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Design, delivery, and evaluation of seminars and hands-on courses worldwide on intraoperative imaging in orthopedic trauma

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ABSTRACT

Introduction: Although intraoperative imaging is important for assessing the quality of several steps during fracture fixation, most trainees and surgeons have received little formal education on this topic and report they learn "on the job" and "through practice". A planning committee of orthopedic trauma surgeons was established to design a curriculum using "backward planning" to identify patient problems, identify gaps in surgeons' knowledge and skills, and define competencies as a framework for education in order to optimize patient care.

Materials and methods: The committee defined 8 competencies related to intraoperative imaging, with detailed learning objectives for each one (e.g. select the imaging modality, set up the operating room). An interactive, case-based half-day seminar to deliver these objectives for 2-D and 3-D intraoperative imaging during the fixation of common fractures was designed. The seminar was delivered in several locations worldwide over a 6-year period and evaluation and assessment data were gathered online. A full-day procedures course was added and delivered 6 times to address the skills component of competencies.

Results: 17 seminars and 6 courses were delivered and attended by an average of 26 and 17 participants respectively (ranges 13–42 and 13–20). Pre-event gap analysis and assessment question scores confirmed needs and motivation to learn in all events. 97% of the 442 seminar participants and 98% of the 100 course participants would recommend the events to colleagues. An average of 88% and 90% respectively learned something new and plan to use it in their practice (range 63%-100%). Commitment to change (CTC) statements showed intended practice improvements related to all competencies.

Discussion: The large percentages of high impact ratings for all events suggest the content met the needs of many participants. Post-event reduction in gap scores and an increase in the desired level of ability for most competencies suggests the content addressed many gaps.

Conclusions: Case-based, interactive seminars and courses addressing knowledge, skills, and attitudes to optimize the use of intraoperative imaging during the fixation of common fractures help address unmet educational needs for trainees and complements existing formal training.

Introduction

Despite the key role of image intensification for intraoperative assessment of fracture reduction and implant positioning during internal fixation procedures for fracture treatment, residents and practicing orthopedic surgeons receive little formal education on

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1. Curriculum development	2. Event design	3. Content development
• Identify the patient problems • List the performance gaps • Define the competencies • Define the knowledge, skills, and attitudes	• Define the relevant fractures, learning outcomes for audience • Choose the educational methods • Define the overall program	• Define the case or station format • Build the case or station content • Review and approve the cases • Develop resources (MCQs, guides, videos, etc)
4. **Faculty preparation**	5. **Participant engagement**	6. **Event delivery and evaluation**
• Select a chairperson • Select the faculty • Assign the cases or stations and tasks • Prepare using online meeting and faculty pre-course • Organize faculty travel and accommodation, etc	• Advertise to target audience • Provide registration information • Invite to complete pre-assessment • Compile and analyze data	• Organize and setup venue • Run the half-day event • Gather evaluation data • Conduct a faculty debrief • Update the content

Fig. 1. Steps in curriculum development and implementation
The six development phases of the curriculum and the implementation.

- Articular fractures, especially lower extremity (calcaneal, ankle, syndesmotic injuries/rupture, pilon, tibial head, proximal femur)
- Upper extremity fractures: distal radius, proximal humerus
- Shaft fractures and issues such as malalignment, malrotation, length discrepancy
- Polytrauma, multiple fractures, diagnostic imaging intraoperatively
- Inadequate joint reconstruction
- Nonunion
- Incorrect implant placement
- Limited range of motion, osteoarthritis, pain, reduced quality of life
- Radiation exposure
- Advanced topics: spine, pelvic ring, acetabulum fractures

Fig. 2. Patient problems and issues related to intraoperative imaging
Patient pathologies which can be addressed with intraoperative imaging.

this topic [1–3]. Surgeons at all levels of training and practice acknowledge difficulties in obtaining optimal high quality intraoperative images which are crucial in assessing the quality of fracture reduction and implant positioning [4,5]. Image intensifiers have developed over the past 10 years and 3D intraoperative imaging is now available in an increasing number of hospitals [6,7]. The optimal use of this sophisticated technology is not feasible in some hospital environments, with a lack of training and a lack of knowledge about appropriate indications being cited as reasons [7–9]. In addition, recent studies show that radiation exposure and protection issues have suboptimal data in orthopedic trauma despite the fact that intraoperative 3D imaging may reduce radiation exposure for operating room staff [10–12].

A curriculum planning committee consisting of 4 orthopedic trauma surgeons with expertise in intraoperative imaging was established. The group was supported by an educationalist to apply a backward planning process to develop a competency-based curriculum based on patient problems and performance gaps that have to be addressed through education [13–15]. The objective was to design a curriculum and educational events to address the gaps and needs of the target audiences (Fig. 1). The committee identified the patient problems and issues (Fig. 2) to address the main areas of performance gaps, which were translated into 8 competencies. Each competency was split into one of the three following qualities: knowledge, skills and attitudes or behaviors. The aim of this procedure was to provide a detailed framework of objectives (Fig. 3).

Options for delivering education on this topic were discussed and the committee designed a half-day seminar and a full-day course with imaging procedures performed on anatomical specimens targeted at residents (i.e. trainees in orthopedics and trauma). To deliver relevant content a case-based approach was chosen. This allowed a highly interactive presentation and direct feedback from faculties. For the seminar as well as for the course, common fractures were selected. The aim was to address pathologies that are common and of high relevance to all participants. The cases were: fractures of the proximal femur and proximal humerus, fractures of the femoral shaft, unstable syndesmotic injuries in the ankle, and articular fractures of the distal radius. To foster interactive discussion, each fracture was presented as a clinical case, starting with standard fractures and progressing to more complex situations. Intraoperative images of the respective fixation were displayed. In small groups, participants and faculty discussed these cases, addressing image relevant questions such as image quality,

Competency 2. Set up the operating room	
Select the type of table required, and set up the C-arm and trolley	Knowledge
Position the patient correctly for each specific procedure	Knowledge
Reduce/keep at a minimum radiation exposure	Knowledge
Outline the processes for sterile draping	Knowledge
Set up the imaging equipment with adequate access, team, etc	Skill
Apply sterile draping	Skill
Follow correct radiation protection steps for patient and staff	Attitude

Fig. 3. Knowledge, skills, and attitudes for one example competency
Competencies which are dealt with throughout the seminar and course.

standard planes, and anatomy. In the discussion, a major point was the necessity of additional images and how to obtain these. At the beginning of the presentation, additional content such as radiation protection and 3D-related content was demonstrated. In contrast to the seminar, where interaction was created in small group discussion and open feedback rounds, the courses contained practical content where participants had to demonstrate how to obtain images in clinical situations. To achieve this, anatomical specimens were prepared to simulate fracture fixation procedures. Each station was moderated by an experienced faculty. All groups rotated to the next station every 90 min, ensuring that all participants had access to all cases.

The committee developed resources to support the events in the form of a set of 16 multiple-choice pre-assessment questions, posters showing the operating room set up, videos showing the use of 2-D and 3-D intraoperative imaging, and labeled images showing anatomical markers and quality criteria for correct imaging. Additionally, they integrated two existing eLearning modules on basic principles.

The aim of the study was to test the following hypotheses:

1 Participants of all experience levels can benefit from training in imaging and recognize individual knowledge gaps
2 Pre-event knowledge gaps (difference between desired level and present level) can be reduced by two different teaching experiences (seminar and course)
3 A case-based approach can be used to address clinically relevant content and is recognized as being very interactive by participants

Materials and methods

Event planning: program finalization, communication, and course organization

Locations were proposed by the planning committee as well as surgeons in the respective regions in where to deliver the seminar and the course. The events were approved and added into the regional planning calendar for selected countries. The program was advertised in the AO Trauma course listings and registration was open for at least 2 months before each event. All events were supported by an educational grant; therefore, there was no registration fee for participants for the seminars and the fee for each course was reduced and based on local event costs.

Faculty selection and assignments

One chairperson from the curriculum committee was appointed for each seminar and one local co-chairperson. 4 faculty were appointed to deliver the 4 cases or stations and additional faculty were appointed as moderators of the small group discussions and to support the lab-based procedures. An online meeting was held 6 weeks before the seminar to discuss cases and key messages, and to answer any questions regarding the content or format. All faculty met for a half day immediately before each event to prepare for the face-to-face delivery.

Participants

Each registered participant received an email 30 days before the event inviting them to complete an online self-assessment and 16 multiple-choice questions (MCQs, 2 per competency), with 3 reminder emails over the following 20 days [16]. At the end of the event, the participants were asked to rate the usefulness of the content and the faculty performance. One day later, they received an email invitation to complete a 12-question online evaluation. 3 months after the event, participants were invited to report the status of their intended practice changes. On completion of the online questions, participants received a certificate of attendance.

Seminar/course delivery, including faculty pre-course and debriefing meetings

Each seminar was delivered as a half-day educational event. During the pre-course meeting, the faculty reviewed the cases and agreed on key messages that needed to be addressed in the seminar and courses. The pre-assessment data of respective participants were analyzed and taken into account regarding the content for group discussions. The learning objectives were pointed out and details of each presentation were discussed. Faculty members visited and previewed the event room to check and finalize the learning environment (e.g. tables, seating, audiovisual system, demonstration equipment). For the course, a more extensive preparation was necessary. In addition to the pre-course faculty meeting, the faculty members had to prepare the anatomical specimen and to install the image intensifiers. The 4 anatomical regions of the course consisted of proximal humerus, proximal femur, ankle joint, and distal radius.

Data collection and analysis

The study was approved by the ethics committee of Rhineland-Palatine (reference number 2020–15,135). All data were gathered using SurveyMonkey and then stored in a management information system used to generate standardized reports. The data values and averages were calculated using Microsoft Excel.

Results

The 17 seminars and 6 courses were delivered in Europe, South America, North America, the Middle East, Asia, and Australia be-

Table 1
Participant profile data for all seminars and courses.

Year	Location	AO Region	Participants	Pre-event responses	Response rate	Delivery	In training/ residency (up to 5 years since graduation)	Access to 3-D imaging
Seminars								
2014	Ludwigshafen (pilot event)	Europe and Southern Africa	18	16	89%	Hospital-based	72%	76%
2015	Warsaw	Europe and Southern Africa	33	25	76%	After a course	44%	12%
2016	Basel	Europe and Southern Africa	22	19	86%	Hospital-based	80%	53%
2016	Stockholm	Europe and Southern Africa	27	21	78%	After a course	14%	28%
2016	San Francisco	North America	23	21	74%	Hospital-based	95%	82%
2016	Cleveland	North America	25	21	84%	Hospital-based	100%	20%
2017	Baden-Baden	Europe and Southern Africa	19	18	95%	Within a conference	38%	62%
2017	Chiang Mai	Asia Pacific	39	20	51%	After a course	25%	45%
2018	Dubai	Middle East and Northern Africa	31	–	–	Self-directed learning day	–	–
2018	Bogota	Latin America	24	21	88%	Hospital-based	81%	29%
2018	Buenos Aires	Latin America	25	19	76%	Hospital-based	80%	74%
2019	Baden-Baden	Europe and Southern Africa	19	13	68%	Within a conference	50%	58%
2019	Ljubljana	Europe and Southern Africa	25	24	96%	Hospital-based	38%	56%
2019	Berlin	Europe and Southern Africa	9	7	78%	Within a conference	14%	71%
2019	Mexico	Latin America	42	19	45%	Hospital-based	90%	37%
2019	Sao Paulo	Latin America	41	21	51%	Hospital-based	84%	17%
2020	Lucerne	Europe and Southern Africa	20	20	100%	Hospital-based	94%	78%
Total	**17**		**442**	**305**				
	Average		**26**	**19**	**77%**		**62%**	**50%**
Courses								
2019	Basel	Europe and Southern Africa	16	13	81%	Standalone lab day	45%	45%
2019	Basel	Europe and Southern Africa	20	20	100%	Standalone lab day	35%	67%
2019	San Francisco	North America	18	14	78%	Standalone lab day	56%	57%
2020	Melbourne	Asia Pacific	19	17	89%	Lab day after Basic Principles	95%	33%
2020	Erlangen	Europe and Southern Africa	14	14	100%	Standalone lab day	60%	60%
2020	Erlangen	Europe and Southern Africa	13	13	100%	Standalone lab day	50%	91%
Total	6		**100**	**91**				
	Average		**17**	**15**	**91%**		**57%**	**59%**

Table 2
Participant evaluation data from seminars and courses.

Type of event and ratings		Participants	Responses	%	Learned something new and will use it in practice	Content rating (Likert scale 1 to 5)	Recommend to colleagues
Seminars							
	Highest	42	21	95%	100%	4.56	100%
	Lowest	9	6	14%	63%	3.63	83%
Total	17	442	239				
	Average	**26**	**19**	**59%**	**81%**	**4.15**	**97%**
Courses							
	Highest	20	18	90%	100%	4.64	100%
	Lowest	13	5	28%	64%	4.0	91%
Total	6	100	65				
	Average	**17**	**11**	**66%**	**86%**	**4.37**	**97%**

tween November 2014 and September 2020. Both the seminars and the courses were delivered as standalone hospital-based events ($n = 10$) or as an optional additional event after an AO Trauma course or a society congress ($n = 7$). The seminars were attended by 442 participants (average = 26, range = 9–42). The courses were attended by 100 surgeons (average = 17, range = 13–20). The profiles of the participants for each event (seminars and courses) are shown in Table 1, and the evaluation data gathered online from the participants are shown in Table 2. 81% of the seminar participants and 86% of the course participants reported "I learned something new and plan to use it in practice", and 97% of the participants would recommend both types of events to their colleagues. The degree to which each event met its objectives is shown in Table 3. The post-event gap scores (desired minus present levels of ability) were lower than the pre-event gap scores for most competencies (Fig. 4). A total of 1399 intended practice changes were reported and these were analyzed by the curriculum committee (Table 4).

Table 3
How well were the event objectives met (on a Likert scale from 1 = not met at all to 5 = fully met)?.

Event type	C1 Select 2-D and 3-D intraoperative imaging modalities	C2 Set up the operating room	C3 Perform intraoperative 2-D imaging	C4 Assess fracture reduction and implant position	C5 Intraoperatively decide on additional use of 3-D imaging	C6 Perform intraoperative 3-D imaging	C7 Process and analyze 3-D images	C8 Decide on postoperative CT scans	Averages
Seminars									
Highest	4.71	4.29	5.00	5.00	5.00	4.54	4.57	4.71	
Lowest	4.00	3.80	4.00	4.00	3.67	3.67	3.33	3.67	
Average	**4.47**	**4.10**	**4.57**	**4.51**	**4.40**	**4.00**	**4.08**	**4.30**	**4.31**
Courses									
Highest	5.00	4.59	5.00	4.78	4.89	5.00	4.77	4.78	
Lowest	4.25	3.88	4.67	4.06	3.88	3.75	3.63	3.44	
Average	**4.55**	**4.31**	**4.84**	**4.45**	**4.33**	**4.51**	**4.37**	**4.02**	**4.42**

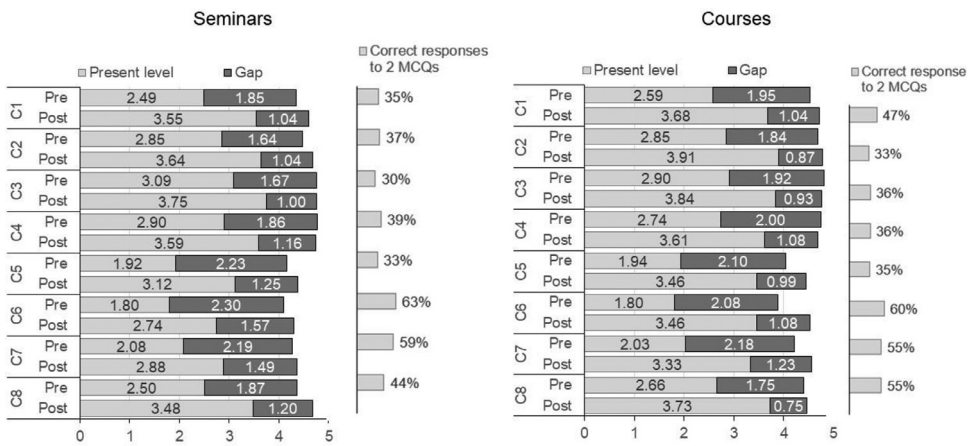

Fig. 4. Pre- and post-event self-assessed levels of ability per competency and pre-event MCQs
Comparison of pre- and post-event levels of ability.

Table 4
Intended practice changes (statements of commitment to change assigned per competency).

	Seminars		Courses	
C1: Select 2-D and 3-D intraoperative imaging modalities based on indications and limitations	98	9%	28	12%
C2: Set up the operating room	94	9%	32	14%
C3: Perform intraoperative 2-D imaging	127	12%	39	17%
C4: Assess fracture reduction and implant positioning	111	10%	37	16%
C5: Intraoperatively decide on additional use of 3-D imaging	71	7%	23	10%
C6: Perform intraoperative 3-D imaging	76	7%	36	15%
C7: Process and analyze 3-D images	70	7%	23	10%
C8: Decide on postoperative CT scans	79	7%	18	8%
Other	333	31%	104	31%
Total	**1059**		**340**	

Discussion

High quality intraoperative imaging is crucial in orthopedic and trauma surgery to ensure optimal patient care by assessing fracture reduction and implant placement. Multiple aspects must be considered to receive good quality intraoperative images and to be able to identify and analyze the visualized anatomy and implant position. It may vary from country to country who performs intraoperative imaging, the OR room personnel or specially trained technicians, but ultimately it is the responsibility of the surgeon to approve the images acquired. The person performing a procedure must have the knowledge of exactly what is required for intraoperative control. In all countries throughout the world we learned that surgeons have not received specialized training to achieve this goal. A C-arm is a complex machine and learning how to operate one requires more than watching someone else using the system.

Therefore, to provide an optimal surgical residency education, the teaching of intraoperative imaging is pivotal. Despite the importance of this issue, intraoperative imaging has not been subject to the general residency training programs in any country [17]. Therefore, a half-day seminar and a full-day procedures course targeting this topic were developed.

With this study we wanted to highlight that this identified teaching gap in surgical training can be sufficiently filled with a seminar as well as a course-based teaching experience, and that our case-based training is perceived as highly interactive by its participants.

The pre- and post-event data suggest that participants increased their knowledge in the field of intraoperative imaging with a half-day seminar. After attending the full-day procedures course, the participants had, on average, a larger increase in self-reported present level of ability for processing and analysis of intraoperative 3D-imaging (C6) (Fig. 4). The present levels in intraoperative 2D-

imaging (C3) and operating room setup (C2) were the highest, and the present level for performing and processing 3D-imaging (C6) was the lowest. In contrast to the stated present level, the evaluation of the pre-event MCQs sometimes revealed a lack of knowledge related to these two competencies. The pre-event gaps between the present and the desired level of ability were higher for intraoperative use of additional 3-D imaging (C5), perform intraoperative 3-D imaging (C6), and process and analyze 3-D images (C7).

Nearly all pre-event gaps were reduced by both the seminars and the courses. There was an increase in the desired level of ability for some competencies after some courses, suggesting that some participants perceived the competency to be more important than they thought before the event. This shows that the seminars and courses achieved improvements in all competencies and also increased the awareness of personal gaps in some areas. Gaps that are recognized by surgeons can be addressed and will ultimately contribute to improved patient care. Gaps that are recognized by performing surgeons can be addressed and will ultimately contribute to improve patient care.

For almost every seminar and course the participant post-event evaluation data also showed high recommendation rates and content ratings. Comparing the courses to the seminars, the post-event data for competencies 2, 3, 6, and 7 show that these were achieved to a higher degree through the hands-on activities than the case and discussion-based seminars. This is also highlighted by higher percentages of intended practice changes related to those competencies (Table 4). There are differences in the pre-event gaps for every event and the chairperson and faculty must review these gaps and the profile of the participants, particularly years of experience and access to 3-D, in order to optimize content delivery for each event (selection of cases, focus of the discussions, etc.). Some limitations of our data analysis include questions administered in English even in countries where it was not the working language of surgeons, missing data from non-completers of the evaluation, and low response rates from some events.

There are very few publications reporting the topic of intraoperative imaging education. The American Board of Orthopedic Surgery (ABOS) has organized a residency program that contains 17 skills modules with simulation training to prepare residents to participate in surgical procedures and to improve surgical skills [18–20]. Marsh et al. developed the module fluoroscopic knowledge and skills in which the needs of the residents were identified. Goals and objectives of the curriculum were defined along with a description of techniques and procedures. The educational training focused on positioning of the C-arm, radiation safety, and general fluoroscopic anatomy. In contrast, the events of the presented study focused on clinical problems and their solutions in a cased-based manner. The accreditation council for graduate medical education (ACGME) and the ABOS have developed milestones to document a resident's progress, individually analyzing skills in several modules [1,21]. This appears to be a valuable tool to track and assess educational development and may be applied in a curriculum consisting of multiple seminars and courses. Yehyawi et al. developed a surgical simulation trainer for complex articular fractures [22] and simulated the operative treatment of a plafond fracture of the distal tibia. 5 senior and 7 junior orthopedic residents used fluoroscopic guidance to reduce the fracture through an anterior approach. The time to achieve reduction and fixation of the fracture as well as the number of hand movements of each participant were documented. This simulation is a method to acquire and practice orthopedic surgical skills outside of the operating room. The simulation of the surgery was a different educational approach than demonstrated in our study, in which obtaining and assessing intraoperative images in multiple anatomical regions was the core focus.

Conclusion

A curriculum for intraoperative imaging is of great value in orthopedic and trauma surgeon education. The contents addressed in the seminars and courses we developed included radiation protection and the acquisition of standard views for most common fractures. This is mandatory to prevent uncontrolled application of ionizing radiation and to assure the success of osteosynthesis. The seminars and courses increased the knowledge levels of the participants. Therefore, the set hypotheses of the study can be accepted. Despite good quality in-hospital training, additional education appears to be beneficial in most parts of the world. Further seminars and courses, supported by webinars, posters, and other teaching aids, are probably required to help improve patient outcomes by applying better intraoperative imaging.

Declaration of Competing Interest

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