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ORIGINAL STUDY

"*Turn laterally to the left!*". The need for uniform C-arm communication terminology during orthopaedic trauma surgery

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To avoid disturbed teamwork, unnecessary radiation exposure, and procedural delays, we designed and tested a uniform communication language for use in fluoroscopy-assisted surgical procedures.

Input of surgeons and radiographers was used to create a set of commands. The potential benefit of this terminology was explored in an experimental setting. There was a tremendous diversity in the currently used terminology. Use of the newly designed terminology showed a reduction of procedural time and amount of images needed.

Our first standardized Dutch language terminology can reduce total fluoroscopy time, number of images acquired, and potentially radiation exposure. For Dutch speaking colleagues, the developed terminology is freely available for use in their OR.

Keywords : Fluoroscopy ; surgery ; communication.

INTRODUCTION

The mobile C-arm with image intensifier (C-arm) has an important use in orthopaedic trauma surgery, most notably in the visualisation of fractures, fracture reduction, and the position of internal or external fixation material (*2*,*4*,*5*,*10*). With increasing applications for minimally invasive orthopaedic surgery, reliance on image intensification (or fluoroscopy) is increasing (*5*).

In most cases, an radiographer operates the C-arm according to instructions from the operating surgeon (*4*,*10*). Accordingly, adequate communication between surgeon and radiographer during C-arm fluoroscopy is vital for efficient imaging. Efficient and safe use of C-arm imaging could protect theatre staff from unnecessary exposure to radiation and can benefit the course of the procedure (*1*,*3*,*6*,*8-10*). In contrast, miscommunication in the operating theatre has been shown to lead to increased risk of errors, disturbed teamwork, potential conflict, and procedural delays (*1*,*3*,*6*,*8-10*).

Despite its importance, in practice, communication between surgeons and radiographers is often incoherent and ambivalent (*7*). Previous studies

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have shown that standard, coherent instructions for C-arm movements are lacking (*4*,*6*,*9*,*10*). Due to the large number of different specialists involved in surgical procedures and the pressure to perform well in these situations, conflicts could easily arise (*1*,*3*,*8*). To solve this problem, standardized sets of commands have been developed, with significant reduction of fluoroscopy time and radiation dose as a result (*6*,*9*,*10*).

In our Level 1 Trauma Centre, both radiographers and surgeons expressed discontent with regard to fluoroscopy during orthopaedic trauma procedures. We hypothesised that the introduction of a clear, uniform set of instructions could increase procedural satisfaction and reduce fluoroscopy time, number of images taken and accordingly reduce radiation dose. Therefore, the objectives of the current study were: 1. to assess the attitude and experience of orthopaedic trauma surgeons and radiographers with regard to intra-operative C-arm fluoroscopy; 2. to evaluate the current terminology used in C-arm communication; 3. to develop a clear and uniform set of Dutch language commands to control the C-arm; and 4. to explore the potential benefit of implementing this terminology.

MATERIALS & METHODS

This study was performed in a level 1 trauma center: in 2014, the orthopaedic, trauma, vascular and general surgeons performed 1255 fluoroscopy assisted procedures.

Assessment of experience during C-arm communication

In February 2014, questionnaires were sent to all trauma and orthopaedic surgeons/residents and radiographers in our hospital. Questionnaires consisted of multiple choice questions to evaluate their experience with intra-operative C-arm fluoroscopy.

Evaluating the currently used terminology

In addition to the multiple choice questions, we provided pictorial representations of C-arm movements in all 6 degrees of freedom (i.e. 12 movements) and asked for the appropriate command to describe the specific movement (open questions). These given commands were compared within groups and between surgeons and radiographers.

Development of uniform terminology

From these questionnaires, four optional verbal instructions per movement were derived. During an expert-meeting in June 2014, 22 trauma- and orthopaedic surgeons voted for the most appropriate instructions. The authors composed a uniform communication language based on these answers.

Fig. 1. — Macroscopic and fluoroscopic images of the soccer ball with A. two random series of predefined positions and B. washers not aligned and C. washers aligned

Exploring the potential benefit of uniform terminology

Inspired by earlier work by Yeo and colleagues, we designed and conducted a fluoroscopy experiment in the operating theatre to explore the potential benefit of the new terminology. For this experiment, we randomly assigned two clinicians (a trauma surgeon and a surgery resident) to an experienced radiographer, forming an experimental team.

The experimental teams were instructed to take fluoroscopic images of two metal washers taped to either pole of a spherical, radiolucent object (a soccer ball) in such a way that the washers would overlap (Figure 1) (*10*). This simulated "limb" was positioned on a carbon operating table and covered with a sheet. Two sets of ten orientations were marked on the object: in each case, the participants were blinded to the orientation of the washers.

Prior to instructing any communication strategy, the total of 10 predefined orientations of the washers were executed per team. The time taken by the surgeon to verbally instruct the radiographer on how to position the C-arm in order to let the washers overlap was recorded, as well as the radiation dose and number of images needed. The surgeon was not allowed to physically adjust the C-arm. After 10 orientations, the surgeons' and radiographers' opinion was evaluated with regard to procedural satisfaction and collaboration.

Subsequently, the newly developed communication terminology was introduced by written and pictorial representations of the commands. The experiment was repeated with another 10 orientations, using the newly introduced C-arm communication terminology. The new instructions were readily available throughout this task.

Data analysis

To reduce the effect of a possible learning curve during the execution of the experiment, only the last 7 observations of each task were compared. Due to the relatively low number of observations, we assumed the obtained data to be unevenly distributed and accordingly used the Wilcoxon signed rank test to compare data. Variables are denoted as median [inter quartile range].

RESULTS

The questionnaire was sent to 24 trauma or orthopaedic surgeons/residents and 76 radiographers. Seventeen (71%) trauma and orthopaedic surgeons/residents and sixteen (21%) radiographers responded to the questionnaire. Surgeons had an average of 9 years of experience; radiographers averaged 17 years of experience.

Assessment of experience during C-arm communication

During fluoroscopy, 82% of surgeons were assisted by a radiographer during 95-100% of procedures. However, 60% of radiographers came to the OR less than twice a week.

The majority of surgeons estimated that in 25-50% of movements, the C-arm would move in the opposite direction than they intended. 65% of surgeons and 70% of radiographers were of the opinion that incorrect movements of the C-arm were caused by miscommunication. 65% of radiographers thought instructions given by surgeons were confusing or unclear. 94% of surgeons were of the opinion that inadequate positioning of the C-arm led to annoyance in the OR, while 88% of surgeons thought it caused a significant delay in the procedure.

Evaluating the currently used terminology

With regard to the pictorial representations of the C-arm movements, a tremendous variety of commands was provided by both surgeons and radiographers. Certain movements had high inter-surgeon agreement but low surgeon – radiographer agreement. Others had low inter-surgeon, inter-radiographer and surgeon – radiographer agreement. Examples of commands suggested by the participants are provided in Figure 2 for two movements: to enable interpretation and overcome the language barrier, Dutch commands were converted into letters. Best possible translations are given for movement B in Table 1.

Development of a uniform terminology

The authors composed a uniform communication terminology based on the votes of 22 trauma- and orthopaedic surgeons. Consensus was reached for all but two single movements, for which the antonym of the opposite direction was chosen.

Exploring the potential benefit

After the introduction of the new terminology, Team 1 showed a reduction in time, images and overall radiation dose needed to achieve overlapping washers. Reduction in both the number of images and the radiation dose reached significance (Table II). Team 2 showed a reduction in both time and images needed, but an increase in radiation dose after the introduction of the new terminology.

All team members unanimously rated the new terminology as clear and instinctive. The terminology was thought to be helpful, especially when working with many different colleagues. Additionally, 3 out of 4 team members remarked it would take additional time to familiarize with the terminology in order to fully utilize its potential.

DISCUSSION

We found a tremendous diversity of commands for C-arm positioning with a lack of agreement between surgeons and radiographers. The majority of surgeons acknowledged that inadequate positioning of the C-arm lead to annoyance in the OR and caused a significant delay in the procedure. The introduction of uniform terminology resulted in a significant reduction of images and time needed to perform fluoroscopy tasks. Currently, our study presents the first Dutch language terminology for the use of assisted fluoroscopy during orthopaedic trauma procedures.

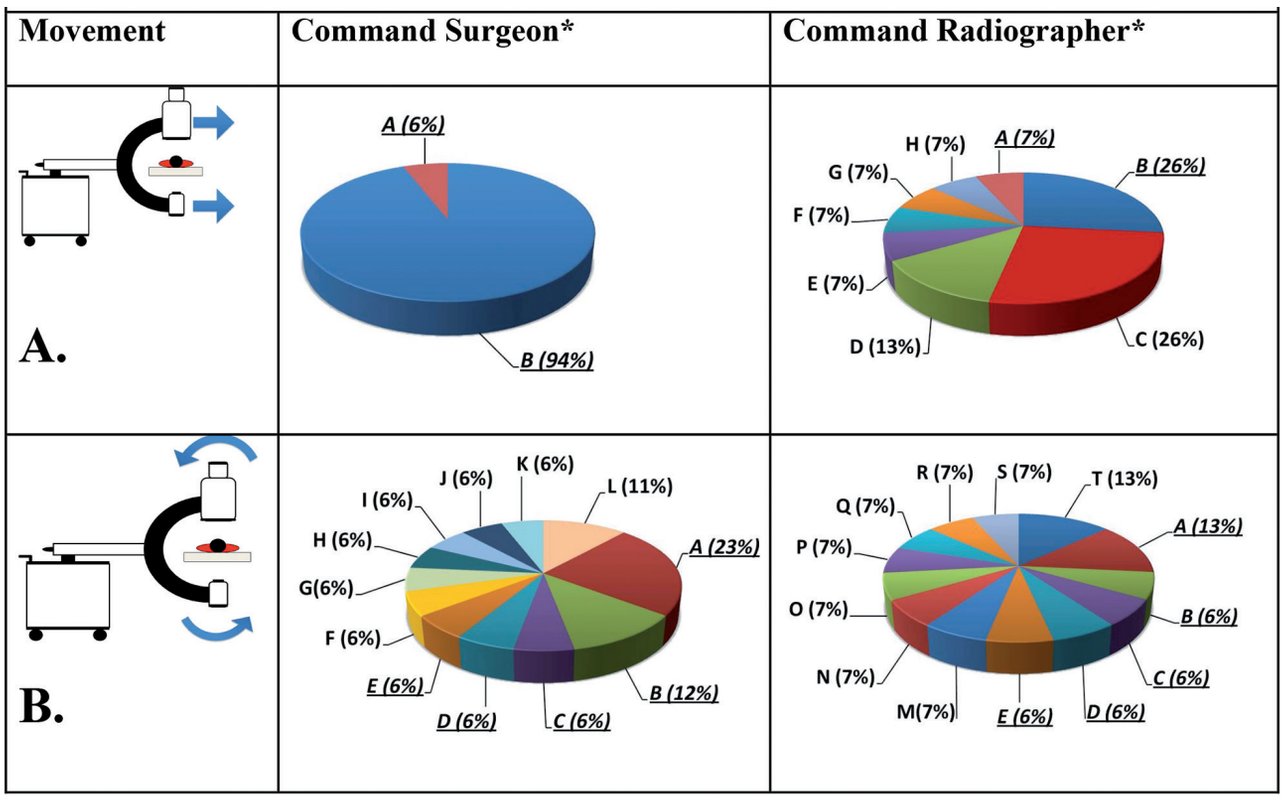

Fig. 2. — Example of two C-arm movements and the suggested commands. Coinciding commands given by both surgeons and radiographers are underlined and in *italics*.

Table I. — Best possible English translations of commands as suggested by surgeons and radiographers for movement B. Coinciding commands given by both surgeons and radiographers are underlined and in italic.

	Dutch command	**English translation**
A	*Boog/buis achterover kantelen/tilten*	*Tilt C-arm/tube backwards*
B	*Buis onder de patiënt door kantelen*	*Tilt tube underneath patient*
C	*Buis terugkantelen*	*Tilt C-arm/tube backwards*
D	*Lateraal doorlichten*	*X-ray laterally*
E	*Buis naar links draaien/kantelen*	*Tilt/turn tube to the left*
F	"Handgebaar"	"Hand gesture"
G	Naar je toe kantelen	Tilt towards you
H	C-boog kantelen van operateur af	Tilt C-arm away from surgeon
I	In-roteren	Rotate inwards
J	Exo-roteren	Exorotate
K	Oblique mediaal	Oblique and medially
L	Onderuit (draaien)	(Turn) downwards
M	Inschieten van mij af (vanuit de chirurg)	Shoot away from me (from standpoint of surgeon)
N	Latero-mediaal of medio-lateraal	Lateromedial or mediolateral
O	LAO	LAO (Left Anterior Oblique)
P	Axiaal/lateraal	Axially/Laterally
Q	Naar links lateraal draaien	Turn laterally to the left
R	Naar jou zwiepen	Swivel towards you
S	Boog naar lateraal anguleren, onderlangs	Angulate the C-arm laterally and underneath
T	Inschieten naar/vanaf links	Shoot to/from the left

We know of three studies that have reported similar experiments. Firstly, Williams et al. (2009) introduced a similar, standardized terminology and showed a significant reduction in time and exposure during a series of 56 targeting manoeuvres (*9*). Although they used a large series of observations, they were done by one single team of surgeon and radiographer (*9*). Secondly, Yeo et al. (2014) designed a standard language and tested it with a similar experiment as the one described in the present study (*10*). Time needed for a successful image and the mean number of images decreased significantly after introduction of their terminology. In contrast to Williams et al., they used 15 pairs of surgeon/radiographer instead of one, yet they only performed 3 sets of ball positions per pair. This design underestimates the effect of the expected learning curve within this task, thus potentially confounding outcome measurements. Finally, Pally and Kreder (2013) developed standard instructions after consulting radiographers and trauma surgeons for the most commonly used commands (*6*). Like the present study, they found tremendous inconsistency in the commands used. They subsequently developed terminology based on the input of 261 surgeons and 225 radiographers, but did not explore the effect of the terminology in an experimental setting.

Overall, despite their shared common goal of minimizing confusion in the operating theatre, the three suggested sets of terminology are in no way identical. For example, an identical orbital rotational movement of the C-arm is respectively called "roll over/under" (Williams), "swing up/down" (Yeo) and "rotate over/back" (Pally). Additionally, the term "swing" as used by Yeo et al for an *orbital* movement is reserved for *horizontal* movements by Williams and Pally. Also, the term "roll" is used by Williams and Yeo for contradictory movements, while it is not used in the terminology of Yeo et al.

In the present study, we found that 60% of radiographers came to the OR less than twice a week. In concordance, Pally and Kreder found that only 4.4% of radiographers spent more than half of their time at work using fluoroscopy in the operating theatre. In addition to a uniform terminology, dedicated OR radiographers could potentially benefit the process of fluoroscopy during surgery.

Strengths of our study include the fact that we used a step-up approach to involve both surgeons and radiographers in the development of a new terminology, and tested this terminology in a realistic experimental setting. Additionally, to our knowledge we are the first to present a Dutch language communication strategy for the use of intra-operative fluoroscopy. Although its use is limited when compared to English variants, the Dutch language caters for approximately 28 million citizens in countries like the Netherlands, Belgium, Surinam and the islands formally known as the Dutch Antilles.

Our study is limited by the number of experimental teams that participated to explore the potential of our new terminology. This was partly due to logistical challenges: the limited availability of C-arms and radiation protected rooms (e.g. operating room) forced us to conduct the experiment outside of office hours, during which the availability of radiographers was limited. The main focus of this study however was the development of new terminology: the experimental part of our study illustrated what to expect when implementing this terminology in day-to-day practice.

Additionally, Team 1 proved to be more successful in completing the tasks compared to the second team. This could be explained by the relative inexperience of the surgery resident in the second team in interpreting fluoroscopic images. Unlike Yeo et al, we did not record the time taken for surgeons and radiographers to become familiar with the terminology (*10*). In retrospect, 3 out of 4 team members suggested that more time was needed to familiarize the terminology. Also, despite using only the last 7 measurements of each session, a learning effect is still plausible. Additional repetitions could minimize this potential effect even further, but would add significant time to the experiment.

Previous studies have shown the importance of efficient and safe use of C-arm imaging: it protects theatre staff from unnecessary radiation and can benefit the course of the procedure (*1*,*3*,*6*,*8*–*10*). In the near future, we plan to implement our terminology throughout our Level 1 Trauma Center and evaluate surgeons' and radiographers' satisfaction. Also, we will further improve the terminology by adding commands for movements when the C-arm is not positioned perpendicular to the OR-table.

CONCLUSION

There is a need for uniform terminology during fluoroscopy assisted orthopaedic trauma surgery. Based on input from both surgeons and radiographers, we developed and experimented with the first standardized Dutch language terminology to be used during intra-operative fluoroscopy. Its

Table II. — Results of experiment before and after introducing uniform terminology for C-arm movements

Variable*		**PRE**	**POST**	**p-value****
Time needed in seconds	**Team 1**	50 [27-65]	32 [27-90]	0.416
	Team 2	126 [45-141]	69 [54-94]	0.128
Number of images needed	**Team 1**	5.00 [4.00-5.00]	4.00 [3.00-4.00]	**0.025**
	Team 2	6.00 [3.00-7.00]	4.00 [3.00-4.00]	0.057
Radiation dose in mGy	**Team 1**	0.009 [0.007-0.013]	0.002 [0.001-0.004]	**0.018**
	Team 2	0.011 [0.0047-0.0154]	0.019 [0.008-0.047]	0.063

*Variables are denoted as median [inter quartile range].

**Differences were tested with the Wilcoxon signed rank test.

implementation could reduce the total fluoroscopy time, the number of images required and potentially reduce the overall radiation exposure, while simultaneously improving collaboration and progress of the procedure in the operating theatre.

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For Dutch speaking colleagues, the developed terminology is freely available for use in their OR. Please contact the corresponding author.

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