Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course: Curriculum development, content validation, and program assessment

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BACKGROUND: The management of hemorrhage shock requires support of central aortic pressure including perfusion to the brain and heart as well as measures to control bleeding. Emerging endovascular techniques including resuscitative endovascular balloon occlusion of the aorta serve as potential lifesaving adjuncts in this setting. The Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course was developed to provide fundamental endovascular training for trauma surgeons.

METHODS: ESTARS 2-day course incorporated pretest/posttest examinations, precourse materials, lectures, endovascular and open vascular instruments, Vascular Intervention System Trainer endovascular simulator, and live animal laboratories for training and testing. Curriculum included endovascular techniques for trauma; review of wires, sheaths, and catheters; as well as regional vascular injury management. Animal laboratories integrated arterial access, angiography, coil embolization, resuscitative endovascular balloon occlusion of the aorta, control of iliac artery injury, and vascular shunt placement. Students completed a knowledge test (precourse/postcourse) and a summative skills assessment. The test measured knowledge and judgment in vascular injury management as defined in the course objectives. Vascular Intervention System Trainer and animal laboratory were used for final examinations. Subjective performance was graded by expert observers using a global assessment scale and performance metrics.

RESULTS: Four pilot ESTARS courses were completed, with four participants each. Knowledge and performance significantly improved after ESTARS. Mean test examination scores increased by 77% to 85%, with a mean change of 9 percentage points [paired t(15) = 7.82, p < 0.0001]. The test was unidimensional (Cronbach’s α = 0.67). Technical skill significantly improved for both endovascular simulation and live animal laboratory examinations. All participants passed the live animal laboratory practical examination.

CONCLUSION: The ESTARS curriculum is effective at teaching a basic set of endovascular skills for resuscitation and hemorrhage control to trauma surgeons. ESTARS was confirmed as a stepwise and hierarchical curriculum demonstrating measurable improvements in performance metrics and should serve as a model for future competency-based structured training in endovascular trauma skills. (J Trauma Acute Care Surg. 2014;76:929–936. Copyright © 2014 by Lippincott Williams & Wilkins)

KEY WORDS: Endovascular; trauma; hemorrhage; resuscitation; aortic balloon occlusion.

Noncompressible torso hemorrhage (NCTH, defined as hemorrhage from the thorax, solid organ injury, axial torso vessel, or pelvic fracture) is associated with high mortality in trauma.12 Civilian studies demonstrate that NCTH accounts for 60% to 70% of deaths following otherwise survivable injuries, underscoring the burden of this injury pattern. Similarly, 80% of combat-related deaths occurring in troops with otherwise survivable injuries are secondary to NCTH.3 5 Early and effective resuscitation and hemorrhage control in the setting of NCTH have the potential to improve survival following military and civilian trauma.

Vascular injury and its management are an increasingly complex part of trauma care.5 11 The rate of vascular injury in the wars in Afghanistan and Iraq has been shown to be five times that previously reported in combat.12 As such, the wars have resulted in significant advances in the management of vascular trauma and hemorrhagic shock.13 One of the most notable has been the establishment of endovascular capabilities into the combat casualty care paradigm.14 16 Implemented early, select catheter-based techniques are associated with decreased morbidity and mortality rates compared with open vascular procedures.17 A potential adjunct to resuscitation in the setting of shock is resuscitative endovascular balloon occlusion of the aorta (REBOA).18 25 This technique provides the physiologic benefit of temporary aortic occlusion without the burden of thoracotomy. While this technique was described in the Korean War, it has yet to be widely evaluated for trauma.26

The ESTARS curriculum was developed as a result of the military’s impetus to deliver effective resuscitation and hemorrhage control adjuncts to the commonly deployed general and trauma surgeon. With an objective to close the gap in understanding and the implementation of potentially lifesaving techniques among these surgeons most likely to be caring for patients in shock, an endovascular skills curriculum was developed. The objective of this study was to define a practice-based curriculum, combining didactics, simulation, and live

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Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course: Curriculum development, content validation, and program assessment
tissue components to teach a basic set of vascular and endovascular skills to trauma surgeons. An additional objective was to use qualitative and quantitative measures to evaluate the effectiveness of the curriculum in translating this skill set to a cohort of participants.

**PATIENTS AND METHODS**

The ESTARS course was developed to meet specific learning objectives (Table 1). Participant goals were to obtain competency in basic endovascular skills used in vascular injury management. After training, learners were expected to (1) demonstrate proficiency in diagnosis, exploration, and control of vascular trauma using endovascular techniques and REBOA; (2) deploy temporary vascular shunts; and (3) repair the vascular injury. The ESTARS course lasted for 2 days and consisted of preinstruction knowledge test, precourse instructional materials (50-page manual) sent to participants before the course, didactic lectures, endovascular simulation, exposure to the endovascular and REBOA instruments, multiple hands-on practice sessions using live swine models and a full assessment regimen (Table 2).

Two initial pilot courses were conducted, each with four learners (n = 8). The instruction methods and assessment instruments were evaluated after these improvements were made using feedback from learners, instructors, and third-party observers. Real-time evidence-based modification of the ESTARS curriculum occurred during these initial pilot courses. ESTARS course validation was then assessed in four additional courses using the revised methods (four learners each, n = 16); the results of these courses are reported in this study.

The course participants were fellowship-trained trauma/critical care surgeons selected from military and civilian centers. No participants had formal vascular or endovascular surgery training. Funding for this research study supported travel/lodging costs, and no course fee was required.

The instructional portion of the course was composed of didactics focused on vascular injury with an emphasis on vascular access and endovascular techniques. Didactics were coupled with hands-on sessions with endovascular supplies including wires, catheters, and sheaths. Summary tables were provided to standardize endovascular knowledge for participants, with separate tables prepared for wires, catheters, and sheaths. Other tables provided typical “must have” supplies including REBOA supplies as well as types of agents for angiography and common contrast injection volumes and rates (Tables 3 and 4).

Simulation was performed on a Mentice Vascular Intervention System Trainer (VIST, Evanston, IL). The VIST system is a high-fidelity, endovascular simulator with a haptic interface enabling hands-on procedural training for interventional radiology procedures, cardiac catheterization, neurointerventional procedures, and other endovascular procedures. Access to the VIST allowed participants the opportunity to become familiar with the endovascular supplies in specific simulated case scenarios. The VIST skills assessment included a standardized set of procedures for diagnostic angiography: thoracic and abdominal aortography, pelvic angiography, and up-and-over technique for selective internal iliac angiography.

Live animal models used for injury simulation were female Sus Scrofa Yorkshire swine (70–90 kg). The animal research protocol (FWH20100190A) was approved by the Institutional Animal Care and Use Committee at the 59th MDW Clinical Research Division Lackland Air Force Base, Texas. Each participant had the opportunity to gain ultrasound-guided percutaneous femoral artery access, with a micropuncture needle on the model followed by upsizing and exchanging of sheaths and the introduction and use of wires and catheters for hemorrhage control. A standardized traumatic injury (iliac artery penetrating injury) was used. Unique to this course are exposure to the use of temporary vascular shunts as well as introduction to basic endovascular techniques for the diagnosis and treatment of vascular trauma including REBOA.

All course sessions were taught by the same two-person team consisting of one board-certified vascular surgeon and one board-certified trauma surgeon. The instructors were knowledgeable in both open and endovascular components of vascular injury management to maintain fidelity of the technical endovascular aspects of the curriculum.

**Assessment**

Trainees in the ESTARS program were assessed on their domain knowledge before and immediately following training. Trainees’ procedural skills for vascular injury management using open and endovascular techniques were assessed using simulator and live models. Using assessment data from 24 trainees during the course of six training programs, we have developed an assessment standard that can certify that a trainee has demonstrated competence in endovascular and REBOA techniques for trauma and resuscitative surgery.

The knowledge test was delivered and scored electronically using a custom-built Web interface and consisted of 68 items of a mixture of 25 multiple-choice, 26 true/false, and 17 multiple true/false items. The purpose of the test was primarily formative; the same items were used for pretesting and posttesting, and the pretest served as a learning tool focusing learners on the content of importance. Mean scores were computed, treating each item as one point (multiple true/false...
responses were scaled with false-positive and false-negative responses treated as 0 point and all correct responses summing to a maximum of 1 point for the entire item).

Trainees performed three tasks on the VIST simulator with guidance from an instructor who also rated the performance, made notes, and completed a standardized task simulator checklist (SC). Simulator objective measures (SOMs) were obtained from the simulator software and were analyzed to assess learners’ normative performance standards for speed and accuracy. The Global Ratings Scale (GRS) was a seven-item form that rated learner’s overall performance quality at a high subjective level. Raters completed each item using a 5-point anchored scale.

**Statistical Analysis**

Assessment measures were tested for unidimensionality using Cronbach’s α. When appropriate, normality was tested using Shapiro-Wilk’s W, and means and SDs were examined for acceptably normally distributed measures. Pretest and posttest results were compared using repeated measures (paired t test). Measures were additionally tested for cohort effects by including pilot number as a categorical predictor variable.

<table>
<thead>
<tr>
<th>TABLE 2. ESTARS Course: Vascular and Endovascular Management of Trauma</th>
<th>Pretest Computer Examination—Completed Before Course</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td></td>
</tr>
<tr>
<td>8:00–8:30 am</td>
<td>Introduction to vascular injury management</td>
</tr>
<tr>
<td>8:30–8:45 am</td>
<td>Endovascular techniques for vascular trauma: what is the evidence?</td>
</tr>
<tr>
<td>8:45–9:00 am</td>
<td>Endovascular techniques in trauma—history</td>
</tr>
<tr>
<td>9:00–9:15 am</td>
<td>Break</td>
</tr>
<tr>
<td>9:15–9:35 am</td>
<td>Endovascular techniques—wires/hands-on session with wires</td>
</tr>
<tr>
<td>9:35–9:50 am</td>
<td>Endovascular techniques—sheaths/hands-on session with sheaths</td>
</tr>
<tr>
<td>9:50–10:10 am</td>
<td>Endovascular techniques—catheters and microcatheters/hands-on session</td>
</tr>
<tr>
<td>10:10–10:30 am</td>
<td>Endovascular techniques in trauma—pearls</td>
</tr>
<tr>
<td>10:30–10:45 am</td>
<td>Introduction to the VIST endovascular simulator</td>
</tr>
<tr>
<td>10:45–11:00 am</td>
<td>Break</td>
</tr>
<tr>
<td>Parallel Sessions</td>
<td></td>
</tr>
<tr>
<td>11:00–1:00 pm</td>
<td>VIST endovascular hands-on training (four students, 30 min per student)</td>
</tr>
<tr>
<td></td>
<td>• Retrograde transfemoral catheterization of abdominal aorta</td>
</tr>
<tr>
<td></td>
<td>• Arch aortogram, abdominal aortogram, pelvic angiogram</td>
</tr>
<tr>
<td></td>
<td>• Selective angiography contralateral iliac artery (up/over)</td>
</tr>
<tr>
<td>11:00–1:00 pm</td>
<td>Retrograde transfemoral access with micropuncture kit (with video)</td>
</tr>
<tr>
<td></td>
<td>Hands-on session: shunts, clamps, surgical instruments for vascular injury</td>
</tr>
<tr>
<td>1:00–1:30 pm</td>
<td>Introduction to porcine anatomy (slides)</td>
</tr>
<tr>
<td>1:30–2:00 pm</td>
<td>Lunch</td>
</tr>
<tr>
<td>2:00–3:00 pm</td>
<td>Live animal laboratory—bilateral femoral arterial access (1 student per side)</td>
</tr>
<tr>
<td>3:00–3:30 pm</td>
<td>Diagnostic aortography—arch aortogram, abdominal, pelvic angiogram</td>
</tr>
<tr>
<td>3:30–4:00 pm</td>
<td>Selective angiography of renal artery, iliac artery (up/over)</td>
</tr>
<tr>
<td>4:00–4:30 pm</td>
<td>Upsize right to 14 Fr Introducer, place aortic occlusion balloon catheter CODA</td>
</tr>
<tr>
<td>4:30–5:00 pm</td>
<td>Standard iliac arterial injury, inflate aortic balloon for hemorrhage control</td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td></td>
</tr>
<tr>
<td>8:00–8:30 am</td>
<td>Vascular injury management—cervical</td>
</tr>
<tr>
<td>8:30–9:00 am</td>
<td>Vascular injury management—abdominal</td>
</tr>
<tr>
<td>9:00–9:30 am</td>
<td>Break</td>
</tr>
<tr>
<td>9:30–10:00 am</td>
<td>Live animal laboratory—bilateral femoral arterial access (one student per side)</td>
</tr>
<tr>
<td>10:00–10:30 am</td>
<td>Selective angiogram of renal artery and bilateral coil embolization of branches (one side per student)</td>
</tr>
<tr>
<td>10:30–11:00 pm</td>
<td>Upsize right side to 14 Fr Introducer, place aortic occlusion catheter Berenstein</td>
</tr>
<tr>
<td>11:00–11:30 pm</td>
<td>Standard iliac arterial injury, inflate aortic balloon, place vascular shunt</td>
</tr>
<tr>
<td>(switch student roles from live animal laboratory Day 1)</td>
<td>Lunch</td>
</tr>
<tr>
<td>11:30–12:00 pm</td>
<td>Live injury animal laboratory practical examination (two students)</td>
</tr>
<tr>
<td>12:00–2:00 pm</td>
<td>VIST simulator practical examination (two students)</td>
</tr>
<tr>
<td>2:00–3:00 pm</td>
<td>Posttest computer examination (done while waiting for other examinations)</td>
</tr>
<tr>
<td>3:00 pm</td>
<td>Debrief and questions</td>
</tr>
</tbody>
</table>
Larger models were tested using univariate general linear models with random effects reduced using iterative restricted estimated maximum likelihood. Analyses were conducted using R version 2.11.1 (http://www.r-project.org/) / JMP Pro 10 (SAS Institute Inc., Cary, NC, USA) for Macintosh.

RESULTS

Learners
There were a total of 8 participants (trauma surgeons) in the two initial pilot courses. There were an additional 16 trauma surgeons in the course validation group. Trauma surgeons were from various institutions and with varying degrees of experience. Only 1 learner of the 16 did not receive a “pass” rating from the instructors. All other learners were deemed to have demonstrated proficiency in the target techniques and met the stated learning objectives. There was a performance checklist for the animal model task. We evaluated live animal model performance, and all participants completed the task, but summarizing the qualitative nature of the assessment is beyond the scope of this article.

Knowledge Test (Pretest and Posttest)
The knowledge test was acceptably unidimensional with a Cronbach’s $\alpha = 0.67$ indicating that the total score on the test is a good indicator of the construct being measured. Total scores across pretraining and postraining administrations ranged from 69% to 90% correct and were clearly bimodal (although not enough to statistically reject normality: Shapiro-Wilk $W = 0.95$, $p > 0.05$). Trainee's knowledge test performance increased after training: posttest scores (mean, 85%; SD, 4 percentage points) were higher than pretest scores (mean, 77%; SD, 4 percentage points) (Welch $t_{29.6} = 6.09$, $p < 0.0001$), and paired $t$ tests by learner were even stronger: the mean increase of 9 percentage points was significant with $t_{15} = 7.82$ ($p < 0.0001$, Fig. 1). Learner improvement did not seem to be caused by any particular pilot session either because of better participants or a better effect of learning in that particular session. A general linear model of total score by participant (as a random factor) and pilot, timepoint (pre- vs. post-) and a pilot-by-timepoint interaction found only an effect of timepoint $[F(1,12) = 13.92$, $p < .005]$ but neither pilot $[F(3,12) = 0.40$, nonsignificant] nor the interaction $[F(3,12) = 0.75$, nonsignificant]. These data are consistent with a training program that is reliably successful at improving trainee's knowledge as measured by the test.

GRS for Live Animal Laboratory
The scale demonstrated high internal consistency (Cronbach’s $\alpha = 0.89$), suggesting that the items all target a common level of quality. No trainees received a rating less than

| TABLE 3. Typical Aortogram Contrast Injection Volume and Rates |
|-------------------|-------------------|-------------------|-------------------|-------------------|
| Study             | Total Contrast Volume and Rate | Contrast Volume and Rate | Appropriate Catheter | Position and Optimal Screen View |
| Aortic arch       | 20–35 mL/s for a total volume of 40–70 mL with high frame rate (six frames per second) | “20 for 40”–20 mL/s for a total volume of 40 mL of full-strength contrast for arch | Usually through a 5 or 6 Fr flush catheter | Steep left anterior oblique (LAO) to see “best curve” for the transverse aortic arch |
| Abdominal aorta   | 15–20 mL/s for a total volume of 30–40 mL (4–6 frames per second) | “15 for 30”–15 mL/s for a total volume of 30 mL of full-strength contrast for abdominal aorta | Usually through a 5 or 4 Fr flush catheter | Catheter at the top of the screen positioned at T12 to L1 |
| Pelvic angiogram  | 8–12 mL/s for a total of 20–30 mL (2–6 frames per second) | “10 for 20”–10 mL/s for a total volume of 20 mL of full-strength contrast for pelvic angiogram | Usually through a 5 or 4 Fr flush catheter | Top of the pelvis to include femoral heads, anteroposterior projection, or right anterior oblique and LAO projections at approximately 30 degrees (contralateral oblique, i.e., right anterior oblique for left side) for complete. |

| TABLE 4. Typical “Must Have” Trauma Endovascular Diagnostic/Treatment Inventory |
|-------------------|-------------------|-------------------|-------------------|-------------------|
| Arterial Access   | Wires             | Sheaths           | Catheters         | REBOA             |
| Micropuncture kit 21 gauge needle 4 Fr or 5 Fr catheter 0.018-in guide wire | 0.035 in starter J 180-cm wire (Boston Scientific) | Pinnacle 4 Fr 10-cm sheath (Terumo) | 100-cm 5 Fr Pigtail Catheter (Cook) | CODA Balloon 14 Fr (32-mm diameter, 120-cm length) Cook Medical |
| Single-wall puncture needle, 19 gauge | 0.035-in Rosen 180-cm wire (Cook) | 0.035 in Floppy angled glidewire 180 cm (Terumo) | Pinnacle 5 Fr 10-cm sheath (Terumo) | 65-cm 5 Fr C2 Cobra Glide Catheter (Terumo) |
|                  |                   |                   | Pinnacle 6 Fr 10-cm sheath (Terumo) | 100-cm 5 Fr Angled Glide catheter (Terumo) |
|                  |                   |                   | Pinnacle Destination 6 Fr 45-cm sheath (Terumo) | 65-cm 5 Fr SOS Omni catheter (Angiodynamics) |
SOM and SC

The SOMs were composed of two reliable factors as follows: exploration efficiency (total time on the simulator, total time using fluoroscopy, total amount of contrast used, number of cines, total cine time, and time per cine) and cine efficiency (number of cines and average time per cine). Together, these factors explained 62% of the performance data. To compute these subscores directly, the number of cines was dropped owing to being somewhat intermediate between the factors and informationally redundant with the average time per cine. The subscores are then computed as the mean of total fluoroscopy time and total contrast time (an exploration efficiency score measured in seconds; lower is better) and time per cine (a cine efficiency score measured in seconds; lower is better).

Performer technical skill significantly improved for endovascular simulation as measured by VIST performance metrics. Participants spent a mean of 17:58 minutes on the entire task, which consisted of recording four cine loops. Procedure times ranged from 11 minutes 6 seconds to 27 minutes 57 seconds.

As is common with duration measures, the SOM subscores fit a log-normal distribution. The 90% point of the log-normal curves for exploration efficiency (mean [SD], 326.6 [115.9] seconds) and cine efficiency (mean [SD], 6.5 [2.8] seconds) were 506 seconds and 12 seconds, respectively: these points would likely make appropriate “red flag” cutoff points to indicate learners who overuse fluoroscopy and contrast (exploration efficiency) or cine time (cine efficiency). The SC did not show enough variance to be quantitatively interesting: no learner scored lower than 95% on the checklist, with 100% being the modal score.

Relationship Between Measures

The exploration efficiency subscore from the SOM correlated negatively with “respect for tissue” and “time and motion” ratings on the GRS. The cine efficiency subscore correlated negatively with “flow of operation and forward planning” ratings on the GRS. While neither of these correlations were statistically significant, they were in the predicted direction; a larger sample might find statistical significance.

Origins of ESTARS

The utility of endovascular maneuvers for select patterns of bleeding has been recognized for decades. However, until recently, these have been mostly used by radiologists or nontrauma surgeons for age-related disease processes. The unprecedented burden of injury during wars in Afghanistan and Iraq has spurred a reappraisal of the effectiveness of endovascular maneuvers. Foremost, the wars have laid bare the imperative to more effectively manage bleeding, specifically shock from NCTH. Also fueling this reappraisal has been the deployment of vascular and endovascular surgeons into a sustained period combat casualty care. In this setting, these surgeons have worked next to general and trauma surgeons unencumbered by practice, referral, and financial factors. In this context, traditional “silos” separating trauma surgeons from endovascular surgeons have been broken down. A final transformative factor has been the revolution in endovascular technologies. Devices are now lower profile, less complicated, and more amenable to use by skilled emergency surgeons. In this milieu, the military’s Combat Casualty Care Research Program in partnership with the University of Michigan developed the ESTARS curriculum to spur translation of potentially lifesaving skills to providers most likely to provide acute care for patients in hemorrhagic shock. Importantly, some trauma surgeons who completed this course were successful in appropriate clinical application.27

Measurement of Proficiency and Knowledge

In this curriculum, proficiency seemed best assessed by both objective (i.e., timing of simulator performance) and

Figure 1. Course participant knowledge assessed by pretest and posttest examination scores.
subjective (i.e., global assessment of performance in live animal laboratory by trainers) measures. As predicted by the learning objectives, exploration efficiency and cine efficiency were dissociable from the performance measures, suggesting that exploration and injury control are independent skills. This insight could be used to focus the training more clearly on each of these skills, perhaps improving its effectiveness. The knowledge test seemed most useful as a formative exercise, with the pretest helping learners approach the didactic sessions with an understanding of the primary learning objectives. The increase in performance from pretest to posttest is to be expected since the content of the test and the didactic sessions were designed in parallel.

**Combined Live Tissue and Simulator Training Models**

The ESTARS course and the current study aligned with the premise that a combination of live animal and simulator training would be best to acquire and maintain endovascular skills. Courses such as the Advanced Surgical Skills for Exposure in Trauma (ASSET),\(^\text{28}\) Trauma Exposure Course (TEC),\(^\text{29}\) or Advanced Trauma Operative Management (ATOM)\(^\text{30}\) are based on this premise and have provided surgeons of various specialties a platform to perform procedures competently. Although based on a similar foundation, ESTARS is unique as it is the first to emphasize the use of endovascular methods for resuscitation and hemorrhage control in a model of hemorrhage and shock.

**Emerging “Hands-on” Training Experiences**

As an indication of the paradigm shift to translate endovascular skills to trauma surgeons and emergency providers, other “hands-on” experiences are being developed. The Basic Endovascular Skills for Trauma program is being implemented by investigators at The R. Adams Cowley Shock Trauma Center in Baltimore. This innovative and concise 2-hour curriculum consists of didactics and hands-on experience with sheaths, wires, and balloons using an endovascular simulator. This curriculum is portable, easily repeated, and focused on familiarizing participants with skills to perform REBOA. As this course matures, it is likely to incorporate novel models of pressurized cadaveric vasculature including the aorta and iliofemoral segments. Similar mini courses or focused experiences using simulators and cadavers are being implemented in trauma centers in Japan by Matsumoto and colleagues. DIRECT is a 1-day course consisting of didactic sessions and hands-on experience with simulators, embolization materials, and computer/computed tomography-assisted software. Participants in the DIRECT course include emergency medicine physicians, interventional radiologists, and trauma surgeons. The development of other experiences and courses underscore the common desire to translate a basic endovascular skill set to providers who are best positioned to use them in the acute setting. However, it is important to note that ESTARS has taken steps to control for factors that may confound the translation of skills and developed a standardized and validated curriculum. In this context, ESTARS may serve as one standard by which to compare distinct and or complementary courses as they are developed.

**Limitations**

Inclusion of only trauma surgeons as participants in this study may have introduced a bias impacting the reported efficacy of this curriculum. Specifically, this cohort of surgeons entered the course with baseline training and experience, which may have elevated the precourse examination results compared with what would have been found with less experienced participants. In this context, this study may have misrepresented the full utility of this curriculum to translate endovascular skills to nontrauma surgeons or emergency providers. We did not examine the relationship between course performance and years of experience because these data were not collected in this study. An additional limitation pertains to this study failing to address actual clinical use and retention of the skills taught by the course. It is not yet possible to determine how frequently these skills might be used by the average trauma surgeon, and it may differ greatly in different institutions. Additional studies will be required to assess this. Despite these limitations, the ESTARS provides a foundation from which to teach providers and to eventually assess longer-term use and retention of the skill set.

**CONCLUSION**

The ESTARS course is a stepwise and hierarchical training curriculum effective at translating basic endovascular skills to trauma surgeons. The curriculum is the first to optimize endovascular training for surgeons using both an endovascular simulator and a standardized, animal model of hemorrhagic shock. The ESTARS course accomplished improvements in performance metrics pertaining to endovascular procedures used for resuscitation and hemorrhage control and should serve as a model for competency-based structured training in endovascular trauma skills.

**AUTHORSHIP**

J.L.E., L.M.N., R.B.S., J.R.S., and T.E.R. contributed to the design of this study. All authors participated in the data collection, analysis, and writing. C.Y.V., J.L.E., L.M.N., R.B.S., and T.E.R. critically revised the final manuscript.

**DISCLOSURE**

This study was funded by the Department of Defense Award F029024-Vascular Injury Advanced Training.

**REFERENCES**


**DISCUSSION**

**Dr. Steven R. Shackford** (San Diego, California): I want to thank Dr. Villamaria for sending me this manuscript well in advance of the meeting. Dr. Villamaria, I want to thank you for your service.

I just want to say at the outset that I am a card-carrying vascular surgeon and I received my endovascular training at a two-day course, but all of my endoluminal cases are done with my colleagues in interventional radiology. Here are my questions:

First, how were the initial 16 trauma surgeon students selected to take this course? Was it random selection by the authors or did the students self-select? Did they have to pay for the two-day course? These questions relate to their potential motivation to do well.

Second, what was the experience level of the trauma surgeons who took the course? In the manuscript you mentioned in the discussion that they had “minimal or no previous exposure to these techniques.” What, exactly, does “minimal” exposure mean? This has to do with their ultimate performance.

Third, we would all agree that hemorrhagic shock is a problem, but preventable death due to hemorrhagic shock is becoming less and less of a problem in the civilian sector with the development of systems and with the lessons that we have learned from the military with respect to damage control resuscitation and damage control surgery.

Fourth, you cite Dr. Rasmussen’s paper describing people dying in the field who don’t have access to this type of skill. In point of fact, the problem of non-compressible hemorrhage in the military has been somewhat reduced with improvements in body armor, now with groin flaps. In fact, Dr. Rasmussen and his colleagues in their most recent article discussing the epidemiology of non-compressible torso hemorrhage describe a total of only 331 casualties reaching medical help of over 15,000 who actually had non-compressible torso injury producing shock in over eight years—an incidence of only about 2% or about one per week and only 41 had major vascular injury or
5 per year. The others had ruptured livers, ruptured spleens and so forth, about which REBOA may or may not be helpful. Is it worth training surgeons to use endovascular skills when they are so infrequently needed and when resuscitative thoracotomy, in your own experimental study, may be equally effective in occluding the aorta and improving cardiac and brain blood flow?

Fifth, utilizing many of the skills outlined in the course, such as selective pelvic angiography, will require imaging and a catheter inventory, which are usually associated with having an IR team who do these procedures several times daily at a busy center. Why would we compete with those skills? Why not just leave it at placement of an aortic balloon in the rare cases that need them?

Finally, regarding the imaging inventory, Dr. Rasmussen in his article described the implementation of endovascular capabilities in war time, states: “The majority of 30 patients in whom angiography led to open surgical repair were best served with this operative course because of the injury pattern and surgeon discretion. There were a small number of patients during this study period in whom an endovascular option may have been preferable but was not attempted because of lack of inventory or imaging capability.”

Do the authors perceive that these endovascular skills will be used in the resuscitation bay and will the inventory and imaging capability be satisfactory?

Dr. Matthew J. Wall (Houston, Texas): I enjoyed your presentation and this is important. Our acute care surgeons are doing endovascular interventions in our operating rooms with a mobile C-ARM, a mobile bed and a single cart with a limited inventory.

Questions. How much of your course is on the failure modes of the technique? Like open surgery and flying airplanes, when everything goes well, it’s easy and the difference between success and failure is dealing with the problems and complications of the technique.

Second, when the students finish the course do you recommend a preceptorship or a partnership with a vascular surgeon when they get home to learn to deal with these pitfalls?

These techniques are important. As trauma surgeons, we thought we cut for a living but what we really do is stop bleeding.

Dr. Randall Friese (Tucson, Arizona): What you presented here today is certainly designed for, as you brought up, the acutely hemorrhaging patient from intraabdominal sources.

But once we get used to these skills this seems to me the natural progression of this will be moving towards actual angioembolization in pelvic fractures and things like that.

I think these endovascular skills and using this as a stepping stone to achieve those is very, very important. And I hope to hear that you agree.

Dr. Carole Y. Villamaria (San Antonio, Texas): Thank you for those questions. I will go ahead and address Dr. Shackford’s question.

As far as selection and participants, some were random and some actually contacted us with a desire to come. There was no payment for this course. This course was solely funded by a DoD grant through the Air Force.

As far as experience level of the participants, they were variable. However, they were all trauma surgeons. It varied from junior faculty to senior faculty trauma surgeons.

We actually had two fellows. One of them was an acute care surgery fellow and one was a vascular fellow who had actually already completed a trauma fellowship.

So is it worth training surgeons to use these endovascular skills? So a recent CRASH 2 trial showed that 5 percent of patients had bleeding as a cause of death which were potentially preventable.

And with this, we see that this is an area where we can potentially save lives. So, yes, we would like to train trauma surgeons these endovascular skills.

And as far are REBOA versus a conventional resuscitative thoracotomy, REBOA, like resuscitative thoracotomy, does increase central perfusion pressures; however, in a recent animal study that our group performed we show that there is less physiologic disturbance than with a thoracotomy in that you have decreased acidosis, decreased serum lactate, decreased PC02 and decreased fluid and pressor requirements.

Additionally, REBOA is less invasive compared to resuscitative thoracotomy. And also in resuscitative thoracotomy there is that challenge posed by clamp on and off as opposed to REBOA you just simply inflate or deflate the balloon.

Also, just as a side note, multiple course participants have actually recently published their experience with REBOA after having gone through this course, confirming that the ability to learn this technique can be done very quickly.

As far as competing with IR and vascular surgeons for these skills, the most important endovascular skill for the acute care surgeon is to learn REBOA.

At institutions where IR is not readily available, the acute care surgeon may want to consider expanding their endovascular skills. However, we believe that we should partner with vascular and IR in performing procedures and not compete with them.

And, lastly, Dr. Shackford’s question was do we need to and implement the skills that they learned from this course. So the inventory for REBOA is actually very minimal.

You just need arterial access, which everyone has in their trauma bay. You need a wire, sheaths and a balloon. And this could actually be packed in a little kit and so very, very minimal inventory.

And as far as imaging capability, all you would need - you could use a C-ARM. However, if you don’t have that you can just use digital radiography and that is adequate. Okay?

And as far as Dr. Wall’s questions, how much is the course focused on failure mode? And so like what I had explained earlier, the most basic part of endovascular skills is actually getting arterial access.

We noticed that some of our students were not able to get ultrasound-guided access initially and after actually three attempts we had the students go ahead and do a cut down. And so that was part of our failure mode.

In terms of partnership with vascular surgeon once done, we go ahead and basically encourage our students to get with their IR department, get with your vascular department and try to do this at your program.

However, as I had mentioned earlier, though, a lot of our students who finish this program go to their home institution and implement the skills that they learned from this course.

And as far as Dr. Friese, yes, I agree with you, sir. This is something that we need to do.