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Initial report on the impact of a perfused fresh cadaver training program in general surgery resident trauma education

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A B S T R A C T

Background: Operative trauma volume for general surgery residents (GSR) continues to decline. This pilot study examines the impact of utilizing perfused cadavers in trauma surgical skills training for GSR.
Methods: GSR (post graduate year (PGY) 1 through 4) participated in trauma surgical skills training utilizing perfused cadavers. GSR completed surveys assessing confidence in their ability to perform critical procedures before and after training.
Results: Sixteen GSR participated in trauma skills training. All PGY 1–2, reported increases in confidence in skills. PGY 4 GSR reported significant increase in confidence in most skills sets including surgical airway, resuscitative thoracotomy/cardiac injury, and abdominal vascular injury. The majority of GSR retained confidence in these skills at 6 months.
Conclusions: Integration of perfused cadavers into GSR curriculum provides high fidelity and dynamic model for training trauma surgical skills. Studies are needed for development and validation of this training and assessment method.

Introduction

In the current era of duty hour restrictions, general surgery residency programs have faced challenges in ensuring adequate trauma training.[1,2] Moreover, changing practice patterns in the care of the trauma patient, including paradigm shifts to catheter-based therapy and non-operative management, have significantly impacted general surgery resident (GSR) operative trauma case volume.[3,4] As a result, GSR graduating today have decreased exposure to complex open surgical procedures in trauma.[5] Drake et al. reported that prior to the implantation of work-hour restrictions, GSR were experiencing declining operative case volume in Accreditation Council of Graduate Medical Education (ACGME) designated trauma operations.[6] More concerning, however, these GSR were performing less operations for intra-abdominal trauma, specifically procedures on the liver and spleen. In a more recent review of GSR case log statistical reports from 1999 to 2014, Strumwasser et al. reported a continued downward trend in operative cases logged by GSR after the implementation of the 80-hour work week. Beyond overall open trauma operative experience, GSR case numbers in the management of organ-specific injury have become dangerously low most noticeably in thoracic, abdominal, solid organ and extremity-vascular trauma.[7] The authors provided additional evidence that participation in a trauma/surgical critical care fellowship can help abate these open case volume deficiencies for GSR.

Advanced simulation training has been proposed as a solution to help address these reported deficits in trauma surgical education.[8] Single-day porcine-simulation (Advanced Trauma Operative Management) and cadaver-based training (Advanced Surgical Skills for Exposure in Trauma) courses have been offered for years through the education program of the American College of Surgeon (ACS) Committee on Trauma (COT). These ACS course offerings have been reported to improve learning in terms of knowledge and skills acquisition.[9–11] Little has been published, however, on the incorporation of cadaver-based trauma simulation in GSR curriculum. To help mitigate this training deficiency at our academic medical center, the West Virginia University Fresh Tissue Training Program (FTTP) was established in January 2018. Shortly after, surgical skills

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training at the FTTP was incorporated into the GSR curriculum.

The FTTP was formed in collaboration between the Critical Care and Trauma Institute, as well as the Departments of Surgery and Pathology, Anatomy and Lab Medicine, and the Human Gift Registry (HGR). This multi-disciplinary educational program allows all levels of physician trainees, access to fresh human cadavers for the purposes of anatomic and surgical skills teaching. Training sessions occur within the FTTP dissection lab, which houses a fully equipped surgical skills training room with standard operating room equipment. Procurement of and procedures performed on all cadavers occurs according to the standard operating procedures of the WVU HGR and FTTP. From July through October, GSR participate in twice monthly trauma surgical skills training session in the FTTP. These sessions are moderated by trauma faculty instructors, utilize fresh, human cadavers with vascular perfusion and include guided dissections and case-based scenarios for surgical management of neck, chest, abdominal and lower extremity vascular injuries.

This is the initial report on the impact of incorporating a fresh, human cadaver with vascular perfusion for trauma surgical skills training in the GSR curriculum. To assess this impact GSR confidence in trauma surgical skills ability was evaluated pre-training as well as immediately post and six months after training sessions.

Materials and methods

Study setting and participants

From July through October 2018, GSR who participated in trauma surgical skills training in the WVU FTTP were asked to provide feedback on the impact of these training sessions via voluntary web-based surveys. GSR were grouped as teams, post-graduate years (PGY 4, 2, and 1). Trauma faculty instructors using fresh, human cadavers with vascular perfusion provided trauma surgical skills training in the management of penetrating neck, chest, complex abdominal trauma, and lower extremity vascular injury. Surgical skills performed included cricothyroidotomy; control of cervical vascular injury; repair of cervical tracheoesophageal injury; management of superficial femoral artery injury; lower extremity four compartment fasciotomy; thoracotomy and repair of cardiac and pulmonary injuries; trauma laparotomy; and management of solid organ and abdominal vascular injury. This study was reviewed and approved by the WVU Institutional Review Board.

Cadaver preparation

Human cadavers used for this training in the FTTP were fresh, non-embalmed, and never frozen. They were stored in coolers maintained at 4 °C and allowed to warm at ambient temperature (20 °C) prior to scheduled training sessions. Fresh human cadavers (FHC) were perfused using a modification of the technique described by both Carey in 2015 and Minneti in 2017.[12,13] Briefly, vascular perfusion of FHC was achieved via exposure and cannulation of the femoral vessels with Simms connectors. Perfusate flow was achieved using a centrifugal pump (Medtronic BPX-40 Bio-Pump; Minneapolis, MN, Medtronic Bio Medicus Bio Console 550, Minneapolis, MN). Red, non-toxic paint with water was used as blood substitute. Perfusion of the vasculature was regulated by serial clamping and unclamping of the blood tubing. To mitigate the primary negative side effect of abdominal fluid accumulation, perfusion was not maintained continuously, and the FHC was only perfused selectively in order to allow for improved vascular anatomy or simulated hemorrhage.

Room preparation

All procedures were performed on FHC on a standard dissection table. After completion of preparation for vascular perfusion, the FHC were prepped and draped in standard operating room fashion for the trauma surgical skills training. Pre-arranged, standard operating room equipment included portable overhead lights; suction devices; electro-surgical devices, and instrument tables. Standard surgical instruments were available depending on the planned procedure. All participants were provided with personal protective equipment.

Survey and dissemination

GSR were provided a web-based survey both prior to and immediately following the training sessions. Demographic information queried included gender, PGY level, and prior experience in the Advanced Surgical Skills for Exposure in Trauma (ASSET) course. Survey questions inquired about GSR' confidence in their ability to perform key surgical skills specific to the management of trauma pre- and post-training, using a 5-point Likert scale, from 0 = no confidence to 5 = complete confidence. Examples of these Likert-style questions include, "*My confidence in exposure and management of carotid artery injury …," "My confidence in four-compartment fasciotomy …," and "My confidence in management of solid abdominal organ injury ….* " Additional surveys asking the same questions were distributed at six-month follow-up intervals in order to assess retention of skills query.

Statistical analysis

Demographic data collected is presented as mean ± standard deviation (SD). Confidence scores for GSR are grouped by PGY level and presented as mean Likert score ± SD. Analysis of variance (ANOVA) was used to determine difference among the mean Likert scores reports for the groups.

Results

From July to October 2018, a total of 16 GSR (7 PGY-1; 5 PGY-2; 4 PGY-4) completed the training sessions, with 63% reported male. Of the four PGY 4 GSR 50% had previously taken ASSET within one year of this trauma surgical skills training course; none of the PGY-2 or PGY-1 GSR had previously completed the ASSET course. Additional demographic information on the participants can be seen in Table 1.

Overall, PGY-4 GSR reported an increase in their confidence levels in all areas of trauma surgical skill training in which the FHC with vascular perfusion was used. Significant increases in confidence levels were seen in the following skills sets: surgical airway, tracheoesophageal injury, thoracotomy-cardiac injury, tractotomy-lung resection, solid abdominal organ injury, and abdominal vascular injury ($p < 0.05$). Notably, there were also increases in confidence levels seen in cervical vascular injury, damage control laparotomy, lower extremity vascular injury and fasciotomy,

Table 1
Demographic information of participating GSR, categorized by PGY.

	PGY-4	PGY-2	PGY-1
Total	4	5	7
Female (%)	25%	0%	71%
Male (%)	75%	100%	29%
Prior ASSET (%)	50%	0%	0%

GSR = General Surgery Resident; PGY = Post Graduate Year; ASSET = Advanced Surgical Skills for Exposure in Trauma.

Table 2
Self-reported confidence levels of PGY-4 and PGY-2 GSRs, pre- and post-training.

SKILLS SET	PGY 4		PGY 2	
	PRE	POST	PRE	POST
Surgical Airway	2	3.33 (±0.57)[a]	1.6 (±1.14)	3[a]
Cervical Vascular Injury	2.5 (±0.57)	3	0.6 (±0.54)	2.75 (±0.5)[a]
Tracheoesophageal Injury	1.5 (±0.57)	2.66 (±0.57)[a]	0.6 (±0.54)	2.75 (±0.5)[a]
Thoracotomy/Cardiac Injury	1.25 (±0.5)	3.33 (±0.57)[a]	1.2 (±1.3)	3 (±0.81)[a]
Tractotomy Lung Resection	1.5 (±0.57)	3 (±1)[a]	0.4 (±0.54)	2.5 (±0.57)[a]
DC Laparotomy	3.5 (±0.57)	4	1.4 (±0.54)	3.25 (±0.5)[a]
Solid Abd. Organ Injury	3.25 (±0.5)	4[a]	1.2 (±1.09)	3[a]
Abdominal Vascular Injury	1.75 (±0.5)	3[a]	0.6 (±0.54)	2[a]
SFA Exposure/Control/Shunt	2.5 (±0.57)	3.33 (±0.57)	1 (±0.70)	2.75 (±0.5)[a]
Lower Extremity Fasciotomy	3	3.66 (±0.57)	2.4 (±0.89)	3.5 (±0.57)

Likert Score as reported by the GSR pre and post training.
GSR = General Surgery Resident; PGY = Post Graduate Year; DC = Damage Control; SFA = Superficial Femoral Artery.
Data represent Mean (±SD).
[a] Indicates significance ($p < 0.05$).

although not significant (Table 2). When analyzing 6-month follow-up survey responses post-training, PGY-4 GSR reported retention in their respective confidence levels in nearly all trauma surgical skills, except for management of surgical airway and traumatic chest injury. Fig. 1 shows the increase in confidence in all trauma surgical skills surveyed with retention of confidence of those skills for PGY-4 GSR. Similarly, PGY-2 GSR reported significant increases in confidence levels for nearly all trauma surgical skill sets surveyed ($p < 0.05$) as is seen in Table 2. While PGY-2 GSR confidence in lower extremity fasciotomy increased this was not significant (Table 2). PGY-2 GSR retained confidence in all trauma surgical skills post training except for thoracic, lower extremity vascular and fasciotomy procedures. Fig. 2 shows the increase in confidence in all trauma surgical skills surveyed with retention of confidence in most of those skills for PGY-2 GSR.

PGY-1 GSR were provided with the same surveys as their senior resident colleagues. While PGY-1 GSR reported increases in confidence for nearly all trauma surgical skills which were queried, it should be noted that the increases improved from no confidence to low confidence. Significant improvements were noted in cricothyroidotomy (Pre-: 0.83; Post-: 1.16, $p < 0.05$) and lower extremity fasciotomy (Pre-: 0.16; Post-: 1.67, $p < 0.05$). PGY-1 GSR were able to maintain the small gains in confidence levels at their respective six-month intervals.

Discussion

This pilot study demonstrates that incorporation of FHC with vascular perfusion in trauma training for GSR is useful in improving their confidence in trauma surgical skills. All levels of PGY GSR report significant increases in their confidence levels among the majority trauma surgical skills evaluated in this study both immediately after training and at 6-month intervals. The results in our pilot study are similar to those obtained by Gunst's evaluation of the Trauma Exposure Course (TEC), which utilized fresh, non-perfused cadavers, in training fellows and chief residents.[14] The TEC includes a similar structure for training in operative trauma exposures as well as pre, post and long-term follow-up of participants self-reported levels of operative confidence. Additionally, retention rates of confidence levels in both studies were shown not

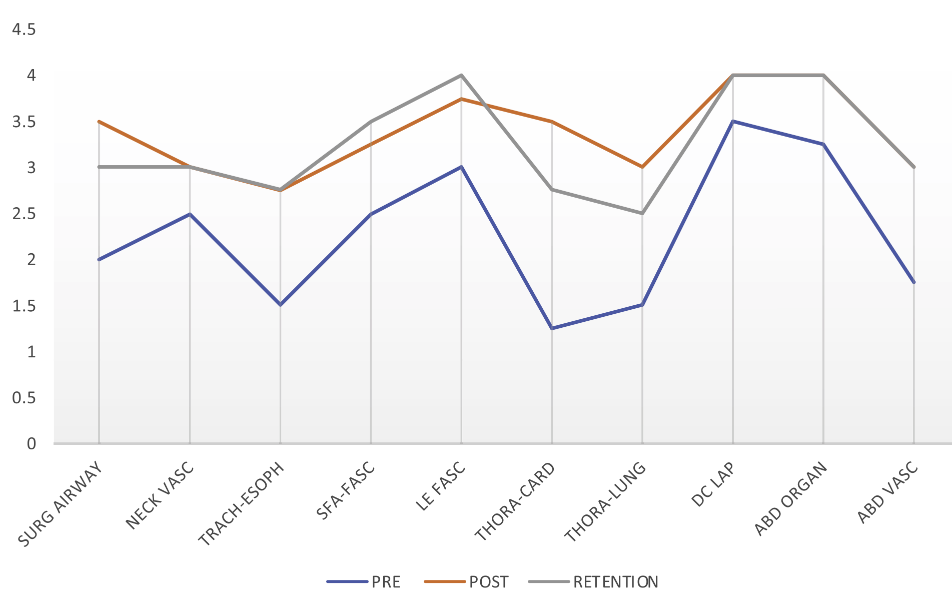

Fig. 1. PGY-4 Confidence in Trauma Skills with Retention
PGY-4 GSR demonstrated increased confidence in trauma skills post training in all procedures surveyed. SFA = Superficial Femoral Artery; LE = Lower Extremity; DC = Damage Control.

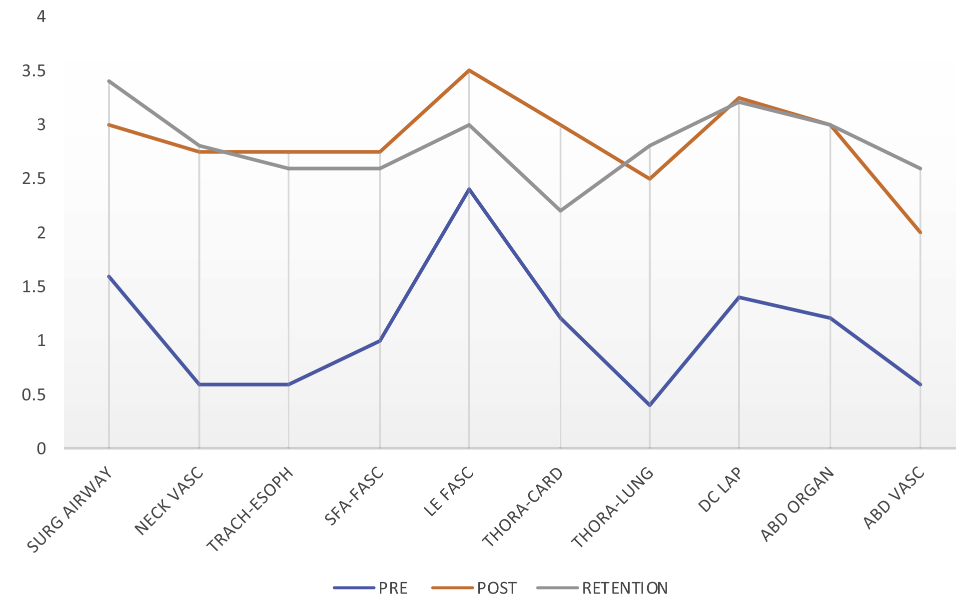

Fig. 2. PGY-2 Confidence in Trauma Skills with Retention
PGY-2 GSR demonstrated increased confidence in trauma skills post training in all procedures surveyed. SFA = Superficial Femoral Artery; LE = Lower Extremity; DC = Damage Control.

to decline on follow-up, with nearly all skill sets being maintained at similar or higher confidence levels as compared to the original post-curriculum survey. The TEC, however, is only a single day course and was not incorporated into GSR curriculum over a series of recurring training sessions as was implemented in our GSR training program.

The use of single day, cadaver surgical skills courses, such as TEC, has become popular for skills learning among surgeons in training and retention for those in active practice. ASSET is a single-day cadaver-based trauma surgical exposure course which has been promulgated nationally and internationally to provide initial trauma surgical skills training as well as serve as a skills refresher. Initial studies have shown that surgical trainees and practicing surgeons who have taken this course have significantly improved self-reported confidence in the exposures needed to care for trauma patients.[10,11] Additional studies report on the performance of the ASSET single day course in improvement in surgical skills ability and confidence for both surgical trainees and practicing surgeons.[15,16] Use of a cadaver-based trauma surgical skills course such as ASSET has also been shown to be useful in surgical performance assessment for specific procedural steps and anatomic knowledge.[17]

Fresh, human cadavers allow for high fidelity tissue handling making them superior to synthetic models. The addition of vascular perfusion allows for three-dimension vascular anatomy of fluid-filled, pressurized and bleeding vessels which adds a dynamic component normally only seen in the real patient scenarios. Garrett described a perfused cadaver model in 2001 that was primarily used for endovascular device development and training.[18] In 2011, Aboud et al. detailed the use of fresh, human cadavers with vascular perfusion for simulating various life-threatening injuries. In their study, fully trained trauma surgeons evaluated the model for repairing various injuries in the chest and abdomen. The surgeons in this study reported that the fresh, human cadavers with vascular perfusion were useful in allowing for simulation of the critical challenges faced during operative trauma as well as allowing for training in the skills necessary to manage vascular injuries.[19]

With decreasing operative case volume in trauma for GSR, simulation must become more of a necessity than a novelty in training programs. The use of fresh, perfused-cadavers are ideal models that can be used to help mitigate the known training case volume deficiency when employed in a GSR curriculum. A single center study from a large, university teaching hospital reported on GSR who participated in anatomy-based education programs utilizing fresh human cadavers to learn surgical anatomy and operative skills in general surgery. The GSR overwhelmingly had a positive view of cadaver training and believed the fresh cadavers to be useful for learning anatomy, learning the steps of the procedure and increasing the confidence in performing the procedure.[20] Woo et al., in 2012 assessed surgical training needs in vascular surgery. Vascular surgery faculty and fellows ranked 52 procedures and skills in vascular surgery using a Likert scale based on need for simulation training. The authors identified procedures, such as carotid artery stent and repair of infrarenal aneurysm as procedures where simulation would be beneficial.[21] Previously, Reed et al., in 2009, reported on 45 GSR who utilized fresh cadavers over a 2-year period to learn basic vascular surgical anatomy and operative technique. Again, the use of FHC was perceived by the trainees to be highly beneficial in educational value and as a training modality.[22] Additional studies have reported on the use of FHC with vascular perfusion incorporated into cardiac and plastic surgery training programs.[23,24]

The WVU FTTP was created in partnership with several stakeholders involved. This has allowed the FTTP to optimize opportunities for surgical training and simulation. Carey et al. reported the cost of the perfused cadaver model to be approximately $1200.00 per cadaver, not including cadaver cost.[12] The FHC perfusion method used in the FTTP is modified from the model described in 2015 by Carey et al. and the costs are similar.[12] Of course, facility fees and cost of procuring cadavers varies by institution. In addition, surgical supplies are additional costs that must be included.

This single-institution pilot study has inherent limitations. Data was collected via surveys of a group of GSR pre, post and 6 months post (retention) training. Surveys on small sample sizes have

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inherent disadvantages. The small sample size in our study may have led to a larger standard deviation. Consequently, with a larger standard deviation our results may be less accurate and less representative of the GSR population.

The goal of this pilot study was to assess the impact of FHC with vascular perfusion training program on GSR trauma education. The overwhelmingly positive impact of this training program has served as a proof of concept for the continued utilization of FHC within GSR curriculum for trauma education. Continued development of the FTTP perfused FHC surgical simulation program will include the added benefit of interactions between OR team members, simulated cadaver responses to interventions, and team training exercises.[13] Additional training metrics to include procedural task performance as well as knowledge assessment will be incorporated into future cadaver-based trauma training sessions as well. In addition, attending surgeon evaluation of resident performance before and after surgical simulation of index procedures may offer additional insights into the value of the program. The success of this pilot study should support additional needs assessments for training in general surgery residency as well as other graduate medical education programs which perform invasive procedures. This may lead to the development of new cadaver-based procedure and skill training programs.

Conclusions

This pilot study provides evidence in support of the use of FHC with vascular perfusion in the training of GSR in trauma surgery procedures and skills. Incorporation of cadaver-based training models into GSR programs may be useful beyond trauma education. Teaching anatomy and procedural skills in other surgical disciplines may be beneficial to additional trainees.

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