Spinal Anatomy Knowledge and Fluoroscopic Image Identification by Intraoperative Staff

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Citation

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Abstract

Background: Wrong-site surgery, and specifically wrong-site spinal surgery, remains a persistent problem despite the measures put in place such as the Universal Protocol and the North American Spine Surgery Sign, Mark, and X-ray (SMaX) protocol. The incidence of wrong-site spine surgery has been reported to be anywhere from 0.04%-5.3% of spine surgeries. Traditional time out protocols are incomplete in their applicability to wrong-site spine surgery: Because it is assumed that only a spine surgeon or a radiologist has adequate knowledge to identify spinal levels intraoperatively, operating room staff do not participate in site confirmation protocols. However, this assumption has never been tested. In this study we assess the ability of intraoperative staff to identify spinal levels on fluoroscopic scout images to test that assumption.
Methods: A 15-item survey was created which assessed intraoperative staff attitudes, basic spinal anatomy knowledge as well as their ability to identify fluoroscopic spinal images. After obtaining IRB exemption, this survey was administered to operating room RNs, CRNAs, Anesthesiologists, Resident Anesthesiologists, Surgical Technicians and Radiology Technicians at Baystate Medical Center.

Results: 168 people completed the survey. The percentage of intraoperative staff that were able to correctly identify the fluoroscopic images ranged from 38.7% to 82.7% overall, depending on job title and image. radiology technicians, as a group, had the highest percentage of members able to correctly identify the fluoroscopic images (range 89.5%-100%). Among anesthesiologists and resident anesthesiologists this percentage ranged from 20%-100%, with a lower proportion of individuals being able to identify correctly identify cervical spine images versus lumbar spine images (20-70% versus 60-100%). Overall, 17.3% of intraoperative staff were able to correctly identify all the fluoroscopic images.

Conclusion: Intraoperative staff, overall, showed a poor ability to identify spinal levels under fluoroscopy. In our survey, radiology technicians were more likely than other groups to correctly identify the fluoroscopic images. The results of this survey show why it is difficulty to enact a more thorough time out protocol, involving intraoperative staff, to help prevent wrong-site spine surgery.

BACKGROUND

Despite being classified as a “never” event, wrong-site surgery remains a persistent problem with an incidence estimated at 1 per 100,000 operations.[1] In 2004, JCAHO (Joint Commission on Accreditation of Healthcare Organizations) mandated the adoption of the Universal Protocol in order to combat this problem. This protocol consists of three steps: 1) Pre-procedural verification; 2) marking of operative site; and 3) a final verification prior to the start of the procedure.[2] The Universal Protocol was adopted for all surgical procedures, but it was incomplete in its applicability to spinal surgery. This resulted in the North American Spine Society (NASS) adopting the “Sign, Mark and X-ray (SMaX)” guideline adding X-ray localization to the Universal Protocol for spine cases.3 However, despite these protocols and guidelines, wrong-site surgery and, specifically, wrong-level spinal surgery, continue to occur.

A survey of Neurological surgeons reported that 50% of surgeons surveyed had performed at least one wrong-level surgery in their careers[4] and that, while difficult to study, the incidence of wrong-level spine surgery has been reported to be between 0.04% to 5.3% of spine surgeries.[4–9] It remains unclear how the Universal Protocol and NASS guidelines have affected the incidence of wrong-site surgery. Vacchani et al. showed a decline in incidence after enacting the

Universal Protocol[10], but a Cochrane review noted that there had already been a downward trend in wrong-site surgery prior to enacting the Universal Protocol and concluded that the effect of the Universal Protocol on the incidence of wrong-site surgery was unclear[11]. A review of wrong-site surgery cases and their root causes found that the most common cause of wrong-site surgery was poor communication; other causes included following the Universal Protocol inadequately or not at all.[11]

While site verification may help foster better communication, and in most surgeries, possibly reduce wrong-site surgery, its effect on spine surgery is questionable given the complexity of the spine. It is assumed that the knowledge of laterality and the ability to identify a region of the body are universal. This assumption allows for the entire intraoperative staff to participate in site verification protocols in terms of laterality or limb verification. But neither the Universal Protocol nor the NASS SMaX guidelines call for verification of the spinal level with the intraoperative staff because it is assumed that only the surgeon is capable of site verification[12]. However, the assumption--that the intraoperative staff cannot identify spinal levels--has never been tested. Since a majority of intraoperative staff undergo training in anatomy, it is conceivable that they may indeed have adequate knowledge of spinal anatomy to participate in site verification.

We surveyed 168 operating room personnel in a large tertiary care, level 1 trauma hospital, to measure their knowledge of and level of confidence in fluoroscopic spinal level identification. The individuals completing the survey were from a variety of training and experience backgrounds.

METHODS

The study was conducted at a tertiary-care, academic medical center and was approved by the center's Institutional Review Board (IRB) Human Research Protection Program. Given the fact that the survey was anonymous and voluntary, individual consent was deemed unnecessary, since voluntary participation was understood to imply consent. An electronic survey was sent to 357 intraoperative staff consisting of surgical technicians (STs), operating room registered nurses (RNs), radiology technicians (RTs), anesthesiologists, certified registered nurse anesthetists (CRNAs), and anesthesiology residents (residents). The study data was collected and managed using Research Electronic Data Capture (REDCap), a web-based application designed to support data collection and management for research studies.[13]

The survey consisted of 15 questions. The first portion of the survey collected data on job title, years of experience, and the self-reported number of spine cases the participant had been involved in. The next set of questions consisted of Likert scales (on a scale of 0-9) asking respondents' degree of confidence in vertebral level identification, how often they pay attention to scout images at the beginning of a spine case, and how likely they were to speak up if they felt the wrong level was being operated on.

The final questions focused on spinal anatomy. The participants were asked to fill in the number of cervical, thoracic, and lumbar vertebrae in the average human. They were then shown five intraoperative fluoroscopic scout images (of the cervical or lumbar spine) and asked to identify either the disc level or vertebral body level through multiple choice questions. The fluoroscopic images were as follows:

Image 1: Cervical disc, C3-C4

Image 1

Cervical disc, C3-C4

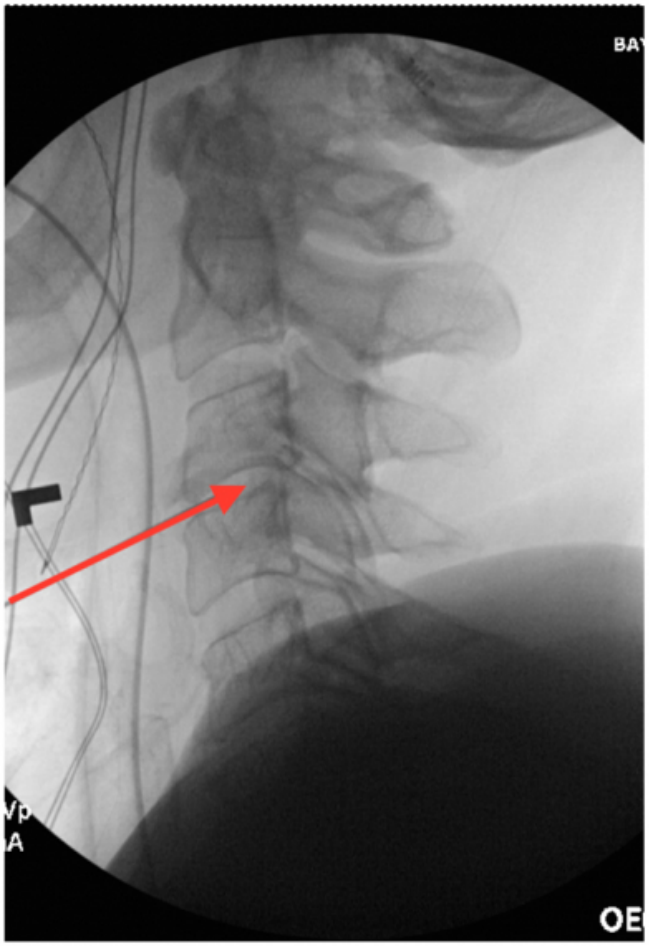


Image 2: Cervical disc, C6-C7

Image 2

Cervical disc, C6-C7

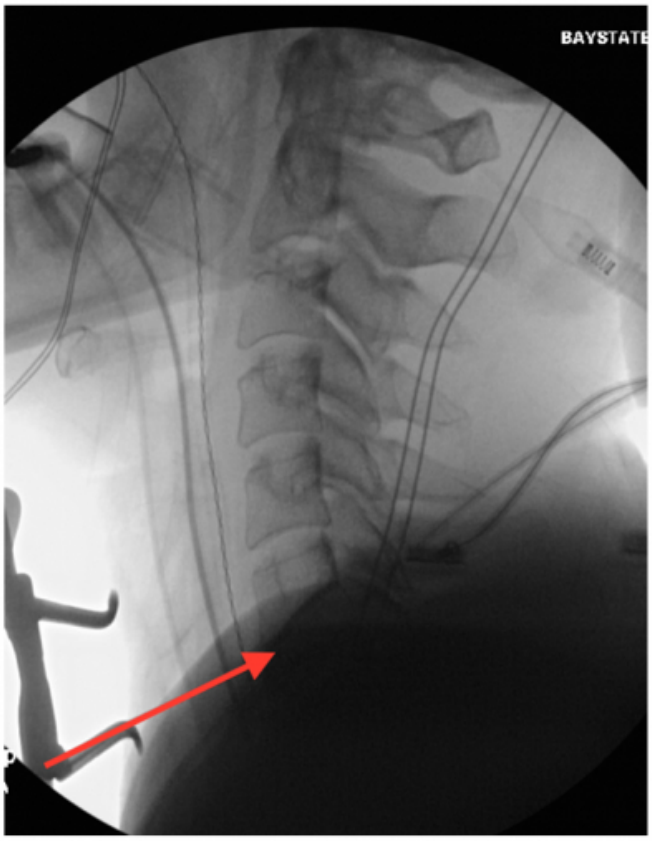


Image 3: Lumbar disc, L5-S1

Image 3

Lumbar disc, L5-S1

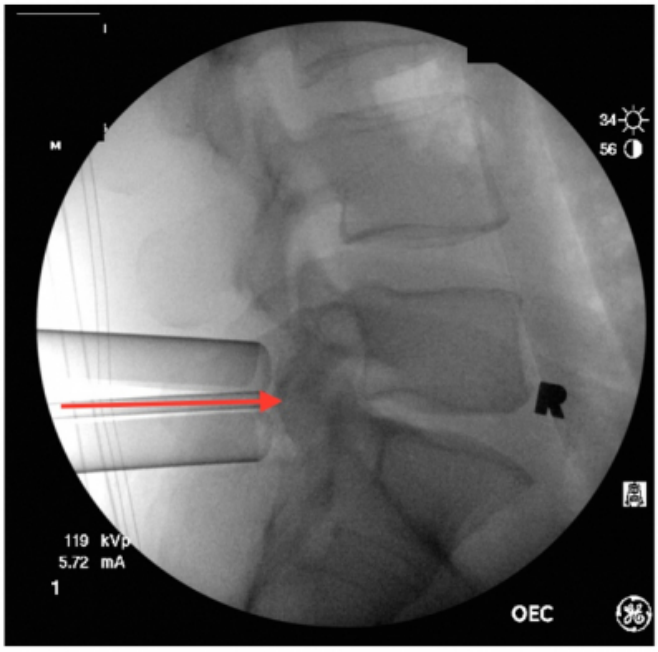


Image 4: Lumbar disc, L4-L5

Image 4

Lumbar disc, L4-L5

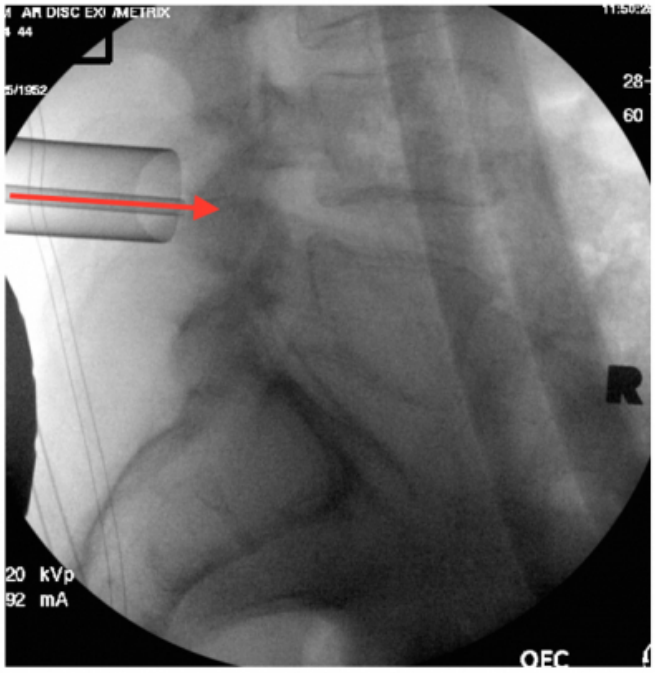
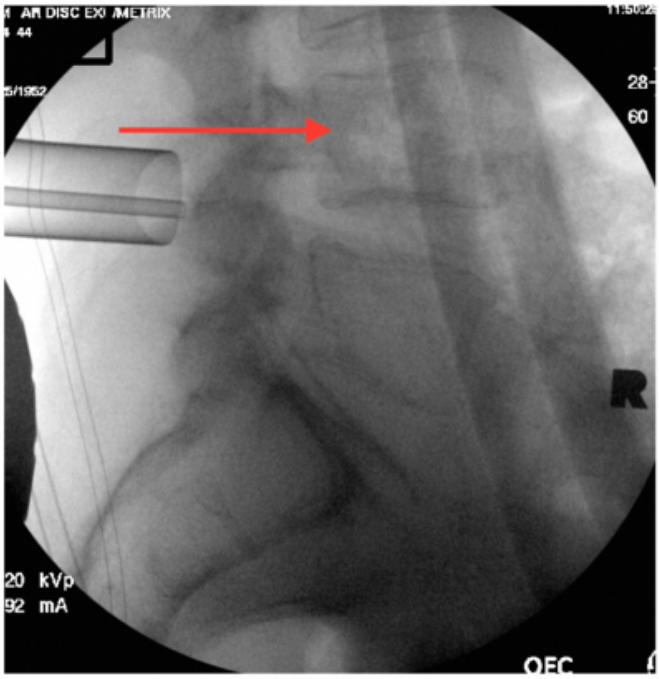


Image 5: Lumbar vertebral body, L4

Image 5

Lumbar vertebral body, L4



Statistical Analysis:

Summary statistics were calculated as mean/standard deviation; median/interquartile range, and number/proportions. A total knowledge summary score was calculated as the sum of correct answers divided by the total asked. Bivariable analyses were performed using Kruskal-Wallis equality of populations rank test or Fisher's exact (nominal), Spearman Rank Correlation or 2 test of trend in odds (ordinal). All hypothesis tests were two-sided, with a critical p-value of <0.05. Stata 14.1 (College Station, TX) was used for all analyses.

RESULTS

A total of 357 employees received an e-mail invitation to participate and 182 entered the survey. Of the 182, 7 subsequently opted out of the survey, for a total response rate of 49% (175/357). We excluded an additional 7 questionnaires with missing responses to job title and/or years in practice. Thus, the final analytic sample size was 168. Of these 168, RNs and CRNAs, combined, comprised the majority (47%) of the overall respondents [See Table 1, below].

Table 1

Respondent Characteristics, by Job Title

	# (%)	# Years in Current Field (Median/25th, 75th)	# Spine Cases in Last 4w (Median/25th, 75th)
All Job Titles	168 (100.0)	8/3,21.5	1/0,4
Registered Nurse (RN)	39 (23.2)	12/5,56	0/0,3
Radiologic Tech (RT)	19 (11.3)	12/10,21	6/4,19
Certified Surgical Tech (CST)	20 (11.9)	24/7,31	0/0,1
Certified Registered Nurse Anesthetist (CRNA)	40 (23.8)	4/2,8	1/0,2
MD/DO Anesthesiologist	30 (17.9)	10/3,24	3/2,5
Resident Anesthesiologist	20 (11.9)	1/0,3	0/0,2
		*P<0.001**	*P<0.001**

*Kruskal-Wallis equality-of-populations rank test. The null hypothesis of this test is that the # of years is distributed evenly across job categories.

Respondents reported a median of 8 years in their current field, and the median number of cases attended in the prior month varied from a high of 6 by RTs and a low of 0 by RNs, STs, and Anesthesia residents. Years of experience and frequency of spinal surgery in the last 4 weeks varied significantly across job title. Self-rated confidence and practice fidelity Likert scores are shown in Table 2. The Likert-scaled confidence rating (overall median of 6) varied significantly by job title and was highest among RTs. RTs also reported the greatest likelihood of attending to scout image at the beginning of spinal surgery, and the greatest likelihood of expressing concerns if the surgeon was operating on the wrong spinal level.

Table 2

Confidence and fidelity ratings by Role and Experience Level (n=168)

	Personal Confidence in Knowledge (Range 0-9)		Attentiveness to Scout Image (Range 0-9)		Likelihood to Correct Surgeon (Range 0-9)	
	Median/ 25th, 75th	P-value*	Median/ 25th, 75th	P-value*	Median/ 25th, 75th	P-value*
Overall Sample	6/4,8		7/3,10		10/7,10	
Role						
RN	4/1,7		6/2,10		10/8,10	
RT	10/10,10		10/10,10		10/9,10	
ST	7/5,9		9/8,10		10/9,10	
CRNA	5/4,7		6/3,8		8/5,10	
Anesthesiologist	6/5,9		7/3,9		10/6,10	
Resident	6/4,8	<0.001	5,2/6	<0.001	8/6,10	0.004
# Years in current field						
Bottom third	6/4,7		6/3,8		8/5,10	
Middle third	7/5,9		8/6,10		10/8,10	
Top third	5/2,9	0.97	8/3,10	0.01	10/9,10	<0.001
# Spine Cases in last 4 weeks						
Bottom third	5/3,7		6/2,9		9/6,10	
Middle third	6/4,7		6/1,10		10/6,10	
Top third	8/6,10	<0.001	9/7,10	<0.001	10/8,10	0.07

*P-values are from Kruskal-Wallis equality-of-populations rank test (Role, Specialty) or Spearman Rank correlation (#years, # cases).

Responses to individual knowledge items are shown in Table 3. Image recognition was relatively poor, with fewer than half of respondents able to identify Image 1 (43.4%, 95% CI 36.1%, 51.1%) or Image 2 (38.7%, 95% CI 31.6%, 46.3%). Image recognition was significantly related to job title: Correct identification of Image 1 ranged from a low of 20.0% among residents, to 94.7% among RTs. Correct identification of Image 2 ranged from a low of 20.0% among STs, to 89.5% among RTs. Image recognition correlated positively with self-reported frequency of spine cases, but not with years of experience. Disk level and vertebral body recognition also correlated significantly with job title, but only disk level 1 correlated with self-reported frequency of spine cases.

Table 3

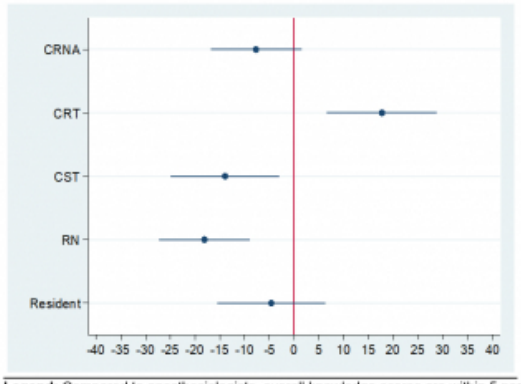
Spinal Anatomy and Fluoroscopic Image Knowledge and its Association with Respondent Characteristics (n=168)

	Basic Anatomy Questions			Scout Image Identification				
	# Cervical Vertebrae	*#Thoracic Vertebrae*	*# Lumbar Vertebrae*	*Cervical Spine Image 1*	*Cervical Spine Image 2*	*Lumbar Disk Level*	*Lumbar Disk Level 2*	*Lumbar Vertebral Body*
	% of Respondents Who Answered Correctly							
Overall	91.1	89.3	89.9	56.6	38.7	56.0	72.6	82.7
Professional State								
RN	84.6	69.2	71.8	66.7	38.5	41.0	48.7	61.5
RT	100.0	100.0	94.7	94.7	89.5	94.7	100.0	94.7
ST	80.0	70.0	80.0	55.0	20.0	55.0	70.0	80.0
CRNA	97.5	100.0	100.0	45.0	35.0	42.5	62.5	82.5
MD/DO	100.0	96.7	100.0	60.0	33.3	60.0	83.3	93.3
Resident	80.0†	100.0‡	95.0‡	20.0‡	25.0‡	70.0†	100.0‡	100.0†
# Years in current field								
Bottom Third	88.1	89.6	91.0	47.8	29.9	59.7	79.1	86.6
Middle Third	95.6	91.1	93.3	71.1	48.9	60.0	80.0	82.2
Upper Third	91.0	87.5	85.7	55.4	41.1	48.2	58.9*	78.6
Average # Spine Cases in last 4 weeks								
Bottom Third	88.9	84.0	82.7	49.4	27.2	48.2	67.9	79.0
Middle Third	94.6	97.3	97.3	46.0	43.2	46.0	67.6	83.8
Upper Third	92.0	92.0	96.0†	76.0 †	54.0 †	76.0 †	84.0	88.0

*P-value <0.05; † P-value<0.01 ‡P-value<0.001. P-values were calculated using Fisher's Exact (profession) or χ2 test for trend of odds (#years in profession; average # spine cases). The null hypothesis is that the proportion correct is the same in each profession (Fisher's exact) or that there is no linear increase in the log-odds for correct status with tertile of years/cases.

Figure 1

Overall Knowledge Scores Relative to Anesthesiologist



Legend: Compared to anesthesiologists, overall knowledge scores are within 5 percentage points for residents (CI -16%, +6%) and are significantly higher for CRTs (+17.7%, 95% CI 6.6%-28.8%).

Knowledge Score (Percentage of Questions Answered Correctly)

The median overall knowledge score was 75% (25th percentile 63%, 75% percentile 88%) and the knowledge score varied significantly with job title, case frequency, scouting frequency, and likelihood of correcting the physician in the event of wrong-site surgery (Table 4). The overall knowledge score was lowest in RNs (63%) and highest in RTs (100%). A small minority (n=29, 17.3%) correctly answered all items, with RTs being 9.2 times as likely as anesthesiologists to do so. Knowledge score increased in an approximately linear fashion with self-rated confidence, scouting frequency, and likelihood of correcting the surgeon. As shown in Figure 1, overall knowledge

relative to anesthesiologists was significantly higher among RTs and was within 5 percentage points among residents.

Table 4

Percentage of Questions Answered Correctly (Range 0 to 100%, n=168

	Mean % Questions Answered Correctly/IQR	P Value
Role		
RN	63/38,75	
RT	100/88,100	
ST	75/44,88	
CRNA	75/63,81	
Anesthesiologist	81/63,88	
Resident	75/63,81	0.001
Confidence Rating		
0-1	50/38, 63	
2-3	63/50,75	
4-5	75/50,75	
6-7	75/63,88	
8-9	88/75,100	<0.001
Scouting Frequency		
0-1	56/38, 75	
2-3	75/63,88	
4-5	63/63,75	
6-7	75/63,88	
8-9	88/63,100	<0.001
Likelihood of Correcting		
0-1	63/50,75	
2-3	69/50,88	
4-5	75/50,75	
6-7	75/63,88	
8-9	75/63,88	0.02

* Kruskal-Wallis equality of populations rank test (role) or Spearman's Rank Correlation (Confidence, Scouting, Likelihood of Correcting)

DISCUSSION

As stated above, the Universal Protocol and site verification guidelines are incomplete when applied to spine surgeries since a key part of the Protocol-- site verification-- requires added knowledge that potentially only a specialist may have. This study is the first to test this assumption--that only a spine surgeon or radiologist has the adequate knowledge for site verification in spinal surgery.

Our survey revealed that a majority of the intraoperative staff had a basic knowledge of anatomy, with most individuals able to answer the basic anatomy questions correctly, but unable to translate this into clinical application when it came to identifying a spinal level from an intraoperative scout image. This was evidenced by an overall low number of individuals able to correctly discern anatomic levels on fluoroscopic images presented on the survey, with only 29 (17.3%) of individuals able to identify all of the fluoroscopic images.

Individuals with a Medical School education or Graduate Medical School education fared very well in the basic anatomy questions in regards to the spine, with 96-100% of attending Anesthesiologists and 80-100% of Anesthesia Residents answering these questions correctly. However, this poorly correlated with clinical application to fluoroscopic scout images since the percentage of attending Anesthesiologists correctly identifying fluoroscopic images dropped to a range of 33.3%-60% for cervical spine images and 60.0%-93.3% for lumbar spine images; the trend was similar for Anesthesia Residents, with 20-25% of them answering correctly for cervical fluoroscopic images and 70-100% answering correctly for the lumbar images.

This poor translation of basic anatomy knowledge to fluoroscopic imaging identification was seen almost across the board, with a higher percentage of RNs and STs also correctly answering the basic anatomy questions, but poorly identifying the fluoroscopic scout images. Only RTs had a very high number of individuals correctly answering both the basic anatomy questions and identifying the fluoroscopic scout images. The RTs were also the most likely to pay attention to a scout image and had the highest confidence in their anatomy knowledge.

The role of RTs in the operating room is centered on fluoroscopic imaging, and they are called in specifically for site verification; this may be the reason they are the only group able to identify the fluoroscopic images with so high a level of accuracy. This difference can also be seen in the response to the question about attentiveness, with RTs having the highest attentiveness and all other intraoperative staff showing only moderate levels of attentiveness to the scout imaging. While not specifically asked in the survey, other intraoperative staff may feel it is not their role to pay attention to the scout imaging, in contrast to RTs, who have that specific role.

Despite their having very high accuracy, our study was limited and does not prove that RTs have sufficient knowledge to participate in site verification since our study questions only evaluated basic fluoroscopic site verification and excluded images with significant anatomic variation, significantly degenerative disease and/or thoracic spine cases where it is more difficult to identify the correct spinal level. The inclusion of these cases may decrease the accuracy of all groups.

This study highlights a significant gap in knowledge when it comes to fluoroscopic identification of spinal levels which presents a barrier to the development of a site verification protocol for spine surgery, but it still leaves open the question of whether or not these knowledge scores can be

improved. Given the problem we still face with the significant number of wrong-site spinal surgeries, it is important to increase the education of intraoperative staff as well as develop new protocols to help prevent wrong-site spine surgery. It is also important to highlight that patient safety and preventing wrong-site surgery is the role of all intraoperative staff and not exclusive to the operating physician.

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Name: Cuong Vu, MD. Assistant Professor, Department of Anesthesiology, Tufts University, School of Medicine, Baystate Medical Center, Springfield, MA.

Contribution: This author conceived the idea, helped design the study, gathered data, reviewed the analyzed data, and wrote the manuscript.

Conflicts of Interest: None.

Attestation: Cuong Vu approved the final version of the manuscript.

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Conflicts of Interest: None.

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Conflicts of Interest: None.

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Conflicts of Interest: None

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Contribution: This author helped design the study and provided the images for the study.

Conflicts of Interest: None

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