Table 3. Unadjusted and Adjusted Prevalence Ratios[a] for Predictors of Follow-up for Calls Made to Poison Centers Regarding Ionizing Radiation in the U.S., 2012-2017

	Attempted Follow Up	Confirmed Follow Up
	PR[c]	PR
Sex		
Male	1.23	1.68
Female	REF	REF
Age, In years		
<1	REF	REF
20-39	1.61	2.47
40-59	1.13	1.20
60+	1.22	1.51
Caller Site		
Health Care Facility	1.45	2.28
Public Call[c]	REF	REF
Region		
West Coast	0.66	0.37
Other	REF	REF
Adjusted PRs[b]		
West Coast	0.64	0.35
Other	REF	REF

[a] NPDS is population data, so prevalence ratios do not need corresponding confidence intervals
[b] Adjusted results reported correspond to a model adjusted for age and caller site
[c]PR is defined as the prevalence ratio comparing follow-up in the West Coast to other regions

Table 4. Characteristics of U.S. Calls Made for Exposures to Ionizing Radiation to Poison Centers, by year, 2012-2017

	All U.S. Calls (n=586)		2012 (n=61)		2013 (n=111)		2014 (n=107)		2015 (n=95)		2016 (n=88)		2017 (n=104)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Sex														
Male	326	57.6	38	62.3	63	56.8	60	56.1	56	59.0	58	65.9	51	4[illegible]
Female	229	40.5	23	37.7	47	42.3	47	43.9	37	39.0	25	28.4	50	4[illegible]
Unknown	11	1.9	0	0.0	1	0.9	0	0.0	2	2.1	5	5.7	3	[illegible]
Age, In years														
<20	77	13.7	7	11.4	18	16,2	16	15.0	16	16.9	7	8.0	13	1[illegible]
20-39	162	28.6	16	26.2	27	24.3	32	29.9	32	33.7	27	30.7	28	2[illegible]
40-59	128	22.6	18	29.5	23	20.7	29	27.1	26	27.4	16	18.2	16	1[illegible]
60+	51	9.0	5	8.2	15	13.5	9	8.4	7	7.4	6	6.8	9	[illegible]
Unknown	148	26.2	15	24.6	28	25.2	17	14.4	14	14.7	32	36.4	38	3[illegible]
US Census Region														
Northeast	81	14.3	6	9.8	20	18.0	11	10.3	20	21.1	11	12.5	13	1[illegible]
Midwest	126	22.3	4	6.6	30	27.0	27	25.2	20	21.1	23	26.1	22	2[illegible]
South	171	30.3	29	47.5	35	31.5	28	26.2	31	32.6	15	17.1	33	3[illegible]
West	188	33.2	22	36.1	26	23.4	41	38.3	24	25.3	49	44.3	36	3[illegible]
Call source														
Health Care Facility	175	30.9	28	45.9	30	27.0	28	26.2	28	29.5	29	33.0	32	3[illegible]
Public Call	383	67.7	33	54.1	80	72.1	77	72.0	65	68.4	58	65.9	70	6[illegible]
Unknown	8	1.4	0	0.0	1	0.9	2	1.9	2	2.1	1	1.1	2	[illegible]

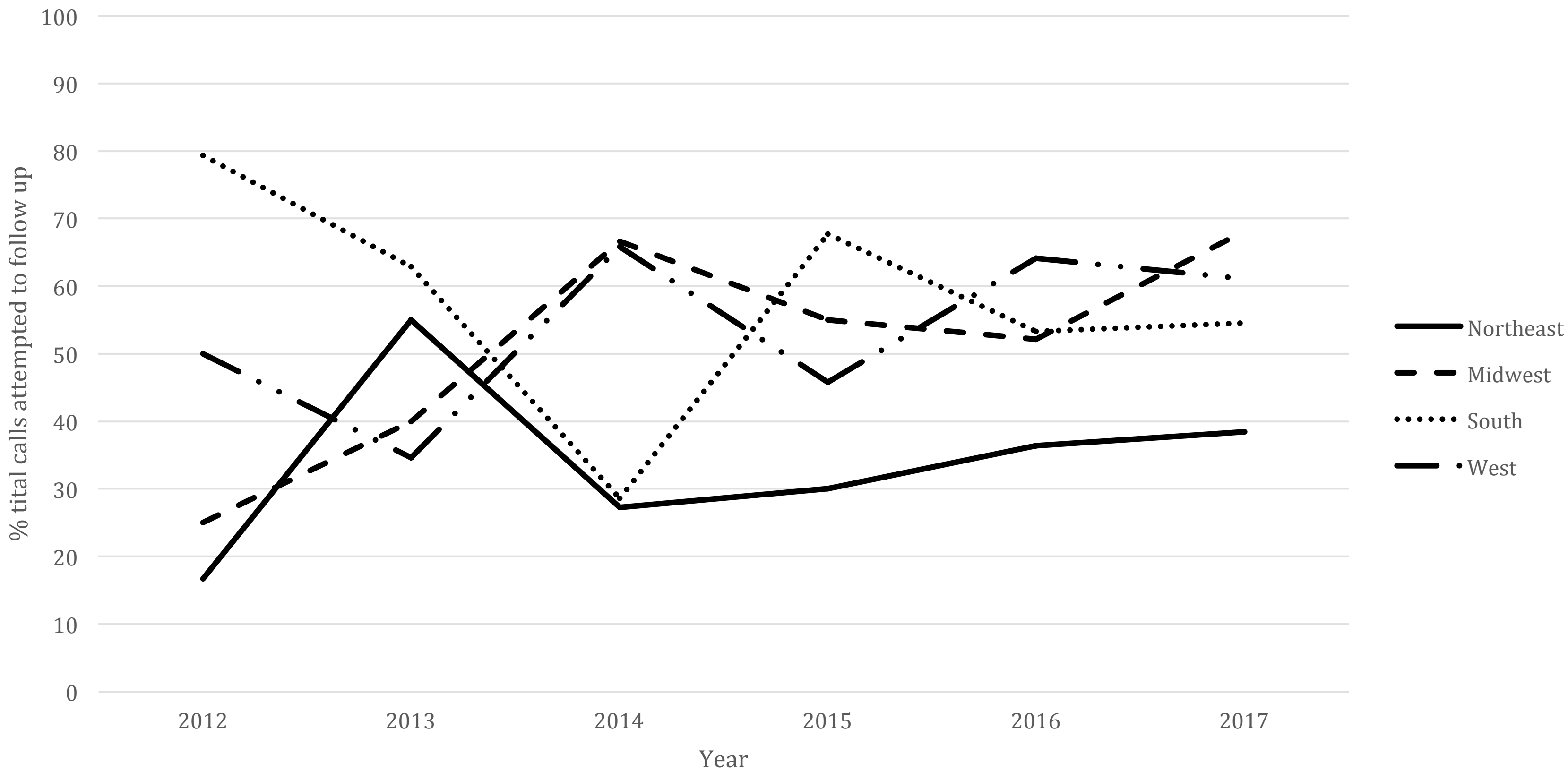

Figure 1. Proportion (%) of United States ionizing radiation exposure calls with attempted follow up by U.S Census Region (2012-2017). Overall, calls from the south had meaningfully more attempted follow up (46.41%) compared to Northeast (20.52%), Midwest (29.61%) and West (27.68%) callers.

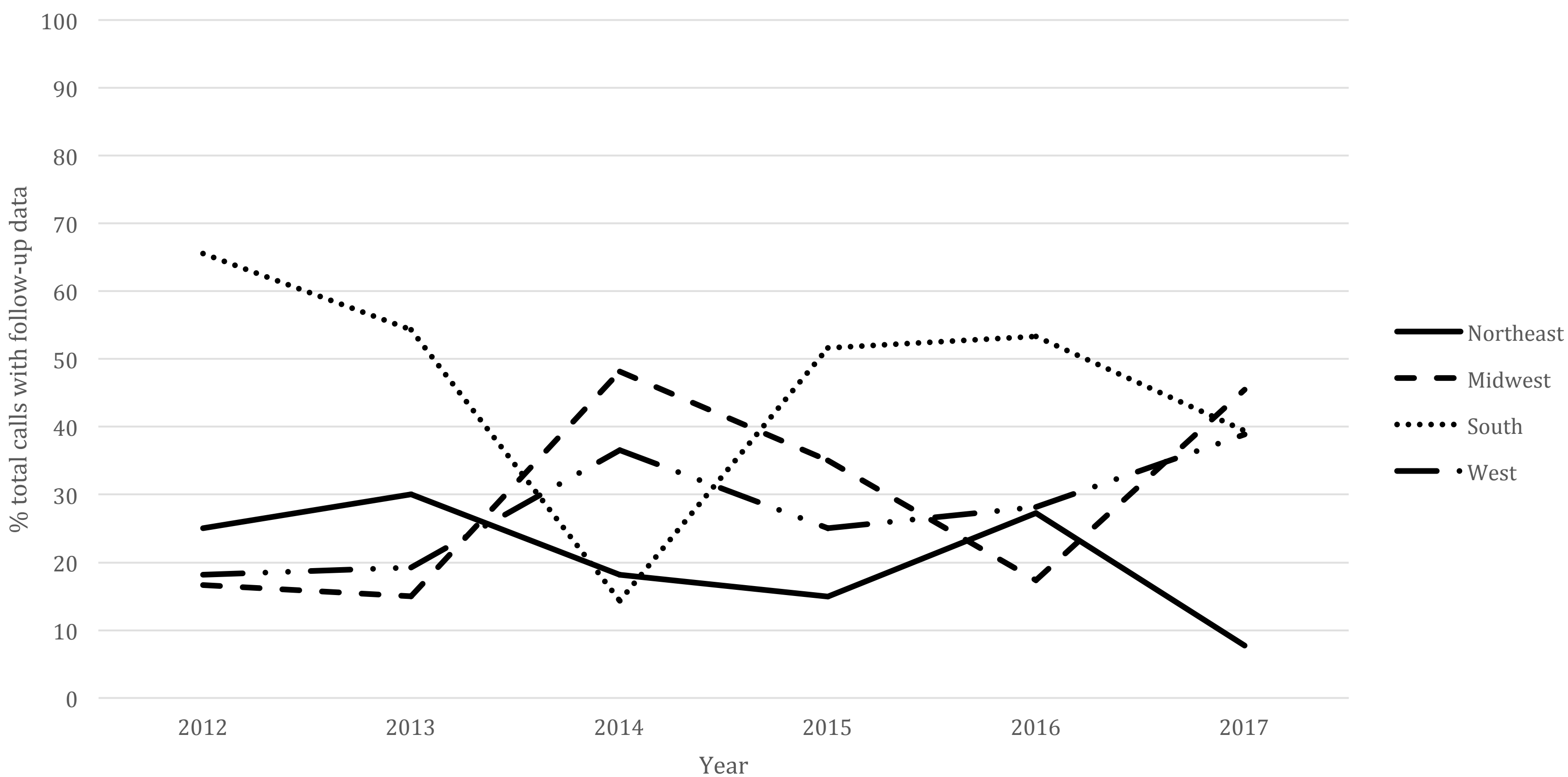

Figure 2. Proportion (%) of United States ionizing radiation exposure calls with confirmed follow up by U.S Census Region (2012-2017). Calls from the northeast had meaningfully less confirmed follow up (33.96%) compared to South (57.73%), Midwest (51.17%) and West (53.59%) callers.