

Impact of low-cost simulator-based liver trauma surgery training on technical skills and short-term retention among general surgeons

Hiroyasu Tojima

Hokkaido University Faculty of Medicine

Saseem Poudel

saseem@med.hokudai.ac.jp

Hokkaido University Faculty of Medicine

Soichi Murakami

Hokkaido University Faculty of Medicine

Yo Kurashima

Hokkaido University Faculty of Medicine

Keita Ishido

Hokkaido University Faculty of Medicine

Toshimichi Asano

Hokkaido University Faculty of Medicine

Takehiro Noji

Hokkaido University Faculty of Medicine

Kazufumi Okada

Hokkaido University Hospital

Yoichi M. Ito

Hokkaido University Hospital

Hiroyuki Kaneko

Kushiro Red Cross Hospital

Yoshimitsu Izawa

Jichi Medical University

Hiroshi Homma

Tokyo Medical University

Satoshi Hirano

Hokkaido University Faculty of Medicine

Keywords: Simulation training, Liver trauma, Damage control surgery, General surgeons, Technical skills, Skill retention, Trauma education

Posted Date: September 24th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10868154/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

General surgeons in low-volume trauma systems may be required to perform emergency damage-control surgery for liver trauma despite limited operative trauma exposure. Simulation-based training has the potential to provide a scalable approach to improving preparedness for these rare but critical procedures. This study evaluated the educational effectiveness and short-term retention of a low-cost simulator-based liver trauma surgery curriculum for general surgeons.

Methods

This prospective single-arm educational intervention study included general surgeons 5–20 years after graduation with limited experience as primary operators in trauma surgery. Participants underwent video-based instruction followed by hands-on simulation training. The curriculum focused on emergency laparotomy, five-point abdominal packing, liver injury packing with manual compression and liver hilar blockade, liver injury suturing, and temporary abdominal closure. Technical skills were assessed using the Abdominal Trauma Objective Structured Assessment of Technical Skills. Knowledge and self-assessed confidence were assessed as secondary outcomes. Assessments were performed before training, immediately after training, and 3–6 months after training. Pairwise Wilcoxon signed-rank tests were used for statistical analysis.

Results

Forty-two general surgeons participated in the training. The median technical skill score increased significantly from 26.5 before training to 39 immediately after training ($P < 0.001$). At follow-up, completed by 26 participants at 15–20 weeks, the median technical skill score decreased to 34 but remained significantly higher than baseline ($P < 0.001$). The median knowledge score increased from 4 to 7 immediately after training ($P < 0.001$). At follow-up, completed by 39 participants at 15–24 weeks, the median knowledge score decreased to 5 but remained higher than baseline ($P = 0.010$). Self-assessed confidence improved significantly after training for all procedures directly practiced during the curriculum and remained higher than baseline at follow-up for these procedures.

Conclusions

A focused, low-cost simulator-based liver trauma surgery curriculum improved technical skills, knowledge, and self-assessed confidence among general surgeons, with partial retention at 3–6 months. This curriculum may provide a scalable approach to strengthening operative trauma preparedness in low-volume trauma systems.

Introduction

Preventable trauma death remains an important challenge in trauma systems, particularly when critically injured patients require timely operative intervention before transfer to specialized trauma centers. Trauma systems vary widely according to geography, resource distribution, and availability of specialized trauma personnel [1]. Compared with countries such as the United States and Canada, the incidence of trauma in Japan is relatively low, limiting opportunities for surgeons to acquire and maintain operative trauma skills through clinical exposure alone [2–6]. In rural areas, where dedicated trauma surgeons are scarce, general surgeons are often required to manage severe abdominal trauma despite limited prior experience, which may contribute to preventable trauma death [7].

Previous work has highlighted this preparedness gap. In a regional survey of general surgeons in Hokkaido, 57.9% had performed fewer than 10 trauma surgeries during their careers, and confidence in many essential trauma procedures was low [7]. Similar concerns have been reported internationally, where declining operative trauma exposure has raised concerns regarding preparedness for emergency trauma surgery [8]. Liver trauma represents an important target for training because it is among the most common forms of abdominal trauma and may require rapid application of core damage-control techniques [9]. In a Delphi consensus study conducted among Japanese trauma surgeons, procedures related to liver trauma were identified among the essential trauma skills required for general surgeons [10]. Simulation-based education may help address these challenges by enabling deliberate practice, structured feedback, and repeated exposure to rare procedures without risk to patients [11]. However, opportunities for hands-on trauma training remain limited. Existing trauma surgery courses using cadavers or animal models provide valuable experience but are costly, logistically demanding, and limited in capacity [12–14].

To address these limitations, our group previously developed and validated a low-cost abdominal trauma simulator and a focused liver trauma surgery curriculum [15]. However, the educational effectiveness and short-term retention of this curriculum among practicing general surgeons had not yet been evaluated. Therefore, the objective of this study was to evaluate the educational effectiveness and short-term retention of a simulator-based liver trauma surgery curriculum for general surgeons.

Materials and Methods

Ethical considerations

This study was approved by the Institutional Review Board of the Faculty of Medicine, Hokkaido University (IRB No. R04-015). Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki.

Study design and participants

Between July 2022 and May 2023, we conducted a prospective single-arm educational intervention study to evaluate the educational effectiveness and short-term retention of a simulation-based liver trauma surgery curriculum for general surgeons. Participants were recruited from general surgeons who attended liver trauma simulation training sessions conducted by our group during the study period. Eligible participants were general surgeons between 5 and 20 years after graduation who were expected to manage abdominal trauma in clinical practice but had minimal experience as primary operators in trauma surgery. Because this was an exploratory educational intervention implemented as part of available training sessions, no formal sample-size calculation was performed.

Participants completed baseline assessments before training, underwent video-based instruction followed by hands-on simulation training, and were reassessed immediately after training. Follow-up assessments were conducted 3–6 months later to evaluate retention of training effects (Fig. 1).

Training curriculum

The curriculum was developed based on previous studies identifying liver trauma as a major component of abdominal trauma and defining essential trauma procedures for general surgeons [7, 10]. It focused on key damage-control procedures for hepatic injury, including emergency laparotomy, five-point abdominal packing, liver injury packing with manual compression and liver hilar blockade, liver injury suturing, and temporary abdominal closure.

Specific learning objectives were established in advance, and corresponding educational materials were prepared, including instructional videos, knowledge tests, the Abdominal Trauma OSATS assessment tool, and a low-cost abdominal trauma simulator developed by our group (Fig. 2). The feasibility and validity of the simulator, curriculum, and assessment tool were demonstrated in our previous study [15]. As previously reported, the simulator was developed for approximately USD 1,000, with each training session requiring under USD 10 in disposable materials [15].

Outcome measures

The primary outcome was improvement in technical skills immediately after training, assessed using the Abdominal Trauma Objective Structured Assessment of Technical Skills (Abdominal Trauma OSATS). The OSATS consisted of 14 procedure-specific items, each scored on a 3-point scale, with higher scores indicating better technical performance. Procedural performance was evaluated using video recordings obtained from wearable cameras worn by participants and fixed cameras positioned during the simulation sessions. Two trauma researchers independently reviewed and scored all video recordings while blinded to participant identity and assessment timing.

Secondary outcomes were changes in knowledge and self-assessed confidence level (SACL), as well as retention of technical skills, knowledge, and SACL at 3–6 months after training. Knowledge was assessed using an 8-item multiple-choice examination developed during the pilot study, with a maximum

score of 8 points [15]. SACL was assessed using a 10-point scale for each procedure included in the curriculum.

Statistical analysis

Continuous and ordinal variables are presented as medians with interquartile ranges, and categorical variables are presented as numbers and percentages. Pre-training and immediate post-training outcomes were compared using the Wilcoxon signed-rank test. For outcomes assessed at three time points (pre-training, post-training, and follow-up), pairwise comparisons between pre-training and post-training, post-training and follow-up, and pre-training and follow-up were performed using the Wilcoxon signed-rank test. No adjustment for multiple comparisons was applied, and these pairwise analyses were considered exploratory. Participants with available paired data were included in each analysis; missing data were not imputed. Statistical significance was defined as a two-tailed P value < 0.05. All statistical analyses were performed using EZR version 1.61 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) [16].

Results

Participant characteristics

A total of 42 general surgeons participated in the training curriculum. Baseline characteristics are summarized in Table 1. The median postgraduate year was 9.5 (IQR 5–18), and 34 participants (81%) were board-certified surgeons. Participants had limited prior trauma surgery experience, with a median of 1.5 prior trauma surgeries (IQR 0–11). Thirty-nine participants (92.9%) had performed fewer than 10 trauma surgeries, and 25 (59.5%) surgeons had not performed any trauma surgery in the previous year.

Table 1
Participant characteristics

Characteristic	Value
Number of participants	42
Gender, male, n (%)	38 (90%)
Postgraduate years, median (IQR)	9.5 (5–18)
Board-certified surgeons, n (%)	34 (81%)
Board-certified gastroenterological surgeons, n (%)	13 (31%)
Prior trauma surgery experience	
Trauma surgeries performed, median (IQR)	1.5 (0–11)
Performed < 10 trauma surgeries, n (%)	39 (92.9%)
No trauma surgery in previous year, n (%)	25 (59.5%)
Previous participation in operative trauma surgery training courses, n (%)	10 (23.8%)
IQR, interquartile range.	

Primary outcome: technical skills assessment

Technical skills improved significantly after training and remained significantly higher than baseline at follow-up. The median Abdominal Trauma OSATS score increased from 26.5 (IQR 25–29.25) before training to 39 (IQR 37.75–41) immediately after training ($P < 0.001$). Follow-up technical skills assessment was completed by 26 participants at 15–20 weeks after training. At follow-up, the median OSATS score decreased to 34 (IQR 31–37), which was significantly lower than the immediate post-training score ($P < 0.001$), but remained significantly higher than the pre-training score ($P < 0.001$) (Table 2).

Table 2
Summary of Outcomes at Pre-Training, Post-Training, and Follow-Up Assessment

Outcome measure	Pre-training	Post-training	Retention	Pre vs. Post	Post vs. Ret.	Pre vs. Ret.
Technical skills (OSATS)						
Median (IQR)	26.5 (25–29.25)	39 (37.75–41)	34 (31–37)	P < 0.001	P < 0.001	P < 0.001
N assessed	42	42	26			
Knowledge score						
Median (IQR)	4 (3.0–6.0)	7 (6.0–8.0)	5 (5.0–6.0)	P < 0.001	P < 0.001	P = 0.010
N assessed	42	42	39			
Self-assessed confidence (median, IQR)						
Emergency laparotomy	6 (5.0–9.0)	7 (5.0–9.3)	7 (6.0–8.0)	N.S.	N.S.	N.S.
Abdominal packing	5 (3.0–5.0)	8 (6.8–9.0)	7 (6.0–8.0)	P < 0.001	N.S.	P < 0.001
Liver injury packing	5 (2.8–5.0)	8 (6.0–9.0)	7 (6.0–8.0)	P < 0.001	P = 0.035	P < 0.001
Liver injury suturing	5 (3.0–5.0)	7 (6.0–8.0)	7 (5.0–7.0)	P < 0.001	P = 0.031	P < 0.001
Temporary closure	5 (5.0–6.0)	7 (6.0–8.0)	6 (5.0–7.0)	P < 0.001	N.S.	P = 0.018
IQR, interquartile range; OSATS, Objective Structured Assessment of Technical Skills; N.S., not significant (P > = 0.05). Pairwise comparisons were performed using the Wilcoxon signed-rank test. No adjustment for multiple comparisons was applied, and pairwise analyses were considered exploratory. Follow-up technical skills assessment was completed by 26 participants, whereas follow-up knowledge assessment was completed by 39 participants.						

Secondary outcomes: knowledge and self-assessed confidence

Knowledge scores also improved significantly after training and remained significantly higher than baseline at follow-up. The median knowledge score increased from 4 (IQR 3.0–6.0) before training to 7 (IQR 6.0–8.0) immediately after training (P < 0.001). Follow-up knowledge assessment was completed by 39 participants at 15–24 weeks after training. At follow-up, the median score decreased to 5 (IQR

5.0–6.0), which was significantly lower than the immediate post-training score ($P < 0.001$), but remained significantly higher than the pre-training score ($P = 0.010$) (Table 2).

SACL improved significantly after training for the procedures directly practiced during the curriculum, including abdominal packing, liver injury packing, liver injury suturing, and temporary abdominal closure. At follow-up, SACL remained significantly higher than baseline for these procedures, although significant declines from immediate post-training levels were observed for liver injury packing and liver injury suturing. No significant change was observed for emergency laparotomy across the three assessment points (Table 2).

Discussion

This study demonstrated that a focused simulator-based liver trauma surgery curriculum significantly improved objective technical performance among general surgeons with limited operative trauma experience. The median Abdominal Trauma OSATS score increased immediately after training and remained significantly higher than baseline at follow-up, although some decline was observed. Knowledge and self-assessed confidence also improved after training, supporting the overall educational effectiveness of the curriculum. Because the Abdominal Trauma OSATS and the simulator-based curriculum were previously developed and validated by our group, the improvement in technical skills provides objective evidence of procedural skill acquisition rather than relying only on self-reported confidence [15].

These findings have important implications for trauma education in low-volume trauma systems. General surgeons in such settings may be required to perform emergency damage-control procedures despite limited opportunities for operative trauma experience. Previous work from Hokkaido demonstrated that many general surgeons had performed few trauma surgeries and lacked confidence in several essential trauma procedures [7]. Similar concerns have been reported internationally, where declining operative trauma exposure has raised questions about the readiness of general surgeons to manage emergency trauma independently [8]. The present findings suggest that even a focused, procedure-specific curriculum can substantially improve operative preparedness among surgeons with limited trauma exposure. Liver trauma is an appropriate target for focused training because it is a common and potentially life-threatening form of abdominal trauma that may require rapid application of damage-control techniques, including packing, hepatic compression, inflow control, and temporary abdominal closure [9]. In this context, structured simulation training may help bridge the gap between limited clinical exposure and the need for operative readiness.

A second important implication of this study is the scalability of the training program. Existing trauma surgery courses using animal models or cadavers, including ATOM and C-BEST, provide valuable high-fidelity experience but require considerable cost, specialized facilities, and logistical support [12–14]. In contrast, the low-cost simulator used in this study allows repeated hands-on practice without cadavers, animal laboratories, or specialized facilities [15]. These characteristics may facilitate wider

implementation in rural or resource-limited settings, where opportunities to gain operative liver trauma experience are limited but initial damage-control capability remains essential.

An important finding of this study was the partial decline in technical skill and knowledge scores during follow-up despite persistent improvement above baseline. This pattern across multiple educational domains suggests that a single educational intervention is unlikely to maintain long-term procedural readiness. These findings are consistent with previous surgical and procedural simulation studies demonstrating that newly acquired skills may decay without reinforcement [17, 18]. Trauma-specific cadaver-based training studies have also suggested that repeated participation or opportunities for clinical practice may help maintain training effects [19, 20]. Periodic refresher sessions, short booster courses, or spaced simulation practice may therefore be necessary to maintain operative trauma competence after initial training. Such repeated training may be particularly important in low-volume trauma systems, where opportunities for real-world operative experience remain limited.

This study has several limitations. First, it was a single-arm educational intervention without a control group; therefore, the effectiveness of the curriculum could not be directly compared with other educational methods. Second, although the simulator enabled repeated practice of essential technical procedures, it did not reproduce active hemorrhage, physiologic deterioration, multidisciplinary team communication, or the psychological stress associated with real trauma surgery. Third, the follow-up period was limited to 3–6 months; therefore, longer-term retention remains unknown. In addition, the follow-up rate for technical skills assessment was 62%. Follow-up assessments were challenging because of several barriers, including difficulties in scheduling evaluations owing to participants' demanding clinical workloads and the considerable distance between institutions (approximately 200 km), which may have introduced attrition bias. Finally, this study evaluated educational rather than clinical outcomes. Whether improved simulator performance ultimately translates into better clinical trauma care or reduced preventable trauma death remains to be determined.

Conclusion

A focused, low-cost simulator-based liver trauma surgery curriculum improved technical skills, knowledge, and self-assessed confidence among general surgeons, with partial retention at 3–6 months. This accessible, repeatable curriculum may help strengthen operative trauma preparedness in low-volume trauma systems.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Faculty of Medicine, Hokkaido University (IRB No. R04-015). Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the Japanese Society for the Promotion of Science KAKENHI [grant number 22K10408], Japan Ministry of Defense's Program on Security Technology Research JPJ004596, and crowdfunding from "The Project to Eliminate Preventable Trauma Deaths in Hokkaido through the Development of Trauma Surgeons".

Authors' contributions

HT, SM, SP, and SH contributed to the conception and design of the study. HT, SM, SP, YK, KI, TA, TN, HK, YI, and HH contributed to curriculum development and implementation. HT, SP, KO, and YMI contributed to data analysis and interpretation. HT and SP drafted the manuscript. All authors critically revised the manuscript and approved the final version.

Acknowledgements

The authors thank all participants and all individuals who contributed to the development and implementation of the liver trauma surgery simulator and training curriculum.

Use of generative AI and AI-assisted technologies in the writing process

ChatGPT (OpenAI) was used to assist with English language editing and manuscript polishing. The authors reviewed and edited all AI-assisted text and take full responsibility for the content of the manuscript.

References

1. Dijkink S, Nederpelt CJ, Krijnen P, Velmahos GC, Schipper IB. Trauma systems around the world: a systematic overview. *J Trauma Acute Care Surg.* 2017;83(5):917–25. 10.1097/TA.0000000000001633.
2. Drake SA, Holcomb JB, Yang Y, et al. Establishing a Regional Trauma Preventable/Potentially Preventable Death Rate. *Ann Surg.* 2020;271(2):375–82. 10.1097/SLA.0000000000002999.

3. Centers for Disease Control and Prevention. National Hospital Ambulatory Medical Care Survey. 2020 Emergency Department Summary Tables.
https://www.cdc.gov/nchs/data/nhamcs/web_tables/2020-nhamcs-ed-web-tables-508.pdf. Accessed 11 May 2026.
4. Simons RK. Injury control and trauma care in Canada: how well are we doing? Trauma Association of Canada Presidential address. *J Trauma*. 2006;61(5):1027–35.
10.1097/01.ta.0000242776.05062.d7.
5. Ministry of Internal Affairs and Communications. Japan.
https://www.soumu.go.jp/main_content/000869993.pdf. Accessed 11 May 2026.
6. Kobayashi K. Challenges for improving trauma care in Japan. *J Trauma*. 2005;58(6):1134–9.
10.1097/01.ta.0000169953.29347.81.
7. Hirose K, Poudel S, Murakami S, et al. How confident are the general surgeons in Hokkaido region in performing essential trauma skills: a cross-sectional questionnaire survey. *World J Emerg Surg*. 2025;20(1):49. 10.1186/s13017-025-00623-5.
8. Strumwasser A, Grabo D, Inaba K, Matsushima K, Clark D, Benjamin E, Lam L, Demetriades D. Is your graduating general surgery resident qualified to take trauma call? A 15-year appraisal of the changes in general surgery education for trauma. *J Trauma Acute Care Surg*. 2017;82(3):470–80.
10.1097/TA.0000000000001351.
9. Coccolini F, Coimbra R, Ordonez C, Kluger Y, Vega F, Moore EE, et al. Liver trauma: WSES 2020 guidelines. *World J Emerg Surg*. 2020;15:24. 10.1186/s13017-020-00302-7.
10. Hirose K, Murakami S, Kurashima Y, Sato N, Poudel S, Tanaka K, et al. Delphi method consensus-based identification of primary trauma care skills required for general surgeons in Japan. *J Acute Care Surg*. 2023;13(2):58–65. 10.17479/jacs.2023.13.2.58.
11. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med*. 2011;86(6):706–11.
10.1097/ACM.0b013e318217e119.
12. Jacobs LM, Burns KJ, Kaban JM, Gross RI, Cortes V, Brautigam RT, Perdrizet GA, Besman A, Kirton O. Development and evaluation of the Advanced Trauma Operative Management course. *J Trauma*. 2003;55(3):471–9. 10.1097/01.TA.0000059445.84105.26. discussion 479.
13. Lefor AK. Trauma surgery simulation education in Japan: the Advanced Trauma Operative Management course. *Acute Med Surg*. 2018;5(4):299–304. 10.1002/ams2.352.
14. Homma H, Oda J, Sano H, Kawata S, Itoh M. The effectiveness of the cadaver-based educational seminar for trauma surgery (C-BEST) for residents. *Signa Vitae*. 2022;18(1):115–21.
10.22514/sv.2021.140.
15. Tojima H, Murakami S, Poudel S, et al. Development of a simulator and training curriculum for liver trauma surgery training for general surgeons. *Global Surg Educ - J Association Surg Educ*. 2024;3(1):36. 10.1007/s44186-024-00233-w.

16. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. *Bone Marrow Transpl.* 2013;48(3):452–8. 10.1038/bmt.2012.244.
17. Higgins M, Madan C, Patel R. Development and decay of procedural skills in surgery: a systematic review of the effectiveness of simulation-based medical education interventions. *Surgeon.* 2021;19(4):e67–77. 10.1016/j.surge.2020.07.013.
18. Legoux C, Gerein R, Boutis K, Barrowman N, Plint A. Retention of critical procedural skills after simulation training: a systematic review. *AEM Educ Train.* 2020;5:e10536. 10.1002/aet2.10536.
19. Homma H, Oda J, Yukioka T, Hayashi S, Suzuki T, Kawai K, et al. Effectiveness of cadaver-based educational seminar for trauma surgery: skills retention after half-year follow-up. *Acute Med Surg.* 2017;4(1):57–67. 10.1002/ams2.230.
20. Murakami S, Shichinohe T, Kurashima Y, Okada K, Tsunetoshi Y, Iizuka R, et al. Validation of cadaver-based trauma surgery training for lifelong skill development. *World J Emerg Surg.* 2025;20:45. 10.1186/s13017-025-00608-4.

Figures

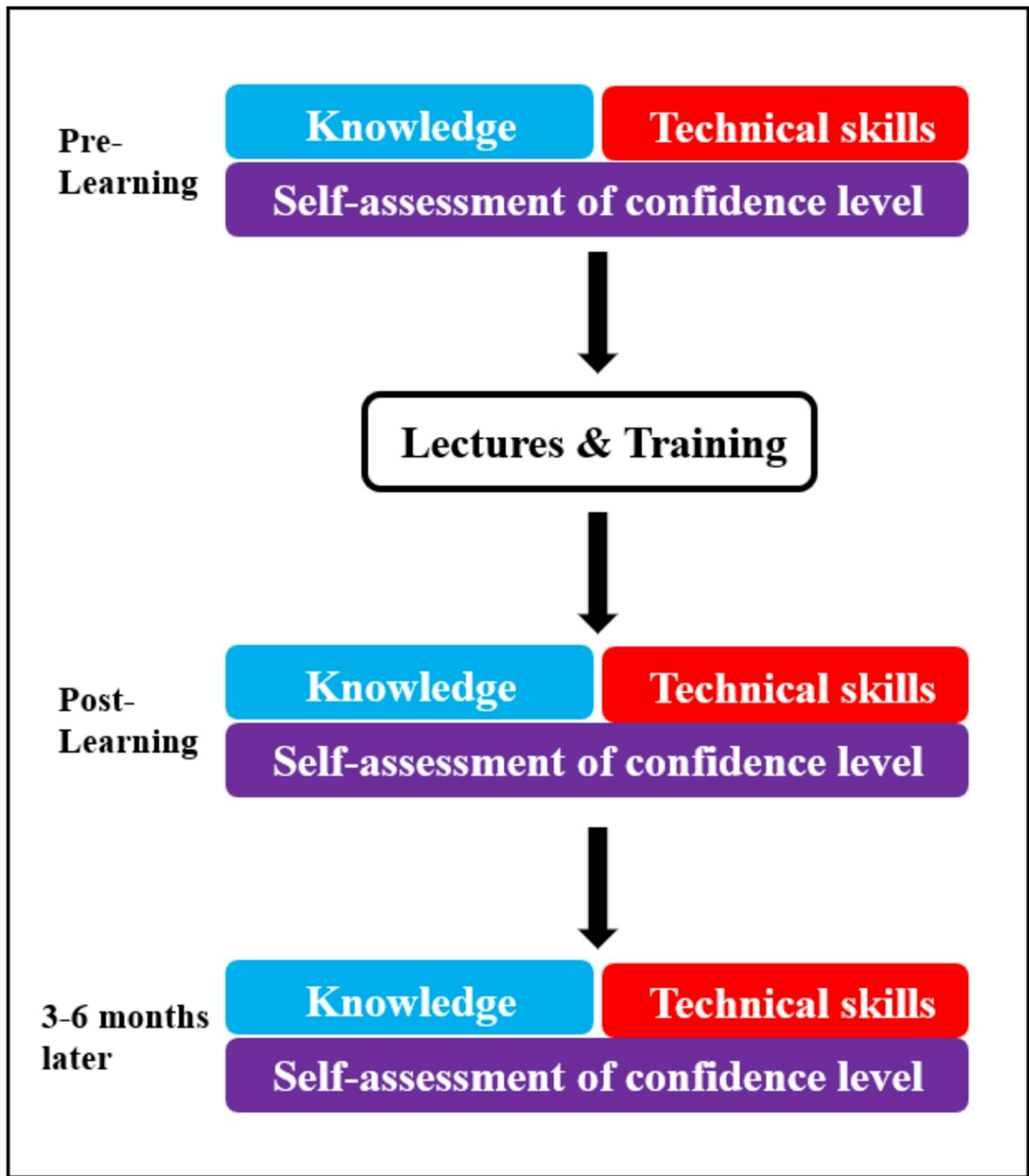


Figure 1

Evaluation method and schedule

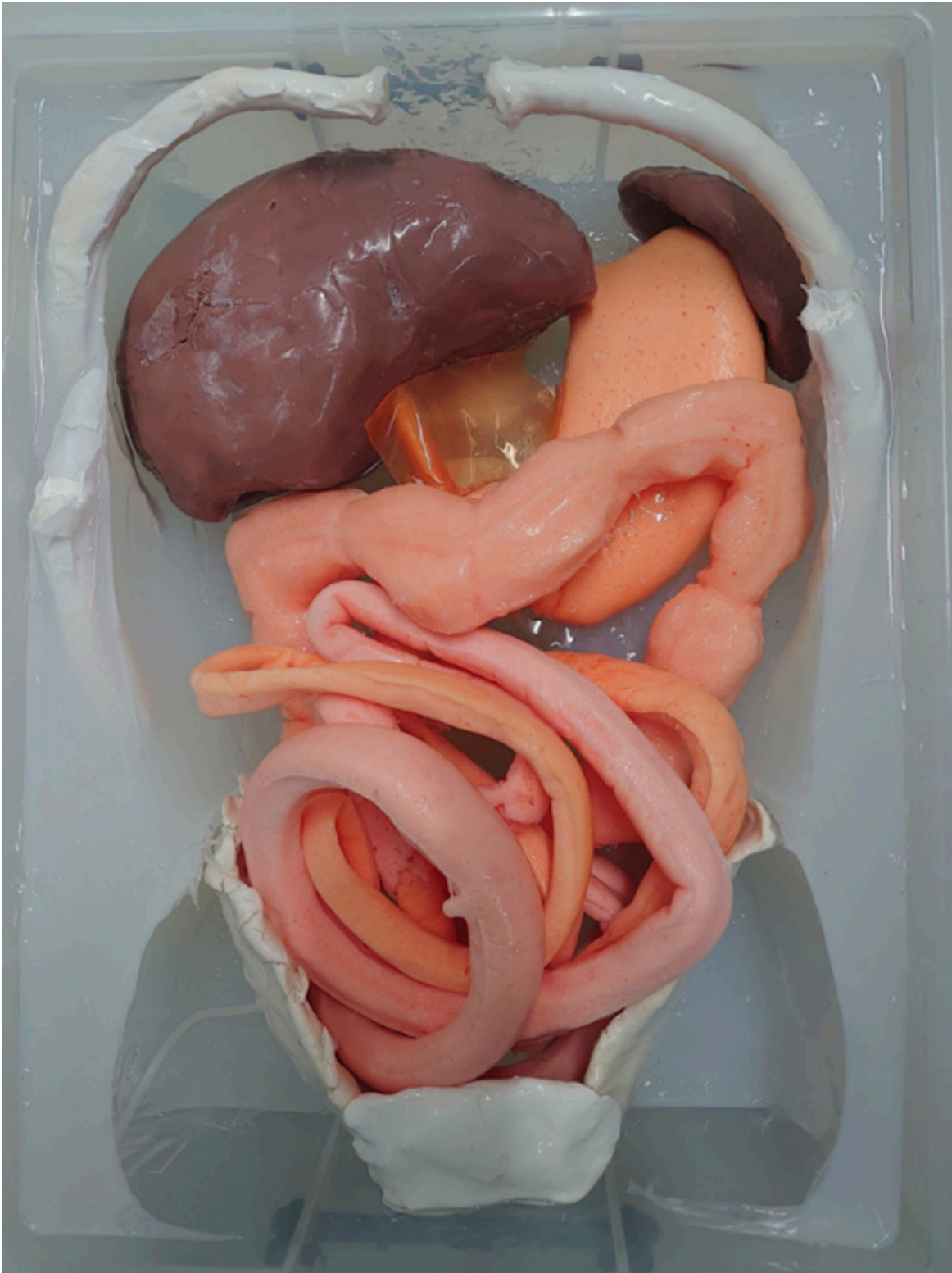


Figure 2

Liver trauma simulator