

Original Article

Advanced cadaver-based educational seminar for trauma surgery using saturated salt solution-embalmed cadavers

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Aim: Senior surgeons in Japan who participated in “cadaver-based educational seminar for trauma surgery (CESTS)” subsequently stated their interest in seminars for more difficult procedures. Therefore, we held a 1-day advanced-CESTS with saturated salt solution (SSS)-embalmed cadavers and assessed its effectiveness for surgical skills training (SST).

Methods: Data were collected from three seminars carried out from September 2015 to January 2018, including a 10-point self-assessment of confidence levels (SACL) questionnaire on nine advanced surgical skills, and evaluation of seminar content before, just after, and half a year after the seminar. Participants assessed the suitability of the two embalming methods (formalin solution [FAS] and SSS) for SST, just after the seminar. Statistical analysis resulted in $P < 0.0167$ comparing SACL results from seminar evaluations at the three time points and $P < 0.05$ comparing FAS to SSS.

Results: Forty-three participants carried out surgical procedures of the lung, liver, abdominal aorta, and pelvis and extremity. The SACL scores increased in all skills between before and just after the seminar, but were decreased by half a year after. However, SACL scores of each skill did not change significantly, except for external fixation for pelvic fracture at just after and half a year after. The SSS-embalmed cadavers were evaluated as being more suitable than FAS-embalmed cadavers for each procedure.

Conclusions: Advanced-CESTS using SSS-embalmed cadavers increased the participants’ self-confidence just after the seminar, which was maintained after half a year in each skill, except external fixation for pelvic fracture. Therefore, SSS-embalmed cadavers are useful for SST, particularly for surgical repairs.

Key words: Advanced seminar, saturated salt solution, cadaver-based educational seminar for trauma surgery, self-assessment of confidence levels, surgical skills training

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INTRODUCTION

WE PREVIOUSLY REPORTED the effectiveness of the “cadaver-based educational seminar for trauma surgery (CESTS)” in Japan for improvement of the skills and confidence of the participants.¹ However, in these seminars, we used cadavers embalmed in formalin solution (FAS), and thus, participants could not experience the actual texture or elasticity of the organs, or observe bleeding. In other seminars, cadavers fixed by Thiel solution (TS), which

contains low concentrations of formalin and food preservative, are sometimes used. However, preparation of the TS mixture is difficult and expensive. Recently, we reported that the use of cadavers embalmed using saturated salt solution (SSS), which was first developed by Coleman and Kogan,² contributed towards considerably solving such problems.^{3,4} Furthermore, senior surgeons who participated in the ordinary CESTS (basic-CESTS) answered in the free-response question after the surgical seminar that they are required to perform more difficult procedures and repairs in actual surgeries. Therefore, we have been holding 1-day advanced-CESTS with SSS-embalmed cadavers since September 2015.

METHODS

Cadaver-based educational seminar for trauma surgery

A TOTAL OF three 1-day advanced-CESTS were held, in September 2015, January 2017, and January 2018. Three cadavers were used in the CESTS in 2015 and two cadavers each in the CESTS in 2017 and 2018. All cadavers were embalmed with SSS. Participants were recruited by e-mail invitation. Namely, senior surgeons who participated in the original basic-CESTS from 2013 to 2017 and who answered questionnaires half a year after the seminars were contacted by e-mail, and all applicants were included. Senior surgeons were defined as holders of the general surgery board certification.

Participants were divided into three groups in 2015, and two groups in both 2017 and 2018, based on their years post-graduation (PGY). They carried out four trauma surgical procedures (lung, liver, abdominal aorta, and pelvis and extremity) on the cadavers, as illustrated in Figures 1–5. Participants alternated between being the surgeon and the assistant so that everybody could sufficiently practice the surgical procedures. In addition, before each procedure, short slide presentations were given by specialists (a thoracic surgeon, liver trauma surgeon, cardiovascular surgeon, and orthopedic trauma surgeon) to explain what the participants were expected to do.

The participants answered the questionnaires, including the self-assessment of confidence levels (SACL) for the nine skills (a 10-point visual analog scale score, as follows: 0 points, cannot do at all; five points, can do with help of an adviser; 10 points, can do independently) and an evaluation of the content, before, just after, and half a year after the seminar. Participants were asked to answer these questionnaires before and half a year after the seminar by e-mail (Fig. 6).

The participants were also asked to assess whether the two different embalming methods (FAS and SSS) are suitable for surgical skills training (SST), just after the seminar. Usefulness of the cadavers embalmed by each method for training regarding skin incision, thoracotomy, laparotomy, approaching the retroperitoneum, vessel maneuver, pelvic packing, and fasciotomy of the lower extremity was evaluated using a 5-point rating scale (1, completely different; 2, somewhat different; 3, neither different nor similar; 4, somewhat similar; and 5, completely similar, to living patients).

Time Schedule

| | |
|---|--|
| 9:00-10:20 Preparation Offering a silent prayer | 14:20 – 15:50 【Abdominal aortic trauma】 Repair of abdominal aortic injury Graft replacement for abdominal aortic injury (aneurysm) |
| AM | |
| 10:20- 11:50 【Lung trauma】 Pneumonectomy Lobectomy | 15:50 – 17:20 【Trauma of pelvis and extremity】 External fixation for pelvic fracture Pelvic packing Fasciotomy of the lower extremity |
| PM | |
| 12:50- 14:20 【Liver trauma】 Suture with omental flap Resectional debridement Hepatectomy Hepatic vascular exclusion | 17:20 – Offering a silent prayer & placing of body in coffin Answering questionnaires |

Fig. 1. Time schedule of the advanced cadaver-based educational seminar for trauma surgery in Japan.

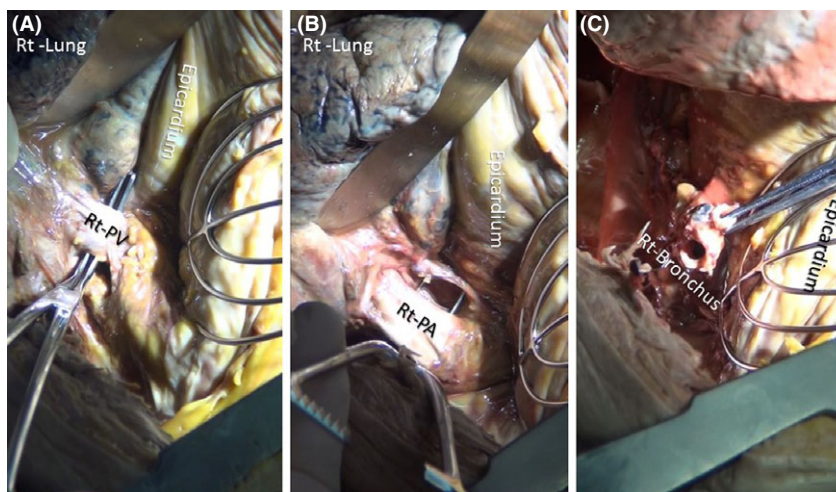


Fig. 2. Right pneumonectomy in an advanced cadaver-based educational seminar for trauma surgery in Japan. A, Ligation and separation of the right pulmonary vein (Rt-PV). B, Ligation and separation of the right pulmonary artery (Rt-PA). C, Ligation and separation of the right bronchus, followed by extirpation of the right lung.

In addition, some participants carried out these procedures using an electro-surgical knife (Sabre Genesis; Conmed, Utica, NY, USA) on the SSS-embalmed cadavers and then undertook the above evaluation using the 5-point rating scale.

Statistical analysis

Evaluation and analysis of all data were carried out using Microsoft Excel 2013 for Windows (Microsoft, Redmond, WA, USA) with paired *t*-tests. A *P*-value of <0.0167 ($=0.05/3$ with a Bonferroni correction for multiple comparisons) was considered to indicate a statistically significant difference when comparing the SACL results from the seminar evaluations at the three time points. A *P*-value of <0.05 was considered to indicate a statistically significant difference when comparing FAS with SSS.

RESULTS

Assessment of SACL after SST with SSS-embalmed cadavers

A TOTAL OF 43 participants completed the SST. Their AGE range was 9–30 (median, 17 years). All 43 participants returned the questionnaires before, just after, and half a year after the SST (response rate, 100%; Table 1).

Self-assessment of confidence levels scores was increased in all skills between before and just after the SST (5.4 ± 2.8 versus 7.1 ± 2.1 , $P < 0.0001$; $n = 43$); however, they decreased between just after and half a year after the seminar

(7.1 ± 2.1 versus 6.8 ± 2.2 , $P < 0.0001$). Analysis of these results for each procedure revealed that SACL did not decrease in each procedure, except for external fixation for pelvic fracture, between just after and half a year after the seminar ($P > 0.0167$).

Assessment of the use of cadavers embalmed by two different methods for SST

The question regarding whether the two different embalming methods (FAS and SSS) were suitable for SST was answered by 38–41 participants depending on the surgical procedure (response rate, 88%–95%). Twenty-four of the participants used an electro-surgical knife during the SST, and hence, their assessments were regarding SST using the knife (Table 2).

For every procedure, SSS-embalmed cadavers were evaluated to be significantly more suitable than FAS-embalmed cadavers. In addition, SSS-embalmed cadavers were evaluated to be approximately 3 points on the 5-point rating scale (neither different from nor similar to living patients). Although only 24 participants evaluated the cadavers based on use of an electro-surgical knife, their scores were approximately 4 points (somewhat similar to living patients). Consequently, the usefulness of SST with SSS-embalmed cadavers was rated as being high (4.1 ± 0.5).

DISCUSSION

IN JAPAN, SURGICAL training using cadavers has been officially spreading among universities, since the Japan

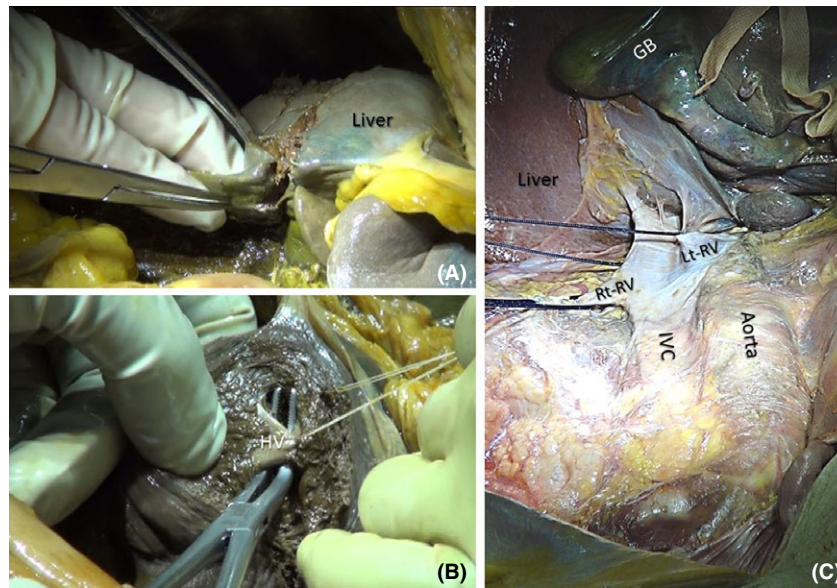


Fig. 3. Liver procedures in an advanced cadaver-based educational seminar for trauma surgery in Japan. A, B, Liver resectional debridement. C, Hepatic vascular exclusion. GB, gall bladder; HV, hepatic vein; IVC, inferior vena cava; Lt-RV, left renal vein; Rt-RV, right renal vein.

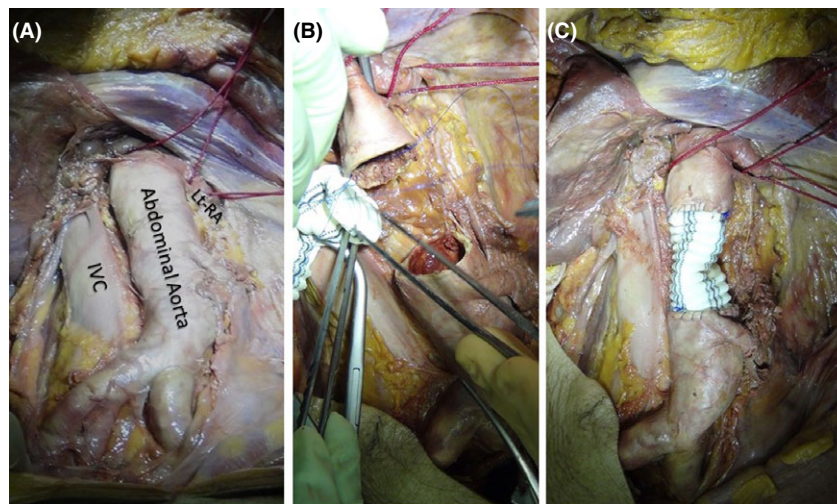


Fig. 4. Graft replacement for abdominal aortic injury (aneurysm) in an advanced cadaver-based educational seminar for trauma surgery in Japan. IVC, inferior vena cava; Lt-RA, left renal artery.

Surgical Society and the Japanese Association of Anatomists announced the Guidelines for Cadaver Dissection in Education and Research of Clinical Medicine in 2012.⁵ In the field of acute care surgery, Advanced Surgical Skills for Exposure in Trauma (ASSET)⁶ and our CESTS are held for cadaver surgical training in Japan.

In particular, basic-CESTS are now being held in many universities, including Tokyo Medical University,

University of Occupational and Environmental Health, Ehime University Graduate School of Medicine, and Hokkaido University Graduate School of Medicine.⁷ The basic-CESTS has been held a total of 46 times in Tokyo Medical University as of March 2018. However, the purpose of this cadaver surgical training course is dissection rather than repair. Senior surgeons who participated in the basic-CESTS answered in the free-response question that they would like

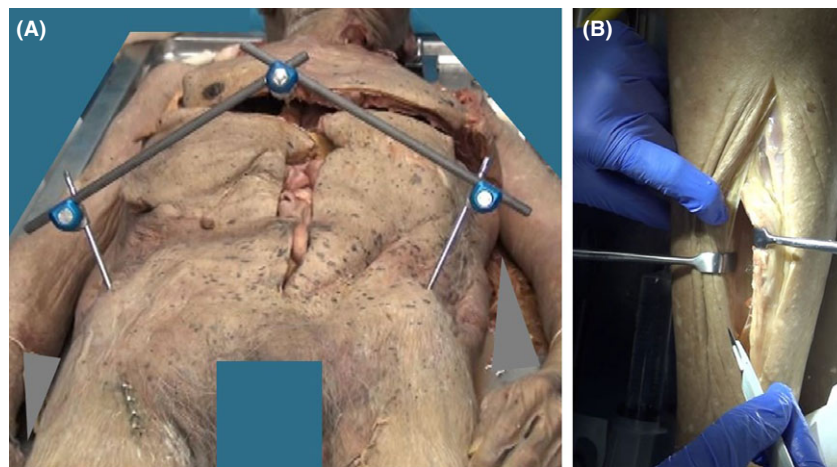


Fig. 5. Procedures of the pelvis and extremities in an advanced cadaver-based educational seminar for trauma surgery in Japan. A, External fixation for a pelvic fracture. B, Fasciotomy of the lower extremity for release of the deep posterior compartment.

QUESTION

Do you have any experience in performing the techniques listed below? If you do not have any experience in performing these techniques on your own, do you have confidence to perform these techniques independently in case of an emergency?

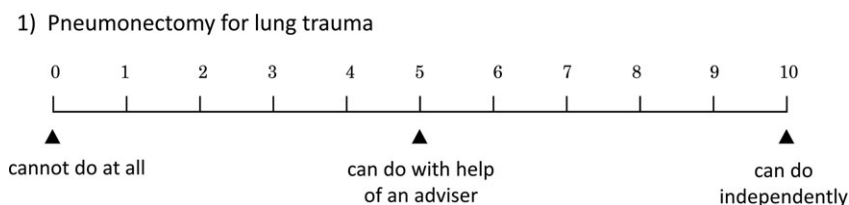


Fig. 6. Self-assessment of confidence levels of surgical skills following an advanced cadaver-based educational seminar for trauma surgery in Japan. Procedure number 1 (pneumonectomy for lung trauma) is shown as an example.

to practice more difficult procedures and repairs; that is, that they wanted to participate in an advanced-CESTS course.

One of the problems in holding advanced-CESTS courses is a suitable embalming method of the cadavers. ASSET in Japan uses TS-embalmed or fresh frozen cadavers, and basic-CESTS uses FAS- or TS-embalmed cadavers. Formalin solution contains 4 L of 20% formaldehyde in 22 L of solution, and FAS-embalmed cadavers are most frequently used in anatomical education of medical students; however, the rigidity of the tissues makes them unsuitable for practicing surgical repairs. Thiel solution contains 0.6 L of 20% formaldehyde in 18.86 L solution, and TS-embalmed cadavers have been widely used for postgraduate hands-on workshops for medical training.⁸ However, TS-embalmed

cadavers have some problems; that is, muscular disintegration, which results in limited time for dissection,⁹ decreased vascular cavities,³ and a complex embalming solution that is expensive to prepare (FAS costs ¥1,500 whereas TS costs ¥30,000 per cadaver).^{3,4} Fresh frozen cadavers are therefore an ideal choice; however, large freezers are required for their preservation and they have the risk of infection, and hence, they are not used widely in SST.

The composition of SSS is 1 L of 20% formaldehyde, 20 kg sodium chloride, 0.2 L phenol, 0.5 L glycerine, 4 L isopropyl alcohol, and 19.3 L water in a 25 L solution.³ Its cost is ¥3,000 per cadaver.⁴ We previously assessed the usefulness of SSS-embalmed cadavers for SST.³ Moreover, SSS-embalmed cadavers have already been used in SST for

Table 1. Self-assessment of confidence levels for surgical skills among senior surgeons in Japan who participated in 1-day advanced cadaver-based educational seminars for trauma surgery

| | <i>n</i> = 43 | SACL score (average ± SD) | | | Statistical significance | | |
|---|---------------|---------------------------|------------------------|------------------------------------|--------------------------|--------------|--------------|
| | | Before the seminar (BS) | After the seminar (AS) | Half a year after the seminar (HS) | BS versus AS | BS versus HS | AS versus HS |
| Lung trauma | | | | | | | |
| 1) Pneumonectomy | | 5.3 ± 2.7 | 6.7 ± 2.0 | 6.5 ± 2.2 | ** | ** | ns |
| 2) Lobectomy | | 4.7 ± 2.6 | 6.5 ± 2.0 | 6.3 ± 2.1 | *** | *** | ns |
| Liver trauma | | | | | | | |
| 3) Resectional debridement | | 6.3 ± 2.5 | 8.0 ± 1.8 | 7.6 ± 2.0 | *** | *** | ns |
| 4) Hepatectomy | | 6.0 ± 2.4 | 7.2 ± 1.8 | 7.0 ± 2.1 | *** | *** | ns |
| 5) Hepatic vascular exclusion | | 5.0 ± 2.8 | 6.5 ± 2.3 | 6.3 ± 2.3 | *** | ** | ns |
| Abdominal aortic trauma | | | | | | | |
| 6) Graft replacement for abdominal aortic injury (aneurysm) | | 3.6 ± 2.7 | 6.1 ± 2.1 | 5.6 ± 2.2 | *** | *** | ns |
| Trauma of pelvis and extremity | | | | | | | |
| 7) External fixation for pelvic fracture | | 4.3 ± 2.8 | 7.1 ± 1.7 | 6.3 ± 2.1 | *** | *** | * |
| 8) Pelvic packing | | 8.0 ± 2.2 | 8.8 ± 1.6 | 8.8 ± 1.5 | * | ** | ns |
| 9) Fasciotomy of the lower extremity | | 5.7 ± 2.2 | 7.3 ± 1.9 | 6.9 ± 2.0 | *** | ** | ns |
| Total | | 5.4 ± 2.8 | 7.1 ± 2.1 | 6.8 ± 2.2 | *** | *** | *** |

Participants answered questionnaires, including a self-assessment of confidence levels (SACL) for surgical skills (0 points, cannot do at all; 5 points, can do with help of an adviser; 10 points, can do independently).

P-values <0.0167 (=0.05/3 with a Bonferroni correction for multiple comparisons) were considered to be statistically significant.

P* < 0.0167 (0.05/3); *P* < 0.001; ****P* < 0.0001. ns > 0.0167 (not significant); SD, standard deviation.

plastic surgery, orthopedic surgery, and neurosurgery.^{10–12} Therefore, we used SSS-embalmed cadavers in advanced-CESTS. In fact, SSS-embalmed cadavers were evaluated as being highly suitable for advanced-CESTS in this study.

The next problem regarding holding advanced-CESTS courses was which surgical procedures to include. The results of the questionnaire survey for acute care surgeons in Japan indicated that acute care surgery should cover not only abdominal injury and disease, but also lung injury (73% of respondents), aortic aneurysm hemorrhage (53%), and external fixation of the pelvis (67%). Kaneko, who undertook this questionnaire survey, also proposed that acute care surgeons should be able to treat abdominal aortic aneurysms under the renal artery.¹³

In addition, most gastroenterological surgeons are not very experienced in treating hepatic injuries, particularly serious hepatic injuries that require special techniques.¹⁴ Moreover, training sessions on pelvic packing and fasciotomy of the lower extremity were highly evaluated by

participants of basic-CESTS; however, we were unable to provide sufficient training when we used FAS-embalmed cadavers. Therefore, we included lung trauma, liver trauma, abdominal aortic trauma (including aneurysm), and trauma of the pelvis and extremity as surgical procedures for advanced-CESTS. Incidentally, we also included external fixation for multiple rib fractures (flail chest) in the September 2015 course; however, we excluded it from the January 2017 course, because of time constraints.

The SACL scores were increased in all skills just after the seminar compared with before; however, they decreased between just after and half a year after the seminar. These results were the same as those from the basic-CESTS.¹ Analysis of the results for each skill indicated that the *P*-value reached significance for external fixation for pelvic fracture (*P* = 0.0134), and just missed statistical significance for graft replacement for abdominal aortic injury (*P* = 0.0191). This means that the results of SACL regarding external fixation for pelvic fracture and graft

Table 2. Assessment of two different embalming methods for surgical skills training

| | <i>n</i> | Evaluation (average ± SD) | | <i>P</i> -value |
|---|----------|---------------------------|-------------------------------|-----------------|
| | | Formalin solution (FAS) | Saturated salt solution (SSS) | |
| Skin incision | 40 | 1.7 ± 0.8 | 3.1 ± 0.8 | <0.0001 |
| Thoracotomy | 41 | 1.8 ± 0.8 | 3.2 ± 0.8 | <0.0001 |
| Laparotomy | 40 | 1.8 ± 0.8 | 3.4 ± 0.7 | <0.0001 |
| Approach for retroperitoneum | 41 | 1.8 ± 0.9 | 3.7 ± 0.6 | <0.0001 |
| Vessel maneuver | 41 | 1.9 ± 0.8 | 3.4 ± 0.8 | <0.0001 |
| Pelvic packing | 41 | 2.0 ± 1.0 | 3.5 ± 0.7 | <0.0001 |
| Fasciotomy of the lower extremity | 40 | 2.1 ± 0.8 | 3.7 ± 0.7 | <0.0001 |
| Use of electro-surgical knife for SSS | 24 | — | 3.6 ± 0.9 | |
| Usefulness for surgical skills training | 38 | 2.4 ± 1.1 | 4.1 ± 0.5 | <0.0001 |

Two different embalming methods (FAS and SSS) were assessed regarding their suitability for surgical skills training. All procedures were evaluated on a 5-point rating scale (1, completely different; 2, somewhat different; 3, neither different nor similar; 4, somewhat similar; and 5, completely similar, to live patients).

P-values <0.05 were considered to indicate a statistically significant difference between two groups.

P-values >0.05 were not significant; SD, standard deviation.

replacement for abdominal aortic injury affected the SACL of all participants between just after and half a year after the seminar. The majority of participants were general surgeons and gastroenterological surgeons. Therefore, these two skills were rarely experienced by them and were unfamiliar to them.

As described above, pelvic packing and fasciotomy of the lower extremity that were included in the advanced-CESTS were common skills that were also included in the basic-CESTS. Therefore, we were able to undertake long-term follow-up of the participants' SACL. The time between participation in the basic-CESTS and advanced-CESTS was a mean of 28 ± 7.7 months ($n = 42$). The SACL of pelvic packing just after participating in the basic-CESTS (AS-basic) was 8.5 ± 1.8 , before the advanced-CESTS (BS-advanced) was 8.0 ± 2.2 , just after the advanced-CESTS (AS-advanced) was 8.8 ± 1.6 , and half a year after the advanced-CESTS (HS-advanced) was 8.9 ± 1.5 . The SACL scores of fasciotomy of the lower extremity were: AS-basic, 6.7 ± 2.0 ; BS-advanced, 5.7 ± 2.2 ; AS-advanced, 7.4 ± 1.8 ; and HS-advanced, 6.9 ± 2.0 . The SACL scores for fasciotomy of the lower extremity decreased between AS-basic and BS-advanced; however, it increased between BS-advanced and AS-advanced and then did not decrease between AS-advanced and HS-advanced (*P*-values < 0.0125 [=0.05/4 with a Bonferroni correction for multiple comparisons] were considered to be statistically significant). The SACL of the pelvic packing did not decrease between AS-basic and BS-advanced, and increased between BS-advanced and AS-advanced, then did not decrease between AS-advanced and HS-advanced. Recently,

Mackenzie *et al.*¹⁵ reported long-term skills retention (30 ± 12.8 months) after the ASSET course. They concluded that trauma skills degradation was associated with a lack of interval procedure performance, not time since training. The results of our present study supported this report, and we believe that skills required for pelvic packing were more familiar to the participants than those of fasciotomy of the lower extremity, as the participants were mostly general surgeons and gastroenterological surgeons. However, participants were able to refresh their skills after the seminar for fasciotomy of the lower extremity. In fact, four participants carried out fasciotomy of the lower extremity in their clinical work after the seminar. Therefore, we believe that repeated participation in these seminars is effective for refreshing participants' skills, and to prevent their loss of confidence after the seminars. Our opinion here is the same as that reported in our previous study on basic-CESTS.¹

Although SSS-embalmed cadavers are suitable for SST, participants still cannot observe bleeding during their surgical training. We are presently developing another seminar using frozen pig organs.¹⁶ Participants will be able to observe artificial bleeding from the defrosted organs, which will be connected to a blood supply by a catheter. We plan to combine CESTS and the seminar using frozen pig organs, and expect that it will be a solution towards a more realistic SST model.

CONCLUSIONS

ADVANCED-CESTS WITH SSS-EMBALMED cadavers provided more self-confidence just after the

seminar for participants, and the effect was maintained after half a year for each skill, except for external fixation for pelvic fracture. Therefore, SSS-embalmed cadavers are useful and appear to be suitable for SST, particularly for surgical repairs.

This is the first report of advanced cadaver surgical training for trauma surgery documenting that SSS-embalmed cadavers are suitable for SST.

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DISCLOSURE

Approval of the research protocol: This study was approved by the institutional review board (IRB) of Tokyo Medical University (IRB nos. 2139 and 3412).

Informed consent: All participants provided informed consent.

Registry and the registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

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