












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Improving surgical technical skills for emergency fixation of unstable pelvic ring fractures: an experimental study using a pelvic ring fracture simulator

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Abstract

Background The management of hemodynamically unstable pelvic ring injuries necessitates surgical intervention, often involving procedures such as external fixation and percutaneous screw placement. Given the infrequent performance of these procedures, regular training is imperative to ensure readiness for emergencies. Our pre- post simulation study aimed to adapt and validate a realistic simulation model for stabilizing unstable pelvic ring injuries, facilitating participants' knowledge retention and procedural confidence enhancement.

Methods A standardized simulator of an unstable pelvic ring utilizing synthetic pelvic bones featuring complete disruption of the symphysis and sacroiliac joint was developed. Trauma surgeons of a level one academic hospital were invited to perform external fixation and emergency sacroiliac screw application under C-arm guidance. Prior to and following the simulation session, participants completed a subjective questionnaire assessing their confidence in emergency interventions on a 10-point Likert scale (10-LS). Objective parameters, such as intraoperative imaging quality, reduction accuracy, and the positioning of screws, wires, and external fixators, were also evaluated as secondary outcome measures.

Results Fifteen trauma surgeons (10 residents, 5 consultants) participated in the simulation over the course of one day. The mean total operation time was 20.34 ± 6.06 min, without significant differences between consultants and residents ($p=0.604$). The confidence for emergency SI-Screw placement increased significantly after the simulator (10-LS: Before = 3.8 ± 3.08 vs. After = 5.67 ± 2.35 ; $p=0.002$) as well as after external fixation (10-LS: Before = 3.93 ± 2.79 vs. After = 6.07 ± 2.52 ; $p=0.002$). In addition, confidence in (intraoperative) pelvic imaging increased significantly (10-LS: Before = 4.60 ± 3.0 vs. After = 6.53 ± 2.39 ; $p=0.011$). Overall, the model was rated as a realistic simulation of clinical practice (10-LS = 7.87 ± 1.13).

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Conclusions Our unstable pelvis fracture model is a tool to practice emergency interventions such as external fixation and percutaneous techniques. Participants benefitted from this in terms of technical instrumentation as well as intraoperative imaging. Further studies are required to validate the objective benefits and improvements that participants undergo through frequent training.

Keywords Pelvis surgery, Simulation training, Emergency stabilization

Background

Emergency stabilization of unstable pelvic ring fractures can be challenging and requires repeated surgical practice to improve surgical skills. This is due to the complex anatomy and potentially fatal consequences of inaccurate instrumentation and the need for three-dimensional understanding of the surgeon [1]. These factors can be exacerbated in the setting of an emergency situation [2].

We hypothesize that a pelvic simulator could be used to develop and maintain essential obtained skills for pelvic fracture treatment, such as placement of external fixation and iliosacral screws [3]. Previous publications have underlined the importance of surgical simulators for practical skill development in the field of pelvic trauma [4, 5]. These simulators, have not been adjusted to current standards of minimal invasive pelvic fracture care yet. Pohlemann et al. introduced a pelvic emergency simulator that can be used to practice emergency procedures such as reduction of a closed pelvic fracture with a C-clamp without radiologic support and preperitoneal packing. In addition, Tucker et al. developed a simulator for percutaneous fixation of nondisplaced pelvic fractures [3]. Since C-clamps are rarely used in clinical practice, the interventions of interest for our simulation were external fixation and emergency SI-Screw application (Rescue Screws) since they best represent the emergency stabilization of the unstable pelvic ring in clinical practice in our department [6].

The aim of this study was to develop a simulation program using a standardized fracture model of the pelvis that can be used for adequate simulation of emergency interventions to prepare surgeons for challenging situations.

Methods

The reporting of this pre-post simulation study was performed in according to the STROBE guidelines (STROBE: Strengthening the Reporting of Observational Studies in Epidemiology) [7].

Setting

This pre- post simulation study was conducted at an academic level one trauma center in March 2024. The operative rooms of the surgical research facilities of the hospital were used. The room was equipped with a C-Arm and a radiolucent operation table, which were utilized for the study. Participation in the model was

enabled for one entire day. Since this study presented a surgical simulation on synthetic bones and medical personnel took part voluntarily on their own time it is considered pursuant to Art. 2 (outside scope) of the Swiss Federal Act on Research involving Human Beings (Human Research Act, HRA). All participants provided informed consent.

Participants

The invitation to participate in this simulation was distributed to the trauma surgery team of the hospital (residents and consultants). Participation was not mandatory and was only realized on the surgeons' individual behalf and in consideration of individual obligations in the clinical routine. Participants were stratified to a random number to account for anonymization during further analysis.

Questionnaire

Participants were asked to fill out a questionnaire, half of which were required to answer before and the other half after completing the simulation. Answers were either provided on a 10-point Likert scale (10-LS), a binary option (yes/no) or free to fill to the respective nature of the question to account for suitable analysis. On the 10-point Likert scale [1], indicated the lowest agreement/negative, and [10] indicated the highest agreement/positive.

Questions before the simulation (part A)

- Are you still in residency? (yes/no)
- How many years of experience do you have? (Free to fill, numeric)
- Did you have experience with any other SI simulator in the past (yes/no)?
- Do you think that training with an SI simulator can improve your ability to place SI screws? (10-LS)
- How prepared do you feel to place SI-screws in an emergency situation? (10-LS)
- How confident are you with intraoperative pelvic imaging (inlet/outlet)? (10-LS)
- How confident do you feel with the installation of an external fixator for the pelvis? (10-LS)

Questions after the simulation (part B)

- The SI-Simulator is a realistic model for placing SI-Screws. (10-LS)
- In the future, I would like to use this SI-Simulator to improve my skills further. (10-LS)
- Training with this SI simulator can improve my ability to place SI screws. (10-LS)
- How prepared do you feel to place SI-screws in an emergency situation now? (10-LS)
- How confident do you feel with intraoperative pelvic imaging (inlet/outlet view)? (10-LS)
- How confident do you feel with the installation of an external fixator of the pelvis after the simulator? (10-LS)
- Further comments (free to fill).

Secondary outcome variables

In addition to the subjective questionnaire, objective outcome parameters were assessed by the organization team of the simulator. These included the amount of radiation in mGray (automatically measured by the C-Arm for each participant), the time of total intervention and the two separate surgical steps (external fixation and SI-Screw). Further parameters assessed were damage of the balloon placed in the pelvic cavity, which simulated damage to the anatomic structures, and overall anatomic reduction, which was rated by the chief pelvic surgeon (range: bad-moderate-good). Sacroiliac screws were assessed for cortical (nonforaminal) and foraminal breaches, and the number of redirections/repositionings of the guidewire or screw was counted. The external fixator was assessed for malpositioning (i.e., contact with the intrapelvic cavity or acetabular joint). These parameters were assessed radiologically as well as by visual inspection of the synthetic pelvis after removal of the soft-tissue-mat.

Conduction of the pelvic fracture model

Our model was adapted from the pelvic simulator described by Tucker N and Mauffrey C et al., as seen and described on “The Ortho academy” website, a free, online platform developed with the purpose to disseminate global education in pelvic and acetabular surgery (<https://www.theorthoacademy.com/>) [3, 8].

SYNBONE® pelvis models with radiopaque coating were utilized for this study (Model 4060.9, SYNBONE®, Zizers Switzerland). Modifications for fracture simulation were incorporated as described subsequently:

First, we drilled in three places at the top and bottom of both ends of the mounting block and fixed it to the wooden plate with three metal screws. The polyethylene part of the mounting block was shaved manually to fit the back posterior part of the sacral bone and allow

plastic-screw application through the S2 foramina into the mounting block.

A surgical wire was applied to the automated drill to then drill through the symphysis in an X-shape from anterior and posterior directions. Afterwards, the symphysis was cut with a scalpel, and two cable ties were applied through the predrilled holes and strapped loosely to ensure instability.

The same procedure was used for the posterior part of the pelvic ring. Two parallel holes were screwed from the back of the right ilium toward the top of the sacrum outside of the direct sacroiliac joint. Next, one cable tie was inserted back and forth through the two holes and closed loosely.

Afterwards, the sacroiliac joint was cut with a scalpel, resulting in complete instability of the right hemipelvis, which was only held loosely by the cable wires.

A balloon with a diameter of 12 cm was placed inside the pelvis to simulate intrapelvic organs. Finally, the pelvic model structure was wrapped with a 0.5 cm thick, white polyester/polyurethane mat to simulate soft tissue coverage (Vlieseline Style-Vil). The edges of the mat and the back of the wooden plate were secured with staples. A collection of images from the simulation is presented in Fig. 1. The entire list of materials utilized is provided as an additional file (see Additional file 1).

Conduction of the simulation

According to the institutions radioprotective guidelines, participants were equipped with X-ray protective clothing and were not allowed to observe other participants during the simulation to control for a passive learning effect. Three conductors of the simulator (FK, KS, RP) attended the simulation and acted as operational personal. One conductor was in charge of positioning the C-Arm and performing the intraoperative imaging according to the participants' request. The other ones handed over the requested surgical material and documented the a priori defined objective outcome parameters (i.e., time). Standard surgical material for these procedures was provided nonsterile.

Before the simulation started, the participant was required to answer questionnaire part A.

At the beginning of each round, the pelvis was already covered in the soft-tissue-mat and placed on the operation table at a 30° anterior tilt to account for anatomical positioning. Before the start, the participant was instructed on a suspected unstable pelvic ring in the synthetic pelvic model and asked to perform (1) external fixation of the pelvis either using a subcrystal or supra-acetabular approach, (2) sacroiliac screw placement on the injured side and (3) reduction of the anterior and posterior pelvic ring. The participants were required to defect the injured side on their own and perform the

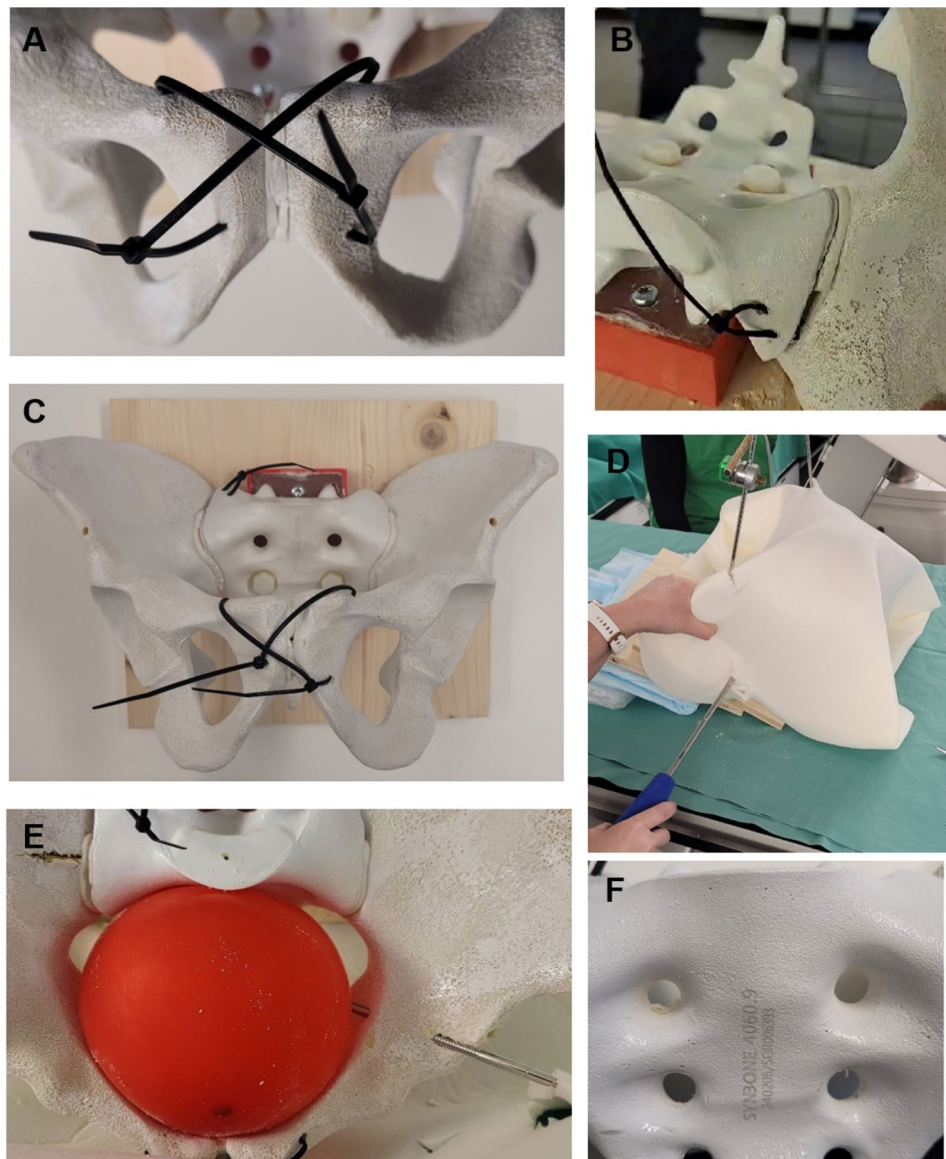


Fig. 1 Pelvic model and postoperative assessment. (A) Symphyseal disruption and fixation, (B) Sacroiliac disruption and fixation, (C) Pelvic model mounted on a wooden plate, (D) Sacroiliac screw application under fluoroscopy, (E) Intrapelvic balloon with penetrating external fixator, (F) Sacral bone with assessment of foraminal penetration on S1 level

aforementioned procedures. Intraoperative imaging was performed according to the participants' instructions by In-, Outlet, Lateral and anterior imaging to simulate clinical practice at best. The participants could choose between cannulated, fully threaded and partially threaded sacroiliac screws. The external fixator consisted of two Schanz pins with associated rods and clamps.

When the participant considered both operative steps to be completed, the soft-tissue mat was removed, and the reduction and placement of the screws and external fixator were inspected. Intraoperative images are presented in Fig. 2. Following the exercise, the participant were asked to complete the second part of the survey (part B).

Data analysis

Continuous data are presented as the mean and standard deviation, and categorical variables are presented as numbers and percentages. Missing data was planned to be excluded from the analysis, yet all data points could be collected. Statistical analysis was performed in R using the 'Stat' and 'Tableone' packages and the 'ggplot2' package for the creation of figures [9]. MS-Excel was used for data visualization. The data were visually checked for normality using histograms. Categorical binary outcome data were assessed using a one-tailed Fisher's exact test, and demographic data were assessed using a two-tailed Fisher's exact test. Dependent parameters were assessed using a paired Wilcoxon test. Continuous parameters

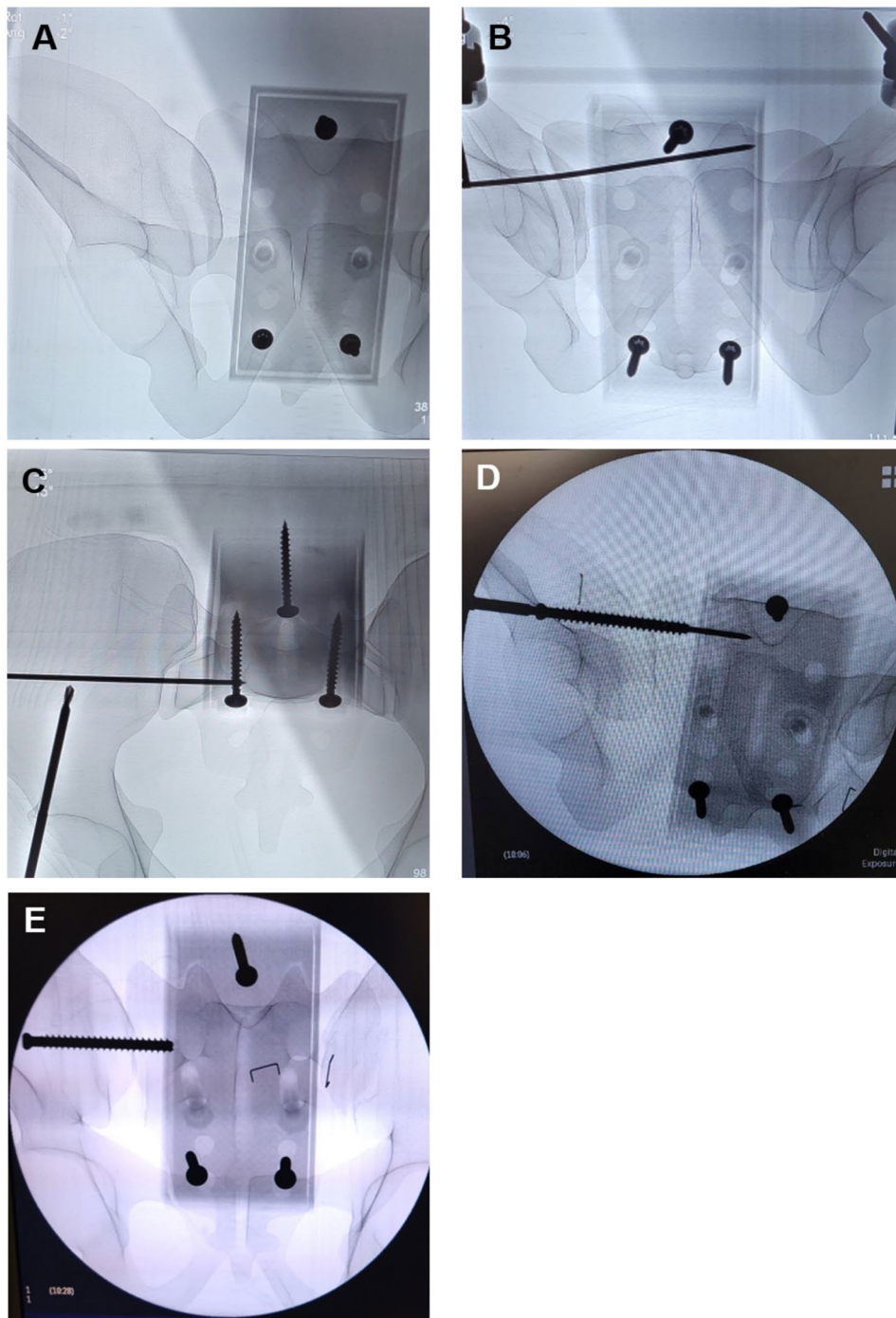


Fig. 2 Intraoperative Imaging of Rescue Screw application. (A) Fluoroscopic presentation of the simulator with symphyseal and sacroiliac disruption on the right side, (B/C) Guidewire instrumentation on S1 level, (D) SI-screw application, (E) Postoperative imaging assessment with insufficient reduction of the posterior ring

were analyzed using Student's t test. The significance level was set at 0.05.

Validity assessment

Messick's framework for construct validity was applied retrospectively to evaluate the effectiveness of our

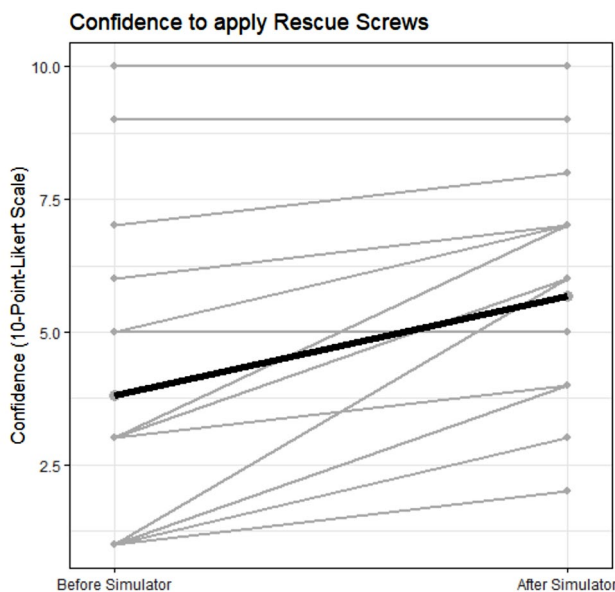
simulation model [10]. All five components of Messick's framework were assessed: content, substantive, structural, generalizability and consequential validity.

Table 1 Demographics and surgical details

Parameter	Data
N	15
Residents, n (%)	10 (67)
Male sex, n (%)	10 (67)
Experience (years), (median/IQR) / (mean/SD)	2 (5.5) / 4.60 (5.75)
Experience in pelvic models, n (%)	3 (20)

Table 2 Operative details

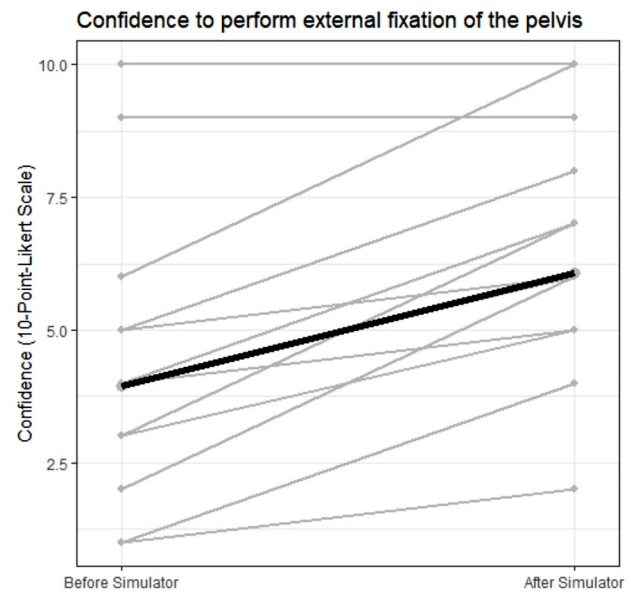
Parameter	Data	p-value (R vs. C)
Total operation time (min), mean (\pm SD)	20.34 (\pm 6.06)	0.604
Residents (R)	20.48 (\pm 5.27)	
Consultants (C)	22.57 (\pm 7.37)	
Time External fixation (min), mean (\pm SD)	9.44 (\pm 2.37)	0.884
Residents (R)	9.51 (\pm 2.21)	
Consultants (C)	9.31 (\pm 3.23)	
Time SI-Screw, (min), mean (\pm SD)	11.18 (\pm 4.51)	0.364
Residents (R)	10.07 (\pm 3.03)	
Consultants (C)	13.25 (\pm 7.00)	
Radiation (mGray), mean (\pm SD)	121.16 (\pm 108.65)	0.042
Residents (R)	78.81 (\pm 99.50)	
Consultants (C)	197.4 (\pm 85.25)	

**Fig. 3** Participants' self-reported confidence of the application of Rescue screws before training on the simulator (grey=participants, black/bold=mean)

Results

Participants

Fifteen trauma surgeons participated in this simulation over the course of one day on the 20th of March 2024. Ten participants (67%) were residents, five (33%) were consultants (senior physicians). One third of the

**Fig. 4** Participants' self-reported confidence of the application external fixation before training on the simulator (grey=participants, black/bold=mean)

participants ($n=5$) were female physicians. The median professional experience of the participants was two years (IQR=5.5), whereas the mean was 4.6 (\pm 5.75) years, representing the partially large experience gap between consultants and residents. Only three participants (20%) had previously participated in some part of the surgical pelvic simulation (Table 1).

Surgical procedures

The entire operative procedure (external fixation+SI-screw) lasted on average 20.34 (\pm 6.06) minutes, without significant differences between residents and consultants ($p=0.604$). The application of the external fixator took an average of 9.44 (\pm 2.37) minutes, and the application of the SI-Screw instrumentation took an average of 11.18 (\pm 4.51) minutes. There were also no significant differences between residents and consultants ($p=0.884/0.364$). Significantly, more radiation was administered by consultants (197.4 mGray (\pm 85.25)) than by residents (78.81 mGray (\pm 81)) (Table 2).

Subjective feedback

There was no significant difference in the estimated benefit of the pelvis simulator before and after conduction, which was very high (before: 9.20 ± 1.32 vs. after: $9.40 (\pm 0.91)$; $p=0.669$). The confidence to perform SI-Screw placement in an emergency increased significantly from a mean of 3.8 (\pm 3.08) to 5.67 (\pm 2.35) after completing the simulation ($p=0.002$) (Fig. 3). The same was true for the application of an external fixator, which increased from

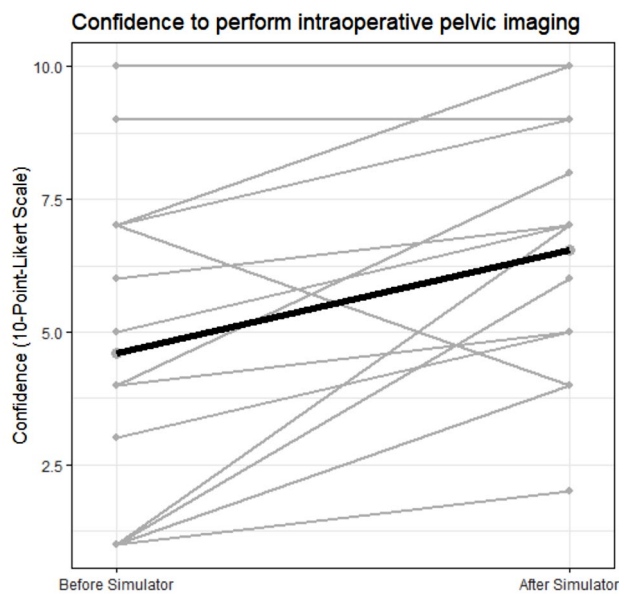


Fig. 5 Participants' self-reported confidence of the intraoperative imaging before training on the simulator (grey = participants, black/bold = mean)

an initial $3.93 (\pm 2.79)$ points on the 10-point Likert scale to $6.07 (\pm 2.52)$ points ($p=0.002$) (Fig. 4). Additionally, in terms of intraoperative pelvic imaging, the participants gained significantly more confidence (before: 4.60 ± 3.0 vs. after: 6.53 ± 2.39 ; $p=0.011$) (Fig. 5) (Table 3). In a sub-analysis, residents in particular benefited in terms of improved confidence in the use of rescue screws, intraoperative imaging and external fixation compared to consultants (Table 3).

Overall, the simulator was rated as a realistic model for clinical practice (7.87 ± 1.13 points on a 10-point Likert scale), and everyone would like to use it again for practice reasons (9.47 ± 0.83 points) (Table 4).

Objective outcome parameters

Damage to the intrapelvic balloon occurred in only one patient (6.7%). Most reduction results were rated as moderate ($n=9$, 60%). Five (33.3%) participants yielded

Table 4 Outcome parameters, 10-point-likert scale (1 = lowest, 10 = highest)

Feedback	Data
Realistic Model, mean (\pm SD)	7.87 (1.13)
Would like to do it again, mean (\pm SD)	9.47 (0.83)

Table 5 Objective outcome parameter

Parameter	Outcome
Balloon damage, n (%)	1 (6.7)
Reduction quality, n (%)	
Good	5 (33.3)
Moderate	9 (60.0)
Bad	1 (6.7)
SI-Screw/Wire	
Cortical breach, n (%)	8 (53.3)
Foraminal breach, n (%)	3 (20.0)
Number redirections, mean (\pm SD)	3.13 (\pm 2.17)
External fixator	
Malpositioning, n (%)	3 (20.0)
Number redirections, mean (\pm SD)	1.20 (1.70)

a good reduction, and only one bad reduction (6.7%) occurred. Eight sacroiliac screws (53.3%) breached the cortical area, and three (20%) breached the foramen. On average, the participants performed $3.13 (\pm 2.17)$ redirections/repositionings of the screw or wire. Three external fixators (20%) were malpositioned, and whereas an overall of average of $1.20 (\pm 1.7)$ redirections was performed (Table 5).

Validity assessment

The study demonstrates robust content, substantive, and structural validity, indicating that the simulation effectively emulates authentic surgical scenarios and enhances participant confidence and proficiency (Table 6).

Areas for further validation: Generalizability could be enhanced with a larger, more diverse sample across multiple settings. Consequential validity would benefit from follow-up studies assessing real-world outcomes post-simulation.

Table 3 All participants, 10-point-Likert scale (1=Lowest, 10=highest)

Question	Before	After	p-value
Usefulness Simulator, mean(\pm SD)	9.20 (\pm 1.32)	9.40 (\pm 0.91)	0.669
Confidence Rescue Screw, mean(\pm SD)	3.8 (\pm 3.08)	5.67 (\pm 2.35)	0.002
Residents	2.00 (\pm 1.41)	4.40 (\pm 1.58)	0.009
Consultants	7.40 (\pm 2.07)	8.20 (\pm 1.30)	1
Confidence Imaging, mean (\pm SD)	4.60 (\pm 3.0)	6.53 (\pm 2.39)	0.011
Residents	3.00 (\pm 2.05)	5.30 (\pm 1.77)	0.036
Consultants	7.80 (\pm 1.64)	9.00 (\pm 1.22)	0.181
Confidence External Fixation, mean (\pm SD)	3.93 (\pm 2.79)	6.07 (\pm 2.52)	0.002
Residents	2.60 (\pm 1.58)	4.70 (\pm 1.70)	0.005
Consultants	6.60 (\pm 2.88)	8.80 (\pm 1.30)	0.174

Table 6 Messick's validity framework

Aspect of Messick's Validity	Definition	Evidence from Study
Content validity	The degree to which the content reflects the construct being measured.	Simulation includes all relevant procedures (e.g., SI-screw placement, external fixation).
Substantive validity	The relationship between participants' responses and the construct.	Increased confidence in performing critical procedures, consistent with the aim of the simulation.
Structural validity	How well the structure of the assessment reflects the construct.	Confidence ratings and procedural outcomes align with expected skill improvements.
Generalizability	The extent to which results apply to other populations and settings.	Participants included residents and consultants; limited by single institution and small sample size.
Consequential validity	The impact of using the assessment on behavior and outcomes.	Increased interest in future practice and improved confidence, but no long-term outcomes (e.g. skills) assessed.

Discussion

In our manuscript, we provide a standardized and easy-to-build unstable pelvic fracture model with a clinical feasibility assessment by surgical experts. In regard to the performed simulation with surgical stabilization techniques, we conclude the following statements:

1. Practice with a pelvic simulator leads to increased confidence in the use of reposition maneuvers, emergency SI-screws, external fixation and intraoperative imaging in unstable pelvic ring fractures.
2. In our cohort, the less experienced participants presented the steepest increase in confidence after the simulation, potentially implying that they might especially benefit from this model.
3. An unstable pelvis fracture model can be built with accessible tools, and the surgical reality can be displayed to a certain extent.

Simulation training in surgery has already been established across several specialties and is reported to be beneficial for surgeons overall [5]. In pelvic surgery, several models already exist. Pohlemann et al. designed a realistic model that requires the application of a c-clamp as well as preperitoneal packing while blood loss is measured [11]. Undoubtedly, this is most likely one of most realistic simulator models available for pelvic emergency situations, yet it requires an extensive setup that might not be affordable for everyone and does not include intraoperative imaging. In addition, the C-clamp is rarely used in modern clinical practice, as percutaneous techniques such as rescue screws are used for the emergency stabilization of posterior pelvic ring fractures and dislocations. Our simulator reflects current standards in the treatment of pelvic injuries.

The Ortho Academy (www.theorthoacademy.com) designed a standardized model for percutaneous fixation of the pelvis that requires affordable material, which is the basis of our fracture simulator [8]. This model has already undergone pilot testing and yielded promising results [3]. The relevant difference here is that our model contains a standardized unstable fracture pattern and might therefore be more suitable for emergency situation training. Additionally, we performed several adjustments, such as the placement of the intrapelvic balloon, which might thereby sharpen the senses of the surgeon for this danger zone and lend the model a slightly drastic touch [4].

Our model is – to the knowledge of the authors – the first model that provides a simulation of an unstable pelvic situation that can be built very easily from everyone who is interested in it.

Frequent repetition of this kind of simulation is reported to provide the best outcome and can thereby quantify the direct impact on surgical performance [12]. The aim of our study was to report the initial subjective benefit reported by the participants and to describe the use of an unstable pelvic fracture simulator. The validation of its objective learning impact is planned for the future.

Simulation-based training is frequently reported in the literature as beneficial for an increase in confidence [13] and seems to be associated with an improved skillset [14]. In the context of surgical simulation, improved operative performance and shorter operation time are aspects that was reported in a recent meta-analysis on this topic [15]. Whether these improvements also occur by using our simulator needs to be assessed by a following study.

Simulation-based training is offered in different variations such as hands-on classes, virtual reality [16] and some hospitals even provide specific simulation centers for their staff [17]. Based on the literature, it may be assumed that especially less experienced participants (i.e. residents) might benefit more from simulation in terms of a steeper learning curve [18] but also more experienced surgeons may profit from a regular “fresh up” to stay in touch with the procedural steps and potential pitfalls. These assumptions are also displayed in our results and are comprehensible.

According to a recent international survey, external fixation is the most common surgical emergency intervention for unstable pelvic ring injuries [6]. With respect to several options for positioning (i.e., supra-acetabular, anterosuperior, etc.), malpositioning and/or inadequate reduction may occur [19]. Emergency sacroiliac screws (“Rescue Screws”) might be somehow more challenging, but – if they are performed properly – they provide sufficient and (at least partial) definitive stabilization of the posterior pelvic ring and close the intrapelvic cavity [20, 21]. Another benefit is that early mobilization is immediately possible in most trauma cases and is limited if external fixation or c-clamps are used. Depending on the overall fracture morphology and the anterior pelvis, an additional external fixator can be placed to manually control the reduction. We propose that these two stabilization techniques should be used by every trauma surgeon.

In an emergency, surgical procedures with the best precision possible are urgently needed. The key to doing so is frequent practice. However, whereas for sacroiliac screw instrumentation, navigated instrumentation has become increasingly established, percutaneous application with the C-Arm view might move into the background [22, 23]. This might occur at the cost of the ability to perform this procedure in an emergency situation, where up-to-date navigation is not feasible due to partially extensive setup times and technical challenges [23]. Frequent

training with a simulator might be one step to be on top of practice and retrieve this knowledge when it is needed.

On the other hand, relatively high malpositioning rates of up to 35% have been reported in the literature [24]. Regular training with a simulator might certainly be a way to improve this kind of complication since it allows a deeper understanding of the safe osseous corridors and surgical instrumentation relying on intraoperative fluoroscopy.

According to our results, the simulator resulted in elevated confidence of particularly the residents in performing emergency repositioning, emergency SI-screws (rescue screws), external fixation of the pelvis and intraoperative imaging. The fact that confidence did not increase significantly in the counsellor group may be explained by the fact that their confidence was already high before the simulation and the sample size ($n=5$) remained relatively small in the sub-analysis; however, an upward trend was also observed in this group. Interestingly, the consultants administered more intraoperative radiation than did the residents. One likely reason is that they are more aware of the benefits of intraoperative imaging and frequent changes in in- and outlet views, as well as dynamic screening, which enables them to provide an improved three-dimensional conception [25].

Strengths and limitations

The strength of our model is that it is easy to use and inexpensive. The utilized synthetic bones with a simulated soft tissue cover reflect the clinical reality to a certain degree and force the surgeon to rely mostly on intraoperative imaging. This cover can be removed easily after the simulation has finished and provides the participant with a detailed look on the anatomic results and placement of the screws/external fixator, which provides a learning benefit. However, our model naturally cannot simulate physiological impediments to imaging, such as intrapelvic organs. Nevertheless, intra-osseous positioning of hardware does not require additional simulation of intrapelvic organs. Our questionnaire and assessment criteria have not specifically been validated before, yet we are confident that it can display our parameters of interest reliably.

However, this easy feasibility is associated with certain restrictions for clinical translation. For example, the pelvic bone is not attached to a femur, which in clinical practice is often necessary as support for adequate reduction of the fracture. Second, the pelvic model is much lighter than a patient is in real life, and the mat covering the pelvis provides only an approximation of the entire soft tissue, which varies greatly depending on the patient's physical condition. Our study size might be relatively small with 15 participants overall and might be underpowered in certain aspects, especially in the subgroup

analysis (residents vs. consultants) and may contain (unintentional) selection bias. Yet, the focus of our study was on the overall feasibility to conduct this kind of simulator training. Whether an increase of confidence to perform a task is directly associated with improved skills is a separate topic and widely discussed in the literature. In order to further validate the relevance of our model in mimicking relevant emergency pelvic cases, a validation study in a different hospital should be planned.

Conclusions

Our unstable pelvis fracture model is a feasible tool for performing emergency interventions and repositioning techniques. Participants benefitted from this in terms of technical instrumentation as well as intraoperative imaging. Further studies are required to validate the objective benefits and improvements that participants undergo through frequent training.

Abbreviations

SI	Sacroiliac
mGray	Milligray
10-LS	10-Point Likert Scale

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13037-024-00412-0>.

Supplementary Material 1

Author contributions

F.K.L.K.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. K.S.: Data curation, Investigation, Writing – original draft, Writing – review & editing. A.M.: Conceptualization, Investigation, Methodology, Writing – review & editing. Y.K.: Conceptualization, Methodology, Writing – review & editing. T.B.: Conceptualization, Methodology, Writing – review & editing. S.H.: Methodology, Writing – review & editing. M.T.: Methodology, Writing – review & editing. V.N.: Methodology, Writing – review & editing. C.M.: Conceptualization, Writing – review & editing. H.-C.P.: Conceptualization, Project administration, Supervision, Writing – review & editing. R.P.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval

Not applicable.

Competing interests

On behalf of all the authors, the corresponding author states that there are no conflicts of interest.

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