JOURNAL OF JPOSNA®

Volume 4, Number 4, November 2022

Original Research

A Universal C-arm Language Improves OR Morale

Ena Nielsen, MD[1] and Jennifer M. Bauer, MD, MS[1]

[1]University of Washington Department of Orthopaedics and Sports Medicine, Seattle, WA

Correspondence: Jennifer M. Bauer, MD, MS; Seattle Children's Hospital, University of Washington Orthopaedic and Sports Medicine Department, 4800 Sand Point Way NE, M/s OA 9.120, Seattle, WA 98105.
E-mail: jennifer.bauer@seattlechildrens.org

Received: July 1, 2022; Accepted: August 21, 2022; Published: November 1, 2022

DOI: 10.55275/JPOSNA-2022-536

Abstract

Background: Miscommunication while using intraoperative fluoroscopy C-arm can increase frustration, time, and radiation exposure. There have been no studies to date that have examined a standardized C-arm language during live cases, nor its durability over time. We aimed to design a directive language for use at a single institution and compare pre- and post-implementation surgeon and radiology technologist satisfaction and sense of operative efficiency.

Methods: All surgeons regularly using intraoperative fluoroscopy and all radiology technicians were surveyed regarding their experience and satisfaction regarding C-arm usage. Respondents provided their preferred terminology for each C-arm motion; the most frequent responses for each movement were used to create a universal language. Users were educated on the language via email and OR/C-arm signage for 1 month. Participants' recall of the terminology and satisfaction with use of the C-arm was evaluated at 1-month and 3-months post-intervention.

Results: 57 people responded to the initial survey—30 radiology technicians and 27 surgical attendings. Initially, surgeons indicated a significantly greater need to correct C-arm movement and repeat fluoroscopy and more case delays due to miscommunication than radiology technicians. At 3 months, surgeons reported significant improvements in how often the C-arm movement had to be corrected due to miscommunication (p=0.007), frustration due to C-arm miscommunication (p=0.002), and frequency of operative delays due to C-arm miscommunication (p=0.03). At 1 month, participants were able to recall the standardized language terms 76.9% of the time (surgical attendings: 74.4%, radiology technicians: 79.2%). This decreased slightly to 72.2% at 3 months (surgical attendings: 66.7%, radiology technicians: 77.6%).

Conclusions: Training in a universal C-arm language significantly improved surgeon but not radiology technician experience using C-arm intraoperatively, with decreased frustration and perceived improvements in efficiency. There was good retention of the language terms at 3 months.

Level of Evidence: IV, case series

Key Concepts

- No universal intraoperative fluoroscopy movement vocabulary exists.
- The lack of agreed-upon terms for C-arm movements leads to frustration.
- A universal C-arm language can be taught and retained for at least 3 months.
- A universal C-arm language improves surgeon experience with intraoperative fluoroscopy.

Introduction

The safe and accurate use of fluoroscopy in the operating room (OR) requires clear communication between the radiology technician operating the machinery and the surgeon directing them. Unfortunately, there is a large diversity of terminology used for the same 12 C-arm directions.[1-4] Even studies that have developed a standardized language for C-arm communication use the same terms for different motions.[1,2,4-6] This inability to communicate clearly may lead to inefficiencies in obtaining imaging, and therefore increased fluoroscopic time, radiation exposure, and frustration among operative staff. Annual radiation exposure to orthopaedic surgeons has increased commensurate with the increased use of C-arm, and patient exposure to radiation in the OR is not insignificant.[7-10]

Previous research has shown that the use of a shared lexicon for C-arm movements can improve efficiency in obtaining desired imaging, leading to decreased fluoroscopic time and radiation exposure.[4-6] In addition, surveys of both surgeons and radiology technicians suggest that improving intraoperative efficiency with the C-arm may decrease overall levels of frustration and improve operative times.[2-4]

However, there have been no studies to date that have examined a standardized C-arm language in real-time intraoperative use, nor the durability of adoption of such a language. We aim to develop a universal C-arm language for use at a single institution and compare pre- and post-implementation operative efficiency, fluoroscopic efficiency, and surgeon and radiology technologist satisfaction. It is our hypothesis that use of a standardized language will 1) improve operating room efficiency and 2) lead to improvements in surgeon and radiology technologist satisfaction.

Materials and Methods

Language Development

After IRB approval, attending surgeons of all specialties who regularly use intraoperative fluoroscopy, per their own report, and all radiology technicians at our institution were queried with a multiple-choice questionnaire to determine the most common phrases used to describe the 12 motions of the C-arm. Each motion was introduced by a photographic depiction to avoid biasing participant answer choices with written descriptions of the motion. Respondents chose from multiple choice options curated by the primary investigators for each motion, with a write-in option available. The results of the multiple-choice questionnaire were compiled, and the most common answer choice for each motion was used for the universal language.

Language Education and Use

The formal education program for the final universal language included training packet e-mails sent to all participants at the start of the program with word descriptions, photographs, and a learning sheet with a graphic depiction of the motion and chosen phrase (Figure 1). The drawings were posted in all ORs and on

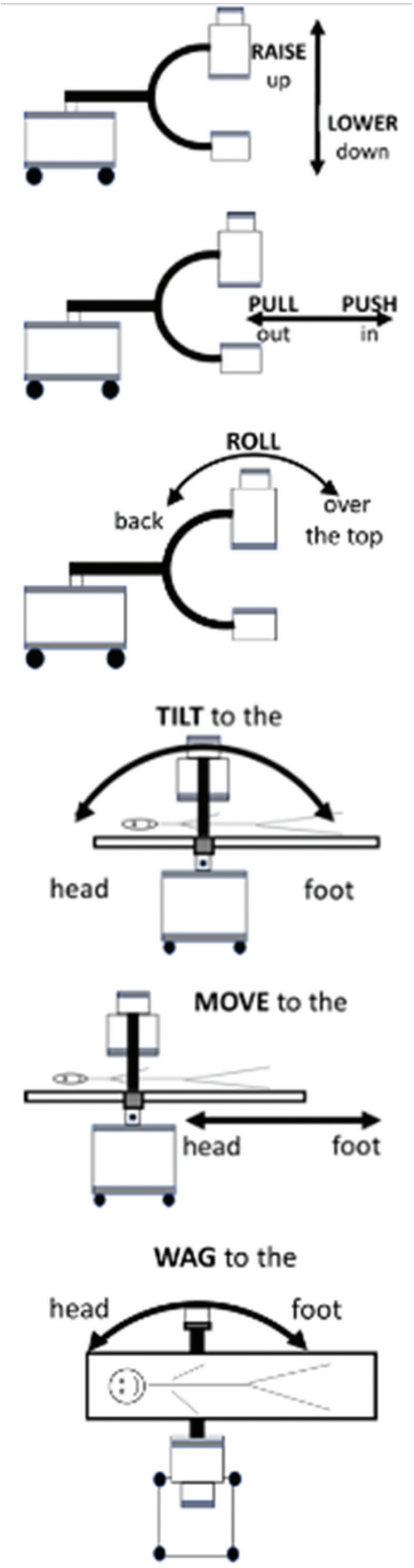

Figure 1. *Graphic depiction of C-arm movements and chosen universal language terms.*

all C-arm machines used across the hospital campus for the duration of the training period of 1 month. The main maneuver word was also affixed to the corresponding handle on each C-arm. After the 1-month training period, the signs were removed from the ORs and C-arm machines.

Participant Feedback

Participants were issued a pre-implementation survey to rate their satisfaction with fluoroscopy efficiency and ease of communication regarding C-arm use. The same pre-implementation survey was sent at 1 and 3 months after the introduction of the universal language. Follow-up surveys included questions regarding how often they used the language and if they perceived any improvements in C-arm usage since implementation. Respondents were also given a four-option multiple-choice survey testing their recall of the universal language terminology at the 1- and 3-month time points.

All surveys were developed in REDCap electronic data capture tools.[11,12] Statistics were performed using Stata/IC 14.0 (StataCorp. 2015. *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP).[13] Descriptive statistics were used for demographic information. Comparison of survey results across all three time points was done using a repeated measures ANOVA; comparison of survey results at two time points was done using unpaired two-tailed t-test. Due to the low number of responses to the 1-month survey, analysis was performed across all time points and then between pre-intervention and 3-month time points alone. Chi-square analysis was used for categorical data.

Results

We initially queried 83 people with 57 responses: 52.6% (n=30) radiology technicians and 47.4% (n=27) surgical attendings. Nineteen (33.3%; 9 surgeons, 10 radiology technicians) participants responded to the 1-month survey and 42 (73.7%; 21 surgeons, 21 radiology technicians) responded to the 3-month survey. Surgical attendings were divided across several departments: 36.7% (n=11) orthopaedic surgery, 23.3% (n=7) general

surgery, 16.7% (*n*=5) urology, 6.7% (*n*=2) plastic surgery, and 6.7% (*n*=2) neurosurgery. 12.3% (*n*=7) of participants had been educated in a universal C-arm language previously. The remainder of the demographic information can be seen in Table 1A, 1B. There was no difference between surgical attendings and radiology technicians in ethnicity, previous education in C-arm usage, or English as a native language. We included this analysis because language use may be affected by these variables. Surgical attendings had, on average, more years of experience in their role (16.1 vs. 6.4 years) and a higher percentage of males (66.7% vs. 6.7%) (Table 1B).

The chosen terms for the universal language and corresponding graphic depictions can be seen in Figure 1.

At 1 month, participants were able to recall the universal language terms 76.9% of the time (surgical attendings: 74.4%, radiology technicians: 79.2%). This decreased slightly to 72.2% at 3 months (surgical attendings: 66.7%, radiology technicians: 77.6%). There was no difference in rate of retention at 1 and 3 months between surgical attendings and radiology technicians; the difference in retention at 1 and 3 months was not significant (Table 2).

Self-reported adoption of the universal C-arm language remained stable between 1 and 3 months (55.6 vs. 58.8), with no difference in use between surgeons and radiology technicians. There was also no difference in the number of participants who felt that use of the C-arm

Table 1A. Participant Demographic Information

		All participants (n=57)	Surgical attendings (n=27)	Radiology technicians (n=30)	p-value
Gender (n, %)	*Male*	20 (35.1%)	18	2	**0.000**
	Female	35 (61.4%)	9	26	
	Prefer not to answer	0 (0%)	0	1	
Ethnicity (n, %)	*Asian*	4 (7.0%)	3	1	0.48
	Black or African American	1 (1.8%)	0	1	
	Hispanic or Latino	4 (7.0%)	2	2	
	Native Hawaiian or Other Pacific Islander	1 (1.8%)	0	1	
	White	41 (71.9%)	20	21	
	Other	1 (1.8%)	1	0	
	Prefer not to answer	5 (8.8%)	1	4	

Table 1B. Participant Demographic Information

	All participants (n=57)	Surgical attendings (n=27)	Radiology technicians (n=30)	p-value
Years of experience in current role (median, range)	9 (0-35)	13 (2-35)	6 (0-15)	**0.000**
Previously educated in a universal C-arm language (n, %)	7 (12.3%)	3	4	0.80
Native English speaker (n, %)	50 (87.7%)	26	24	0.06

Table 2. Participant Use and Retention of the Universal Language at One and Three Months

		All participants	Surgical attendings	Radiology technicians	p-value
Use of the c-arm has improved since implementation of the universal language (%"yes")	*1-month*	47.4%	66.7%	30.0%	0.11
	3-months	38.1%	38.1%	38.1%	1.0
	p-value	0.49	0.15	0.66	
How often have you used the universal language intraoperatively? (% of time used)	*1-month*	55.8%	55.7%	55.9%	0.56
	3-months	58.8%	50.1%	67.4%	0.39
	p-value	0.73	0.68	0.27	
Retention of universal language terms (via quiz)	*1-month*	76.9%	74.4%	79.2%	0.59
	3-months	72.2%	66.7%	77.6%	0.12
	p-value	0.43	0.41	0.84	

had improved since implementation at 1 and 3 months (47.4% vs. 38.1%) (Table 2).

There was a significant difference in the pre-implementation perception of C-arm usage between surgeons and radiology technicians. Using a 0-100 sliding scale, with 0=never and 100=always, surgeons indicated more frequent need to correct C-arm movement (p=0.009), need to repeat fluoroscopy (p=0.008), and more case delays (p=0.01) than radiology technicians (Table 3). These differences remained significant when comparing the average scores of all time points together between the two groups. Compared to pre-implementation, at 3 months surgeons reported significant improvements in three of the six themes: how often the C-arm movement had to be corrected due to miscommunication (46.0 vs. 28.8, p=0.02), frustration due to C-arm miscommunication (44.0 vs. 23.4, p=0.007) and frequency of operative delays due to C-arm miscommunication (47.5 vs. 31.7, p=0.02) (Table 3). They reported no improvements in ease of communication, confusion over terminology, or need for repeat fluoroscopy due to miscommunication. Radiology technicians did not report any significant improvements in C-arm usage for any survey question during the study period; however, they did rate their ability to communicate the desired C-arm movements at 3 months significantly higher than surgeons did (81.3 vs. 65.1, p=0.009).

Discussion

Training in a universal C-arm language led to significant improvement in surgeon experience using C-arm intraoperatively, with decreased frustration and perceived improvements in efficiency. The same results were not experienced by radiology technicians, who reported no significant improvements in any of our markers after training in the language, though they did have a positive trend in how well they felt they were able to communicate the desired C-arm movements which was significantly higher than surgeons' score at 3 months.

These improvements in communication and efficiency are consistent with prior studies. Williams et al. trained traumatologist and radiology technician pairs in a standardized language and demonstrated a significantly decreased number of "radiographs" and decreased time needed to orient a targeting guide through locking holes drilled through a synthetic distal femur.[5] A similar study was done by Yeo et al., with substantially decreased time and number of images needed to obtain "perfect circles" in a controlled nonoperative setting with model femurs.[6] Such improvements are unsurprising, as multiple prior papers have postulated that implementation of a universal

Table 3. Participant Perceptions of C-arm Usage, as Reported on a 0-100 Sliding Scale (Never =0; Always = 100). All Participants Included in Shaded Rows; Broken into Groups in Non-shaded

	Pre-Intervention	1-month	3-month	p-value: all time points	p-value: Pre- vs 3-month
How often does the movement of the c-arm have to be corrected due to miscommunication?	37.7	26.8	25.5	**0.007**	**0.02**
Radiology technician	30.4	23.6	22.1	0.33	0.14
Surgical attendings	46.0	30.3	28.8	**0.02**	**0.007**
p-value	**0.009**	0.18	0.24	**0.004**	
How frustrated are you due to miscommunication about c-arm movements during cases?	37.7	24.5	21.8	**0.02**	**0.01**
Radiology technician	32.2	19.3	20.2	0.78	0.11
Surgical attendings	44.0	30.2	23.4	**0.007**	**0.002**
p-value	0.10	0.26	0.60	0.07	
How well do you feel you are able to communicate the desired c-arm movements?	71.4	76.4	73.2	0.98	0.94
Radiology technician	74.7	79.1	81.3	0.76	0.22
Surgical attendings	67.7	73.3	65.1	0.88	0.68
p-value	0.19	0.43	**0.009**	**0.005**	
How often are you confused due to different terms used to control c-arm movements?	32.1	27	27.1	0.61	0.90
Radiology technician	28.9	24.5	24.4	0.82	0.50
Surgical attendings	35.8	29.8	29.9	0.63	0.40
p-value	0.33	0.56	0.39	0.16	
How often do you have to repeat fluoroscopy due to miscommunication?	23.0	21.6	18.2	0.32	0.26
Radiology technician	17.3	19.6	13.2	0.28	0.26
Surgical attendings	29.7	23.9	23.2	0.40	0.31
p-value	**0.008**	0.50	0.08	**0.002**	
How often do you think miscommunication contributes to delays in cases?	37.8	32.6	29.4	0.31	0.21
Radiology technician	29.3	34.6	27.1	0.67	0.66
Surgical attendings	47.5	30.3	31.7	**0.02**	**0.03**
p-value	**0.01**	0.65	0.51	**0.04**	

language would be beneficial due to the high level of variability in terminology used between and within groups of surgeons and radiology technicians.[1-4]

It is surprising that only surgeons experienced statistically significant benefits from adoption of the universal language despite similar levels of retention and adoption between surgeons and radiology technicians. One explanation for this may be that the radiology technicians typically work with multiple surgeons, requiring them to interpret many styles of communication. If they were frequently switching between surgeons who had and had not adopted the universal language, they may have experienced less benefit than those who were consistently able to use the language. While surgeons work with multiple radiology technicians as well, their time in the OR is limited to only one part of the work week while the technicians, working there each day, would thus encounter more variability. Due to the nature of the working relationship, the radiology technicians have less autonomy in which terms are used, which may also lead to frustration and decreased benefits from a universal language. However, their ability to equally contribute to the creation of the language may have ameliorated that for this study.

There was good retention of the language after 3 months, with an average score of 72.2% on a terminology quiz and no difference between surgeons and radiology technicians. There have been no prior studies examining durability of a C-arm language. It is possible that with increased adoption of the language, this score could increase further, as repetition would facilitate retention. It is also possible that use of the universal language may have been higher if signs remained posted in the ORs, although if this were the case, we could not have tested retention. Additionally, a more standardized teaching regimen could help facilitate ease of use and language retention. In these early efforts at implementation of our language, we directed all participants to review the terminology themselves, with diagrams and reminders posted in the ORs for 1month. While the diagrams were likely helpful, attempting to learn a language while also focusing on the intricacies of operating or running fluoroscopy machinery is likely less efficient than classroom or module teaching.

Other limitations of this study include its lack of objective measures of operative efficiency. We sought to test the feasibility of implementing a universal language at our institution and therefore focused our efforts on the users' perception of efficiency, communication, and adoption of the language. At even just under 60% adoption, the universal language facilitated improvement in perceived efficiency and communication for surgeons. Moreover, those who believe in a universal language may have scored their experience to be improved, even if objectively there was no evidence for that. However, because negative experiences like frustration are subjective, this response would still be an important outcome. Because every surgery is different, even choosing a single fracture fixation surgery to compare radiation usage pre- and post-implementation is clouded by variables of surgeon technique, level of trainees, and specific details of fracture difficulty. Efforts at our institution will now focus on more rigorous adoption of the language and future studies to determine more objective measures of improvement. As with any quality improvement effort, there are ongoing cycles of refinement and analysis.

Another limitation was poor response to the follow-up surveys at 1 month, making it difficult to assess utilization and outcomes of the universal language at that time point. We attempted to account for this by analyzing our data across all time points as well as only comparing pre- and 3-month post-intervention time points. However, it is possible that there was a decline in the benefit of the universal language at 3 months compared to 1 month that was hidden by response bias. There may also be bias in the reported scores because the respondents were not shown what their original responses were. Perhaps they may have wanted to report that their experience was improved (or not), but without knowing what the first score was, their subsequent response may not have been accurate.

The majority of prior research on this subject focused on controlled trials of a universal language outside of a real operation.[4-6] These neglect to account for the realities of inconsistent adoption, varied experience, retention, and operative stresses that limit the utility of such a language. This study focused on real-time operating suite implementation of a universal language and demonstrated benefits in efficiency and communication despite less than 60% rate of adoption and variable retention of the language terms at 3 months. This information allows us to focus future quality improvement initiatives and research on refining the language and increasing adoption at our institution. It may also serve as proof of concept for other institutions seeking to improve their C-arm communication.

What this study provided was a communication tool and shared understanding between the surgeons and radiology technicians to achieve shared goals in the OR. This study highlights the importance of teamwork. Similar success in OR morale may be achieved at other institutions by simply agreeing on the terms of C-arm movement at the start of a case with a short discussion. This alone may lead to a decreased sense of frustration and better camaraderie among operating room participants.

Implementation of a universal C-arm language improved surgeons' perception of intraoperative communication and efficiency at a single institution. More rigorous training methodology and increased adoption of the language has the potential to further improvements for surgeons and radiology technicians that could lead to improvements in OR throughput, radiation exposure, and interpersonal frustration.

Disclaimer

No funding was received for this project. The authors have no conflicts of interest to report.

References

1. Chaganti S, Kumar D, Patil S, et al. A language for effective communication between surgeons and radiographers in trauma theatre. *Ann R Coll Surg Engl.* 2009;91:509-512.
2. Stirton JB, Savage AD, Pally EM, et al. A standard universal C-arm language: assessing its need and its likelihood of acceptance. *J Orthop*. 2019;16:61-63.
3. Pally E, Kreder HJ. Survey of terminology used for the intraoperative direction of C-arm fluoroscopy. *Can J Surg*. 2011;56:109-112.
4. De Muinck Keizer RJ, Klei DS, Van Koperen PJ, et al. "Turn laterally to the left!". The need for uniform C-arm communication terminology during orthopaedic trauma surgery. *Acta Orthop Belg*. 2017;83:146-152.
5. Williams TH, Syrett AG, Brammar TJ. W.S.B.--a fluoroscopy C-arm communication strategy. *Injury*. 2009;40:840-843.
6. Yeo CH, Gordon R, Nusem I. Improving operating theatre communication between the orthopaedics surgeon and radiographer. *ANZ J Surg*. 2014;84:316-319.
7. Caird MS. Radiation safety in pediatric orthopaedics. *J Pediatr Orthop*. 2015;35:S34-S36.
8. Frane N, Megas A, Stapleton E, et al. Radiation exposure in orthopaedics. *JBJS Rev*. 2020;8:e0060.
9. Giordano BD, Grauer JN, Miller CP, et al. Radiation exposure issues in orthopaedics. *J Bone Joint Surg Am*. 2011;93:e69(1-10).
10. Hayda RA, Hsu RY, DePasse JM, et al. Radiation exposure and health risks for orthopaedic surgeons. *J Am Acad Orthop Surg*. 2018;26:268-277.
11. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42:377-381.
12. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
13. StataCorp. Stata Statistical Software: Release 14. College Station, Tx: StataCorp LP; 2015.