

# Hospital-Level Factors Associated With Use of Pediatric Radiation Dose-Reduction Protocols for Head CT: Results From a National Survey

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**Objectives:** To examine hospital-level factors associated with the use of a dedicated pediatric dose-reduction protocol and protective shielding for head CT in a national sample of hospitals.

**Methods:** A mixed-mode (online and paper) survey was administered to a stratified random sample of US community hospitals (N = 751). Respondents provided information on pediatric head CT scanning practices, including use of a dose-reduction protocol. Modified Poisson regression analyses describe the relative risk (RR) of not reporting the use of a pediatric dose-reduction protocol or protective shielding; multivariable analyses adjust for census region, trauma level, children's hospital status, and bed size.

**Results:** Of hospitals that were contacted, 38 were ineligible (no CT scanner, hospital closed, do not scan infants), 1 refused, and 253 responded (35.5% response rate). Across all hospitals, 92.6% reported using a pediatric dose-reduction protocol. Modified Poisson regression showed that small hospitals (0-50 beds) were 20% less likely to report using a protocol than large hospitals (>150 beds) (RR: 0.80, 95% confidence interval [CI]: 0.65-0.99; adjusted for covariates). Teaching hospitals were more likely to report using a protocol (RR: 1.10, 95% CI: 1.02-1.19; adjusted for covariates). After adjusting for covariates, children's hospitals were significantly less likely to report using protective shielding than nonchildren's hospitals (RR: 0.64, 95% CI: 0.56-0.73), though this may be due to more advanced scanner type.

**Conclusion:** Results from this study provide guidance for tailored educational campaigns and quality improvement interventions to increase the adoption of pediatric dose-reduction efforts.

**Key Words:** CT imaging protocols, pediatric head CT, trauma center, radiation dose, national survey

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## INTRODUCTION

Increasing exposure to medical radiation among children is a major public health concern [1]. Contributing to this trend is the use of CT for the diagnosis and monitoring of illnesses and injuries. Over the last decade, the percent of pediatric emergency department visits that included a CT examination increased 5 fold [2]. Studies show that CT examinations take place frequently: 5.9% of child visits to the emergency department in 2008 included CT procedures [2]. The increasingly frequent use of imaging procedures is concerning because there is no known “safe” threshold for ionizing radiation. Despite evidence-based guidelines pertaining to appropriate diagnostic imaging criteria [3], use of CT imaging for head injuries, in particular, remains common also. An estimated 7.9% of children under the age of 18 have received at least 1 CT scan in childhood, and 3.5% received 2 or more, with CT scans of the head being the most frequent [4]. An average child may receive up to 7 procedures with ionizing radiation before the age of 18 [4]. Children are more sensitive to ionizing radiation than adults [5,6], and increasing exposure may increase lifetime cancer risk [5].

To reduce risk associated with exposure, the patient dose from each CT examination should be optimized to “as low as reasonably achievable (ALARA).” However, pediatric CT scanning protocols may not be the default [7,8]. National efforts to minimize radiation exposure in children, such as the Image Gently® campaign ([www.imagegently.org](http://www.imagegently.org)), deliver guidance to radiology providers on imaging applications and techniques to achieve the lowest dose necessary for diagnostic procedures on children [9-11]. However, there is limited research investigating the extent to which child-appropriate CT protocols are adopted and implemented. For children with traumatic brain injury, evidence suggests substantial variation in head CT protocols between centers that are pediatric-focused and those that are not [12].

Adoption of appropriate protocols may lead to reduction in radiation exposure and optimal injury treatment and management. This research seeks to examine hospital-level variation in the use of dedicated pediatric dose-reduction protocols for head CT scans in the United States.

## METHODS

### Survey design

We developed a survey based on instruments used previously in Washington State [12,13]. The survey comprised 5 sections (available as an [online supplement](#)). Questions focused on CT scans for head trauma among pediatric patients; other scanning modalities or body regions were not covered. First, respondents were asked if they performed head CT scans on 0 to 1-year-old children being seen for trauma. If they did not, they

were subsequently excluded from the study. Respondents were asked to indicate whether their institution had a dedicated protocol for a pediatric trauma patient having a head CT scan (no specific age range indicated), whether their hospital uses external (lead or bismuth) shielding to protect organs during head CT scans, and if shielding was used, which organs were shielded.

### Sampling and administration

We used a stratified random sampling approach to select 623 community hospitals from the American Hospital Association (AHA) 2010 Annual Survey database of 5,429 community hospitals. Strata were based on census region, bed size, and trauma level. An additional 129 hospitals were added to the sample to oversample institutions with service primarily to children (freestanding children’s or children’s specialty hospitals, according to the Children’s Hospital Association). Of the oversampled children’s hospitals, detailed information from 52 was available through the AHA database. For the remaining 77, hospital-level information (eg, mailing address, bed size, trauma level, teaching status) were obtained through Internet searches or contacting the institutions directly. The final survey sample included 751 hospitals. We derived sampling weights to adjust survey results to represent the larger sample of US community and children’s hospitals.

Using contact information from the AHA database or from our children’s hospital search, we mailed paper copies of the survey instrument to the lead CT technologist in the department of radiology. For a random sample of hospitals ( $n = 287$ ), we conducted Internet searches and/or called hospitals directly to determine the contact information for the lead CT technologist, which, if obtained, was included on the mailing. A self-addressed stamped envelope was included in the mailing. In the cover letter, respondents were asked to return the completed paper survey or complete the survey online. If an institution did not respond to the initial survey, up to 4 follow-up mailings were sent approximately 2 to 4 weeks apart. A retail gift card (up to \$10) and entry into a raffle for an iPad mini (\$329 value) were offered as incentives to the first respondent from each institution. Surveys were administered and responses were collected from October 2012 through June 2013. Because survey questions inquired about institutional and not individual practices, this study was considered exempt from human subjects review by the University of Washington institutional review board.

### Hospital data

We obtained descriptive data about each institution in our sample from several sources. The AHA annual survey for 2010 provided the following information: region (Northeast, South, Midwest, West), location

**Table 1.** Use of a dedicated pediatric dose-reduction protocol for head CT imaging as reported by a nationally representative sample of US community and children's hospitals

Characteristic	Dedicated Protocol (n = 230)		No Dedicated Protocol (n = 17)		Sig <sup>†</sup>
	N	Percent*	N	Percent*	
Region					0.73
Northeast	43	15%	2	6%	
Midwest	55	30%	5	30%	
South	61	26%	6	39%	
West	71	29%	4	25%	
Location <sup>‡</sup>					0.89
Rural	74	46%	6	43%	
Urban	156	54%	11	57%	
Service					0.94
General hospital	179	95%	13	95%	
Children's hospital	51	5%	4	5%	
Trauma level					0.24
Regional trauma center	67	13%	4	5%	
Community trauma center	47	12%	2	2%	
Rural trauma center	63	29%	7	38%	
Nontrauma center	53	47%	4	55%	
Bed size					0.17
Small (0-50 beds)	39	28%	7	58%	
Medium (51-150 beds)	83	29%	3	20%	
Large (>150 beds)	108	43%	7	22%	
Teaching status <sup>§</sup>					<0.01
Nonteaching	135	63%	14	93%	
Teaching	95	37%	3	7%	
ACR CT imaging accreditation <sup>  </sup>					0.86
Yes	113	44%	6	41%	
No	117	56%	11	59%	
ACR pediatric CT accreditation <sup>  </sup>					0.94
Yes	106	42%	6	41%	
No	124	58%	11	59%	
Number of scanners					1.00
1	99	59%	8	59%	
2	76	24%	4	23%	
3 or more	55	18%	5	18%	

\*Weighted.

†Significant difference between groups, based on weighted results, design-based Pearson  $\chi^2$  test.

‡A hospital located in a metropolitan statistical area is considered urban, and one in a non-metropolitan statistical area is rural.

§A hospital is considered a teaching hospital if it has a residency training program approved by the Accreditation Council for Graduate Medical Education, medical school affiliation reported to the American Medical Association, or a member of the Council of Teaching Hospital or the Association of American Medical Colleges.

||Based on Accredited Facility Search on the American College of Radiology (ACR) website.

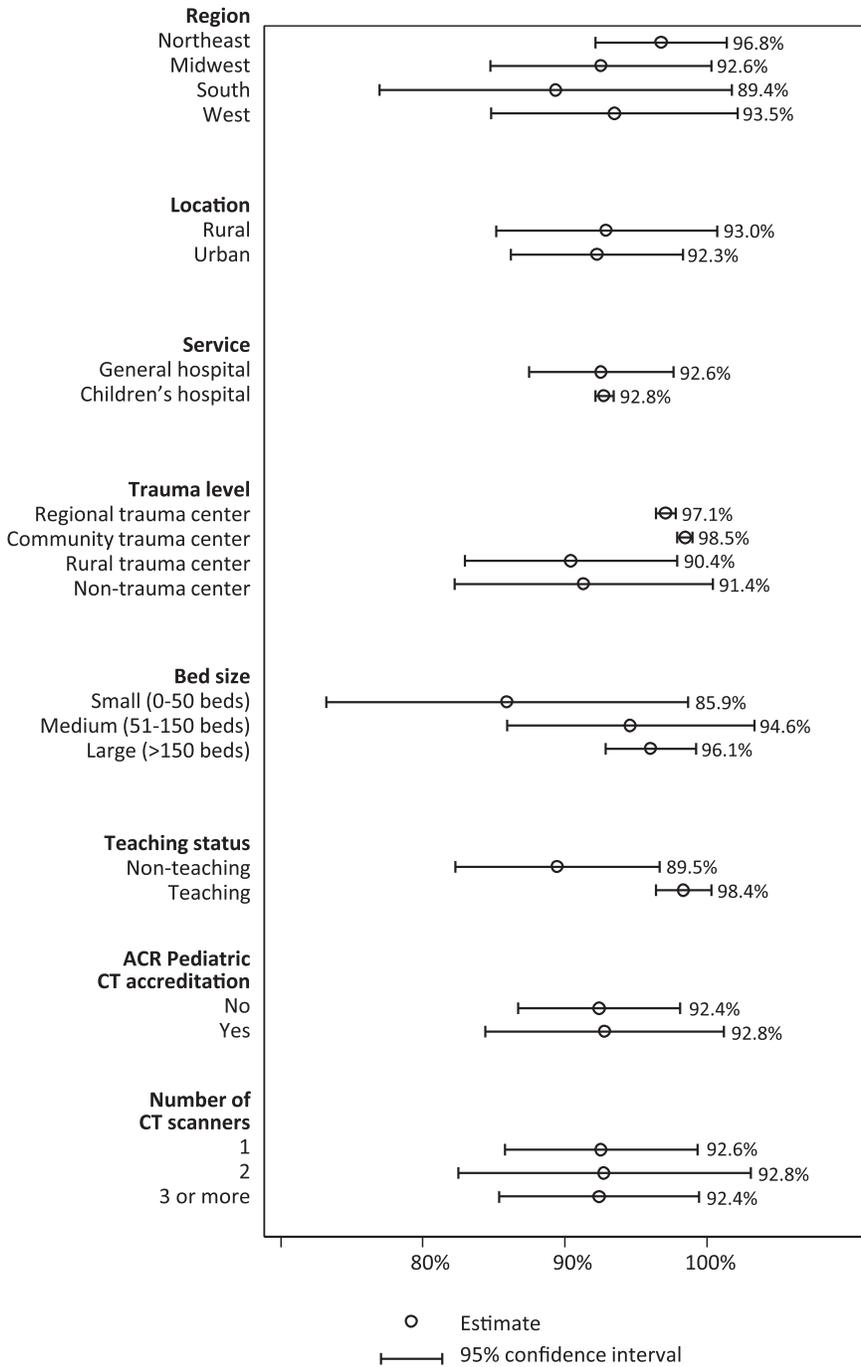
(urban or rural), service (children's or general hospital), trauma level (regional, community, rural, or nontrauma center), bed size (0-50 beds, 51-150 beds, >150 beds), and teaching status. Hospital location was based on Core Based Statistical Areas; urban hospitals are located within a metropolitan or division statistical area, rural hospitals are located in micropolitan or rural area. Teaching status was based on whether a hospital met 1 of the following criteria: has a residency training program approved by the ACGME, reported medical school affiliation to the American Medical Association, or was a member of the Council of Teaching Hospitals of the Association of American Medical Colleges. We cross-referenced the list of hospitals in our sample with the Accredited Facility Search on the ACR website [14] to determine whether an institution had ACR

accreditation for CT imaging and special accreditation for pediatric CT imaging.

### Analysis

Based on survey responses, we developed 2 outcome measures for this study: (1) report of not having a dedicated pediatric dose-reduction protocol for head CT scans (negative response to survey question "Does your hospital have a dedicated protocol for a pediatric trauma patient having a head CT scan?"), and (2) report of not using protective shielding for pediatric head CT scans (negative response to survey question "Does your hospital use external [lead or bismuth] shielding to protect organs during head CT scans?").

Weighted analysis of survey results were conducted using the *svy* commands available in the Stata/SE 11.2



**Fig 1.** Estimated proportion of hospitals with a dedicated dose-reduction protocol for pediatric head CT, by institutional characteristics (values weighted to account for survey design).

statistical software [15]. We calculated descriptive statistics to summarize characteristics of respondents and nonrespondents and between outcome measures for respondents. We described the overall proportion of hospitals that reported using a dedicated pediatric protocol and protective shielding. We used design-based Pearson  $\chi^2$  tests to evaluate differences in hospital characteristics between outcome measures to account for the weighted survey design.

Modified Poisson regression with robust error variance was used to estimate the likelihood of each outcome measure across hospital factors [16]. Multivariable

models estimated the likelihood of not have a dose-reduction protocol or not using shielding for each hospital-level characteristic while controlling for covariates. The results of analyses were presented as incident rate ratios (IRRs) with 95% confidence intervals (CIs); IRR is the inverse of natural logarithm of  $\beta$  (or  $e^\beta$ ) and demonstrates the multiplicative influence of 1 unit change in exposure on the rate of the outcome. Here, IRRs can be interpreted as relative risk of not having a dose-reduction protocol or not using shielding (lead and/or bismuth). Multivariable regression models adjusted for the following covariates: region, urbanicity,

**Table 2.** Use of a protective shielding for pediatric head CT imaging as reported by a nationally representative sample of US community and children's hospitals

Characteristic	Use of Protective Shielding (n = 176)		No Use of Protective Shielding (n = 75)		Sig <sup>†</sup>
	N	Percent*	N	Percent*	
Region					0.24
Northeast	36	16%	12	10%	
Midwest	42	32%	18	21%	
South	49	28%	19	29%	
West	49	24%	26	40%	
Location					0.48
Rural	63	48%	20	41%	
Urban	113	52%	55	59%	
Service					<0.01
General hospital	149	97%	47	90%	
Children's hospital	27	3%	28	10%	
Trauma level					0.33
Regional trauma center	42	10%	29	18%	
Community trauma center	38	11%	11	11%	
Rural trauma center	52	28%	20	33%	
Nontrauma center	44	51%	15	38%	
Bed size					0.46
Small (0-50 beds)	36	33%	13	29%	
Medium (51-150 beds)	64	29%	22	22%	
Large (>150 beds)	76	38%	40	49%	
Teaching status					0.92
Nonteaching	108	66%	45	67%	
Teaching	68	34%	30	33%	
ACR CT imaging accreditation					0.09
Yes	79	39%	41	56%	
No	97	61%	34	46%	
ACR pediatric CT accreditation					0.07
Yes	73	37%	39	55%	
No	103	63%	36	45%	
Number of scanners					0.32
1	82	62%	28	51%	
2	56	21%	25	32%	
3 or more	38	17%	22	17%	

\*Weighted.

†Significant difference between groups, based on weighted results, design-based Pearson  $\chi^2$  test.

trauma level, service, teaching status, ACR pediatric CT accreditation, and number of CT scanners. (General ACR CT accreditation was correlated with pediatric CT accreditation and, therefore excluded from the regression model.)

## RESULTS

Overall, 291 hospitals responded to the survey, of which 253 (86.9%) were eligible. Reasons for ineligibility included not having a CT scanner (n = 15), not scanning infants (n = 16), not seeing pediatric patients (n = 4), hospital closed (n = 2), and not seeing trauma patients (n = 1). The response rate was 35.5%.

Eligible respondent hospitals (n = 253) were similar to the total sample with regard to all characteristics, except teaching status, region, and trauma level (Supplementary Table 1). Eligible respondent hospitals were more often located in west and northeast regions of the United States and more likely to function as regional and rural trauma centers than nonrespondents ( $P < .01$ ).

Among the 253 eligible respondent hospitals, 247 answered the question about the pediatric dose-reduction protocol. The majority of hospitals (n = 230; 92.6%, weighted for survey design) indicated that their institution utilized a dedicated dose-reduction protocol for a pediatric patient having a head CT scan; 17 reported not having a protocol (7.4%, weighted). Nonteaching hospitals constituted the majority of hospitals that reported not having a dedicated dose-reduction protocol (93%), compared with 63% of hospitals that reported having a protocol ( $P < .01$ , Table 1). No other significant differences were observed between hospitals that reported having a protocol and those that did not (Fig. 1).

Of the 251 hospitals that answered the survey question regarding use of external shielding, 176 (70.1%) reported use of shielding when conducting a pediatric head CT scan for trauma. Free-response indication of organs shielded included eye lens (14% of hospitals that reported using shielding), thyroid (38%), breast (19%), gonads (31%), and torso shield, which could be used to shield any

**Table 3.** Factors associated with reporting use of dedicated dose-reduction protocol using protective shielding for pediatric head CT scans; Multivariable regression results

Characteristic	Dedicated Protocol		Protective Shielding	
	Unadjusted RR (95% CI)	Adjusted* RR (95% CI)	Unadjusted RR (95% CI)	Adjusted* RR (95% CI)
Region				
Northeast	.99 (.93-1.15)	1.00 (.88-1.13)	1.26 (1.00-1.59)	1.36 (1.04-1.78)
Midwest	.99 (.87-1.12)	.93 (.83-1.04)	1.25 (.98-1.60)	1.25 (.97-1.61)
South	.96 (.81-1.13)	.92 (.77-1.09)	1.14 (.85-1.53)	1.19 (.91-1.56)
West	Ref	Ref	Ref	Ref
Location				
Rural	1.00 (.90-1.12)	1.09 (.95-1.24)	1.07 (.89-1.27)	.97 (.77-1.22)
Urban	Ref	Ref	Ref	Ref
Service				
General hospital	Ref	Ref	Ref	Ref
Children's hospital	1.00 (.95-1.06)	.98 (.94-1.03)	.63 (.57-.70)	.64 (.56-.73)
Trauma level				
Regional trauma center	Ref	Ref	Ref	Ref
Community trauma center	1.01 (1.00-1.02)	1.02 (.99-1.06)	.80 (.63-1.01)	1.22 (.95-1.56)
Rural trauma center	.93 (.86-1.01)	.95 (.84-1.07)	.95 (.75-1.21)	1.09 (.85-1.40)
Nontrauma center	.94 (.85-1.04)	.92 (.82-1.03)	.90 (.73-1.12)	1.19 (.90-1.57)
Bed size				
Small (0-50 beds)	.89 (.77-1.04)	.80 (.65-.99)	1.10 (.86-1.39)	1.21 (.85-1.72)
Medium (51-150 beds)	.99 (.89-1.09)	.91 (.79-1.05)	1.14 (.92-1.40)	1.22 (.86-1.55)
Large (>150 beds)	Ref	Ref	Ref	Ref
Teaching status				
Nonteaching	Ref	Ref	Ref	Ref
Teaching	1.10 (1.01-1.19)	1.10 (1.02-1.19)	1.01 (.82-1.24)	1.09 (.90-1.31)
ACR CT imaging accreditation†				
Yes	1.01 (.91-1.13)	-	.86 (.70-1.04)	-
No	Ref	-	Ref	-
ACR pediatric CT accreditation				
Yes	1.00 (.90-1.12)	.99 (.88-1.21)	.84 (.69-1.03)	.83 (.68-1.01)
No	Ref	Ref	Ref	Ref
Number of scanners				
1	Ref	Ref	Ref	Ref
2	1.00 (.88-1.14)	.87 (.72-1.05)	.85 (.64-1.13)	.96 (.73-1.27)
3 or more	1.00 (.90-1.11)	.86 (.73-1.00)	.97 (.82-1.15)	1.13 (.90-1.44)

CI = confidence interval; RR = relative risk.

\*Adjusted model controls for all other covariates in the model (except for general ACR CT imaging accreditation).

†General ACR CT imaging accreditation was excluded from multivariable analyses because of collinearity with ACR Pediatric CT accreditation.

organ in the chest (breast), abdomen, or pelvis (gonads) (49%). Proportionally more hospitals that reported not using protective shielding were children's hospitals (10%), compared with hospitals that did use shielding (3%) ( $P < .01$ , Table 2). Other hospital characteristics, including region, location, service, trauma level, teaching status, and accreditation were not associated with use of protective shielding in the bivariate comparison (Table 2). Northeast hospitals were 36% (RR: 1.36, 95% CI: 1.04-1.78) more likely to report using protective shielding than hospitals in western states, after adjusting for other institutional characteristics. Children's hospitals were 36% (RR: .64, 95% CI: .56-.73) less likely to report protective shielding use for head CT scans among pediatric patients, after adjusting for other institutional characteristics.

### CT Accreditation Status

Thirty-nine percent of respondents' hospitals were accredited for general CT by the ACR, and 37% were

accredited for pediatric CT. As noted above, neither general nor pediatric accreditation were associated with higher use of protective shielding in bivariate analyses (Table 2).

### Multivariable Results

Results from multivariable analyses show that compared with large hospitals with more than 150 beds, small hospitals were 20% (RR: .80, 95% CI: .65-.99) less likely to report using a pediatric dose-reduction protocol for head CT scans, after adjusting for region, urbanicity, trauma level, service, teaching status, ACR pediatric CT accreditation, and number of CT scanners (Table 3). Teaching hospitals were 10% more likely to use a dedicated protocol than nonteaching institutions.

### DISCUSSION

This nationally representative survey estimated that 93% of US community hospitals use pediatric dose-reduction

protocols for head CT scans. Protective shielding use was also high (70%), but not universal. The wide adoption of these practices suggested high awareness of the importance of mitigating radiation exposure among young injured patients. The Image Gently campaign, launched in 2008, aims to educate healthcare providers and parents about the importance of radiation dose-reduction efforts [9-11].

We found that small hospitals have lower adoption of dose-reduction efforts than larger institutions. This variation provides guidance for developing targeted intervention efforts to promote the adoption of pediatric safety initiatives. Teaching hospitals were more likely to use a dedicated dose-reduction protocol. The presence of a training program may correlate with increased awareness of pediatric radiology safety issues, which contributed to the increased likelihood of teaching hospitals reporting protocol use in this study. It is important to note, however, that the teaching status measure in this study is defined broadly using AHA data and does not specifically identify hospitals with radiology or medical physics training programs.

Children's hospitals were less likely to report the use of protective shielding than nonchildren's hospitals. However, appropriate shielding use is contingent upon CT scanner type (ie, automatic tube current modulation technology does not necessitate shielding). Indeed, use of bismuth shielding with automatic exposure control or tube current modulation may increase dose or reduce image quality [17,18]. It is possible that CT scanners at the children's hospitals did not warrant shielding use.

This study has several limitations. First, although the response rate for this survey was only 35.5%, this response is typical for a primarily mail-based survey to a facility [19,20]. Also, this survey was administered to a sample derived from the universe of US community hospitals, so we were able to describe differences between respondents and nonrespondents. Second, the outcome measures from this study are based solely on self-report. We did not confirm nor audit the compliance with the use of a dedicated pediatric protocol or shielding at each hospital. We were not able to verify the results of the surveys with institutions. It is possible that report of protocol or shielding use or non-use does not reflect actual practice. Third, it is possible that institutions may collaborate as radiology groups, thus sharing decisions about the use of dose-reduction protocols. We were not able to measure this aspect in this study.

In summary, this nationally representative survey provided a snapshot of current pediatric head CT dose-reduction practices in place in US community hospitals. Whereas the majority of hospitals report using dedicated pediatric head CT imaging protocols and protective shielding, variation across hospital characteristics suggests that ongoing awareness and educational efforts should be supported and targeted approaches may be a logical next step. National efforts like Image Gently,

collaborative guidelines for appropriate CT use that apply to multiple specialties, and national publication of optimized CT protocols, such as those produced by the American Association of Physicists of Medicine [21], should continue to maintain the current high level of adoption of patient safety practices.

## TAKE-HOME POINTS

- The majority of U.S. community hospitals employ pediatric dose reduction protocols and protective shielding for head CTs for infants with head trauma.
- There is some variation in the use of protocols and shielding by hospital characteristics and accreditation status.
- National campaigns to reduce pediatric radiation dose, such as Image Gently aim to educate providers and parents about the importance of radiation dose reduction efforts.
- Results from this study may be used to create targeted intervention efforts to promote the adoption of pediatric safety initiatives.

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## SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at <http://dx.doi.org/10.1016/j.jacr.2013.12.002>.

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**Supplementary Table 1.** Characteristics of sampled hospitals, respondents, and nonrespondents

Characteristic	Respondents				Nonrespondents (n = 457) and Refusals (n = 1)		Total Sample (n = 751)	
	Eligible (n = 253)		Ineligible (n = 38)		n	Percent*	n	Percent*
	n	Percent*	n	Percent*				
Region								
Northeast	48	15%	3	5%	96	13%	147	13%
Midwest	60	29	13	38	107	30	180	30
South	69	28	11	23	185	43	265	38
West	76	28	11	34	72	14	159	19
Location <sup>†</sup>								
Rural	170	46	21	57	304	43	256	44
Urban	83	54	17	43	156	57	495	56
Service								
General hospital	197	95	36	99	385	97	618	97
Children's hospital	56	5	2	1	75	3	133	3
Trauma level <sup>  </sup>								
Regional trauma center	72	12	7	9	111	8	190	9
Community trauma center	49	11	6	8	105	11	160	11
Rural trauma center	7	29	10	22	98	15	180	19
Nontrauma center	60	48	15	61	146	66	221	61
Bed size								
Small (0-50 beds)	49	32	16	49	104	28	169	31
Medium (51-150 beds)	86	28	9	29	150	30	245	29
Large (>150 beds)	118	41	13	22	206	41	337	40
Teaching status <sup>‡</sup>								
Nonteaching	154	66	29	81	328	69	511	31
Teaching	99	34	9	19	132	31	240	69
ACR CT imaging accreditation <sup>§</sup>								
Yes	120	43	15	34	189	37	324	39
No	133	57	23	66	271	63	427	61
ACR pediatric CT accreditation <sup>§</sup>								
Yes	112	41	9	19	170	33	291	34
No	141	59	29	81	290	67	460	66

\*Weighted.

<sup>†</sup>A hospital located in a metropolitan statistical area is considered urban, and one in a non-metropolitan statistical area is rural.<sup>‡</sup>A hospital is considered a teaching hospital if it has a residency training program approved by the ACGME, medical school affiliation reported to the American Medical Association, or a member of the Council of Teaching Hospitals of the Association of American Medical Colleges.<sup>§</sup>Based on Accredited Facility Search on the ACR website.<sup>||</sup>Significant difference between groups, based on weighted results, design-based Pearson chi2 test,  $P < .05$ .