Initial Experience Using a Pelvic Emergency Simulator to Train Reduction in Blood Loss

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Abstract

Background Because the average exposure of surgeons to pelvic injuries with life-threatening hemorrhage is decreasing, training opportunities are necessary to prepare surgeons for the rare but highly demanding emergency situations. We have developed a novel pelvic emergency simulator to train surgeons in controlling blood loss.

Questions/purposes We (1) described the design and use of the simulator; and (2) determined whether the simulator correctly identified proper and improper mechanical stabilization and bleeding control.

Methods The device contained two tube systems. The tubes of the first system were passed through the disrupted sacroiliac joint and the symphysis. By reduction (manual traction on the leg) and compression (application of the

C-clamp) of the disrupted pelvis, the tubes were pinched by the synthetic bones leading to a stop of simulated blood flow through the tubes of the first system. The tubes of the second system ended in a foam representing the presacral and paravesical venous plexus. By correct preperitoneal packing, the flow into the foam was stopped. Simulated bleeding was monitored by quantifying flow out of a fluid reservoir and flow into fluid samplers.

Results The pelvic emergency simulator has been used for eight training sessions since 2002. Bleeding control by packing was achieved after 6 ± 3 minutes. Total simulated blood loss during the training session was 1296 ± 892 mL.

Conclusions Our data suggest the simulator can be used as a tool to train surgeons to reduce blood loss in severe pelvic ring injuries.

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Introduction

Disruption of the pelvic ring is a rare injury, which places patients at high risk for life-threatening hemorrhage [3, 6, 9, 23, 24, 31]. One of the central challenges for the clinician managing a patient with pelvic ring fracture is to recognize and control this threat. The most common sources of bleeding in pelvic injuries are the presacral and paravesical venous plexus as well as exposed cancellous fracture surfaces [9, 16, 32]. Only in 10% to 15% of cases does hemorrhage derive from arterial injuries [9, 32]. Emergency treatment strategies rely on immediate reduction and stabilization of the pelvic ring, eg, using the pelvic C-clamp to minimize osseous bleeding by direct compression of cancellous fracture areas [9, 10, 22, 33]. In cases not responding to stabilization, preperitoneal packing of the presacral and paravesical space reportedly controls bleeding [5, 10, 22].

The application of these life-saving procedures requires surgical skills and a certain training status. Because the average exposure of surgeons to pelvic injuries with life-threatening hemorrhage is decreasing [15, 23, 30], training opportunities are necessary to prepare surgeons for the rare but highly demanding emergency situations. In the past, simulator-based training has been introduced as an important teaching tool for surgeons, particularly to practice rare procedures such as the application of the pelvic C-clamp and the minimally invasive insertion of sacroiliac screws [18, 28]. Several reports have described isolated simulator-based training for the application of the pelvic C-clamp as well as training of preperitoneal packing in corpses [2, 18]. These types of training are useful to teach technical aspects of the procedures but do not reflect a realistic emergency situation, which is characterized first and foremost by mental pressure and pressure of time resulting from major hemorrhage. Therefore, we developed an emergency simulator to train surgeons in mechanical stabilization and bleeding control techniques in pelvic fractures.

The purposes of this study were to (1) describe the design and use of an emergency simulator for the training of mechanical stabilization and bleeding control techniques in pelvic fractures; and (2) determine whether the simulator correctly identifies proper and improper mechanical stabilization and bleeding control.

Materials and Methods

The pelvic emergency simulator was designed in cooperation with the AO Development Institute, Davos, Switzerland, following our specifications as a plastic torso incorporating a commercially available synthetic pelvis (Pelvis 4060; Synbone, Bettlach, Switzerland) simulating a complete disruption of one sacroiliac (SI) joint and the symphysis (Fig. 1A). Rubber bands were used to induce a standardized cranial displacement of the separated hemipelvis (Fig. 1A). The simulator device contained two tube systems. Tubes of the first system were passed through the disrupted SI joint and symphysis (Fig. 1A). By reduction (manual traction on the leg) and compression (application of the C-clamp) of the disrupted pelvis, the tubes were pinched by the synthetic bones leading to a stop of the simulated blood flow through the tubes of the first system.

The hollow visceral structures of the small pelvis were simulated by foam and silicone structures (Fig. 1B). In the presacral and paravesical regions, recesses were created, which also were filled with foam. The tubes of the second system ended in this foam (Fig. 1B). The ventral and lateral aspects of the torso were sealed by a waterproof rubber membrane simulating the fascia of the abdominal wall and

Fig. 1A–C The pelvic emergency simulator was designed as a plastic torso incorporating a commercially available synthetic pelvis (Pelvis 4060; Synbone, Bettlach, Switzerland) with disruption of one SI joint and the symphysis (A). Rubber bands were used to induce a standardized cranial displacement of the separated hemipelvis (arrow). The simulator device contained two tube systems. Tubes of the first system were passed through the disrupted SI joint and symphysis (arrowheads). By reduction (manual traction on the leg) and compression (application of the C-clamp) of the disrupted pelvis, the tubes were pinched by the synthetic bones leading to a stop of the simulated blood flow through the tubes of the first system. The hollow-visceral structures of the small pelvis were simulated by foam and silicone structures (B). In the presacral and paravesical regions, recesses were created, which also were filled with foam (arrow). The tubes of the second system ended in this foam (arrowhead). The ventral and lateral aspects of the torso were sealed by a waterproof rubber membrane, simulating the fascia of the abdominal wall and the gluteal fascia (C).

the gluteal fascia (Fig. 1C). If there was persistent hemorrhage after mechanical stabilization, this membrane had to be opened for preperitoneal packing. The standard approach for preperitoneal packing was simulated by a midline incision from the pubic symphysis cephalad [5]. The surgeon was now faced with a realistic pelvic bleeding

situation with minimal direct visualization of the pelvic contents and mainly tactile information on soft tissues. The space that had to be filled by surgical packing represented the typical trauma-generated space in a clinical scenario. Effective compression of the recesses was only possible if the packing was inserted successively from posterior to anterior and sufficient stabilization of the bony compartment had been achieved before. By correct preperitoneal packing, the flow into the foam was stopped. Red-colored and heated water was used as fluid to increase reality of the training. The flow of the tube systems was monitored by quantifying flow out of a fluid reservoir and flow into fluid samplers (Fig. 2A-B). We measured flow versus no flow for each tube system.

Fig. 2A–B The flow of the tube systems was monitored by quantifying flow out of a fluid reservoir (A) and flow into fluid samplers (B).

The pelvic simulator training was performed during eight of 10 pelvic courses held in Homburg, Germany, since 2002. The remaining two courses were held in a different format, more focusing on state-of-the-art discussions [21]. Each of the eight practical courses consisted of 10 training sessions. The training was performed as a realistic emergency operating room scenario with the use of an operating room table and draping as well as simulation of anesthesia and operating room personnel (Fig. 3A-B). After detailed theoretical lectures, discussions, anatomy laboratories to explore the approaches and the relations within the small pelvis, and a technical exercise for safe application of the C-clamp, groups of two to five participants were briefed for an emergency situation in a room adjacent to the simulation operating room. One individual of each group was the trauma leader, whereas the other members of the group worked as assistants. Operating room clothing was mandatory for this wet laboratory. Using a standard presentation format, the arrival of a severely injured patient was developed and discussed,

Fig. 3A–B The training was performed as a realistic emergency operating room scenario, in which simulated bleeding had to be stopped by reduction and compression (application of the C-clamp) of the pelvic ring (A) and preperitoneal packing (B).

ending with having an unstable patient in the operating room waiting for surgical help. Then, the group was taken to the simulated operating room. The given tasks were immediate pelvic ring stabilization, analysis on whether blood flow was stopped, and, as persisting blood flow was observed, application of preperitoneal packing. After the session, the technical performance and the measurements including time and general observations were analyzed by a debriefing with the tutor. This session can be part of a practical evaluation program, providing individual results to all of the participants.

During each training session, the following parameters were recorded: (1) time until successful reduction and stabilization of the pelvis by the C-clamp (defined as stop of flow through the tubes of the first system); (2) time between stabilization of the pelvis and decision for preperitoneal packing; (3) time between decision for preperitoneal packing and effective bleeding control by packing (defined as stop of flow through the tubes of the second system); and (4) total blood loss during the training session.

Results

We found the simulator correctly identified proper and improper mechanical stabilization and bleeding control. If the clamp was applied correctly but packing was insufficient (and vice versa), the bleeding was reduced but not stopped. Only if both mechanical stabilization and preperitoneal packing were performed correctly was bleeding controlled. In 5% of cases, no effective bleeding control could be achieved after 20 minutes. In the other cases, hemorrhage was stopped by reduction and stabilization of the pelvis with the C-clamp and preperitoneal packing after a mean of 6 ± 3 minutes (Table 1). Mean total simulated blood loss during each training session was 1296 ± 892 mL.

Discussion

Pelvic ring injuries still represent a life-threatening injury with a mortality rate ranging from 5% to 46% [1, 3, 4, 7, 8, 11, 12, 15, 17, 25, 26, 29]. In most cases, major

hemorrhage in pelvic injuries derives from the presacral and paravesical venous plexus or exposed cancellous fracture surfaces [9, 16, 32]. These forms of bleeding can be treated very successfully by mechanical stabilization of the pelvic ring and preperitoneal packing [5, 9, 10, 22, 33]. Simulator training provides a promising teaching method to prepare surgeons for such relatively rare emergency procedures. Thus, the aim of the present study was to develop and evaluate a novel pelvic emergency simulator.

We recognized limitations of our study. First, we have no data showing that the simulator training is capable of reducing blood loss during repeated training sessions. These data might be collected prospectively from the participants of the sessions to evaluate the effectiveness of the simulator training in the clinical situation. Second, we did not compare the skills in pelvic emergency measures between surgeons participating in the training and surgeons who had not performed the simulator training. This would require a prospective study including one group of surgeons undergoing simulator training and one group of nonsimulator-trained surgeons. Third, we did not quantify flow rates during the simulator training. These data would provide additional information on the dynamics of stabilization and bleeding control.

The pelvic simulator was used for the first time in team training during the Homburg pelvic course in 2002. Since then, 80 teams consisting of two to five persons each participated in regular training sessions using the pelvic emergency simulator. In these sessions, only orthopaedic trauma surgeons attended the training; however, also general surgeons may be involved in the procedure. The simulator operated successfully by now for more than 8 years. To our knowledge, the herein introduced simulation model is the first one that allows standardized training of emergency stabilization of the pelvic ring in combination with preperitoneal packing. Previous reports from the literature described an isolated simulator-based training for the application of the pelvic C-clamp as well as training of preperitoneal packing in corpses [2, 18]. These types of training are useful to teach technical aspects of the procedures but do not reflect a realistic emergency situation, which is characterized first and foremost by mental pressure and pressure of time as a result of major hemorrhage. One option to exercise these components of emergency situations is to practice damage control surgery including preperitoneal packing in living animals like pigs [13]. However, for ethical reasons, animal courses can be offered only to a limited number of participants, whereas simulator-based training can be provided repeatedly to large groups of surgeons. Besides, training of mechanical stabilization techniques in pigs is not appropriate, because the pelvic anatomy differs considerably between pigs and humans.

Table 1. Parameters recorded during the training session included (1) time until successful reduction and stabilization of the pelvis by the C-clamp; (2) time between stabilization of the pelvis and decision for preperitoneal packing (PPP); (3) time between the decision for PPP and effective bleeding control by packing; and (4) total time until effective bleeding control

Parameter	C-clamp	Decision	PPP	Total
Time (seconds)	173 ± 83	50 ± 45	153 ± 120	375 ± 167

We showed bleeding was reduced but not stopped when the C-clamp was applied correctly but the packing was insufficient (and vice versa). Only if both mechanical stabilization and preperitoneal packing were performed correctly was bleeding stopped. Mean total simulated blood loss during the training session was 1296 mL, which is in comparison to the clinical situation very high. Analyzing 759 blunt trauma patients who sustained pelvic fracture, Blackmore and coworkers [4] found a mean pelvic fracture-related blood loss of 149 mL with a range of 0 to 1423 mL. These data indicate that simulated blood loss in the present model reflects a pelvic injury with severe hemorrhage. Our data showed the participants of the training required a mean time of 173 seconds to stabilize the pelvic ring with the C-clamp. These data correspond to those of a previously introduced pelvic simulator training reporting a mean time of 134 seconds for the application of the C-clamp [18]. In the present simulator model, effective bleeding control was achieved after a mean of 6 minutes, which is very fast. Advanced Trauma Life Support guidelines recommend that major trauma centers provide facilities ensuring the control of life-threatening hemorrhage within the golden hour [19]. A survey of 31 major trauma centers in Scotland revealed only eight units were able to stabilize a pelvic ring fracture within this time period. Sufficient fracture stabilization within 10 minutes, which corresponds to the timeframe of our simulator training, was achieved by only two hospitals. Interestingly, 10 trauma centers had no staff available that was experienced in the application of emergency measures for the treatment of severe pelvic ring injuries. Although these data derive from 1998 and facilities might be different in other Western countries, these alarming data highlight the tremendous need to provide systematic training of emergency treatment of pelvic ring injuries.

In conclusion, the pelvic simulator represents a potentially valuable technical tool to practice emergency procedures for the treatment of severe pelvic ring injuries. The simulator can be applied for team training representing an important tool to improve communication skills and teamwork in the emergency room and operating room [14, 20, 27].

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