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14. ABSTRACT: Reduced clinical opportunities for open surgical control of hemorrhage and lack of surgeon technical skills performance metrics are large capability gaps. Validation of Advanced Surgical Skills Exposure in Trauma (ASSET) Course training was undertaken. We enrolled 106 surgeons to develop, test, and validate surgeon performance metrics(individual procedure score = IPS) for non-technical and technical skills acquired in ASSET, using both cadavers and realistic models, by testing surgeons before and after ASSET training and up to 4 years later. Improvement occurred across all metrics with ASSET procedural skills training. Benefits from training were: correct incision landmarks, procedural steps, including less time to vascular control, error reduction and increased error recognition. Fasciotomy was inadequately performed by the majority of surgeons. Generally, interval experience NOT time since training was correlated with reduced performance and more errors. Regression lines for technical performance vs up to 4 years since ASSET training in 85 surgeons show no skill degradation vs threshold of time. Physical model-based assessments could not identify skill degradation, as the same surgeons have 1/3rd less errors and take ½ procedural time in the models than in the cadaver. Recommendations:1) IPS scoring should be used during ASSET course training to provide performance feedback for formative evaluation and to determine readiness for surgeon deployment.2)Video recorded formative performance evaluations can replace co-located evaluations; 3) technical skills refreshers should be targeted to landmarks, procedural steps, anatomy; 4) database de-identification and distribution;5) fielding of data collection tool.

15. SUBJECT TERMS
Performance evaluation, ASSET, vascular trauma, surgical training, medical education

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EXECUTIVE SUMMARY

Civilian trauma surgical experience has decreased for four reasons: 1) the Accreditation Council of General Medical Education (ACGME) committee 2003 ruling reduced training hours from 30,000 to 19,200; 2) Endovascular balloon occlusion and embolization has replaced many open surgeries for emergency control of hemorrhage; 3) Fewer motor vehicle occupant injuries and gunshot wounds nationwide; 4) New blood-use protocols (1:1:1 red cell: plasma: platelet) and tranexamic acid reduced the need for open surgical interventions to control bleeding.

PROBLEM: Reduced clinical opportunities for open surgical control of hemorrhage and lack of surgeon technical skills performance metrics opened a large capability gap transcending U.S. military and civilian need. Furthermore, the absence of validated competency metrics impedes assessment, making it unclear whether these technical skills improve with training, if these skills degrade with time since training, or if there is a need for refreshing these skills.

Approach: The study analyses of were anchored around the ASSET course training, a one day cadaver-based course covering 59 different trauma-related procedures. Since there are no available metrics to quantify training benefits of the ASSET course, we developed, tested, and validated surgeon performance metrics for non-technical and technical skills acquired in the ASSET course. We used both unpreserved cadavers and realistic physical models, testing surgeons before and after ASSET training and up to 4 years later .

Five questions were addressed by this study: Do core trauma surgical procedural skills show improvement with training? Which components among these skills benefit most from training? Does training reduce the occurrence of errors? Can we identify a time since training when skills may need to be refreshed? Can a hyper-realistic physical model replace the unpreserved cadavers used in this study?

We enrolled 106 surgeons recruited from 13 different residency training programs, from surgical practices and Trauma Centers in the North-East US and Canada. Twenty surgeons participated in development and initial validation testing of the performance metrics for axillary (AA) , brachial (BA) femoral artery (FA) exposures on unpreserved cadavers. We next assessed performance of 86 additional surgeons in trauma core procedural skill using the metrics we developed including a 100-140 item checklist, the

Individual Procedure Score (IPS), Global Rating Scores (GRS) and errors: critical technical errors (CTE) , management errors (CME) and morbidity errors (ME).

The surgeon cohorts studied were:

Group 1 = 10 expert trauma surgeons (mean 18 years in practice) and 10 untrained surgical residents performed the four trauma core competency procedures to develop and initially test the performance metrics. Analysis of Group 1 surgeon performance informed the measurement instruments (IPS, GRS, errors).

Group 2 = 40 Resident/Fellows from 13 Surgical Training Programs in MD , DE, PA, DC, VA were evaluated before and within 4 weeks of taking the ASSET Course. 38 out of 40 returned to be re-evaluated between 12- 18 months (mean 1.2 years) later. This met *a priori* sample size calculations indicating that >90% retention of Group 2 enrolled surgeons would be required to address skill degradation with time since training.

Group 3 = 35 surgeons, from a variety of surgical specialties who took the ASSET Course mean 2.5 years earlier were evaluated .

Group 4 = 10 Expert practicing (mean 14 years and all different to Group 1 experts) Attending Trauma Surgeons from 6 different Level 1 US trauma centers.

General Methods: We audio-video recorded and evaluated Groups 2-4 with two trained co-located evaluators while they performed the 4 American College of Surgeons core competency trauma procedures (AA,BA,FA, FAS) on unpreserved cadavers and realistic models. Evaluations included the components of Non-Technical and Technical skills described by IPS checklists developed for each procedure, the GRS, error assessments and procedure time, all embedded in a standardized script. For data collection, we used a custom Mobile application (App) running on an Android Tablet with a built in timer. The App ensured, by a software prompt, 100% data entry of the 100- 140 different evaluation points. We identified 7 features of performance that are amenable to training interventions. These were: 1) Anatomy (Landmarks; Skin Incision; Procedural Steps; Correct Vessel identification), 2) Knowledge of procedure, 3) Management/Indications, 4) Technical Skills, 5) Errors (Critical technical; Critical Management; Morbidity), 6) Error recovery, 7) Time to complete procedure. We defined a Trauma Readiness Index (TRI) as the sum of all IPS scores for all vascular procedures. Linear mixed models (including cadaver body characteristics and anatomic variants; gender of surgeon; evaluator status: anatomist v physician; surgeons interval experience), multivariate (MANOVA) and univariate analyses were used to compare mean differences between Groups2-4.

FINDINGS:

Results: Question 1: *Do core trauma surgical skills show improvement with training?*

Improvement across all metrics was significant (p <0.001) with procedural skills training. Among the component parts of the IPS in Group 2 surgeons, within 4 weeks after ASSET training: procedural steps improved 57%, Anatomic skills increased 43%, Trauma Readiness Index increased 25% and time to proximal control by passage of a double vessel loop around the artery decreased by an average of 2.5 minutes. ASSET training showed benefit regardless of surgical resident year of training, but was influenced by prior experience. No change occurred in trauma patient management (not specifically taught in the ASSET course). GRS, errors (CTE, CME, ME) and error recovery were all significantly improved with ASSET training.

Errors: Large variation in errors occurred both before and after ASSET training. At an IPS cut-off of 60%, CTE and CME increased exponentially. Overall, CTE were significantly reduced with training.

Performance: IPS scores showed great variability (range = < 50% to > 80%) among 40 Group 2 surgeons after ASSET training, 5 of whom failed to show any performance benefit from training..

FAS performance: IPS was variable and had the most technical errors (failure to completely decompress all four compartments) by all enrolled surgeons. 50% of Group 2 surgeons failed to adequately decompress a single FAS compartment before and 50% successfully decompressed all 4 FAS compartments after ASSET training.

Results: Question 2: *Which components among these skills most benefit from training?*

Most beneficial training performance improvements were: correct incision landmarks, procedural steps reduced time for vascular control, error reduction and increased error recognition. We retained 100% (40/40) Group 2 surgeons for follow-up evaluation within 4 weeks of training. Group 2 had significantly higher overall IPS, fewer errors and better error recovery for the 3 vascular control procedures, immediately after taking the ASSET course than pre-training. After ASSET training, as judged by IPS components, twenty one of the 40 Group 2 surgeons came within one nearest neighbor classifier (about one standard deviation) of Group 4 expert performance in identification of the correct incision landmarks and procedural steps for the vascular control procedures. Seven of the Group 2 surgeons after taking the ASSET course did not improve correct incision landmarks and procedural steps for vascular control sufficiently to leave the one nearest neighbor classifier cohort of pre-training performance

When performance was reviewed without bias (blind review of randomly ordered before and after training video clips by 5 trained evaluators) there was near-perfect rater agreement between video and co-located evaluators for anatomy, technical skills and readiness to perform the procedure independently, recognition of errors and overall rater evaluations for all four procedures.

Training interventions: tracking IPS component scores and errors predicted need for refresher training. On the basis of plotting IPS component scores against Pre-training score, the training benefit is greater for correct landmarks than procedural steps.

Performance on one core procedure predicting performance on another: the fit on a contour plot of IPS on a single vascular control procedure, can predict (R=0.6) the IPS performance metric on the other two.

Results: Question 3*:-* *Does training reduce the occurrence of error?*

Critical Technical Errors were reduced and error recovery increased with training. Only 13/38 (34%) of Group 2 surgeons performed the vascular control procedures free of CTE (vessel loop around incorrect structure or fail to control <20 minutes). Five of these same surgeons (12.5%) had a disproportionate incidence of consistent repeated error despite training. For the remaining surgeons there was a significant decrease in the incidence of error from 60% to about 20% in the same surgeons with ASSET training. There was also an increase in self-recognition and correction of technical errors related to incorrect identification of anatomic structure and failure to complete vascular control within 20 minutes. When CTE and CME were plotted against years since ASSET training, only 41% (35/85) Group 3 surgeons, 34% (13/38) Group 2 and 50% (5/10) Group 4 experts performed the vascular control procedures free of either CTE or CME. IPS scores, but not GRS, were correlated with technical errors in preventing hemorrhagic exsanguination. CTE reduction in Group 2 surgeons persisted in follow-up evaluation (mean of 1.2 years later), and was accompanied by increased error recognition and recovery.

Results: Question 4: *Can we identify a time since training when skills may need to be refreshed?*

MANOVA generally showed interval experience NOT time since training was correlated with lower IPS and more errors in Group 3 surgeons. The 35 Group 3 surgeons (mean 2.5 years after training) showed a large variety of interval experience since taking the ASSET course (orthopedic, pediatric, plastic, general surgeons, critical and acute care surgeons etc). CTE and CME were significantly greater and error recovery less than either the Group 2 surgeons immediately and mean 1.2 years after training. Group 3 made more "errors" (Group 2 = 2.4±0.66, Group 3 = 4.1±1.01, Group 4 = 2.2±0.7 errors/surgeon, $p<0.05$), indicating that fewer procedures were correctly completed. Errors increased and error recovery decreased in Group 3 surgeons with longer time since ASSET training. Group 4 expert surgeons were better performers overall and had least errors among Groups. Group 2 surgeons had significantly higher overall IPS, fewer errors and greater error recovery after taking the ASSET course than Group 3 surgeons.

Years since ASSET Training: Regression lines for the TRI plotted against years since ASSET training in all 85 surgeons show no fall off in performance and no threshold of time since ASSET Training after which skill degradation was detected by the IPS or GRS metrics. Analysis with a linear mixed model accounting for cadaver habitus, interval experience and evaluator reliability reveals significantly more critical errors and decreased error recognition and recovery in the Group 3 surgeons peaking mean 2.5 year after ASSET Training. Four GRS and one overall evaluator rating did not reflect the skill degradation or CTE detected by IPS.

Fasciotomy Results Different from Vascular Procedures: Training did increase the number of LE Fasciotomy compartments decompressed. However, only 20/40 Group 2 surgeons succeeded in decompressing all 4 compartments immediately after training. Group 3 surgeons decompressed significantly fewer FAS compartments than Group 4 or Group 2 surgeons. The majority of 85 surgeons evaluated after training, including 4/10 experts, failed to decompress at least one FAS compartment. FAS was the most error-prone procedure because of incomplete decompression of the anterior or deep posterior compartments. FAS is a sentinel trauma procedure, as it both demonstrates the benefits of ASSET training and it detects the occurrence of skill degradation.

Results: Question 5: *Can hyper-realistic physical models of each procedure replace the unpreserved cadavers used in this study?*

The physical model tested cannot replace cadaver for competency evaluations because on the model IPS scores are higher, there are 1/3rd less errors and time to complete procedures is half that of the same surgeons performing the same procedures on the cadaver. For every procedure and for every group of surgeons a shorter time is required to find the artery or decompress the compartments because models fail to capture the complexity and variability of the human cadaver. The model facilitates discrimination, so that anatomical structures are much easier to recognize. The model-based assessment could not identify skill degradation, as the same surgeons have fewer errors in the models than in the cadaver.

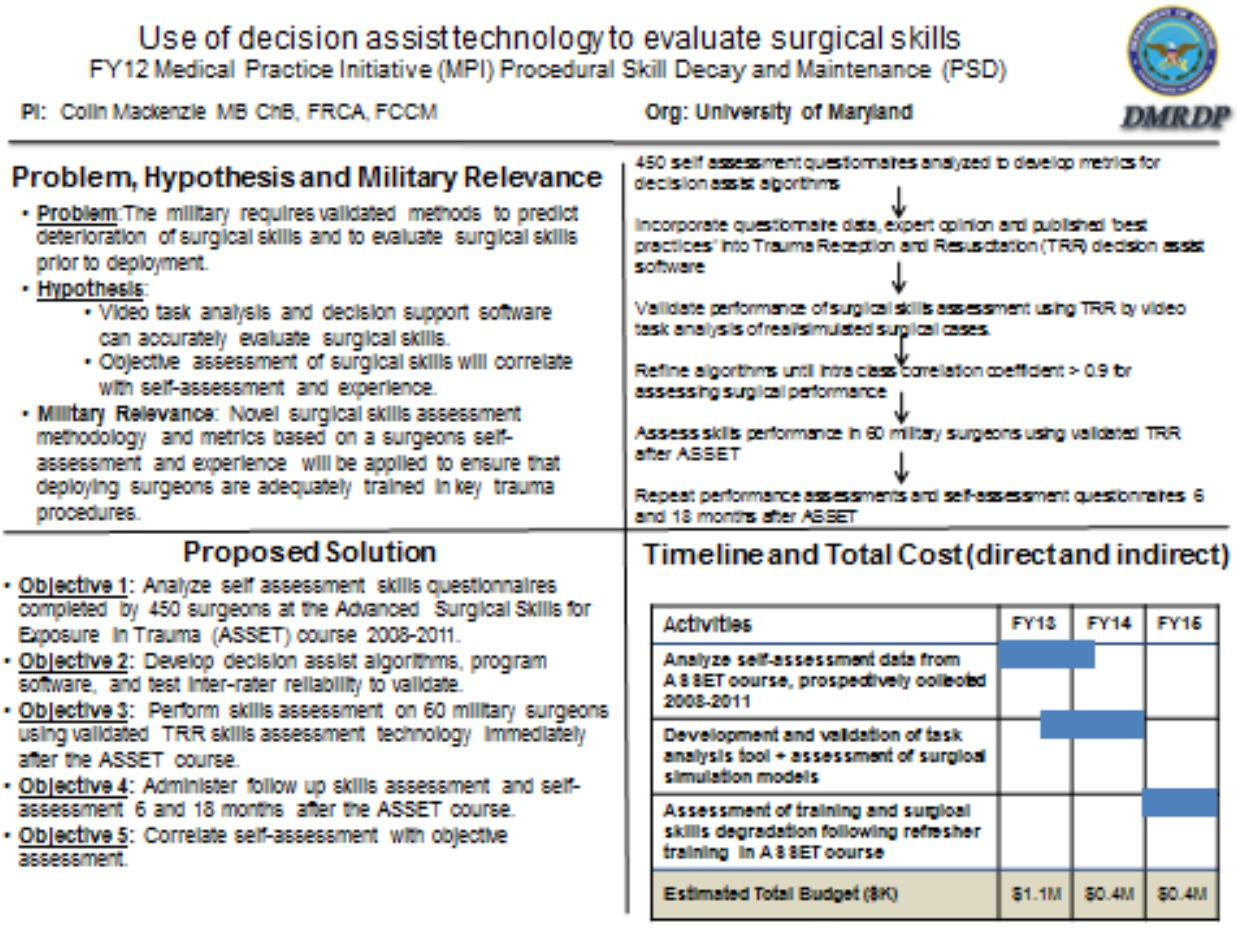
RECOMMENDATIONS:

1) **IPS scoring should be used during ASSET course training for AA, BA, FA, and FAS to provide performance feedback and formative evaluations to determine readiness for surgeon deployment.**
2) **Remote evaluation of video recorded performance of surgeons operating on physical models should be tested as a surrogate alternative to cadaver use as a mobile training platform not exclusively for formative assessment.**

3) **Targeted skills refresher should include correct incision landmarks, procedural steps and structural anatomy for AA, BA , FA and FAS procedures.**
4) **The Mobile App should be fielded to centers holding ASSET courses**
5) **The database and video recordings associated with this study should be de-identified and made available for other users and training uses**

DELIVERABLES:

1) **Software to evaluate IPS for 3 vascular procedures and lower extremity fasciotomy.**
2) **A Mobile Android App for data collection**
3) **Physical Models evaluated for AA, BA, FA and FAS procedures**
4) **A Mobile Platform for evaluation and analysis of vascular control and fasciotomy procedures**



Body

Statement of Work

Phase I – Preliminary investigations, TRR audit modification, and validation of Advanced Surgical Skills for Exposure in Trauma (ASSET) Performance testing methods

Task 1a) IRB submission; Kick–off meeting of clinical and research staff, months 0-2. Due Days from Award (DFA): 60 days; Acceptance Criteria (AC): Meeting minutes and presentation materials, IRB approval; Percentage of Cost (POC): 1%

- Kick-off Meeting February 14th 2013 Agenda and Minutes Recorded (Appendix 44). IRB Protocol submitted to UM IRB (13 Dec 2012) and approved (8 Jan 2013).

Task 1b) Acquisition of hardware, Trauma Reception and Resuscitation (TRR) software and equipment; months 0-2. DFA: 60 days; AC: Equipment etc. acquired; POC: 5%

- See attached Invoices for Acquisition of surgical hardware for surgeons to perform procedures during evaluations (Appendix 45). See Attached TRR Acquisition for software and equipment (Appendix 46).

Task 1c) Analyze data from self-assessments provided by >600 past ASSET trainees, months 0-3; DFA: 90 days; AC: Statistical analysis of dataset; POC: 3%.

- We compared self-reported confidence of participants (n=523) with surgical tasks (n=47) at baseline and directly after ASSET training to examine the effect of training. All surgeons recorded improved confidence in all five anatomic body regions after ASSET training ($p<0.0001$). Following the course, surgeons reported a high confidence level in 78% of the 47 procedures. Residents/fellows achieved the greatest improvement in confidence levels. This study highlights the broad positive impact of the ASSET course on trauma surgical skills. An objective performance measure of surgical skills would be valuable for future course development (Appendix 47). See important supporting data (Figures 1-3; Tables 1-3).

Task 1d) Audio-visual (AV) recording of "thinking out loud," and responses to questions on technical and non-technical skills and fidelity of physical models vs cadaver during ASSET procedures by 10 expert surgeons and 10 surgeons without prior ASSET training, months 3-7. DFA: 210 days; AC: Completion AV recording and AV data collection synthesis; POC: 10%

- See attached Invoice for Acquisition of physical models for use during Expert and Novice performance evaluations (Appendix 48).
- We developed an index (Trauma Readiness Index) to quantify surgical performance and competence derived from knowledge, procedural, and technical skills components.
- To establish a "gold standard" range for expert performance suitable for comparisons with surgeons in later phases, it was necessary to assess 10 additional expert surgeons using the same skills assessment tool. Data from the 10 expert surgeons has been

compared with Phase 2 and Phase 3 performance assessment data. These data provide a benchmark to compare the magnitude of skills performance improvement after training and degradation in the years following training (Appendix 2, Figure 1). Expert and Novice performance evaluations were completed in October 2013.

- Results from assessing the performance of Novice surgeons with the Trauma Readiness Index metric were presented at MHSRS (August 2014). We found that this metric discriminated expert from novice performance in both technical and non-technical skills with excellent interrater reliability (Appendix 2).
- The importance of assessing Novice performance utilizing the technical and non-technical skills identified by the expert surgeons was also presented as an abstract at Association of Military Surgeons of US (AMSUS) (Society for Federated Health Professionals) in Dec 2014. We found that expert surgeon technical skill metrics provide a reliable technical skill assessment for less experienced surgeons. It distinguished Expert from Novice surgeons with excellent inter-rater reliability (Appendix 1).

<u>Task 1e)</u> *Revise all conventional assessment instruments in collaboration with the participants.*

- This aspect of Task 1e) was accomplished by April 2013. During the "thinking out loud" by the 10 experts, several key points became apparent that were then noted and included in possible discriminators. A consensus meeting of the experts occurred. Draft evaluation criteria were developed and then tested on 10 novice (2nd to fourth year surgical residents). With minor iterations occurring in the content and format of the evaluations as each successive novice candidate was evaluated.

<u>Task 1e cont.)</u> *Establish key steps and landmark evaluation points for the ASSET procedures from AV records, months 6-7. DFA: 210 days; AC: Revised assessments, ASSET steps and landmarks defined; POC: 6%*

- An Evaluator Training Handbook and training videos were developed before inter-rater reliability testing (Appendix 42; Handbook and Videos).

- A Script was finalized for each of the four procedures. The Knowledge Content and Technical Skills assessments were finalized so that one script covered all four procedures with breaks between procedures. The breaks allow the sequence of the procedures to be changed so that 'carry-over' between before and after ASSET training was minimized. In addition this break was necessary so that one candidate would not hear the answers given or see the procedure being performed by another nearby candidate as might occur if they were doing the same procedures, at the same time alongside each other. We also have included a consent form for the participants to sign (Appendices 41, 43, and 49; Script, Script Slides, Video Evaluation Sheet, and Consent Form).

<u>Task 1f)</u> *Modify TRR software to include these points, and conduct inter-rater reliability by multiple expert reviewers of ideal and non-ideal ASSET procedure performance, months 5-9. DFA: 270 days; AC: TRR Software modified and TRR Performance Audit tool validated; POC: 18%*

- Major modifications of TRR software were accomplished by November 2013, minor re-modifications were completed by April 2014. The technology was implemented for

evaluations 21 April 2014. A training module was developed for evaluators (Appendix 4).

- Inter-Rater reliability testing using 5 expert reviewers of 80 video records and the evaluations described above (under Task 1e) is summarized below in an Abstract Submitted to the American College of Surgeons for consideration to be presented at their Annual Scientific Meeting. For this Abstract each of 5 experts reviewed video recordings of all the four procedures (Axillary, Brachial, Femoral Artery Exposure and Lower Extremity Fasciotomy) for all 10 experts and all 10 novices). Interrater reliability was assessed using intra-class correlation coefficient (ICC). The ICC can discriminate expert from novice performance for the four surgical procedures evaluated through the use of discriminating performance characteristics. These characteristics may be useful for objective surgical skill assessment (Appendix 50). An example of an Expert performance of an Axillary Artery exposure can be found in the attached digital file (Appendix 51).
- The mobile platform was described and presented as a poster at MHSRS in August 2014. This poster describes the head camera, pan/tilt/zoom camera, audio capture and Android software used for non-intrusive skills assessment with the ability for remote evaluation (Appendix 5).

Phase II: Using the revised and validated ASSET Testing tools developed in Phase I (as described in Task 1e), examine the efficacy of the ASSET training curriculum on acquisition and retention of ASSET skills, including the relative efficacy of unpreserved cadaver versus selected non-live-tissue models in skills training.

- The relative efficacy of unpreserved cadaver versus selected non-live-tissue models in skills training was assessed using the attached questionnaire given to participating surgeons (Appendix 6). In addition, participants were issued another questionnaire used to compare the unpreserved cadaver to a live patient (Appendix 7). We found that participants considered cadavers to be more realistic and/or useful, but the models still received favorable ratings. These data we presented at the MHSRS 2015 (Appendix 29).
- Each surgeon was asked to rate their confidence for performing vascular surgery in the upper and lower extremities before and after each evaluation using the attached questionnaire (Appendix 8).
  Findings indicated that the confidence of senior residents in their ability to perform the 3 vascular procedures and lower extremity fasciotomy was significantly higher than their skills performance evaluations. These data were compiled and presented at ASC (Academic Surgical Congress) in February 2015 and a manuscript submitted in January 2015 (Appendix 9).

<u>Task 2a)</u> Train forty (in cohorts of 10) ASSET-untrained surgeons: test base-line skills, provide ASSET course, do post-test, months 10-17. DFA 510 days; AC: training and Phase 1 assessments complete; POC: 15%

- We completed enrollment, baseline before-training skills assessment, ASSET course training, and post-training assessments for 39 of the proposed 40 ASSET naïve surgical residents Sept 3 2014 (Figure 2). The final 40th resident will complete the post-training

assessment by March 16 2015. A last minute enrollment drop-out necessitated this substitution and delay in completion.

- To date, five additional abstracts and two manuscripts have been completed detailing the assessment of surgical skills for before and after training co-located evaluations and remote video review. This includes a manuscript was accepted for publication in the Journal of Trauma detailing the performance evaluations before and after training (Appendices 9 - 15).

Task 2b) Mid-term review meeting with investigators and consultants - 2 days in month 18. DFA: 540 days; AC: meeting minutes and presentation materials as appropriate; POC: 1%

- Midterm In Progress Review (IPR) was conducted August 2014 in Orlando Florida. The presentation slides and subject matter expert reviews are attached (Appendices 16 a & b).

Task 2c) Forty surgeons from 2a) perform 4 ASSET procedures in random sequence on physical model and cadaver, months 11-18. DFA: 540 days; AC: assessments for physical model v cadaver; POC: 10%

- See response to Task 2a) above

Task 2d) Revaluate 2b/2c surgeons at either 12 (n=20) or18 months (n=20) on physical model & cadaver. DFA: 990days; AC: TRR Performance Audit records and other performance assessments; POC: 15%

- We were able to schedule and complete 38 of the 40 follow-up evaluations.

Phase III: Examine various aspects of skills degradation over time, including comparison of skills degradation among 40 surgeons participating in past ASSET courses (cadaver model training only) and those participating in the study-based ASSET training curriculum.

Task 3a) Recall and retest previously ASSET-trained surgeons on cadaver at intervals of 2-5 years from original training, months 11-30. DFA: months 32-36 DFA; AC: Repeat ASSET procedures in 40 previously trained surgeons. Complete skills assessments as originally administered and TRR Performance Audit; POC: 15%

- 35 surgeons trained 2 to 5 years ago were evaluated. Follow-up evaluations concluded 2 October 2015.
- Three abstracts were submitted to MHSRS for 2015 using preliminary retention data comparing skills levels of the ASSET alumnae to the 39 pre and post-training surgical resident and 8 expert scores (Figure 1 & 3; Table 2).
- During 37 of the 40 Phase 2 follow-up, 21 of the Phase 3 evaluations, and 2 of the Expert evaluations, we implemented an additional fifth procedure to their assessment: the carotid artery exposure. This was employed in an effort to eliminate practice bias since participants have not been previously exposed to this procedure during earlier evaluations (2 October 2015) (Appendix 52; Script with Carotid Artery Procedure addition and updated Powerpoint slides).

Task 3b) Data analysis; draft paper and present results, 37 months DFA; AC: Final report

acceptance; POC 1 %

- Data analysis and paper drafting involved error analysis, skill degradation, transcript analysis, cadaver vs. model, blind video analysis, literary review of trauma surgical technical skills, item analysis, and longitudinal analysis.
- Created and submitted Final Report (15 Mar 2016).

Key Research Accomplishments

- Utilized the comprehensive database of video clips demonstrating surgical technique from Phase 1 Expert and Novice subjects and the training manual to train a total of 23 additional surgeons and anatomists as reviewers to evaluate surgical skill and technique (15 August 2013 – 4 June 2015).
- Submitted 2013 Quarterly Reports for the periods of 15 February 2013 – 15 May 2013, 15 May 2013 – 15 August 2013, 15 August 2013 – 15 November 2013, and 15 November 2013 – 15 February 2014.
- Kristy Pugh established her role as the project's research assistant (1 April 2014 – 14 Feb 2016) (Table 4).
- Continued collaboration with TRR software developers from Swinburne Australia to refine collected evaluation data (7 April 2014 – 14 Feb 2016).
- Successfully employed the evaluation application and conducted co-located surgical skills evaluations solely on the tablets using the RASP Application in real-time (21 April 2014 – 2 October 2015) (Appendix 4).
- Attended the annual meeting of the American Association of Anatomists at FASEB and presented results from the ASSET historical dataset analysis (27 April 2014) "The Assets of ASSET: Improving surgical performance through an anatomy and skills review course for surgeons." We found that after taking the ASSET course, there were significant gains in confidence scores for surgeons of all specialties. This demonstrates the value of continuing education in applied anatomy for clinical practice (Appendix 17).
- Budget modification submitted and accepted to properly reallocate funds (June 2014 (submitted) – 2014 (accepted)) (Appendix 3).
- Completed the baseline evaluations of 40 of the 40 Phase II surgeons (before receiving ASSET training) (11 February 2015) and 39 of the 40 surgeons post-training (3 September 2014).
- Completed review of anonymized videos for the first 12 completed pre and post evaluations (11 September 2013).
- Cris Imle has established herself as a full-time schedule coordinator to find, contact, recruit, and schedule evaluations for Phase II surgeons 12 or 18 month follow-up and Phase III surgeons until the completion of the participant evaluations (1 October 2014 – 9 October 2015).
- UM IRB annual continuing review submitted (March 2013, 14 November 2014, and August 2015) and accepted (17 November 2014 and 4 August 2015).
- Held a consultants meeting with experts Valerie Shalin and James Shanteau to address how we assess and understand expertise and examine the possibility of new metric methods for analysis (20-21 Nov 2014).

- Presented an abstract at the AMSUS 2014 (3 December 2014) reporting the assessment of technical skills through video evaluations "Evaluation of individual surgeon technical skills during four emergency procedures" (Appendix 1).
- Submitted 2014 Annual Report for the period of 15 February 2014 to 15 February 2015.
- Submitted Quarterly Reports for the periods of 15 February 2014 to 15 May 2014, 15 May 2014 to 15 August 2014, 15 August 2014 to 15 November 2014, and 15 November 2014 to 15 February 2015.
- Recruited a substitute surgeon for the Phase II drop out – thus completing the enrollment of 40 of the 40 Phase II participants (12 January 2015).
- Presented abstract at Eastern Association of Surgery for Trauma (EAST) (13 January 2015) regarding the preliminary results of Trauma Readiness Index for pre and post-training data "Development of a Trauma Readiness Metric Score for Surgeons" (Appendix 2).
- Manuscript associated with abstract submitted for the EAST 2015 meeting was accepted for publication in Journal of Trauma (16 January 2015) "Development and Validation of Trauma Surgical Skills Metrics: Preliminary Assessment of Performance after Training" (Appendix 2).
- Abstract accepted for presentation at the Federated American Societies of Experimental Biology (16 January 2015) "Surface Anatomy in the Performance of a Lower Extremity Fasciotomy before and after Training." We found that after lower extremity fasciotomy training, surgical residents improved in their landmark identification, incision placement, and successful 4 compartment decompression (Appendix 15).
- Completed base-line evaluation of 40 of the 40 proposed Phase II surgical residents (10 February 2015).
- One surgeon was unable to complete their post-training evaluation due to scheduling conflicts. We were able to recruit a replacement Phase II surgeon and completed both their baseline and post-training evaluations (11 February 2015 - 16 March 2015).
- Completed evaluations of 10 of 10 Expert surgeons with the same metrics used to assess the Phase II and III surgeons to create a systematic "expert range" of surgical skill for comparison with other study participants (8 June 2015) (see Figures 1 & 3).
- Completed evaluations on 40 of the 40 Phase II participants before and after ASSET training (16 March 2015).
- Second budget modification submitted and accepted to pay for additional cadaver use. (March 2015 (submitted) – November 2015 (accepted)) (Appendix 21).
- Held a meeting with Advisory Board Member, Prof Nick Sevdalis (London UK) in Seattle at the ASE meeting (April 21-25 2015) to address how to validate our Individual Procedure Score (IPS) performance metric and to update Prof Sevdalis on project progress.
- Presented a poster and 2 podium presentation at the Association for Surgical Education (ASE) (April 21st and 22nd 2015) "Management of Vascular Trauma by Senior Surgical Residents: Perception Does Not Equal Reality", "Mobile Platform for Assessing Emergency Trauma Surgical Skill Performance", and "Assessment of surgical anatomy skills in upper and lower limb vascular control and before and after training." We found that our tablet is able to capture surgeon evaluation metrics during assessments with little intrusion and without paper copies, and that ASSET training may help accelerate acquisition of emergency surgery specific skills to compensate for shortened training hours (Appendices 9, 11, and 13).

- Presented poster at Federated American Societies of Experimental Biology (FASEB) for the American Association of Anatomists "Surface anatomy in the performance of a lower extremity fasciotomy before and after training" (April 30, 2015) (Appendix 15).
- Completed 17 of the 40 Phase III ASSET alumni evaluations. Scheduled a further 12 Phase III surgeons for skill retention evaluation (12th May 2015).
- Made significant progress in re-programming RASP Application for Android Tablet to allow addition of other surgical procedures and for changes to be made to screens in-house rather than through sub-contractor (Appendix 4).
- Presented poster at American Association of Clinical Anatomists 2015 meeting "Anatomic knowledge increases after participation in ASSET training" (12 June 2015). We found that anatomic knowledge benefits significantly from ASSET training (Appendix 25).
- Dr. Guinevere Granite, PhD, has established her position as Research Coordinator (1 July 2015 – 14 Feb 2016) (Table 4).
- Mrs. Nyaradzo Longinaker has established her position as graduate research assistant and statistician to manage the collected data for the project and organize it for use in future publications (1 July 2015 – 4 December 2015).
- Manuscript published in The Journal of Trauma and Acute Care Surgery (July 2015) "Development and validation of trauma surgical skills metrics: Preliminary assessment of performance after training." Using our Trauma Readiness Index as a single performance score that combines completion time and performance assessment metrics, we can detect improvement in specific procedure steps, overall procedure completion time, and anatomic knowledge after the ASSET course (Appendix 10).
- Manuscript published online in the Journal of Surgical Education (23 July 2015) "Using an Individual Procedure Score Before and After the Advanced Surgical Skills Exposure for Trauma Course Training to Benchmark a Hemorrhage-Control Performance Metric." We found that improved surface landmark knowledge, obtained during the ASSET course, correlates with increased IPS, faster procedures, more accurate incision placement, and successful vascular control (Appendix 26).
- Presented 4 podium presentations at the Military Health System Research Symposium (17 - 20 August 2015) "Performance of Combat Surgical Skills before and after ASSET training**", "**Are Physical Models Comparable to Cadaver for Assessing Combat Surgical Technique?**",** and "Accurate Assessment of Surgical Skill Improvements after Training: Development and Validation of Trauma Surgical Skills Metrics, Preliminary Assessment", and "How successful is ASSET at training residents in lower extremity fasciotomy compared to experienced trauma surgeons?" Findings from these presentations include: previously trained surgeons in active surgical practice would benefit from a trauma-specific skills refresher course, combat surgical procedure performance degrades significantly 2 to 5 years later, and correct identification of surface landmarks and incisions are associated with improved vascular control performance (Appendices 12, 28, 30, and 33).
- Presented Plenary Session Podium presentation as a Finalist for the Young Investigator Award at the Military Health System Research Symposium (17 - 20 August 2015) "How successful is ASSET at training residents in lower extremity fasciotomy compared to experienced trauma surgeons?" (Appendix 28).
- Completed evaluations on 38 of the 40 Phase II participants during their follow-up period (12 to 18 months) following ASSET training (14 September 2015).

- Request for Statement of Work modification submitted and accepted to add carotid artery surgical procedure to modified RASP Android application, and pay additional evaluators (submitted (September 2015) and accepted (January 2016) (Appendix 35).
- Third budget modification submitted and accepted to pay for additional cadaver use. (September 2015 (submitted) – January 2015 (accepted)) (Appendix 36).
- Completed random pre- and post-video review for inter-rater consistency review. Analysis of four evaluators blind review 4 pre- and post- procedures for each procedure from upper, mid, and lower tertiles of performance (September 2015).
- Completed 35 of the 40 Phase III ASSET alumni evaluations (2 October 2015) (see Figs. 1 & 3).
- Downloaded final data set from Cloud and tablet co-located data (3 October 2015).
- After completing our final participant evaluation, we downloaded the complete raw evaluation data set from the cloud and began preparing additional manuscripts to be submitted to peer-reviewed surgical journals (3 October 2015).
- Hosted an advisory board meeting with Dr. James Shanteau, psychologist and expert on expert performance analysis, Dr. Valerie Shalin, psychologist and expert in cognitive task analysis and human factors, and Prof. Nick Sevdalis, an experimental psychologist and expert in patient safety in hospital environments from King's College, London (7-9 October 2015 at University of Maryland, Baltimore) (Appendix 22).
- Organized and error checked the final data set, created a data dictionary and calculated IPS and TRI metrics for data set analysis for current and future publications to begin analysis for use in current and future publications (23 November 2015).
- Applied the data dictionary to statistical analyses for use in current and future publications and began preparing additional manuscripts to be submitted to peer-reviewed surgical journals.
- Presented at the International Meeting for Simulation in Healthcare (IMSH) (18 January 2016) "Acquisition & Retention of Trauma Surgical Skills". We presented the following findings: ASSET training benefitted procedural steps (57% increase), Anatomic skills (43%), Technical skills (25%), and readiness to perform vascular procedures (28%) with a mean decrease of 2.5 minutes for procedure time. (Appendix 24).
- Submission and acceptance of IRB renewal (Appendix 35).
- Submitted Annual Report for the period of 15 February 2014 to 15 February 2015.
- Submitted Quarterly Reports for the periods of 15 February 2015 to 14 May 2015, 15 May 2015 to 14 August 2015, 15 August 2015 to 14 November 2015, and 15 November 2015 to 14 February 2016.
- Submitted abstract "Critical Errors in Rarely Performed Procedures 0.5-5 Years After Training Among 85 Surgeons" to the International Anesthesia Research Society (IARS) and the Association of University Anesthesiologists (AUA) 2016 meeting (22 January 2016) (Appendix 53).
- Submitted manuscript "Sensor-Free Computer-Vision Hand-Motion Entropy and Video-Analysis of Technical Performance during Open Surgery: Proof of Concept Report of Methodology and Analysis" for the Human Factors & Ergonomics Society (HFES) 2016 meeting (3 February 2016) (Appendix 31).

Reportable Outcomes

- Compiled an extensive surgical video library over a range of skill levels from head camera and ceiling mounted cameras.
- Completed the development and implementation of a mobile skills evaluation platform including a metric tool in an Android-based software application.
- Twelve abstracts/podium presentations/posters were presented at various relevant professional meetings (AMSUS 2014, ASC 2014, ASA 2014, EAST 2014, FASEB 2014, MHSRS 2014, AACA 2015, ASE 2015, FASEB 2015, MHSRS 2015) (Appendices 1, 9-13, 15, 25, 27, 28, and 33)
- Submitted a pre-proposal to continue to assess the acquisition and retention of surgical skill by examining the efficacy of multiple skills and knowledge refreshing methods: BA150077 – "Refreshing Combat Surgical Skills" (December 2014) (Appendix 40).
- Invited to submit a full proposal of BA150077 – "Refreshing Combat Surgical Skills" (15 January 2015, Appendix 19) and submitted a full proposal (30 March 2015, Appendix 38).
- We have completed, error checked, updated and used our entire dataset (including Phase 2, Phase 3, and Experts data) for multiple analyses.
- Dr. Colin Mackenzie (PI) successfully defended his candidacy for his UK Doctoral degree based on this research effort. He presented his thesis proposal "Assessment of Surgical Performance: Early Stage Assessment " (November 2015) (Appendix 20).
- Completed the (40 of 40) Phase II surgeon evaluations by co-located evaluators before and after ASSET training (16 March 2015).
- Completed 38 of the 40 Phase II surgeon follow-up evaluations 12 to 18 months after ASSET (21 September 2015).
- Completed 35 of the 40 Phase III ASSET alumni evaluations (2 October 2015).
- Manuscript published in The Journal of Trauma and Acute Care Surgery "Development and validation of trauma surgical skills metrics: Preliminary assessment of performance after training" (July 2015) (Appendix 10).
- Manuscript published online in the Journal of Surgical Education "Using an Individual Procedure Score Before and After the Advanced Surgical Skills Exposure for Trauma Course Training to Benchmark a Hemorrhage-Control Performance Metric" (submitted 7 April 2015, published 23 July 2015) (Appendix 26).
- Completed preliminary analysis of tracking hand movement during open surgery using an infrared imaging camera and analysis system (ICI 9640 P, Infrared Cameras Inc., Beaumont, TX) using different colored gloves to indicate dominant and non-dominant hand for experts vs. novice surgeons. (July-August 2015).
- Received rejection letter for full proposal submission of BA150077 - Titled Refreshing Combat Surgical Skills (20 September 2015).
- Completed collecting and recording new data (63 total evaluations) involving implementation of carotid artery exposure as a fifth procedure during follow-up evaluations for Phase II participants, retention period evaluations for Phase III participants, and Expert participants. This was employed in an effort to eliminate practice bias since participants have not been previously exposed to this procedure during earlier evaluations (2 October 2015).
- Submitted Final Report for the period of 15 February 2013 to 15 February 2016.
- Completed Principal Component Analysis of Pre and Post course co-located evaluations with complete data set of 38 participants in Phase II and 35 participants in Phase III.

- Performed analyses on completed data set for use in current and future publications.
- Continued to prepare and present abstracts and manuscripts for various aspects of data analysis (Appendices 24 and 31).
- Modified the Android data collecting tool application to allow for accurate storage of evaluation data to the tablet before uploading it to the Cloud. This will allow for revisions to the data during procedure de-briefing prior to uploading the data to the Cloud. We also adapted the Android data collecting tool application to facilitate creation of new procedures to be used during future evaluations (January – February 2016).
- Modified our original Individual Procedure Score (IPS) metric to exclude errors and procedure time, which we designated as Adjusted IPS for publications involving error analysis and other data analysis topics.
- To facilitate comprehension and use of the final RASP data set, we developed a complete data dictionary for all current and future research team members.
- Applied our modified Individual Procedure Score (IPS) metric that excludes errors and procedure time (designated as Adjusted IPS) to our error occurrence analysis, error recovery analysis, skill degradation analysis, and other data analysis topics for journal publications.
- Applied our developed data dictionary for use by all current and future research team members in understanding our data set and statistical analyses for publication writing.
- Abstract submitted to the International Anesthesia Research Society (IARS) and the Association of University Anesthesiologists (AUA) 2016 Meeting "Critical Errors in Rarely Performed Procedures 0.5-5 Years After Training Among 85 Surgeons" (22 January 2016) (Appendix 53).
- Manuscript submitted to the Human Factors & Ergonomics Society (HFES) 2016 meeting "Sensor-Free Computer-Vision Hand-Motion Entropy and Video-Analysis of Technical Performance during Open Surgery: Proof of Concept Report of Methodology and Analysis" (3 February 2016) (Appendix 31).

Future Plans

- Submitted pre-proposal (September 2015) (Appendix 39). Invited to submit full proposal ASSET 3 Full Proposal BA150808 – "Emergency Refreshing of Combat Surgical Skills" (December 2015) (Appendix 23). Complete full proposal by due date: 20 March 2016.
- Submitted pre-proposal "Autonomous Analysis for Technical Performance of Combat Surgical Skills" to the Office of Naval Research (30 September 2015). Request to modify submission (2 October 2015). Submitted modified pre-proposal (January 2016) (Appendix 37). Awaiting outcome of submission.
- Continuing write-up of data for peer-reviewed journal publications.

Conclusion

This project progressed extremely well and was on target for all Statement of Work tasks. Institutional Review Board approvals were obtained swiftly and are up to date. Comparisons of the Phase II (before and after training) resident skills to those of expert surgeons and previously trained surgeons yielded results that were generally supportive of the study hypotheses. These results also indicated that the metric tool developed to assess skill was capable of discriminating skill levels. The mobile platform and cloud-based evaluation download greatly facilitated the

utility of the metric. However, additional adjustments were necessary to improve efficiency. Preliminary Analyses of Phase I and Phase II video task analysis indicated that there was good inter-rater reliability for many of the evaluation criteria for distinguishing expert surgical technical performance and confirmed the utility of remove skills evaluation. Phase 2 studies compared surgical technical skills metrics before and after ASSET training and 38/40 Phase 2 surgeons completed their follow-up 12 to 18 months after their ASSET training. Phase 3 (previously ASSET trained) collected 35 evaluations. The logistics of travel, the recent winter weather and limitations of access to current contact information impacted the process of recruiting this group. However, analyses of the complete data set indicated that the skills degradation for this group followed expected and objectively measurable patterns. This population yields fruitful lines of inquiry. Ten experts were also evaluated and these data greatly enhanced comparisons of skill and objective identification of competency and improvement.

Discuss according to Phase II data (longitudinal study): No skill degradation seen for whole cohort in vascular exposure and control procedures (12-18 months after training); a priori effects and sample size were met since 95% (38 out of 40) surgeons returned for complete follow-up, however, there was a wide variety of surgeon performance amongst the cohort; more than half of the surgeons reached within 1 nearest neighbor classifier (equivalent to 1 standard deviation) of the expert trauma attending surgeon cohort; remained with no change at the 18 months follow-up after training; critical error rates were high pre-training and significantly reduced as a result of the ASSET training; specific components of performance that were significantly improved include anatomic knowledge, landmarks and skin incision, procedural steps, and shortened time to successful passage and double vessel looping; error recovery also improved after ASSET course training

Phase III: there was skill degradation but we don't have the pre data to compare it to; 1) overall IPS 2) issues related to increase in critical error and 3) error recovery was significantly different

Fasciotomy: sentinel ASSET procedure discriminating ASSET training Phase III surgeons from others after training; identifying incomplete fasciotomy as an error prone outcome

Experts: 4 of the 10 failed to adequately decompress at least one of the four lower extremity compartments

Mitigation plans

Appendices

Appendix 1: Evaluation of Individual Surgeon Technical Skills during Four Emergency Procedures

Colin F Mackenzie, Evan Garofalo, Hegang Chen, Valerie Shalin, Kristy Pugh, Stacy Shackelford, Sharon Henry, Mark Bowyer, Mark Fitzgerald, Joost Funke Kupper, George Hagegeorge, Peter Hu, Kon Mouzakis.

Background: Maintaining trauma specific surgical skills is a challenge for military surgeons. Objective assessment of surgical readiness is needed. We hypothesized that expert surgeon technical skill metrics could provide a reliable technical skill assessment for less experienced surgeons.

Methods: After Institutional Review Board approvals, surgical technical skills assessment metrics were developed from discussion with 10 expert surgeons, video review performing three vascular exposure procedures and lower extremity fasciotomy on both cadavers and hyper-realistic physical models, and a consensus conference. These same metrics were tested in 10 residents using Android tablet software and a head camera to capture 16 specific steps and techniques and 5 performance global ratings during the four procedures. Performance was then assessed on random video-clips of both experts and novices by 5 trained evaluators and compared with regression modeling and inter-rater reliability (ICC) analysis.

Results: Among 10 residents, scores showed no evidence of floor or ceiling effects. Occurrence of 16 expert technical skills, agreed upon by experts, was found in 51-59% of residents during the 4 procedures. Global overall performance rating was 54%. Global technical performance was 69%. ICC ranged from 0.79-0.99 for agreement both between raters and among most skills ratings.

Discussion: Evaluation metrics discriminated novices from an expert standard with excellent inter-rater reliability. Validation in a larger population and before/after skills training is required. Further work with simulated physical models may provide a mobile skills evaluation platform without cadavers.

Support: US Army (USAMRMC) W81XWH-12-JPC1

Evaluation of Individual Surgeon Technical Skills During Four Emergency Procedures

Colin F Mackenzie MD - Principal Investigator

Col Stacy Shackelford MD FACS, Col (R)Mark Bowyer MD FACS, Sharon Henry MD FACS. Evan Garofalo PhD. Co-Investigators

Appendix 2: Development of a Trauma Readiness Metric Score for Surgeons

Evan Garofalo, Stacy Shackelford, Valerie Shalin, Megan Holmes, Jason Pasley, Elliot Jessie, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

Background: Maintaining trauma-related surgical skills during peace-time practice is a challenge. Vascular exposure skill in trauma is an essential preparation for deployment. To create the necessary trauma-specific skills evaluation protocol, we hypothesized that comparison of expert and novice surgical knowledge and technical skills would identify discriminatory metrics for deployment readiness.

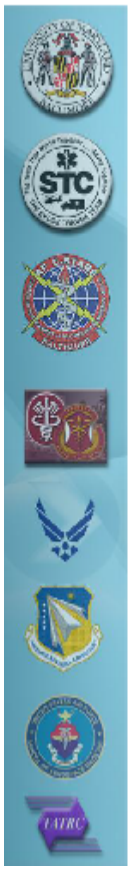
Methods: Through video task-analysis of 10 attending trauma surgeons and 10 general surgery residents performing three vascular exposures [axillary (AA), brachial (BA), femoral arteries (FA)] and lower extremity fasciotomy (FAS) in fresh cadavers, we identified knowledge and technical skills common among experienced surgeons. *Knowledge*: 8 questions, including knowledge of injuries, indications for surgery and complications, *Technical*: completion of 10 specific surgical steps and techniques, 6 operative maneuvers common to experts, and 5 performance global ratings were combined to create a trauma readiness score. These were assessed for 10 residents in a blinded video review by 5 trained evaluators with item analysis and descriptive regression modeling for development Trauma Readiness Index (TRI).

Results: Inter-rater reliability, determined by intra-class correlation coefficient ranged between 0.79-0.98. Average scores were: knowledge questions AA 62%, BA 81%, FA 93%, FAS 62% answered correctly; expert technical skills found in residents: AA 55%, BA 51%, FA 59%, FAS 53%. Global ratings (median Likert 1-5, average % correct): Technical Skills: 3, 54; Indications/Complications: 3, 81; Anatomy knowledge: 3, 78; Readiness 2.5; Global evaluation impression score (1-100) 69. The average TRI for all procedures was 62/100.

Conclusion: Trauma readiness metric discriminated expert from novice performance in both technical and non-technical skills with excellent interrater reliability. Validation in a larger population and with trauma skills training is required.

W81XWH-13-2-0028

Development of a Trauma Readiness Metric Score for Surgeons



Evan Garofalo, Stacy Shackelford, Valerie Shalin, Megan Holmes, Jason Pasley, Elliot Jessie, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie (Presenter)

University of Maryland STAR Research Center, USAF C-STARS, Baltimore, Wright State University , George Washington University & USUHS

Funding: W81XWH-13-2-0028

Appendix 3: Request for Budget Modification with Justification 2014

June 27, 2014

Dear Ms. Bane,

I would like to request approval of some budget modifications to W81XWH-13-2-008

"Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposure for Trauma (ASSET) Surgical Skills". The Title was abbreviated as Retention and Assessment of Surgical Performance (RASP)

PRINCIPAL INVESTIGATOR: Dr. Colin Mackenzie.

These budget modifications will not change the overall cost of the project, nor will they change the scope of work or the deliverables.

The justification for the requested budget changes is shown below and the source of funds is the carry-over of $212K. That occurred from year 1:-

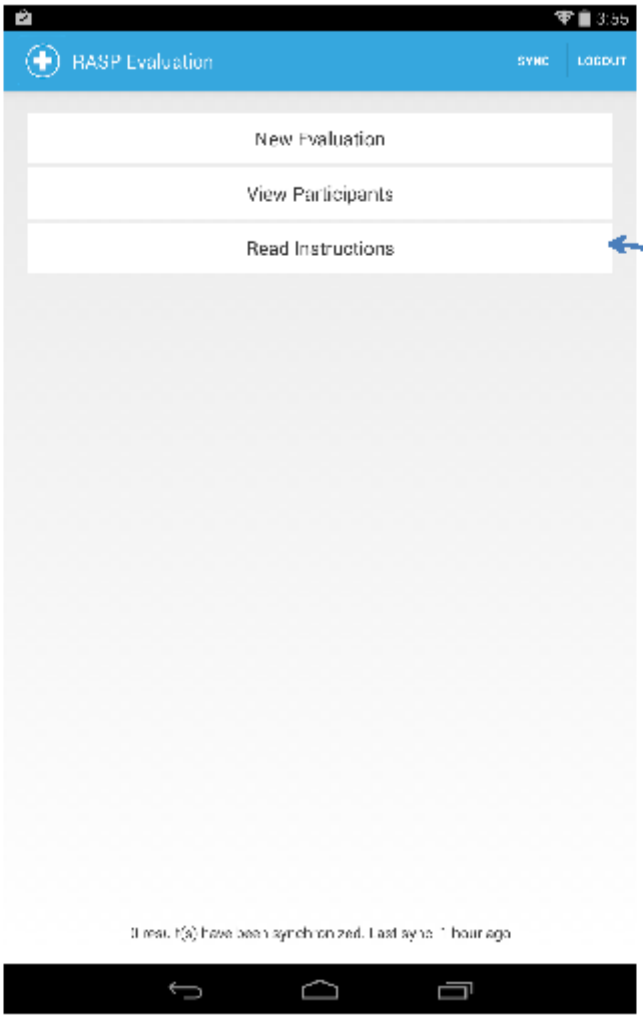
The carry-over of funds that occurred in Year 1 was due to factors shown in 1) below, including slow start-up due to:

1) an inability to hire qualified personnel candidates with expertise in Human Anatomy for the Research Associate/Assistant positions despite advertising in the Anatomy journals, newspaper and within the UM system, 2) Non-hiring of a Bio-informatics person as we originally had no data, but now plan to hire for this position (see 7 below). We were constrained by Sequestration for our Kick-Off meeting in April 2013. No personnel were able to travel from Ft Detrick, but we set up a Telecommunication line. In addition the mid –term meeting we had scheduled coincides with a Mid Term reporting invitation by Ft Detrick.so these fund expenditures were less than budgeted. Dr. Valerie Shalin, one of our Consultants was on Sabbatical Leave in France, so although she did participate in our weekly conferences by Telecommunications it was not for as many hours as budgeted. She is now back from Sabbatical and will 'catch up' these hours. Travel re-imbursement requests for Phase 1 and Phase 2 candidates were less than budgeted and Evaluator honorarium were not all paid out as approval has not been obtained (see item 3 and 9 below). Our video technician (George Hagegeorge) was budgeted at 50% effort, but only provided 30% effort during year 1 start up. Now that we are collecting and rendering hugely increased amounts of video data we would like approval to increase his effort to 70% as of July 1st 2014

We request modification of the budget to use the year 1 carry-over funds as follows:

1) **Increase in expenditure on Faculty Salary**: Faculty Salary costs have increased beyond budget because Dr. Hegang Chen (Statistician to the effort) has been promoted from Associate to Full Professor in the Department of Epidemiology (budgeted+15%: $130,002) and Dr. Hu has been promoted from Assistant to Associate Professor in the

Appendix 4: Application Training Module



Appendix 5: Mobile Platform to Evaluate Individual Surgeon Technical Skills

Mobile Platform to Evaluate Individual Surgeon Technical Skills

Colin F Mackenzie[1], Mark Fitzgerald[2], Kon Mouzakis[2], Joost Funke Kupper[2], George Hagegeorge[1], Peter Hu[1], Evan Garofalo[1], Mark Bowyer[3], Sharon Henry[1], Stacy Shackelford[4].

[1]Shock Trauma Anesthesiology Research, University of Maryland Baltimore; [2]The Alfred Hospital and Swinburne University, Melbourne, Australia; [3]USUHS Bethesda USA; [4]USAF C-STARS Baltimore

Background: We developed surgical technical skills assessment metrics based on discussion with expert surgeons, video review of them performing four surgical procedures and a consensus conference. We describe the utility of a mobile app and video/audio capture system to gather data on surgical technical skills useful for training, telemedicine applications, evaluation in real surgery, cadavers and simulated surgical models.

Methods: Software was developed for Android tablets to capture assessments, which were uploaded to the cloud for analysis by trained evaluators (Fig 1). The system was tested during axillary, brachial, femoral artery exposure, and lower extremity fasciotomy surgery. For video/audio capture we compared three camera systems: a) Pan-tilt-zoom [PTZ] ceiling mounted, b) on mobile stand, c) head-mounted camera with laser pointer (Figs 2-4) and three audio capture systems: a) head worn boom microphone (Fig 5), b) ceiling mounted and, c) audio capture with head camera).

Results: The tablet facilitates capture of surgeon evaluation metrics less intrusively and without paper copies. Data from multiple evaluations stored in the cloud avoids data transcription. The $120 head- mounted laser-directed camera captured up to 1.5 hours of surgical video and audio adequately to assess performance metrics remotely. The PTZ camera with boom/overhead audio system ($90K) gave the best image, but was obstructed by the surgeon's head. The mobile stand mounted camera required constant movement to capture images of the surgical field.

Discussion: An inexpensive mobile data and video/audio capture system could be used to non-intrusively collect data to evaluate surgeon technical performance, with remotely situated evaluators. Further work will test simulated physical models (Fig 6) of the four surgical procedures with enough fidelity to realistically challenge surgical technique, to provide a mobile surgical skills evaluation platform ready for pre-deployment testing without the constraints of cadaver.

Figure 1
Tablet Showing RASP App, with Script, Case History, and Evaluation metrics

Figure 2
Detail of Head Cam and Laser

Figure 3
RASP evaluation showing participant wearing head camera

Figure 4
Focusing the Head Cam laser pointer

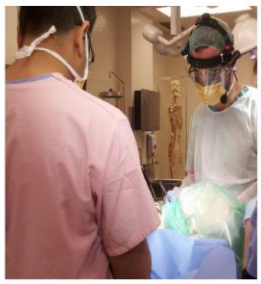


Figure 5
Head Cam and boom microphone

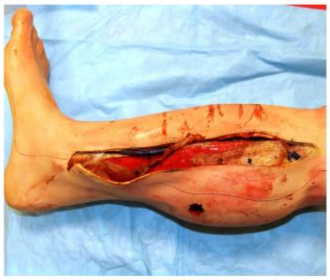


Figure 6
Hyper-Realistic Physical Model for Fasciotomy

Approved for release . U.S. Army Medical Research & Materiel Command (USAMRMC) and the Telemedicine & Advanced Technology Research Center (TATRC), at Fort Detrick, Md under Contract Number: W81XWH-13-2-0028

Appendix 6: Physical Model Realism Questionnaire

Upper Extremity Model Realism Feedback

Please score the realism of Upper Extremity Model features below on a scale of 1 to 5

	1= No reality				5 = Very realistic
Skin	1	2	3	4	5
Subcutaneous tissue	1	2	3	4	5
Muscle	1	2	3	4	5
Fascia	1	2	3	4	5
Vasculature	1	2	3	4	5
Usefulness for Training	1	2	3	4	5
Realism for training	1	2	3	4	5
Anatomic reality	1	2	3	4	5

For the Upper Extremity model, please provide feedback on the following:

What are the strengths of the model?

What are the weaknesses?

Did you find anything about the model distracting?

Do you have suggestions for improvement?

Any other comments?

Thank you for your participation!

Appendix 7: Cadaver vs. Live Patient Questionnaire

Cadaver Upper Extremity Realism Feedback

Compared to a live patient, please score the cadaver upper extremity on a scale of 1 to 5

	1= No reality				5 = Very realistic
Skin	1	2	3	4	5
Subcutaneous tissue	1	2	3	4	5
Muscle	1	2	3	4	5
Fascia	1	2	3	4	5
Vasculature	1	2	3	4	5
Usefulness for Training	1	2	3	4	5
Realism for training	1	2	3	4	5
Anatomic reality	1	2	3	4	5

For the cadaver upper extremity, please provide feedback on the following:

What are the strengths of the model?

What are the weaknesses?

Did you find anything about the model distracting?

Do you have suggestions for improvement?

Any other comments?

Thank you for your participation!

Appendix 8: Study Participant Information and Confidence Questionnaire

RASP Study Participant Information

Demographic Information

Name_____ Age _____ Sex _____

Institution_____ Clinical years_____

Status (circle one): Resident Chief Resident Fellow (PGY-6__ PGY-7__) Attending

Address_____

Email_____ Phone_____

Surgical Experience

What is your surgical (sub) specialty?_____

Number of months on:

Trauma Service_____ non-trauma Acute Care Service_____

Please estimate the time since you last performed surgery: Years ____ Months___ Days___

Please give the approximate number of patients for each of the following:

Trauma patients you have treated or evaluated_____

Percentage of trauma patients with penetrating trauma_____ %

Estimate the number of trauma-related procedures you have participated in for the following:

1. Upper extremity vascular repairs (open) _____
2. Upper extremity vascular repairs (endovascular) _____
3. Lower extremity vascular repairs (open) _____
4. Lower extremity vascular repairs (endovascular) _____
5. Lower extremity fasciotomy _____

Estimate the number of non-trauma related procedures you have participated in for the following:

1. Upper extremity vascular procedures for dialysis access _____
2. Other upper extremity non-dialysis vascular procedures _____
3. Lower extremity open vascular procedures _____
4. Lower extremity endovascular procedures _____
5. Lower extremity fasciotomy _____

Other than anatomy laboratory during medical school, please estimate the number of hours you have spent in a cadaver laboratory: _____

Have you taken any cadaver based courses since medical school? ____Yes ____No

If yes, please specify: _____

Estimate the amount of time you have spent in a skills laboratory during your training or in other activities:

Minimally Invasive skills tasks: _____hours

Open operative skills tasks: _____hours

ASSET course date _____ Participant ID _____

Appendix 9: Management of Vascular Trauma by Senior Surgical Residents: Perception Does Not Equal Reality

Abstract Detail

10th Annual Academic Surgical Congress

Abstract ID ASC20150892

Title Management of Vascular Trauma by Senior Surgical Residents: Perception Does Not Equal Reality.

Authors and Affiliations

Primary Author - **Mark. W. Bowyer**, MD [1]
Additional Author - **Stacy. A. Shackelford**, [1,2]
Additional Author - **Evan. Garofalo**, [1,2]
Additional Author - **Kristy. Pugh**, [2]
Senior Author - **Colin. Mackensie**, [2]

1. Uniformed Services University Of The Health Sciences
   Bethesda, MD USA
2. University Of Maryland
   Baltimore, MD USA

Classifications

Type	Education
Scientific Area	Resident Education
Clinical Area	Trauma/Critical Care

Conflict of Interest Declarations Off Label Use: No

Introduction: Experience with the management of vascular trauma by senior surgical residents is limited. When queried about their understanding of anatomy and ability to perform specific vascular exposures, residents express a moderately high level of confidence. We hypothesized that this perception does not equal reality.

Methods: 42 senior surgical residents participating in an ongoing validation study of the Advanced Surgical Skills for Exposures in Trauma (ASSET) course were asked to self-assess their baseline (pre-course) confidence of their understanding of the anatomy required to perform, and their ability to perform exposures of the Axillary (AA), Brachial (BA), and Femoral (FA) Arteries, as well as Lower Extremity Fasciotomy (LEF) using a 5 point Likert scale. The residents then performed the 4 procedures on a cadaver model and were scored in real time by pre-trained trauma experts using both a global assessment (5 point Likert scale) of "understanding of anatomy" and "resident is ready to perform", as well an overall numerical score (1-100) of the performance. Statistical analysis was performed

Appendix 10: Development and Validation of Trauma Surgical Skills Metrics: Preliminary Assessment of Performance after Training

EAST 2015 PLENARY PAPER

Development and validation of trauma surgical skills metrics: Preliminary assessment of performance after training

Stacy Shackelford, MD, Evan Garofalo, PhD, Valerie Shalin, PhD, Kristy Pugh, MS, Hegang Chen, PhD, Jason Pasley, DO, Babak Sarani, MD, Sharon Henry, MD, Mark Bowyer, MD, *and* **Colin F. Mackenzie, MBChB,** *Baltimore, Maryland*

BACKGROUND: Maintaining trauma-specific surgical skills is an ongoing challenge for surgical training programs. An objective assessment of surgical skills is needed. We hypothesized that a validated surgical performance assessment tool could detect differences following a training intervention.

METHODS: We developed surgical performance assessment metrics based on discussion with expert trauma surgeons, video review of 10 experts and 10 novice surgeons performing three vascular exposure procedures and lower extremity fasciotomy on cadavers, and validated the metrics with interrater reliability testing by five reviewers blinded to level of expertise and a consensus conference. We tested these performance metrics in 12 surgical residents (Year 3–7) before and 2 weeks after vascular exposure skills training in the Advanced Surgical Skills for Exposure in Trauma (ASSET) course. Performance was assessed in three areas as follows: knowledge (anatomic, management), procedure steps, and technical skills. Time to completion of procedures was recorded, and these metrics were combined into a single performance score, the Trauma Readiness Index (TRI). Wilcoxon matched-pairs signed-ranks test compared pretraining/posttraining effects.

RESULTS: Mean time to complete procedures decreased by 4.3 minutes (from 13.4 minutes to 9.1 minutes). The performance component most improved by the 1-day skills training was procedure steps, completion of which increased by 21%. Technical skill scores improved by 12%. Overall knowledge improved by 3%, with 18% improvement in anatomic knowledge. TRI increased significantly from 50% to 64% with ASSET training. Interrater reliability of the surgical performance assessment metrics was validated with single intraclass correlation coefficient of 0.7 to 0.98.

CONCLUSION: A trauma-relevant surgical performance assessment detected improvements in specific procedure steps and anatomic knowledge taught during a 1-day course, quantified by the TRI. ASSET training reduced time to complete vascular control by one third. Future applications include assessing specific skills in a larger surgeon cohort, assessing military surgical readiness, and quantifying skill degradation with time since training. (*J Trauma Acute Care Surg.* 2015;79: 105–110. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Surgical skills assessment; ASSET course; Trauma Readiness Index.

Trauma surgical training remains a core competency of general surgery residencies; however, opportunities to train and develop trauma-specific surgical skills have decreased during the past decade. A number of factors have combined to reduce the total operative trauma cases for graduating chief residents, including a gradual shift in management strategies for traumatic injuries with increased nonoperative management,[1–3] a shift in the epidemiology of traumatic injury with reduced penetrating trauma nationwide,[4] and implementation of work hour restrictions since 2003.[5,6]

Simultaneously, advances in simulation training have occurred, offering a potential mechanism to supplement surgical skills training. Simulation training options include virtual-reality trainers,[7–10] models or manikins,[11–13] human cadaver training,[14–16] and animal laboratories.[17–20] A number of surgical skills assessment methods have been developed during the past decade, which include the general categories of task-specific checklists, global rating scales, procedure-specific rating scales, and nontechnical skills assessments.[21–23] An objective method of assessing competency in surgical skills specific to trauma surgery would be very beneficial to surgical training programs. Military surgeons are faced with the additional challenge of maintaining trauma-specific surgical skills necessary for wartime deployments. Routine trauma care is not provided in the daily practice of most military surgeons,[24] so that interval assessment of trauma-specific surgical skills over time is needed to ensure that previously trained surgeons remain prepared for deployment.

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The study was presented at 28th Annual Scientific Assembly of the Eastern Association for the Surgery of Trauma, January 13–17, 2015, in Lake Buena Vista, Florida.

The views, opinions, and/or findings contained in this publication are those of the authors and do not necessarily reflect the views of the Department of Defense and should not be construed as an official Department of Defense/Army/Air Force position, policy, or decision unless so designated by other documentation. No official endorsement should be made.

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Appendix 11: Mobile Platform to Evaluate Individual Technical Skills American Society of Anesthesiologists, October 2014

Colin F Mackenzie, Mark Fitzgerald, Kon Mouzakis, Joost Funke Kupper, George Hagegeorge, Peter Hu, Evan Garofalo, Mary Njoku, Stacy Shackelford

Background: Many medical specialty Boards have proposals to include a simulated patient encounter to test technical skills in addition to knowledge-based oral examinations in future certification processes. We developed surgical technical skills assessment metrics based on discussion with expert surgeons, video review of 10 experts performing four procedures, and a consensus conference. We describe the utility of a mobile app and video/audio capture system that was used to gather data and results of testing such surgical technical skills metrics, as the principles have widespread applicability for evaluation of anesthesiology training and real-time clinical management, as well as for telemedicine and research applications.

Methods: After Institutional Review Board approvals, an audio-video data capture system was tested during four surgical procedures performed on both cadavers and hyper-realistic physical models by 10 residents. Software was developed for Android tablets to capture assessments of knowledge (indications, complications) and technical skills (10 specific steps and techniques, 6 technical maneuvers and 5 performance global ratings) common to the 10 experts. Results were uploaded to the cloud for blinded video analysis by 5 trained evaluators and tested with regression modeling and inter-rater reliability (ICC) analysis. We also tested three camera systems (Pan-tilt-zoom [PTZ] ceiling mounted, on mobile stand, head-mounted camera with laser pointer) and three audio capture systems (head worn boom microphone, ceiling mounted and audio capture with head camera).

Results: The tablet facilitates capture of surgeon evaluation metrics with little intrusion and without paper copies. Data from multiple evaluations stored in the cloud avoids data transcription. The $120 head-mounted laser-directed camera captured 1.5 hours of surgical video and audio adequately to assess performance metrics remotely. The PTZ camera with boom/overhead audio system ($90K) gave the best image, but was obstructed by the operator's head. The mobile stand mounted camera required constant movement to capture images of the surgical field. Inter-rater reliability (ICC) among technical skills assessments ranged between 0.79-0.98. Among 10 residents, knowledge questions: 62- 93% were answered correctly. Occurrence of 16 expert technical skills was found in 51-59% of residents. Global ratings (median Likert 1-5 and overall %);Technical: 3 overall 54%; Indications/Complications 3 with 81% correct; Anatomy knowledge 3 with 78% correct, Global Evaluation 69%.

Discussion: Using an inexpensive mobile data and video/audio capture system with remotely situated evaluators, performance metrics discriminated experts from novices for technical and non-technical skills with excellent inter-rater reliability. Validation in a

larger population and before/after skills training is required. Further work will test the simulated physical models of the four procedures with enough fidelity to realistically challenge technique, to provide a mobile skills evaluation platform. Funded by W81XWH-13-2-0028.

Appendix 12: Accurate Assessment of Surgical Skill Improvements after Training
Presentation: Eastern Association of Surgery for Trauma (EAST, January 2015)

Stacy Shackelford, MD, Evan Garofalo, PhD, Valerie Shalin, PhD, Kristy Pugh, MS, Jason Pasley, DO, Babak Sarani, MD, Sharon Henry, MD, Mark Bowyer, MD, Colin Mackenzie MBChB

Background: Maintaining trauma specific surgical skills is an ongoing challenge for surgical training programs. An objective assessment of surgical skills is needed. We hypothesized that a reliable surgical skills assessment tool could detect knowledge and skill differences following a training intervention.

Methods: After Institutional Review Board approval, we developed surgical technical skills assessment metrics based on discussion with expert surgeons, video review of 10 experts performing four vascular exposure procedures on both cadavers and hyper-realistic physical models, and a consensus conference. We then tested knowledge and technical skill metrics in 12 surgical residents (year 3-5) before and 2 weeks after vascular exposure skills training with the Advanced Surgical Skills for Exposure in Trauma course. Performance was assessed by six trained evaluators; data was recorded using Android tablet software and a head camera to capture technical skill assessments. Performance was assessed in three areas: knowledge (anatomic, indications, management), procedural steps, and technical skills. Time to completion of procedures was recorded.
Performance scores were calculated before and after training. Wilcoxon paired t was used to examine statistical significance at alpha< 0.05.

Results: Trauma Readiness Index for three vascular exposures and lower extremity fasciotomy improved by 14% after training. Sorted by specific skills, the skill most improved by 1-day skills was procedural steps, scores increased 20%. Technical skill scores improved 12%. Overall knowledge improved 3%, with further analysis localizing this effect to a 17% improvement in anatomic knowledge. Time to complete procedures decreased 4.3 minutes (13.4 to 9.1 min).

Conclusion: A detailed surgical skills assessment is a valuable tool to assess a variety of surgical training programs. The measurement tool detected improvements in specific procedural steps and anatomic knowledge taught during a 1-day course. The tool also detected improvements in technical skills and management normally acquired during the course of residency training. Future applications will include assessing specific skills acquired during the course of residency training.

Surgical Skills Assessment Scores

	Pre-training		Post-training			
	Mean	Std Dev	Mean	Std Dev	Improvement	P-value
Knowledge score*						
• Overall	50	13	53	14	3	0.013
• Anatomic	50	16	50	16	17	0.00001
• Management	43	17	45	15	2	0.044
Technical skills score*	59	18	71	17	12	0.0001
Procedure steps score*	46	23	67	16	20	0.0000001
Time (minutes)	13.4	5.9	9.1	4.5	-4.3	0.000001
Trauma Readiness Index*	50	12	64	10	14	0.0001
*Scores represent the percentage of expert surgeon performance skills found in residents						

Accurate Assessment of Surgical Skill Improvements after Training:

Development and Validation of Trauma Surgical Skills Metrics, Preliminary Assessment

Integrity ★ Service ★ Excellence

Stacy Shackelford, MD,
Evan Garofalo, PhD, Valerie Shalin, PhD,
Kristy Pugh, MS, Hegang Chen, PhD,
George Hagegeorge, BS, Jason Pasley,
DO, Sharon Henry, MD, Mark Bowyer,
MD, Colin Mackenzie, MBChB

Appendix 13: Assessment of Surgical Anatomy Skills in Upper and Lower Limb Vascular Control before and after Training

Podium presentation: Association for Surgical Education (April 2015)

Evan Garofalo, PhD, Stacy Shackelford, MD, Valerie Shalin, PhD, Kristy Pugh, MS, Hegang Chen, PhD, Jason Pasley, DO, Babak Sarani, MD, Sharon Henry, MD, Mark Bowyer, MD, Colin Mackenzie MBChB

Background: Maintaining trauma specific surgical skills is a challenge for military and civilian surgeons. We hypothesize that a trauma training course including rapid upper and lower limb vascular exposure improves correct identification of surgical landmarks, anatomical structures, and shortens time to vascular control. Specifically, improved knowledge of surface landmarks is associated with faster procedures and more successful vessel identification and control.

Methods: We developed a surgical skills evaluation tool through discussion with expert trauma surgeons, video review of 10 experts performing three open vascular exposures (axillary [AA], brachial [BA] and femoral arteries [FA]) on cadavers, and a consensus conference. An Android application was designed to run the tool and two trained evaluators assessed the technical skills of 34 surgical residents (years 3-5) while performing these procedures before and after completing the Advanced Surgical Skills for Exposure in Trauma (ASSET) course. Correct identification of surface anatomical landmarks, incisions, structures in surgical procedural steps, and time to completion of procedure were compared before and after training using Pearson Correlation and Linear Mixed Models test.

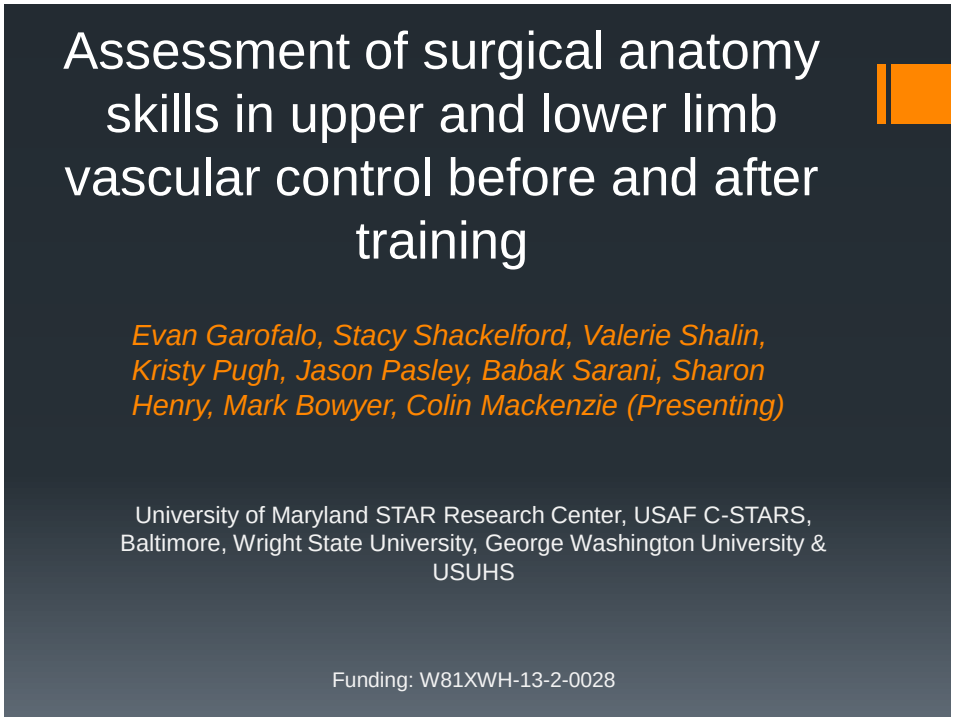
Results: Table 1 details results of the analyses. In AA and FA procedures, there is a significant effect of ASSET training showing decreased procedure time ($p<0.001$), improved surface landmark identification ($p<0.001$: AA 40%; BA 15%; FA 24%), correct vessel identification and vessel control (AA, FA $p<0.001$). There was significant correlation between correct surface landmarks, incisions and artery identification with successful vascular control for AA and FA (r=0.25 to 0.44; all correlations $p<0.001$). Decreased procedure time was correlated with correct surface landmarks ($p<0.02$) and incisions ($p<0.001$) for the BA procedure. Neither residency year nor evaluator had an effect on the pre and post scores.

Conclusions: Documentation of correct surface landmarks and incisions was associated with swift successful control of upper/lower limb vasculature. By this measure, structural recognition during specific procedural steps and surface anatomic knowledge were highly impactful information taught during a 1-day course. This training approach, normally acquired during the entirety of residency training, may help accelerate acquisition of emergency surgery specific skills to compensate for shortened training hours or when just-in-time training is necessary.

Table 1: Comparison of anatomical knowledge and surgical performance between Pre and Post training for Axillary, Brachial and Femoral artery exposures using Linear Mixed Models

		Procedure				
		Axillary Artery	Brachial Artery	Femoral Artery		
		mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD
Surface Landmarks (% correct)	Pre	35 ± 4	49 ± 3	56 ± 3		
	Post	74 ± 4	65 ± 3	81 ± 3		
	diff	39 ***	15 **	24 ***		
Adequate Incision ¥	Pre	-1.2 ± 0.3	1.1 ± 0.4	-0.7 ± 0.3		
	Post	1.6 ± 0.3	2.9 ± 0.6	1.2 ± 0.3		
	diff	2.9 ***	0.6 **	1.9 ***		
Procedure Time (mins)	Pre	11.7 ± 0.6	10.4 ± 0.7	16.6 ± 0.7		
	Post	7.9 ± 0.6	9.5 ± 0.7	13.6 ± 0.7		
	diff	-3.8 ***	-0.8	-2.9 ***		
				CFA†	SFA†	PFA†
Correct Artery Identificatio	Pre	-0.2 ± 0.3	0.15 ± 0.4	-0.7 ± 0.4	0.2 ± 0.4	-0.4 ± 0.3
	Post	2.3 ± 0.5	0.9 ± 0.4	1.6 ± 0.4	3.5 ± 0.07	1.8 ± 0.3
	diff	2.5 ***	0.8	2.3 ***	3.4 ***	2.2 ***
Successful Artery Control ¥	Pre	-0.7 ± 0.3	0.2 ± 0.4	-0.4 ± 0.3	-0.1 ± 0.4	-0.6 ± 0.4
	Post	1.9 ± 0.4	1.3 ± 0.4	1.8 ± 0.4	3.0 ± 0.6	1.4 ± 0.4
	diff	2.5 ***	1 *	2.3 ***	3.1 ***	2.1 ***

†CFA: Common Femoral Artery; SFA: Superficial Femoral Artery; PFA: Profunda Femoral Artery;
¥ Binary data analysed with General Linear Mixed Model, logitistic model
Significance of difference demarked as α=0.05: ***p≤ 0.0001; ** p< 0.001; *p< 0.05



Appendix 14: Mobile Platform for Assessing Emergency Trauma Surgical Skill Performance

Accepted for poster presentation: Association for Surgical Education (April 2015)

Colin Mackenzie, Stacy Shackelford, Evan Garofalo, Hegang Chen, Jason Pasley, Sharon Henry, George Hagegeorge, Kristy Pugh, Mark Bowyer.

Background: Surgical resident's operative trauma experience has decreased from 60-35 cases 1999-2012. A mobile platform would be useful for residency programs to evaluate competence in trauma skills. We tested the hypothesis that remote review of video clips discriminated pre from post training performance in vascular control no differently than co-located performance evaluation.

Methods: Performance of surgical skills were evaluated by two co-located trained experts during three video-recorded vascular exposure procedures (Brachial artery (BA), Axillary Artery (AA), and Femoral Artery (FA)) performed on fresh cadavers by ten 3rd - 5th year surgical residents before and within 2 weeks of Advanced Surgical Skills for Exposure in Trauma (ASSET) training. Metrics included landmarks, specific steps and techniques, expert discriminators and global performance ratings common to 10 experts. The performance metrics were previously validated for BA, AA, and FA with inter rater reliability (ICC) analysis showing ICC 0.7- 0.98 among 5 raters. In this study, Pre/Post training video clips of 10 residents for each procedure were randomly ordered for blinded analysis by 2 trained evaluators and compared to same-procedures simultaneously assessed by co-located evaluations. Co-located and video evaluations were compared with Pearson Correlation and Linear Mixed Models.

Results: Evaluation metrics showed no floor or ceiling effects. Expert discriminators (skin incision, logical sequence, anatomic knowledge etc.), procedural steps (correct structure identification) and global ratings (1= poor - 5=excellent) of anatomy were no different among co-located and video evaluators for BA, AA, FA. Differences in other global ratings of skills, readiness and overall grade (%) were variable between video and co-located evaluations (Table).

Discussion: Remotely situated video review, had agreement in objective pre/post training performance with co-located evaluators, but not in more subjective assessments. Video focused on the surgeon's hands could account for these differences. Video recordings of cadaveric vascular exposure, with remote evaluations of objective metrics assess residents' vascular exposure competence.

		Landmarks (%) mean ± SD	Technical Points (%) mean ± SD	Expert Discrimination (%) mean ± SD	Procedural (%) mean ± SD	Global Anatomy mean ± SD	Global Tech Skill mean ± SD	Global Readiness mean ± SD	Grade (%) mean ± SD
Axillary	Pre	86 ± 6	57 ± 3	55 ± 5	38 ± 5	2 ± 0.2	3 ± 0.2	2.2 ± 0.2	65 ± 2.3
	Post	46 ± 6	73 ± 3.5	75 ± 5	85 ± 5	3.5 ± 0.2	3.5 ± 0.2	3.7 ± 0.3	81 ± 2.4
	Post training Delta	40 ***	16 ***	20 ***	47***	1.4***	1 ***	1.5***	16 ***
	Co-located vs. Video (*p* value)	0.8	0.02*	0.59	0.1	0.09	0.02*	0.3	0.1
Brachial	Pre	60 ± 6	62 ± 3	61 ± 5	62 ± 5	2.4 ± 0.2	2.8 ± 0.2	2.5 ± 0.2	69 ± 3
	Post	66 ± 6	68 ± 3	65 ± 5	79 ± 6	3.1 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	75 ± 3
	Post training Delta	7	7	5	18 ***	0.8 ***	0.3	0.5 *	5.5 *
	Co-located vs. Video (*p* value)	0.75	0.02*	0.02*	0.46	0.15	0.27	0.1	0.1
Femoral	Pre	70 ± 3.9	56 ± 3.6	37 ± 5	44 ± 6.3	2.5 ± 0.2	2.4 ± 0.2	2.2 ± 0.2	66 ± 2.3
	Post	85 ± 3.9	70 ± 3.6	70 ± 5	87 ± 6.3	3.5 ± 0.2	3.2 ± 0.2	3.4 ± 0.2	79 ± 2.3
	Post training Delta	14 *	14 ***	33 ***	44.5 ***	1 ***	0.9 ***	1.2 ***	13 ***
	Co-located vs. Video (*p* value)	0.004 ***	0.04 *	0.5	0.7	0.2	0.07	0.04 *	0.004 ***

α=0.05. Significance is demarcated as: *** p< 0.0001; ** p< 0.001; * p< 0.05

Table: Shows mean ± standard deviation (SD) of metrics across top X axis. Along the Y axisare shownAxillary, Brachial and Femoral artery vascular exposure and control procedures performed by 10 surgical residents with the Pre Post training differences and whether the evaluators used video or were co-located. Expert, and Procedural evaluations and Anatomy Global Ratings were not different between video and co-located evaluators.

Appendix 15: Surface Anatomy in the Performance of a Lower Extremity Fasciotomy before and after Training

Accepted for poster presentation: Federated American Societies for Experimental Biology, American Association of Anatomists (FASEB, AAA March 2015)

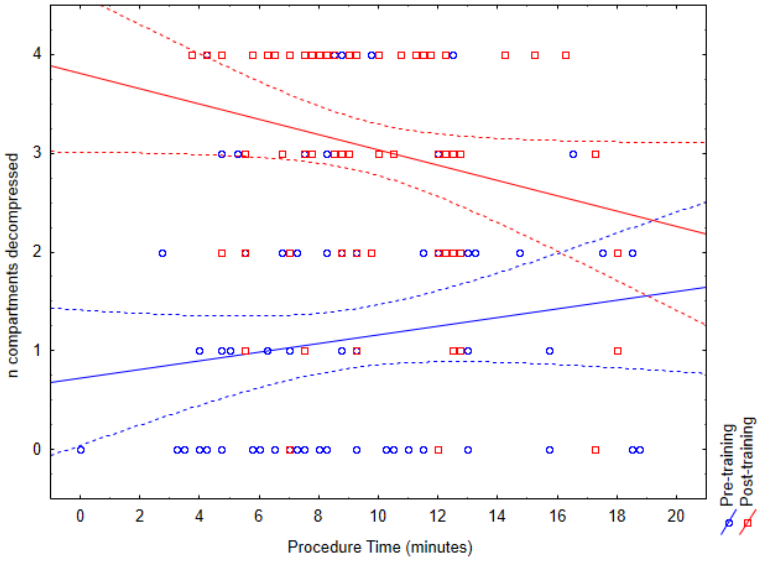
Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

With shorter training hours, acquiring trauma surgical skills on-the-job is challenging for civilian and military surgeons. We hypothesize that a training course including lower extremity (LE) fasciotomy will improve knowledge of surgical landmarks, anatomical structures, and procedure time. Specifically, improved knowledge of surface landmarks will correlate with faster and successful 4 compartment decompression.

Surgical residents (n=34) were tested with validated metrics performing a 2 incision 4 compartment fasciotomy on a cadaver before and after the Advanced Surgical Skills for Exposure in Trauma (ASSET) course. Surface landmarks, incision placement, surgical procedural steps, and procedure time were compared before and after training with Linear Mixed Models and Pearson Correlation.

After training, residents improved in landmark identification (+33%), incision placement (+34%), and successful 4 compartment decompression (all $p<0.001$). More compartments were completely opened in less time (ANCOVA $p<0.05$; figure). Correct landmarks and incisions correlated with successful decompression (r=0.42-0.5; $p<0.001$).

Improved surface anatomic knowledge increased successful fasciotomy. This knowledge is normally acquired on the job during residency but specific training may help accelerate the acquisition of fasciotomy skills to compensate for reduced training hours.



Anatomy in the performance of a lower extremity fasciotomy before and after training

Evan Garofalo[1], Stacy Shackelford[2], Valerie Shalin[3], Kristy Pugh[1], Hegang Chen[4], Jason Pasley[2], Babak Sarani[5], Sharon Henry[2], Mark Bowyer[6] and Colin Mackenzie[1]

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Purpose

Acquiring and maintaining surgical skills for trauma has become challenging for military & civilian surgeons due to mandated shorter training hours (fewer surgical cases observed), more non-operative management for trauma, and infrequent encounters with specific procedures and injuries. However, skill-specific training programs can supplement on-the-job training and are used to maintain trauma surgical skills for deploying surgeons treating combat-related injuries. For example the Advanced Surgical Skills for Exposure in Trauma (ASSET) course is a 1 day case-based program using cadavers.

One procedure that most surgeons have little exposure to is a fasciotomy (for trauma[1]) for compartment syndrome of the leg – caused by increased pressure from swelling or external pressure within defined space. This restricts volume and, when uncorrected or incomplete, can result in loss of limb from nerve and tissue necrosis or possible death. During conflicts in Iraq and Afghanistan, 17% of fasciotomies performed in the field were incomplete[2]. We suspect that familiarity with the surgical anatomy improves successful performance.

H_1: knowledge of surgical landmarks, anatomical structures are associated with faster and more successful 4 compartment decompression

Methods

- Developed & validated objective performance tool and metrics (Fig 1 & 2) using a case-based scenario evaluation platform
  - Assessed knowledge and technical skills by checklist for components: Surface landmarks, incision placement, structure identification, surgical procedure steps, management, technical skills (Fig 3)
  - Scores calculated as points awarded/points possible and combined into a composite score Individual procedure score (IPS)
- Surgical residents (n=34)
  - Evaluated within 2 weeks Before & After taking ASSET course with performance tool performing a 2 incision 4 compartment fasciotomy on a cadaver.
- ANOVA (repeated measures for pre and post-training)
- Pearson correlations for time, number of compartments decompressed, anatomical knowledge, surface landmarks, and IPS.
- Plotted with evaluation data from 8 expert practicingtrauma surgeons

Figure 1

Figure 2

Fig 1 & 2: Fasciotomy surface landmark and procedure performance checklist

Results

Training improved surgical performance for all variables but time (+30 secs) (Table 1, Fig 4)

- +28% surface landmark identification after training
- +32% Incision placement after training
- + compartment decompression (pre-training= 1; post-training=3.1)

Correct anatomical structural identification is correlated with more complete procedures, more successful compartmental decompression, and higher IPS (Table 2)

Correct landmark identification and incision placement correlated with successful decompression (Table 2, Fig 5)

Residents decompressed more compartments in a similar amount of time after training (Table 2; Fig 6)

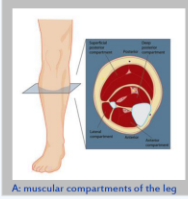
Table 1: Descriptive statistics for Pre and Post-training component and IPS scores for surgical residents

	n	Time (min) mean	Time (min) St Dev	Structure ID mean	Structure ID St Dev	Landmarks mean	Landmarks St Dev	Skin incision mean	Skin incision St Dev	Procedure steps mean	Procedure steps St Dev	Procedure steps mean	Procedure steps St Dev
ANOVA		(F: 1.7)	(*p* <0.17)	(F: 21.2)	(p<0.00001)	(F: 20.8)	(p<0.00001)	(F: 18.9)	(p<0.00001)	(F: 18.8)	(p<0.00001)	(F: 24.6)	(p<0.00001)
Pre	39	9	4.3	0.21	0.25	0.40	0.27	0.50	0.34	0.31	0.18	0.48	0.1
Post	39	9.5	3.5	0.64	0.23	0.68	0.19	0.82	0.27	0.6	0.18	0.65	0.09

Table 2: Pearson correlation coefficients for pre and post-training surgical residents (italics = significance at $p<0.05$)

	training	Procedure score	IPS	n Compartments
Incision	Pre	*0.70*	*0.69*	*0.35*
Incision	Post	*0.66*	*0.55*	*0.45*
Surface landmarks	Pre	*0.66*	*0.63*	0.25
Surface landmarks	Post	*0.63*	*0.57*	*0.41*
Procedure time	Pre	-0.36	-0.20	0.14
Procedure time	Post	-0.33	-0.45	-0.24
Structure ID	Pre	*0.93*	*0.90*	*0.74*
Structure ID	Post	*0.96*	*0.91*	*0.82*

Figure 3: A) Muscular compartments and B & C) surface landmarks / surgical incisions



A: muscular compartments of the leg

B: medial leg

C: lateral leg

Figure 4:

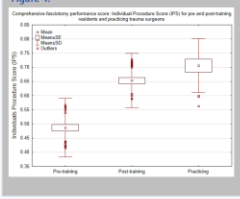


Figure 5:

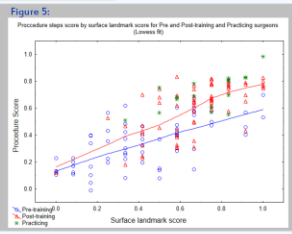
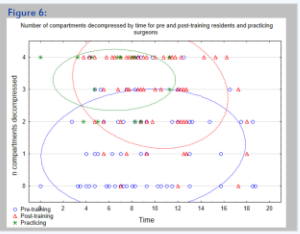


Figure 6:



Conclusions

It is apparent that the correct identification of surface landmarks and incisions was associated more successfully decompressed compartments. By this measure, structural recognition during specific procedural steps and surface anatomic knowledge were highly impactful information even when taught during a 1-day course. This training approach, normally acquired during the entirety of residency training, may help accelerate acquisition of emergency surgery specific skills to compensate for shortened training hours or when just-in-time training is necessary.

While there is no doubt that this repeated deliberate practice of unfamiliar procedures will improve skill and knowledge, the surgeons were also given no guidance or prompting while they were performing the procedures. Performing non-routine procedures completely independently during residency is a highly unusual. Although many mistakes were made, the residents also felt that they improved from learning what they did not know and having to think through a case and surgery critically.

Works Cited

[1] Accreditation Council for Graduate Medical Education. http://www.acgme.org/acgmeweb/Portals/0/PDFs/GSNatData1011.pdf

[2]Ritenour et al. 2008, Complications after fasciotomy revision and delayed compartment release in combat patients. J Trauma, 64: S153-S162.

Supported by USAMRMC: W81XWH-13-2-0028

Appendix 16a: In Progress Review (August 2014)

DEFENSE HEALTH AGENCY - JOINT PROGRAM COMMITTEE – 1 (JPC-1)

In Progress Review (IPR) August 2014 (Orlando, FL)

"USE OF PERFORMANCE MEASURES TO EVALUATE, DOCUMENT COMPETENCE AND DETERIORATION OF ASSET SURGICAL SKILLS – MPI-PSD" – Univ. of Maryland; PI: Dr. Colin Mackenzie

1) Strength(s) of Scientific Methodology / Approach	2) Strength(s) of Investigative Team's Risk Identification / Risk Management Approach	3) Strength(s) of Investigative Team's Schedule / Performance - Goals, tasks, milestones, and deliverables	4) Strength(s) of Results / Deliverables / Outcomes Regarding respective (a) needs of Military / End User and (b) project's goals, tasks, milestones, and deliverables	5) Recommendation, based on how well it addresses needs of the DOD or any individual agency (e.g., Army, Air Force, Navy, Marines) based on capability being developed. Identify any Military Organization, Individual Subject Matter Expert, End-User, &/or Advanced Developer who may be able to accelerate transition.	6) Overall Global Score
Score: 3 - Good **Hypothesis: 1. Metrics can be used to document surgical competence. 2. The metrics can document decay of skills after five years.**	Score: 3 - Good RISK: Q1. Getting enough ASSET alumni to take the ASSET course. 1. Develop performance metrics for surgeons and their skills degradation using the ASSET course. DONE 2. Four injuries: femoral artery injury, auxiliary artery, compartment syndrome, and fasciotomy.	Score: 3 - Good 1. Develop performance metrics for surgeons and their skills degradation using the ASSET course. DONE 2. Four injuries: femoral artery injury, auxiliary artery, compartment syndrome, and fasciotomy.	Score: 3 - Good Doing before and after checklist on video recordings on residents and staff doing the ASSET course. Developed a new metric (RTI) to score the procedures.	Met essential needs	Score: 3 - Good
Score: 4 - Outstanding **Well stated problem to be addressed skill decay of trauma surgical skills vascular injuries. Sound methodological approach.**	Score: 3 - Good cohort of 500 surgeons data collection after period of non-use	Score: 3 - Good seems to be on schedule	Score: 4 - Outstanding excellent study has the potential to contribute significantly to patient safety.	Met essential needs Significant study results will positive impact combat surgery.	Score: 3 - Good Excellent study recommend continue funding.
Score: 3 - Good	Score: 3 - Good	Score: 3 - Good	Score: 3 - Good Seems like JPC/DoD is creating several automated	Met essential needs	Score: 3 - Good

Appendix 16b: In Progress Review: presentation slides (pdf and ppt with video)

Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposures for Trauma (ASSET) Course Surgical Technical Skills

Colin F Mackenzie MD - Principal Investigator

Col Stacy Shackelford MD FACS, Col (R)Mark Bowyer MD FACS, Sharon Henry MD FACS. Co-Investigators

Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposures for Trauma (ASSET) Course Surgical Technical Skills

Colin F Mackenzie MD - Principal Investigator

Col Stacy Shackelford MD FACS, Col (R)Mark Bowyer MD FACS, Sharon Henry MD FACS. Co-Investigators

Appendix 17: The Assets of ASSET: Improving Surgical Performance Confidence through an Anatomy Skills Review Course for Surgeons

Evan M Garofalo[1], Stacy Shackelford[1,2], Megan A Holmes[1,3], Colin Mackenzie[1], Mark W Bowyer[4]. [1]University of Maryland, Baltimore, MD, [2]C-STARS, Baltimore, MD, [3]Johns Hopkins University, [4]USUHS, Bethesda, MD

Rapid control of major hemorrhage is a primary goal in trauma surgery. However, many surgeons have little practical experience with the required vascular exposures. To address this, the American College of Surgeons developed the Advanced Surgical Skills for Exposure in Trauma (ASSET) course to review anatomy, skills and techniques for major vascular exposures. Since 2008, a broad range of participants have attended, including surgeons of many specialties, deploying military surgeons and surgery residents.

We compared self-reported confidence of participants (n=562) in surgical tasks (n=47) at baseline and directly after ASSET training to examine the effect of the course stratified by surgical experience level (resident/fellow; <8 years post-residency; 8+ years post-residency), specialty (trauma/vascular; general surgery; other specialties), and body region.

Results of Freeman-Halton 3x2 tests indicated significant gains in confidence scores for all specialties ($p<0.02$), particularly for general surgeons ($p<0.01$) and exposures in the chest ($p<0.001$), after ASSET. There was no difference in confidence gained by surgical experience. This study demonstrates the value of continuing education in applied anatomy for clinical practice. Given the frequency of vascular trauma in current military conflicts, the impact of ASSET is particularly relevant for preparing deploying surgeons for the theatre.

Funding support from: US Army W81XWH-13-2-0028

The assets of ASSET: improving surgical performance confidence through an anatomy and skills review course for surgeons.

Evan M Garofalo[1,2], Stacy Shackelford[3], Megan A Holmes[2,4], Colin Mackenzie[2], Mark W Bowyer[5].

[1]Anatomy & Neurobiology, University of Maryland School of Medicine, Baltimore MD; [2]Shock Trauma & Anesthesiology Research, University of Maryland School of Medicine, Baltimore MD, [3]R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, Baltimore MD; [4]Center for Functional Anatomy & Evolution, Johns Hopkins University School of Medicine; [5]Surgery, Uniformed Services University of the Health Sciences, Bethesda, MD

Abstract 536.11/B45

Rapid control of major hemorrhage is a primary goal in trauma surgery. However, many surgeons have little practical experience with the required vascular exposures. To address this, the American College of Surgeons developed the Advanced Surgical Skills for Exposure in Trauma (ASSET) course to review anatomy, skills and techniques for major vascular exposures. Since 2010, a broad range of participants have attended, including surgeons of many specialties, deploying military surgeons and surgery residents.

We compared self-reported confidence of participants (n=562) in surgical tasks (n=47) at baseline and directly after ASSET training to examine the effect of the course stratified by surgical experience level (resident/fellow; <8 years post-residency; 8+ years post-residency), specialty (trauma/vascular; general surgery; other specialties), and body region.

Results of Freeman-Halton 3x2 tests indicated significant gains in confidence scores for all specialties ($p<0.02$), particularly for general surgeons ($p<0.01$) and exposures in the chest ($p<0.001$), after ASSET. There was no difference in confidence gained by surgical experience. This study demonstrates the value of continuing education in applied anatomy for clinical practice. Given the frequency of vascular trauma in current military conflicts, the impact of ASSET is particularly relevant for preparing deploying surgeons for the theatre.

Introduction

Work hour restrictions for residents, implemented in 2003, reduced in-hospital work hours to 80 hours/week.[1] Surgical residents are performing fewer vascular exposures during their surgical training.

- ↓ average cases / graduating general surgery chief residents from 1999 to 2012[2]:
  Total cases: 60.4 to 35.5
  Major vascular procedures: 8 to 0.7

The Advanced Surgical Skills for Exposure in Trauma (ASSET) course was developed to address declining residency training experience:

- Launched in 2010 and approved by American College of Surgeons
- 1 day cadaver-based course reviews anatomy and surgical skills to perform all major vascular exposures, emphasizing swift exposure as vital for control of major hemorrhage.
- Part of military pre-deployment training and surgical residency programs to review trauma surgical skills.

Research question: *Is there an effect of the level of surgical experience or surgical specialty on confidence to perform procedures independently after ASSET training?*
We hypothesize that general surgeons (B Specialty) and Resident / Fellows will report the greatest improvement in confidence.

Materials

Enrollment questionnaires from 53 ASSET courses offered nationally from 2010 to 2013[3] to gather basic professional demographics and surgical confidence from a broad range of surgeons (n=562). Analysis was conducted by experience level and surgical specialty (Table 1).

Surgical confidence, Pre & Post-ASSET:
Self-reported confidence level for 47 procedures[4] partitioned into upper limb, lower limb, chest, neck, pelvis & abdomen procedures (5 point Likert Scale[5]: 1=no confidence; 5=quite a bit of confidence)

Table 1: Sample

		n	Years in practice: mean	SDev
Surgical Specialty	A) Trauma/vascular	50	8.3	7.5
	B) General surgery	96	7.8	8.2
	C) Other specialties	51	3.6	3.4
	All Specialties	197	6.8	7.4
Experience level	Resident	244	PGY 4.5	–
	Jr. Attending	171	3	2.1
	Sr. Attending	108	15	8.3
	All Experience	562	8.8	9.1

Methods

Likert scale values of 1-3: low confidence and; and 4-5: high confidence.
Delta for median confidence to perform procedures independently Pre- to Post-ASSET training compared by:
Body region: Wilcoxon matched pairs test
Direction of change: (increase, decrease, stayed the same) by Experience, Specialty and Body region (Freeman-Halton contingency tests)

Results

Figures 1 & 2 report the average number of select procedures reportedly performed. Pre- confidence levels generally align with number of procedures reportedly performed by specialty and experience level.

Tables 2 & 3 detail the median Pre- & Post-ASSET confidence scores by experience and specialty. Confidence increased significantly for all Pre-Post pairs at α=0.05

Of low Pre-ASSET confidence:
- 39% high Post confidence for all procedures.
- 49% high Post confidence for upper limb procedures

Experience: Significant effect of experience on Post-ASSET confidence, for all body regions but lower limb (Table 5).
Residents report low to high confidence shifts most, particularly for lower limb and pelvis. Senior Attendings (>8 years practice) report low confidence Pre & Post training.

Specialty: Significant effect of specialty on Post-ASSET confidence, for all regions but lower limb (Table 6).
Most improved confidence: General Surgery (B)
Least improved body region: chest, abdomen & pelvis

Figure 1: Average number of procedures performed by specialty group

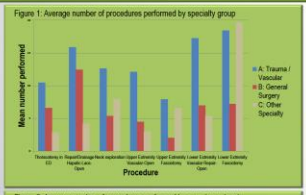


Figure 2: Average number of procedures performed by experience level

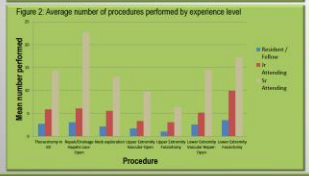


Table 2: Summary of median Pre- and Post-ASSET confidence scores for body region by experience level. *(all pair comparisons are significant at p<0.05 - Wilcoxon matched pairs)*

		All Regions	Upper Limb	Lower Limb	Neck	Chest	Pelvis & Abdomen
Resident	Pre	3	3	3	3	2	3
	Post	4	4	4	4	4	4
Jr. Attending	Pre	3	3	4	4	3	4
	Post	4	4	5	4	4	5
Sr. Attending	Pre	4	3	4	4	3	4
	Post	5	5	5	5	4	5

Table 3: Summary of median Pre- and Post-ASSET confidence scores for body region by Specialt. (all pair comparisons are significant at p<0.05 - Wilcoxon matched pairs)

		All Regions	Upper Limb	Lower Limb	Neck	Chest	Pelvis & Abdomen
A Specialty	Pre	4	4	5	4	4	5
	Post	5	5	5	5	5	5
B Specialty	Pre	3	3	3	4	3	4
	Post	4	4	4	4	4	5
C Specialty	Pre	2	3	3	2	1	1
	Post	4	5	4	4	3	3

Table 4: Direction of change in self-reported confidence (% of all 523 surgeons) after ASSET training by body region *Low confidence is defined as Likert 1 to 3, high confidence Likert 4 to 5. Results are given Freeman-Halton 1x3 contingency testing comparisons of directional change among all surgeons undergoing training.*

		All Regions	Upper Limb	Lower Limb	Neck	Chest	Pelvis & Abdomen
All Surgeons	Low to High	39	49	40	39	45	32
	Stayed Low	20	17	22	20	24	18
	Stayed High	39	33	37	40	30	48
	Freeman-Halton p	0.025*	<0.0001*	0.06	0.021*	0.017*	0.001 *

Table 5. Direction of change in self-reported confidence by body region and experience level (noted as % of participants)

		All Regions	Upper limb	Lower limb	Neck	Chest	Pelvis & Abdomen
Resident	Low to High	43	46	52	42	45	52
	Stayed High	20	23	22	27	24	26
	Stayed Low	36	30	25	30	30	21
Jr Attending	Low to High	24	36	51	42	36	42
	Stayed High	20	18	10	15	16	23
	Stayed Low	55	45	38	42	47	34
Sr Attending	Low to High	21	31	44	37	33	35
	Stayed High	11	14	11	18	15	19
	Stayed Low	66	53	44	44	51	45
	Freeman-Halton 3x2 *p*	0.019*	0.012*	0.125	0.031*	0.007*	<0.0001*

Table 6. Direction of change in self-reported confidence by body region and Specialty (noted as % of participants)

		All Regions	Upper limb	Lower limb	Neck	Chest	Pelvis & Abdomen
A Specialty	Low to High	19	34	26	16	19	12
	Stayed Low	8	8	11	5	8	5
	Stayed High	60	50	49	57	53	68
B Specialty	Low to High	38	55	41	40	46	23
	Stayed Low	10	10	16	10	12	5
	Stayed High	35	28	30	40	30	46
C Specialty	Low to High	30	41	35	33	33	19
	Stayed Low	36	15	18	36	52	47
	Stayed High	23	40	39	23	9	17
	Freeman-Halton 3x3 *p*	0.007*	0.006*	0.082	0.0005*	0.0002*	0.036*

Discussion / Conclusion:

Analyses show that all specialties and experience levels derived benefit from ASSET by improving overall confidence levels with vascular exposures. Confidence improved most for procedures in the upper limb. Residents/fellows and General surgeons achieved the greatest improvement in confidence levels, particularly in body regions seen the least often clinically. This method of study has limitations, relying on memory recall and subjective confidence metrics. Studies are underway to develop objective metrics to assess surgical skills.

Acknowledgements / References:

Thank you to the ongoing effort of American College of Surgeons and local ASSET course sites to offer these course and collect this information and to the participants and programs who continue to enroll in the program. Funding support from: US Army W81XWH-13-2-0028

1) Wilkey RN. Federal Whistleblower Protection: a means to enforcing maximum-hour legislation for medical residents. William Mitchell Law Review 2003;30:331-35. 2) Accreditation Council for Graduate Medical Education. General Surgery: National Program Statistics Report, 1999-2012. 3) Kuhls DA, Rouzzo DA, Bowyer MW, Luchette FA. Advanced surgical skills exposures for trauma: a new surgical skills cadaver source for surgery residents and fellows. J Trauma Acute Care Surg 2013;74:664-670. 4) Bowyer MW, Kuhls DA, Haskin D, et al. Advanced surgical skills for exposure in trauma (ASSET). the first 25 courses. J Surg Res 2013;183:553-558. 5) Likert R. A technique for the measurement of attitudes. Arch Psych 1932;22-55.

Appendix 18: Current List of Works

Abstracts for Presentation/Publication

1. **The assets of ASSET: Improving surgical performance confidence through anatomy and skills review course for surgeons**
   (Poster: Federation of American Societies for Experimental Biology (April 2014)
   Authors: Evan Garofalo, Stacy Shackelford, Megan Holmes, Colin Mackenzie, Mark Bowyer

2. **Development of a Trauma Readiness Metric Score for Surgeons**
   (Podium: Military Health Services Research Symposium (MHSRS, August 2014)
   Authors: Evan Garofalo, Stacy Shackelford, Valerie Shalin, Megan Holmes, Jason Pasley, Elliot Jessie, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

3. **Mobile Platform to Evaluate Individual Surgeon Technical Skills**
   (Poster: Military Health Services Research Symposium MHSRS, August 2014)
   Authors: Colin F Mackenzie, Mark Fitzgerald, Kon Mouzakis, Joost Funke Kupper, George Hagegeorge, Peter Hu, Evan Garofalo, Mark Bowyer, Sharon Henry, Stacy Shackelford

4. **Mobile Platform to Evaluate Individual Technical Skills**
   (Presentation: American Society of Anesthesiologists (ASA, October 2014))
   Authors: Colin F Mackenzie, Mark Fitzgerald, Kon Mouzakis, Joost Funke Kupper, George Hagegeorge, Peter Hu, Evan Garofalo, Mary Njoku, Stacy Shackelford

5. **Evaluation of individual surgeon technical skills during four emergency procedures** (Podium Presentation: Association of Military Surgeons of US (AMSUS, December 2014))
   Authors: Colin F Mackenzie, Evan Garofalo, Hegang Chen, Valerie Shalin, Kristy Pugh, Stacy Shackelford, Sharon Henry, Mark Bowyer, Mark Fitzgerald, Joost Funke Kupper, George Hagegeorge, Peter Hu, Kon Mouzakis

6. **Anatomy in the performance of a lower extremity fasciotomy before and after training**(Publication: Journal of Surgical Education 2014)
   Evan Garofalo, Stacy Shackelford, Valerie Shalin, KristyPugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

7. **Accurate assessment of surgical skill improvements after training**
   (Presentation: Eastern Association of Surgery for Trauma (EAST, January 2015))
   Authors: Stacy Shackelford, Evan Garofalo, Valerie Shalin, Kristy Pugh, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

8. **Management of Vascular trauma by senior surgical residents: Perception does not equal reality**
   (Presentation: Academic Surgical Congress (ASC February 2015))
   Authors: Mark Bowyer, Stacy Shackelford, Evan Garofalo, Kristy Pugh, Colin Mackenzie

9. **Assessment of surgical anatomy skills in upper and lower limb vascular control and before and after training**
   (Podium: Association for Surgical Education (April 2015))
   Authors: Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

10. **Mobile Platform for Assessing Emergency Trauma Surgical Skill Performance**
    (Poster: Association for Surgical Education (April 2015))
    Authors: Colin Mackenzie, Stacy Shackelford, Evan Garofalo, Hegang Chen, Jason Pasley, Sharon Henry, George Hagegeorge, Kristy Pugh, Mark Bowyer. STAR and Shock Trauma Center, Departments of Anatomy and Epidemiology, University of Maryland School of Medicine, USAF and USUHS Bethesda MD

11. **What's on the surface matters too: assessment of surgical anatomy and successful performance of a lower extremity fasciotomy before and after training**
    (Poster: Federated American Societies for Experimental Biology, American Association of Anatomists (FASEB, AAA March 2015))
    Authors: Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

12. **Anatomic knowledge increases after participation in ASSET training**
    (Poster: American Association of Clinical Anatomists 2015)
    Authors: Kristy Pugh, Evan Garofalo, Brandon Bonds, Colin Mackenzie

13. **Using an Individual Procedure Score (IPS) before and after the ASSET course training to benchmark a hemorrhage-control performance metric**
    (Publication: Journal of Surgical Education2015)
    Authors: Colin Mackenzie, Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Adam Puche, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer

14. **How successful is ASSET at training residents in lower extremity fasciotomy compared to trauma surgeons?**
    (Podium: Military Health System Research Symposium 2015)
    Authors: Evan Garofalo,Mark Bowyer, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, George Hagegeorge, Babak Sarani, Jason Pasley, Sharon Henry, Colin Mackenzie

15. **Which combat surgical skills degrade after training?**
    (Podium: Military Health System Research Symposium 2015)
    Authors: Stacy Shackelford, Evan Garofalo, Valerie Shalin, Kristy Pugh, Hegang Chen, George Hagegeorge, Jason Pasley, Sharon Henry, Mark Bowyer, Colin Mackenzie

16. **Are physical model assessments comparable to cadaver for combat surgical technique?**
    (Podium: Military Health System Research Symposium 2015)
    Authors: Brandon Bonds, Evan Garofalo, Kristy Pugh, Mark Bowyer, Stacey Shackelford, Colin Mackenzie

Peer Reviewed Journal Articles

1. **Development and validation of trauma surgical skills metrics: Preliminary assessment of performance after training**
   (Publication: Journal of Trauma and Acute Care Surgery (July 2015))
   Authors: Stacy Shackelford, Evan Garofalo, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie

2. **Perception does not equal reality for resident vascular trauma skills**
   (Publication: Journal of Surgical Research (October 2015))
   Authors: Mark Bowyer, Stacy Shackelford, Evan Garofalo, Kristy Pugh, Colin Mackenzie

3. **Using an individual procedure score before and after the Advanced Surgical Skills Exposure for Trauma Course training to benchmark a hemorrhage-control performance metric**
   (Publication: Journal of Surgical Education (November/December 2015))
   Authors: Colin Mackenzie,Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Adam Puche, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer

4. **Computer-assisted video hand-motion analysis combined with image identification as a step to automated evaluation of surgeon technical performance: a preliminary report of methodology and analyses**

(Publication: (in review) Ergonomics)
Authors: Colin Mackenzie, Darcy Watts, Rajan Patel, Shiming Yang, George Hagegeorge, Evan Garofalo, Peter Hu, Adam Puche, Valerie Shalin, Kristy Pugh,Guin Granite, Lynn Stansbury, Stacy Shackelford, Sam Tisherman

5. **Trauma training courses for surgeons and validation of their efficacy**
(Publication: (in review) J. Am Coll Surg)
Authors: Colin Mackenzie, Kristy Pugh, SamTisherman, Stacy Shackelford, Mark Bowyer.

6. **Sensor-free Computer-Vision hand-motion entropy and video-analysis of technical performance during open surgery: proof of concept report of methodology and analysis**

Accepted for Publication Human Factors and Ergonomics
Colin F Mackenzie, Darcy Watts, Rajan Patel, Shiming Yang, George Hagegeorge, Evan Garofalo, Peter F Hu, Adam Puche; Kristy Pugh, Guinevere Granite, Lynn G Stansbury, Stacy Shackelford, Samuel Tisherman, Valerie Shalin

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Appendix 19: Full Proposal Invitation Letter 2015 for BA150077 – "Refreshing Combat Surgical Skills for Vascular Control"

DEPARTMENT OF THE ARMY
U.S. ARMY MEDICAL RESEARCH ACQUISITION ACTIVITY
820 CHANDLER STREET
FORT DETRICK MD 21702-5014

January 15, 2015

SUBJECT: BA150077 - "Refreshing Combat Surgical Skills for Vascular Control"

Colin MacKenzie
University of Maryland, Baltimore
419 Redwood Street, Suite 225
Baltimore, MD 21201

Dear Dr. MacKenzie:

You are invited to submit a proposal/application to the Fiscal Year 2015 (FY15) Department of Defense (DoD) Broad Agency Announcement (BAA) for Extramural Medical Research. The reviewers found your pre-proposal/pre-application to be of interest to US Army Medical Research and Materiel Command (USAMRMC) programs aimed at the solution of medical problems of military importance.

In accordance with the Federal Acquisition Regulations, the USAMRMC advertised for research and development proposals/applications using a BAA. Since your proposal/application will be submitted after October 1, 2014, you are required to submit it under the FY15 BAA (released on October 1, 2014 at www.grants.gov under CFDA 12.420) and to use the forms identified in the announcement. Attempts to submit any forms from a previous iteration of the DoD BAA will be rejected by Grants.gov.

In addition, your proposal/application must include the requisite components, comply with preparation instructions, include the log number BA150077, and be submitted by 11:59 p.m. Eastern time on April 15, 2015 as described in the FY15 BAA and General Submission Instructions.

Please note that your proposal/application may be rejected for administrative reasons without further review if the budget or research project as described in the pre-proposal/pre-application differs significantly from the full proposal/application.

Based on the information provided in the pre-application, you should address the following in your application: the inclusion of a trauma and combat surgeon or equivalent expert to advise on this study, detailed statistical design including power analysis accounting for recuitment and retention of subjects, and justification for the proposed period of performance.

Appendix 20: Dr. Mackenzie Doctoral Candidacy Presentation

Title: Assessment of Surgical Performance: *Early Stage Assessment*

Colin F Mackenzie MB ChB
Shock Trauma Anesthesiology Research Center (STAR), University of Maryland School of Medicine
cmack003@umaryland.edu

Appendix 21: Request for Budget Modification with Justification March 2015

March 31st 2015

Dear Ms. Bane,

I would like to request approval of some budget modifications to W81XWH-13-2-008

"Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposure for Trauma (ASSET) Surgical Skills". The Title was abbreviated as Retention and Assessment of Surgical Performance (RASP)

PRINCIPAL INVESTIGATOR: Dr. Colin Mackenzie.

These budget modifications will not change the overall cost of the project, nor will they change the scope of work or the deliverables. This modification is intended to optimize the allocation of the remaining available funds for this project to ensure the best deliverable products of this overall effort.

In general therefore, this budget modification requests re-allocation approval for salary support of additional experts to assist with data analysis and interpretation and to account for salary increases of the existing investigators, and additional equipment to use newly identified tools to interpret these data

The justification for the requested budget changes is shown below and the source of funds is $737,712.60 funds as outlined in the attached budget showing the funds remaining

Carry-over of funds occurred in Year 2 due to factors below 1) Travel re-imbursement requests for Phase 1 and Phase 2 candidates were less than budgeted. 2) More military surgeons than expected were enrolled, so study participation payments were less as no payments made to these military surgeon enrollees. Military surgeons cannot accept study participation payments for US Army funded studies. 3) We did not get an earlier salary increase approved for investigators because of a freeze on salaries in the University of Maryland. Some of the carry over funds will be used to cover salary increases. 4) The PI has obtained additional funding (starting July 2015) and will have to reduce funded effort on the project between July 2015 until project end March 1 2016.

We request modification of the budget to use these funds as follows:

1) Increase in expenditure on Salary: Salary costs will increase beyond budget because salary increases have been approved for Drs Garofalo and Mackenzie and Ms Kristy Pugh , effective July 1st 2015. Dr Garofalo is funded at 100% effort as the Research Coordinator of this project effort and is an Assistant Professor in the Department of Anatomy at the University of Maryland School of Medicine. As of July 1st 2015 we would like approval to increase Dr Garofalo's salary by 14.9 % to $79,374 for her excellent performance and high

Appendix 22: Schedule for Advisory Board Meeting 2015

RASP/ASSET Advisory Board Meeting 2015

Attendees: Advisory Board Members; James Shanteau PhD, Nick Sevdalis PhD, Valerie Shalin PhD, Guests: Kevin Kunkler MD, William Chiu MD FACS,. Project Investigators : Colin Mackenzie MD (Project PI) , Col (Rtd) Mark Bowyer MD FACS (USUHS) , Col Stacy Shackelford MD FACS (USAF ISR), Maj Jason Pasely DO, FACS (USAF C-STARS Baltimore), Shiming Yan PhD, Research Staff: Guin Granite PhD, Kristy Pugh MS, Support Staff; Barbara McGee. Telecof Attendee: COR Tony Story USAMRMC

Advisory Board Meeting at UNIVERSITY OF MARYLAND, October 2015

RETENTION & ACQUISITION OF SURGEON PERFORMANCE (RASP)

Date*: Thursday October 8th*: Time: *8 am- 5 pm*

Place*: Room TIR12 Shock Trauma Directors Conference Room, Baltimore MD 21201(410-627-5616)*

Agenda Day 1 of RASP Advisory Board meeting:-

8am- 8:30 am Coffee and Breakfast Pastries

8:30 am – 8 :45 am: Welcome and Self- Introductions

8:45 am – 9:15 am Overview of Surgeon Performance study Objectives Hypotheses and Data Collection: Colin Mackenzie

9 :15 am – 9:45 am Results: Performance effect of ASSET training: Colin Mackenzie

9:45 am – 10 am REFRESHMENT BREAK

10 am – 11 am Results: Skill degradation compared to immediate post-ASSET training and expert performance. Stacy Shackelford and Colin Mackenzie

11am- 11:45 am: Ray Perez: "ONR interests in performance and learning"

11:45 am – 12 noon: Discussion

12 Noon: LUNCH BREAK. Tour Shock Trauma Resuscitation Unit and Simulation Center (if interested).

1pm- 1:30pm Kevin Kunkler: US Army JPC-1: Technical Skills retention and Refreshing

1: 30 pm: Valerie Shalin, Eric Robinson: "Planning vs. execution: detecting qualitative differences in surgical skills"

Appendix 23: Full Proposal Invitation Letter 2016 for BA15808 – "Emergency Refreshing of Combat Surgical Skills"

DEPARTMENT OF THE ARMY
U.S. ARMY MEDICAL RESEARCH ACQUISITION ACTIVITY
820 CHANDLER STREET
FORT DETRICK MD 21702-5014

December 21, 2015

SUBJECT: BA150808 - "Emergency Refreshing of Combat Surgical Skills"

Colin MacKenzie
University of Maryland Baltimore
11 S. Paca Street
Lower Level
Baltimore, MD 21201

Dear Dr. MacKenzie:

You are invited to submit a proposal/application to the Fiscal Year 2016 (FY16) Department of Defense (DoD) Broad Agency Announcement (BAA) for Extramural Medical Research. Your pre-proposal/pre-application was reviewed by the U.S. Army Medical Research and Materiel Command (USAMRMC) scientific staff. Invitations to submit full proposals/applications were based upon technical merit, programmatic considerations, and availability of funds. The reviewers found your pre-proposal/pre-application to be of interest to the USAMRMC programs aimed at the solution of medical problems of military importance.

In accordance with the Federal Acquisition Regulations, the USAMRMC advertised for research and development proposals/applications using a BAA.

You are required to submit a proposal/application under the FY16 BAA (released on October 1, 2015 on Grants.gov [http://www.grants.gov/] under CFDA 12.420) and to use the forms identified in the announcement. Attempts to submit any forms from a previous iteration of the DoD BAA will be rejected by Grants.gov.

Your proposal/application must include the requisite components, comply with preparation instructions, include the log number BA150808, and be submitted by 11:59 p.m. Eastern time on March 21, 2016 as described in the FY16 BAA and General Submission Instructions.

Please note that your proposal/application may be rejected for administrative reasons without further review if the budget or research project as described in the pre-proposal/pre-application differs significantly from the full proposal/application.

Proposals/Applications must be submitted by the Authorized Organizational Representative through Grants.gov (www.grants.gov). For synopsis details, full BAA, and proposal/application package including instructions, go to http://www.grants.gov/web/grants/search-grants.html and enter Funding Opportunity Number W81XWH-16-R-BAA1 under "Basic Search Criteria."

Appendix 24: International Meeting for Simulation in Healthcare (IMSH) 2016 Agenda, Summary, & Presentation

International Meeting for Simulation in Healthcare (IMSH) 2016
January 18, 2016
Department of Defense Special Session – Program Schedule

1300-1305	SSiH Welcome and Introduction (Dayna Downing; Gerald R. Moses)
1305-1330	Current Projects & Future Vision (K. Kunkler)
1330-1400	Research Presentations (15 min/presentation): MODERATOR: K. Kunkler 1. Development of Direct Observation and Automated Assessment Tools for Multiple-Casualty Scenarios (J. Lopreiato) 2. Autonomous Mentoring Systems for Procedural Skill Acquisition and Assessment (G. Miller)
1400-1415	BREAK
1415-1515	Skills Decay Research Presentations (15 min/presentation): MODERATORS: K. KUNKLER; R. PEREZ 1. Skill Degradation Evaluation Toolkit for Eliminating Competency-loss Trends (Skill-DETECT) (E. Baker) 2. Psycho-Motor and Error Enabled Simulations: Modeling Vulnerable Skills in the Pre-Mastery Phase (C. Pugh) 3. Use of Performance Measures to Evaluate, Document Competence and Deterioration of ASSET Surgical Skills (C. MacKenzie) 4. Surgical Skills Training and Assessment Instrument (SUSTAIN) (A. Skinner)
1515-1545	Expert Panel: "Understanding and Minimizing Skill Decay" (Dr. PEREZ LEADS)
1545-1600	BREAK
1600-1715	Research Presentations (15 min/presentation): MODERATOR: H. MAGEE 1. Results of Development and Testing of a Conversational Virtual Patient for Healthcare (T. Talbot) 2. BioGears: Designing and Building an Extensible, Modular, Open Source Human Physiology Engine (J. Webb) 3. Human Tissue Characterization: Comparing Properties of Human vs Simulated Tissues (J. Norfleet) 4. STOMP – Simulation Training for Operational Medicine Providers (M. Spooner) 5. The Development of the Objective Assessment of the Effectiveness of Military Medical Training (A. LaPorta)
1715-1730	Questions/Discussion/Adjourn

Acquisition & Retention of Trauma Surgical Skills

Colin Mackenzie & RASP Group+*

Shock Trauma Anesthesiology Research Center, University of Maryland School of Medicine , Baltimore

- *RASP Group: Stacy Shackelford, Sam Tisherman, Adam Puche , Valerie Shalin, Hegang Chen, Kristy Pugh, Evan Garofalo, Guinevere Granite, George Hagegeorge, Sharon Henry, Mark Bowyer, Nyaradzo Longinaker, Peter Hu, Shiming Yang, Mayur Narayan, Elliot Jessie, Jason Pasley, Babak Sarani, Niki Squires, Amechi Anazodo, Brandon Bonds, William Teeter, Ann Romagnoli , Eric Robinson, Megan Holmes, Alexys Monoson, Joseph Pielago*

- *+ Funding:* U.S. Army Medical Research & Materiel Command W81XWH-13-2-0028.

Appendix 25: Anatomic Knowledge Increases after Participation in ASSET Training

PUGH, Kristy R., Evan M. GAROFALO, Brandon W. BONDS, and Colin F. MACKENZIE. Shock Trauma & Anesthesiology Research Center & Department of Anatomy and Neurobiology. University of Maryland School of Medicine, Baltimore, MD 21201, USA.

INTRODUCTION. Rapid open vascular exposure and repair can be life-saving in both civilian and combat casualty situations and requires mastery of anatomic knowledge, which is generally built by repetition in training. With limitations in training hours, the opportunities for surgeons to gain proficiency in performing open vascular exposures have been reduced. The Advanced Surgical Skills for Exposure in Trauma (ASSET) course is a training program that teaches surgeons over forty key vascular exposures using cadaveric models. We hypothesized that ASSET training improves anatomic knowledge. METHODS. Surgical residents were evaluated by two co-located evaluators on four selected ASSET procedures (axillary, brachial and femoral artery exposure, and lower extremity fasciotomy) using previously validated metrics including anatomic knowledge, landmarks, and skin incision location before and after ASSET training. Pre and post-ASSET scores were compared using paired t-test, $p<0.05$ was significant. SUMMARY. Forty surgical residents with an average of 3.6 clinical years of experience were evaluated. Mean scores for anatomic knowledge were significantly improved after training (Pre= 40.5 ± 13.2 vs. Post= 69.8 ± 10.8; $p<0.00001$.) CONCLUSION. Anatomic knowledge for the exposure of traumatic vascular injuries, where mistakes and delays can have dire consequences, benefits significantly from ASSET training. Supplemental courses, such as ASSET, provide alternative surgical training to allow infrequently performed procedures to be practiced.

(Sponsored by Grant No.W81XWH-13-2-0028 from USAMRMC JCP-1 and CDMRP)

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American Association of Clinical Anatomists

Anatomic knowledge increases after participation in ASSET training

Kristy Pugh, Evan Garofalo, Brandon Bonds and Colin Mackenzie
Shock Trauma & Anesthesiology Research Center and Department of Anatomy and Neurobiology. The University of Maryland School of Medicine, Baltimore, MD 21201, USA

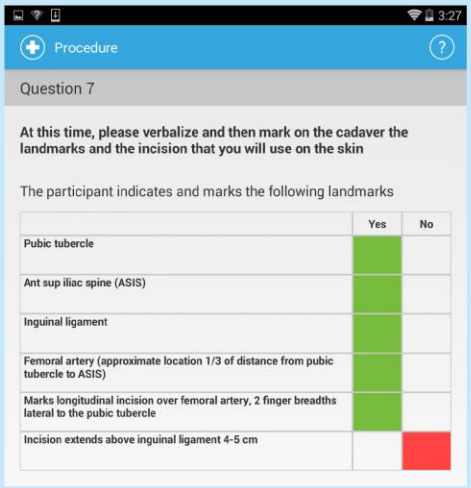
University of Maryland School of Medicine

Introduction

Rapid open vascular exposure and repair can be life-saving in both civilian and combat casualty situations and requires mastery of anatomic knowledge, which is generally built by repetition in training. With limitations in training hours, the opportunities for surgeons to gain proficiency in performing open vascular exposures have been reduced. The Advanced Surgical Skills for Exposure in Trauma (ASSET) course is a training program that teaches surgeons over forty key vascular exposures using cadaveric models. We hypothesized that ASSET training improves anatomic knowledge.

Methods

Surgical residents were evaluated by two co-located evaluators on four selected ASSET procedures (axillary, brachial and femoral artery exposure, and lower extremity fasciotomy) using previously validated metrics including anatomic knowledge, landmarks, and skin incision location before and after ASSET training. Pre and post-ASSET scores were compared using paired t-test, $p<0.05$ was significant.



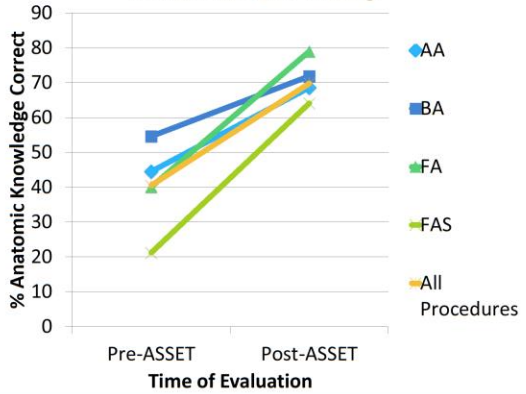
Summary

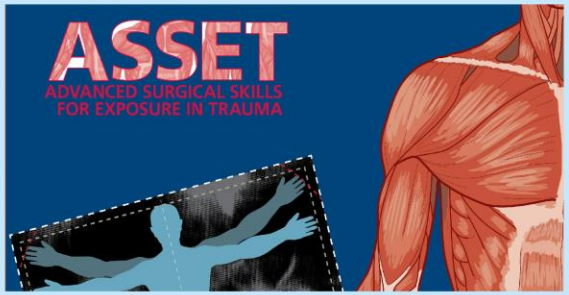
Forty surgical residents with an average of 3.6 clinical years of experience were evaluated. Mean scores for anatomic knowledge were significantly improved after training (Pre= 40.5 ± 13.2 vs. Post= 69.8 ± 10.8; $p<0.00001$.)

Table 1. Percentage of Anatomic Knowledge Pre and Post-ASSET Training

	Pre-ASSET Training	Post-ASSET Training
Axillary Artery	44.5 ± 13.4	68.6 ± 12.9
Brachial Artery	54.6 ± 15.4	71.9 ± 11.4
Femoral Artery	40.1 ± 35.8	79 ± 23.1
Lower Extremity Fasciotomy	21.2 ± 25.7	64.1 ± 23.1
All Procedures	40.5 ± 13.2	69.8 ± 10.8

Figure 1. Percentage of Anatomic Knowledge Pre and Post-ASSET Training





Conclusions

Anatomic knowledge for the exposure of traumatic vascular injuries, where mistakes and delays can have dire consequences, benefits significantly from ASSET training. Supplemental courses, such as ASSET, provide alternative surgical training to allow infrequently performed procedures to be practiced.

(Sponsored by Grant No. W81XWH-13-2-0028 from USAMRMC JCP-1 and CDMRP)

Appendix 26: Using an Individual Procedure Score (IPS) Before and After the ASSET Course Training to Benchmark a Hemorrhage-Control Performance Metric

ORIGINAL REPORTS

Using an Individual Procedure Score Before and After the Advanced Surgical Skills Exposure for Trauma Course Training to Benchmark a Hemorrhage-Control Performance Metric☆,☆☆

Colin F. Mackenzie, MBChB,[*,†] *Evan Garofalo, PhD,*[*,‡] *Stacy Shackelford, MD, FACS,*[§] *Valerie Shalin, PhD,*[‖] *Kristy Pugh, MS,*[*] *Hegang Chen, PhD,*[¶] *Adam Puche, PhD,*[‡] *Jason Pasley, DO, FACS,*[§] *Babak Sarani, MD, FACS, Sharon Henry, MD, FACS,*[**] *and Mark Bowyer, MD, FACS*[††]

[*]Shock, Trauma and Anesthesiology Research Center, University of Maryland School of Medicine, Baltimore, Maryland; [†]Department of Anesthesiology, University of Maryland School of Medicine, Baltimore, Maryland; [‡]Department of Anatomy and Neurobiology, University of Maryland School of Medicine, Baltimore, Maryland; [§]US Airforce Center for the Sustainment of Trauma and Readiness Skills, Baltimore, Maryland; [‖]Department of Psychology, Wright State University, Dayton, Ohio; [¶]Department of Epidemiology, University of Maryland School of Medicine, Baltimore, Maryland; Department of Surgery, George Washington University School of Medicine, Washington, District of Columbia; [**]Department of Surgery, University of Maryland School of Medicine, Baltimore, Maryland; and [††]Department of Surgery, Uniformed Services University of the Health Sciences, Bethesda, Maryland

OBJECTIVE: Test with an individual procedure score (IPS) to assess whether an unpreserved cadaver trauma training course, including upper and lower limb vascular exposure, improves correct identification of surgical landmarks, underlying anatomy, and shortens time to vascular control.

DESIGN: Prospective study of performance of 3 vascular exposure and control procedures (axillary, brachial, and femoral arteries) using IPS metrics by 2 colocated and trained evaluators before and after training with the Advanced Surgical Skills Exposure for Trauma (ASSET) course. IPS, including identification of anatomical landmarks, incisions, underlying structures, and time to completion of each procedure was compared before and after training using repeated measurement models.

SETTING: Audio-video instrumented cadaver laboratory at University of Maryland School of Medicine.

PARTICIPANTS: A total of 41 second to sixth year surgical residents from surgical programs throughout Mid-Atlantic States who had not previously taken the ASSET course were enrolled, 40 completed the pre- and post-ASSET performance evaluations.

RESULTS: After ASSET training, all components of IPS increased and time shortened for each of the 3 artery exposures. Procedure steps performed correctly increased 57%, anatomical knowledge increased 43% and skin incision to passage of a vessel loop twice around the correct vessel decreased by a mean of 2.5 minutes. An overall vascular trauma readiness index, a comprehensive IPS score for 3 procedures increased 28% with ASSET Training.

CONCLUSIONS: Improved knowledge of surface landmarks and underlying anatomy is associated with increased

☆The article was presented at the Surgical Education Week, April 21-25, 2015, Seattle, WA, and has not been published nor is it under consideration to for publication elsewhere.

☆☆Disclaimer: This research and development project was conducted by the University of Maryland, School of Medicine and was made possible by a cooperative agreement that was awarded and administered by the U.S. Army Medical Research and Materiel Command (USAMRMC) and the Telemedicine and Advanced Technology Research Center (TATRC) at Fort Detrick, MD, under Contract no. W81XWH-13-2-0028. The views, opinions, and findings contained in this publication are those of the authors and do not necessarily reflect the views of the Department of Defense and should not be construed as an official Department of Defense position, policy, or decision unless so designated by other documentation. No official endorsement should be made.

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Appendix 27: How Successful is ASSET at Training Residents in Lower Extremity Fasciotomy Compared to Trauma Surgeons

Evan M Garofalo, PhD[1], Mark Bowyer, MD[2], Stacy Shackelford, MD[3], Valerie Shalin, PhD[4], Kristy Pugh, MS[1], Hegang Chen, PhD[1], George Hagegeorge[1], Babak Sarani, MD[5], Jason Pasley, DO[3], Sharon Henry, MD[1], Colin Mackenzie, MBChB[1]

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[8]Department of Surgery, University of Maryland School of Medicine

Acquiring and maintaining combat casualty specific surgical skills is challenging for military and civilian surgeons. Due to multiple factors, the cases of major vascular trauma reported by graduating chief surgeons in the last decade have reduced by approximately half and the average cases reported for lower extremity fasciotomy (FAS) is 1.2. However, specific skill training programs have been developed to supplement gaps in training opportunities. One such course is the Advanced Surgical Skills Exposure for Trauma (ASSET) course, created to fill this training capability gap and includes a fasciotomy module. Incomplete or delayed decompression has contributed to loss of life and limb in the current conflicts. Here we hypothesize that significantly improved post-training skills in the performance of lower extremity fasciotomy will show evidence of degradation through time without further practice.

Methods: We evaluated the performance of lower extremity FAS with the same objective procedural, knowledge, and subjective psychomotor skills metrics for a) third to sixth year surgical residents before and after ASSET training (n=39); b) current skill in surgeon trained 2-5 years previously (n=11); and c) expert trauma surgeons (n=8). The objective assessment is a case-based scenario with checklists for technical and non-technical skill components including: knowledge (diagnostic/management, anatomical including surface landmarks, incision placement, and structure identification), procedural steps, technical skills (subjective psychomotor tissue handling) and procedure time. Scores were calculated for each component and as a composite Individual Procedure Score (IPS). Assessments were conducted by two co-located trained evaluators on unpreserved cadavers. Performance evaluations were compared before and after ASSET and between surgeon groups using repeated measures ANOVA.

Results: ASSET training significantly improved performance in surgical residents for all measures except time (all ANOVAs $p<0.0006$). The average number of compartments successfully decompressed increase from 1 to 3 while the duration of surgery increased by 30 seconds. IPS improved by 34% (48.7-65.3; $p<0.00001$). Most improved measures were a 90.5% (31.9-60.8; $p<0.00001$) increase in procedural steps, a 200% (21.2-64.1; $p<0.00001$) increase in anatomic knowledge and a 31.4% (57.3-75.3; $p<0.00001$) improvement in technical skills. Post ASSET training, the surgical resident performance was comparable to that of experts, three of whom failed to decompress at least 1 of 4 compartments (average 3.3 compartments decompressed). In comparison to post ASSET-trained residents, surgeons evaluated 2-5 years after training show overall degradation (IPS: -3%; 65.3-63.1), decrease in anatomic knowledge (-15.7%; 64.1-54), procedural steps (-5.9%; 60.8-57.2) with fewer decompressed compartments (mean 2.7) and an increase in surgical time (+2 min).

Conclusions: Anatomical knowledge is a critical feature of successful decompression of the four compartments of the leg. Anatomical knowledge and the ability to identify landmarks and structures showed the highest amount of score degradation 2-5 years after training. The 1 day ASSET course was highly impactful for improving surgical skills to compensate for the decreasing on-the-job training during residency. These results also show the need for refreshing or just-in-time re-training the knowledge and skills acquired from supplementary courses.
Supported by W81XWH-13-2-0028 from USAMRMC JCP-1 and CDMRP.

Learning Objectives

1: Supplementary surgical skills training significantly improves performance competency.

2: Knowledge of anatomical structures and surface landmarks are critical for successful 4 compartment lower extremity fasciotomy.

3: Within 5 years of training, competency in performing a 4 compartment lower extremity fasciotomy declines. This indicates the need for periodic skills refreshing.

Appendix 28: Which Combat Surgical Skills Degrade after Training?

Stacy Shackelford[1], Evan Garofalo[2], Valerie Shalin[3], Kristy Pugh[4], Hegang Chen[5], George Hagegeorge[4], Jason Pasley[1], Sharon Henry[6], Mark Bowyer[7], Colin Mackenzie[4].

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[2]Department of Anatomy and Neurobiology, University of Maryland School of Medicine
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[7]The Norman M. Rich Department of Surgery, Uniformed Services University of Health Sciences

INTRODUCTION: Bleeding is the leading cause of early preventable death in military and civilian casualties. Trauma surgeons must maintain proficiency in the surgical exposure and control of major blood vessels. The ability to objectively measure durability and decay of such combat-specific surgical skills is crucial to training and maintaining casualty care teams in a state of readiness. We hypothesized measurable categories of combat surgical skill degradation occurring 2 or more years after training in the absence of direct practice.

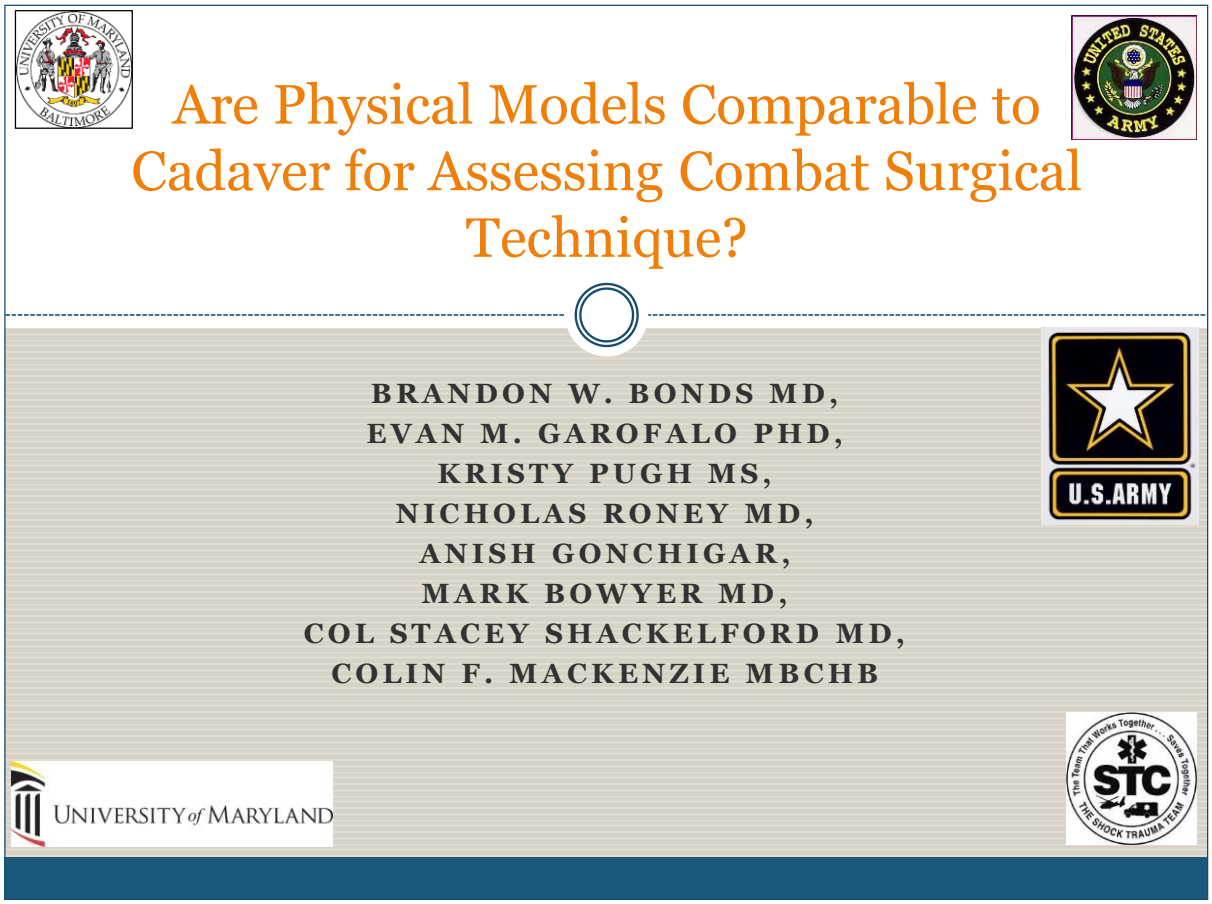
METHODS: We evaluated individual surgeon performance within 2 weeks of completing the Advanced Surgical Skills for Exposure in Trauma (ASSET) course in 39 fourth and fifth year surgical residents and compared these surgeons' performance to that of 10 surgeons ASSET-trained 2-5 years ago and to 8 expert trauma surgeons in practice an average of 16.1 +/- 10.8 years. All surgeons were evaluated with a case-based scenario and evaluation script while performing the same 4 procedures (axillary, brachial, femoral artery exposure and lower extremity fasciotomy) on unpreserved cadavers. Two co-located trained evaluators conducted evaluation. Performance measure included previously validated technical and non-technical skills metrics obtained by checklists, and global ratings for these 4 procedures. Individual procedure scores for each procedure and a composite score for all four procedures, termed trauma readiness index (TRI) were compared between immediately post-ASSET versus ASSET-trained 2-5 years ago and experts. Skill subtype categories included overall knowledge, anatomic knowledge, patient management knowledge, technical skills, and procedural steps to determine possible retraining needs.

RESULTS: The performance of expert surgeons was significantly better than all other groups (TRI expert=68, $p<0.00001$). For 39 residents, mean TRI scores improved significantly after ASSET training (TRI pre=46, TRI post=61, $p<0.00001$), and scores decreased slightly for surgeons ASSET-trained 2-5 years ago (TRI=57, $p>0.05$). The anatomic knowledge score for surgeons trained 3 to 4 years ago was lower than residents after ASSET training ($p<0.00001$);

there was also a trend for decreased procedural steps scores ($p>0.02$). Patient management knowledge and technical skills did not decline.

CONCLUSION: Relative to performance immediately after ASSET training, performance of important combat surgical procedures degraded significantly 2-5 years later. Relative to recently trained residents, practicing surgeons who received ASSET training 2-5 years ago yielded significantly lower scores for anatomic knowledge, with a trend toward lower procedural step scores. This suggests that previously trained surgeons in active surgical practice would benefit from a trauma-specific skills refresher course that focuses on review of anatomy and procedure specific steps, rather than patient management or surgical technical skills. Commercial pilots must pass semiannual evaluations on full-mission flight simulators to maintain licensure. Surgeons have no such operative skills re-evaluation requirement. This study shows that re-training of surgeons is needed in rarely performed combat casualty surgical skills within a minimum of two years, but the optimal timing and method of refreshing these skills and preventing degradation requires assessment. Supported by W81XWH-13-2-0028 from USAMRMC JCP-1 and CDMRP.

Appendix 29: Are Physical Model Assessments Comparable to Cadaver for Combat Surgical Technique?



Appendix 30: Perception Does Not Equal Reality for Resident Vascular Trauma Skills

Mark W. Bowyer, MD,[a,*] Stacy A. Shackelford, MD,[b] Evan Garofalo, PhD,[c] Kristy Pugh, MS,[d] and Colin F. Mackenzie, MBChB[d]

[a] The Norman M. Rich Department of Surgery, Uniformed Services University of the Health Sciences, Bethesda, Maryland
[b] USAF Center for Sustainment of Trauma and Readiness Skills, R Adams Cowley Shock Trauma Center, University of Maryland, Baltimore, Maryland
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[d] Shock Trauma Anesthesiology Research Center, University of Maryland School of Medicine, Baltimore, Maryland

Background: Experience with the management of vascular trauma by senior surgical residents is increasingly limited. When queried about their understanding of anatomy and ability to perform specific vascular exposures, residents express a moderately high level of confidence. We hypothesized that this perception does not equal reality.

Methods: A total of 42 senior surgical residents participating in an ongoing validation study of the Advanced Surgical Skills for Exposures in Trauma course were asked to self-assess their baseline (pre-course) confidence of their understanding of the anatomy required to perform and their ability to perform exposure and control of the axillary, brachial, and femoral arteries, as well as lower extremity fasciotomy using a 5-point Likert scale. Residents then performed the four procedures on a fresh cadaver model and were scored in real time by experts using a global assessment of anatomic knowledge and readiness to perform." The Student t-test was used with a set at $P < 0.05$.

Results: Residents consistently rated their understanding of anatomy and their ability to perform the procedures significantly higher than expert evaluator ultimately scored them. Evaluators also deemed that residents would be unable to perform without help 65%e86% of the time.

Conclusions: Senior residents are ill-prepared to perform the procedures studied and have an unwarranted confidence in their knowledge and abilities. Perception clearly does not equal reality in preparing these trainees to perform as advertised. The low global scores for anatomy and performance should be a wake-up call for surgical educators prompting curricular reform and evaluation.

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journal homepage: www.JournalofSurgicalResearch.com

Perception does not equal reality for resident vascular trauma skills

Mark W. Bowyer, MD,[a,*] Stacy A. Shackelford, MD,[b] Evan Garofalo, PhD,[c] Kristy Pugh, MS,[d] and Colin F. Mackenzie, MBChB[d]

[a] The Norman M. Rich Department of Surgery, Uniformed Services University of the Health Sciences, Bethesda, Maryland

[b] USAF Center for Sustainment of Trauma and Readiness Skills, R Adams Cowley Shock Trauma Center, University of Maryland, Baltimore, Maryland

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Anatomical knowledge

ABSTRACT

Background: Experience with the management of vascular trauma by senior surgical residents is increasingly limited. When queried about their understanding of anatomy and ability to perform specific vascular exposures, residents express a moderately high level of confidence. We hypothesized that this perception does not equal reality.

Methods: A total of 42 senior surgical residents participating in an ongoing validation study of the Advanced Surgical Skills for Exposures in Trauma course were asked to self-assess their baseline (precourse) confidence of their understanding of the anatomy required to perform and their ability to perform exposure and control of the axillary, brachial, and femoral arteries, as well as lower extremity fasciotomy using a 5-point Likert scale. Residents then performed the four procedures on a fresh cadaver model and were scored in real time by experts using a global assessment of anatomic knowledge and readiness to perform." The Student *t*-test was used with α set at $P < 0.05$.

Results: Residents consistently rated their understanding of anatomy and their ability to perform the procedures significantly higher than expert evaluator ultimately scored them. Evaluators also deemed that residents would be unable to perform without help 65%–86% of the time.

Conclusions: Senior residents are ill-prepared to perform the procedures studied and have an unwarranted confidence in their knowledge and abilities. Perception clearly does not equal reality in preparing these trainees to perform as advertized. The low global scores for anatomy and performance should be a wake-up call for surgical educators prompting curricular reform and evaluation.

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1. Introduction

Traumatic injury continues to be a leading cause of worldwide morbidity and mortality [1,2]. Rapid identification and control of bleeding blood vessels are paramount to survival. Additionally, the ability to perform limb-saving skills such as extremity fasciotomy is vital to optimal outcomes. It is therefore vital that surgical trainees be proficient in the management of

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Appendix 31: Sensor-Free Computer-Vision Hand-Motion Entropy and Video-Analysis of Technical Performance during Open Surgery: Proof of Concept Report of Methodology and Analysis

Sensor-free Computer-Vision hand-motion entropy and video-analysis of technical performance during open surgery: proof of concept report of methodology and analysis

Colin F Mackenzie, [1,3] Darcy Watts, [1] Rajan Patel,[1] Shiming Yang,[1,3] George Hagegeorge, [1] Evan Garofalo,[2,6] Peter F Hu,[1,3,4,5] Adam Puche;[2] Kristy Pugh, [1] Guinevere Granite, [1,2] Lynn G Stansbury,[1] Stacy Shackelford,[4, 5,8] Samuel Tisherman.[4], [5] Valerie Shalin;[7]
[1]Shock Trauma Anesthesiology Research Center; [2] University of Maryland School of Medicine Departments of Anatomy and Neurobiology, [3]Anesthesiology, and [4] Surgery; [5] R Adams Cowley Shock Trauma Center, University of Maryland Medical Center; [6] University of Arizona , Department of Anatomy, Phoenix Arizona, [7] Wright State University Department of Psychology, Dayton Ohio [8] US Airforce Center for the Sustainment of Trauma and Readiness Skills, Baltimore.

Domains such as piloting, driving or laparoscopic surgery support the collection and analysis of motor control data because human action is executed through instruments. However, domains lacking such instrumentation, such as conventional surgery, cannot exploit instrument-dependent data collection methods. Compensatory approaches employing hand-motion sensors risk task interference and complicate performance analysis. Standard observational judgment is costly and logistically challenging. We employ computer vision (CV) hand motion analysis, video and Shannon Joint Entropy analysis to demonstrate the potential for a partially automated evaluation of surgical technical performance. Color coded gloves and marked surgical hand-tools support a video-based approach to performance evaluation. We demonstrate the promise of this approach for discriminating between expert trauma surgeons, surgical residents and anatomists performing axillary artery exposure and control (AA) on fresh cadavers, and correlate the results with an independently validated observational approach (IPS) to surgical skill evaluation. Hand motion analysis techniques, which were congruent with IPS evaluations, can discriminate levels of surgical skill and training.

Background:

Skilled motor behavior is key to task success in many domains, such as aviation and driving. But in these example domains, instruments mediate behavior, facilitating the collection and analysis of motor behavior. In contrast, surgical skill is not necessarily executed using instruments that facilitate data collection. This challenges the evaluation of surgical competence, for example of surgical residents. Time-consuming observational methods are logistically challenging, requiring the co-location of evaluators and candidates, and may include evaluator biases. Efforts have been made to standardize surgical trainee evaluations and eliminate bias (Martin et al., 1997). However, these observation-based approaches still suffer from logistical challenge.

Hand-motion analysis has potential as an unbiased, accurate, and cost-effective means to evaluate surgeon technical performance. The elements of manual dexterity on which surgical skill depends have been increasingly well documented over the last decade and are related to levels of experience (Ahmidi et al., 2015; D'Angelo et al., 2015; Datta et al., 2001; Datta et al., 2006; Overby & Watson, 2014). However, these studies rely on synthetic models or partial tasks to simplify the hand motion analysis (Watson, 2014) or focus on endoscopic or specialized environments. (Ahmidi et al., 2015; Watson, 2014) Few studies evaluate open surgical procedures because capturing hand movement in this setting is more complex. Open surgical procedures vary widely, requiring assessment methods that allow for freedom of hand and instrument movement. Ideally, these methods should be sensor-free to avoid interference with hand motion and surgical performance.

The combination of kinematic data collection and analysis, and video surgical gesture-recognition has potential to address these requirements, but exploration has been limited to date to laparoscopic procedures.(Dosis et al., 2005). Dynamic systems theory of motor development emphasizes a reduction in variability as part of the learning process; optimal movement variability balances the benefits of rigid control and randomness of movement, thus, a complexity measurement might be expected to differ during training. (Mackay, 2003) Shannon Joint Entropy has been used to summarize the systematic information conveyed by bimanual hand movements, using computer vision (CV) algorithms derived from measurement of frequency, direction, and speed of movement changes. (Watson, 2012; Mackay, 2003) Entropy should decrease with hand motion efficiency and has been used to analyze hand movements in training models of suturing (Watson, 2012) but not in open surgery.

We conduct entropy analysis of surgical skill with modest modifications of the task. A panel of trauma experts was consulted for assistance in the development of the procedural analyses as previously described (Mackenzie et al., 2015; Shackelford et al., 2015) to provide metrics that might differentiate between novice and experienced surgeons. Other possible hand-motion metrics were obtained from review of the existing literature (Ahmidi et al., 2015; Overby & Watson, 2014). Different glove colors for each hand support the use of CV algorithms without requiring special hand sensors. Our environment provides numerous measures of skilled motor behavior, including smoothness of movement, velocity and acceleration, path length of the hand, idle time, and bimanual dexterity. To examine the variability of measures with respect to expertise, we tested participants with likely differences in skill: attending trauma surgeons, surgical residents before and after training in a specific procedure, and Ph.D. anatomists (as a surrogate for anatomically knowledgeable, but inexperienced clinical surgery operators). Furthermore, we associated the measures of skilled motor behavior with our own validated

Appendix 32: Trauma Training Courses for Surgeons and Validation of their Efficacy

Objective: Review the existing literature on trauma training courses. Summarize currently available data on validation of trauma surgical skills training and course benefits.

Design: Literature search of Pubmed systematic review database was conducted identifying systematic reviews of trauma training courses.

Setting: Shock Trauma Anesthesiology Research Center, University of Maryland School of Medicine, US Airforce Center for the Sustainment of Trauma and Readiness Skills, Baltimore, Uniformed Services University of Health Sciences, Bethesda, Maryland.

Results: Multiple surgeon trauma training courses were found that were evaluated with self-reported confidence or in 3 courses with subjective ratings. The benefits of the Advanced Surgical Skills for Exposure in Trauma (ASSET) course have undergone preliminary validation with, objective ratings, checklists, global and self-reported confidence evaluations. No objective skill-durability data have been published for hands-on cadaver or live-tissue hemorrhage control courses. Introductory surgical boot camps for new surgical residents teaching procedural skills are correlated with In-Training exam scores and assist cumulative resident evaluations. There are no controlled clinical trials of Advanced Trauma Life-Support (ATLS) showing that training changes trauma management outcomes or mortality. There are studies showing that ATLS improves organizational and priority approaches and clinical skills for management of multiple trauma patients.

Conclusions: There are a large number of different trauma skills -training courses. Very few have been validated to show benefit with objective metrics. Large variations in duration, resource requirements and cost suggest benefits from standardization of the trauma surgical training component of these courses. A trauma surgical performance benchmark is essential and needed to measure the adequacy and quantitate benefits of surgical training and competence of trauma surgeons.

Key Words: clinical competence, psychomotor performance, hemorrhage control skill, educational measurement instrument, observational evaluation, open vascular surgical procedures, resident education, performance benchmark.

Competencies: Medical Knowledge, Practice Based Learning and Improvement, Systems-Based Practice, Patient Care

Title: Trauma training courses and validation of their efficacy

Authors: Colin F Mackenzie MBChB [1,3], Kristy Pugh MS[1] , Samuel Tisherman MD FACS FCCM[4], Stacy Shackelford MD FACS [5,6], Mark Bowyer MD FACS[6]

Affiliations: Shock Trauma Anesthesiology Research Center [1], Departments of Anatomy and Neurobiology[2], Anesthesiology[3], Surgery[4] , University of Maryland School of Medicine, US Air Force Center for the Sustainment of Trauma and Readiness Skills, Baltimore[5], and Department of Surgery, Uniformed Services University of Health Sciences and Walter Reed National Military Medical Center, Bethesda, Maryland[6]

Conflict of interest: The authors report no conflicts of interest.

Affirmation: The manuscript has not been published nor is it under consideration to published elsewhere.

Sources of support: U.S. Army Medical Research & Materiel Command Contract Number: W81XWH-13-2-0028

Disclaimer: This research and development project was conducted by the University of Maryland, School of Medicine and was made possible by a cooperative agreement which was awarded and administered by the U.S. Army Medical Research & Materiel Command (USAMRMC) and the Telemedicine & Advanced Technology Research Center (TATRC) at Fort Detrick, MD under Contract Number: W81XWH-13-2-0028.The views, opinions and/or findings contained in this publication are those of the authors and do not necessarily reflect the views of the Department of Defense and should not be construed as an official DoD position, policy or decision unless so designated by other documentation. No official endorsement should be made.

Appendix 33: Performance of Combat Surgical Skills before and after ASSET training

Performance of Combat Surgical Skills before and after ASSET training

Colin Mackenzie, Evan Garofalo, Stacy Shackelford, Kristy Pugh, Valerie Shalin, Hegang Chen, George Hagegeorge, Shiming Yang, Mayur Narayan, Elliot Jesse, Jason Pasley, Sharon Henry , Mark Bowyer.

Shock Trauma, Anesthesia, Research Center, Departments Anesthesiology, Anatomy, Epidemiology and Surgery, University of Maryland School of Medicine, Wright State University, Uniformed Services Health Sciences University, and USAF C-STARS , Baltimore

Funded by US Army Medical Research and Materiel Command: Grant #W81XWH-13-20028

Military Health System Research Symposium (MHSRS)

Appendix 34: IRB Approval Letter 2015

University of Maryland, Baltimore
Institutional Review Board (IRB)
Phone: (410) 706-5037
Fax: (410) 706-4189
Email: hrpo@som.umaryland.edu

APPROVAL OF RESEARCH NOTIFICATION

Date: August 4, 2015

To: Colin Mackenzie
RE: HM-HP-00054443-6
Protocol Version and ID #: N/A
Type of Submission: Modification
Type of IRB Review: Expedited
Modification request dated: 7/22/2015

Modification Approval Date: 8/4/2015
Approval for this project is valid until 11/16/2015

This is to certify that the University of Maryland, Baltimore (UMB) Institutional Review Board (IRB) approved the above referenced modification request for the protocol entitled, "*Use of performance measures to evaluate, document competence and deterioration of ASSET surgical skills*".

The IRB approved this modification via expedited review pursuant to Federal regulations 45 CFR 46.110(b)(2)/21 CFR 56.110(b)(2).

The IRB made the following determinations regarding this submission:
- Written informed consent is required. Only the valid IRB-approved informed consent form(s) in CICERO can be used.

Below is a list of the documents attached to your application that have been approved:
Eligibility Checklist for HP-00054443_3 v1-10-2014-1389391163858
ASSET proposal
Study Timeline
Uniformed Services University of Health Sciences
JSURG_1155 Proof.pdf
Script of Interview.docx
Patel CITI certification 2015.pdf
Robinson Citi certificate.pdf
Robinson Citi certificate.pdf
Watts_Citi certificate.pdf
Teeter_citiCompletionReport1787049_2.pdf
tisherman citi courses 1-12-15.pdf
Granite CITI.pdf

In conducting this research you are required to follow the requirements listed in the INVESTIGATOR MANUAL. Investigators are reminded that the IRB must be notified of any changes in the study. In addition, the PI is responsible for ensuring prompt reporting to the IRB of proposed changes in a research activity, and for ensuring that such changes in approved research, during the period for which IRB approval has already been given, may not

Appendix 35: Request for Statement of Work Modifications September 2015

UNIVERSITY of MARYLAND
SCHOOL OF MEDICINE
SHOCK, TRAUMA AND ANESTHESIOLOGY
RESEARCH CENTER

COLIN F. MACKENZIE
Professor Anesthesiology
Associate Professor Physiology

[illegible]

September 2015

I request consideration of three changes/modifications to the Statement of Work (SOW) for **W81XWH-13-2-008**

"*Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposure for Trauma (ASSET) Surgical Skills*". The Title was abbreviated as Retention and Assessment of Surgical Performance (RASP)

Principal Investigator: Dr. Colin Mackenzie, University of Maryland, Baltimore (UMB).

A. Request approval for 3 Changes/Modifications to the original SOW

1) Add an additional surgical procedure to avoid "learning bias". For the 40 surgeons whose performance we have evaluated before and within 2 weeks of ASET training (see paper attached) we are further evaluating them (as per original SOW) 12 or 18 months after training to assess skill retention. However, there is a "training bias" with this methodology in that the surgeon gains knowledge and improves performance because of repeated testing on the same 4 procedures and the debrief that occurs each time. In the requested modification to the SOW, we will add evaluation of an additional further procedure, carotid artery exposure (CAE) and control of common internal and external carotid artery, to the 12 or 18 month evaluations. Because this procedure was taught on the ASSET course but not evaluated either before or after training, this evaluation will be a true "skill degradation" since ASSET Training. We do also collect surgical case logs from each surgeon, so we can determine if the surgeon performed any carotid exposure procedures in the interval between post – ASSET training evaluation and skill retention evaluation performed 12 or 18 months later. There is no cost for this modification.

2) Add evaluation of a cohort of expert practicing trauma attending surgeons. We developed the script with input from expert practicing trauma surgeons but we have no experts who were evaluated using the same standardized script while they perform the same procedures as all

Appendix 36: Request for Budget Modification September 2015

UNIVERSITY of MARYLAND
SCHOOL OF MEDICINE
SHOCK TRAUMA AND ANESTHESIOLOGY
RESEARCH CENTER

COLIN F. MACKENZIE
Professor Anesthesiology
Associate Professor Physiology

[redacted]

September 2015

I request consideration of modifications to the Budget for **W81XWH-13-2-008**

"*Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposure for Trauma (ASSET) Surgical Skills*". The Title was abbreviated as Retention and Assessment of Surgical Performance (RASP)

Principal Investigator: Dr. Colin Mackenzie, University of Maryland, Baltimore (UMB).

Request for Modifications to the Budget

Personnel

1) Recruitment and hiring of replacement for Surgeon COL Stacy Shackelford with potential candidate Dr Bill Teeter. Dr Teeter , a surgeon at the University of Maryland will be trained to assist with video analysis and help with conduct of the procedures in the Anatomy Board and evaluate enrolled surgeons. COL Shackelford will take up duties at Institute Surgical Research in San Antonio Tx on July 1st. Budget for including Dr Teeter at 25 % effort July 1st to the end of the project February 14th 2016 to replace COL Stacy Shackelford . Total cost between July 1, 2015 & February 14, 2016 at 25% for Dr. Teeter = $10,332 (Salary $8,266 Fringe $2,066)
2) Recruitment and hiring of replacement for Evan Garofalo PhD anatomist with potential candidate Guinevere Granite PhD anatomist. On June 15th 2015, Dr Garofalo (Research Coordinator and Co-Investigator) moved to a Faculty position at University of Arizona School of Medicine Department of Anatomy starting July 1st. No Cost to support an Anatomist to replace Dr Garofalo
3) Increased effort for Principal Investigator during transition when COL Shackelford left because request to obtain administrative support was not approved. The Principal Investigator has had to take on a lot of unexpected additional work effort during this personnel transition including: a) Processing of IRB renewals to make requests for addition of evaluators and investigators to replace those leaving and to add their

Appendix 37: Office of Naval Research Modified Pre-Proposal "Autonomous Analysis for Technical Performance of Combat Surgical Skills"

WHITE PAPER
BAA Number ONRBAA15-001

Project Title: Autonomous Analysis for Technical Performance of Combat Surgical Skills.

Principal Investigator (PI): Adam Puche PhD (Co-PI's) Valerie Shalin PhD, Shiming Yang PhD

Co-Investigators: Sam Tisherman MD FACS. Col. Stacy Shackelford MD FACS, Maj. Jason Pasley DO FACS, Mark Bowyer MD FACS, Hegang Chen PhD, Peter Hu PhD. Consultants: Colin F Mackenzie MD, Nick Sevdalis PhD.

Contact:

Adam C. Puche, Ph.D.

Associate Professor

Dept. Anatomy & Neurobiology

University of Maryland School of Medicine

20 Penn St. Rm., 251 (mailing)

685 West Baltimore St., Rm. 280M (office)

Baltimore, Maryland, 21201

Email: apuche@som.umaryland.edu

Ph. (410) 706 3530

Fax (410) 706 2512

Appendix 38: Full Proposal for BA150077 – "Refreshing Combat Surgical Skills"

TECHNICAL ABSTRACT: Refreshing Combat Surgical Skills

Background: Bleeding remains the commonest cause of preventable combat casualty death, so trauma surgeons must maintain proficiency in surgical exposure and control of major blood vessels. Equally, combat medics must be able to recall and use life-saving skills. The Advanced Surgical Skills Exposures for Trauma (ASSET) course was developed to provide training in exposure and control of major vascular trauma, however, little data exists on how durable this training is or on optimal intervals, methodology, or cost/benefit ratios of refresher training. We propose two related parallel studies to test refresher training to achieve best performance with least cost for: 1) surgeons ASSET-trained 2-6 years ago and 2) medical students (as combat medic surrogates) trained two years previously in selected relevant techniques. We will compare the performance and cost/benefit of a) interval cadaveric practice or video mental rehearsal to b) just-in-time assistance via a Heads-up-Display of procedural-step video clips (HUD) or tele-mentoring (TM) to c) no refresher training.

Hypotheses: 1) significant degradation in performance of vascular control surgical procedures occurs with no refresher; 2) periodic mental rehearsal and/or just-in-time refresher assistance is as effective as cadaveric practice; 3) just-in-time refresher methods like HUD or expert real-time TM improve surgical performance in both surgeons and combat medic surrogates; and 4) HUD will have the best cost/benefit ratio of all of the skills-refresher methods tested. **STUDY 1** tests which of the refresher methods gives best cost/benefit with respect to multiple criteria such as time, equipment, site presence, infrastructure requirements, materials, etc, for ASSET trained surgeons. ***Aim 1.1*** of this study compares two "fixed-time interval" refresher methods, video mental rehearsal or deliberate cadaveric practice. ***Aim 1.2*** compare two "just-in-time" refresher approaches, HUD or TM. **STUDY 2** tests whether Study 1 refresher methods can generalize to other combat trauma care providers. ***Aim 2)*** evaluates STUDY 1 refresher methods in a study group of medical students used as surrogates for combat medics trained in femoral artery exposure. Finally, ***Aim 3)*** evaluates which of "fixed-time interval" or "just-in-time" refreshing skills produces the best surgeon individual procedure scores (IPS), also improves IPS in medical student/medic surrogates, and documents competence in comparison to historic IPS data on experts and just-trained surgeons from our previous study.

Design & methods: STUDY 1: 60 surgeons trained in 4 ASSET procedures 2-6 years ago will have one-year-interval cadaveric practice (n=15) or video mental rehearsal (n= 15) versus just-in-time assist with HUD (n=15) or TM (n =15) without interval refresher intervention, all followed by a multiple choice question (MCQ) test. We will test 3 of the 4 refreshed procedures and add a fourth 'surprise' ASSET procedure, unrehearsed, unpracticed or unassisted, to determine degradation with no refresher intervention. **STUDY 2: 40 1st year medical students will be trained in a single ASSET procedure on a cadaver,** after video mental rehearsal (in 2nd year, n=10), all forty will be assessed in third year on this procedure on a cadaver, using HUD or TM assist or no interval/rehearsal/assist (n = 10 each) followed by the MCQ test, having had (like combat medics) no interval exposure to surgery or practice after training. Using combinations of **STUDIES 1 & 2** we will compare quality of performance outcomes by refresher method to determine if low-cost, just-in-time assistance can compensate for fixed-time interval practice/rehearsal of surgeons or combat medic surrogates.

Data Collection and analysis: Two trained co-located evaluators will conduct evaluations on a mobile wireless custom App using a standardized script, validated IPS metrics and audio/visual recording of all procedures. Testing includes evaluating non-technical and technical skills performance, individual checklists as well as validated IPS metrics, Global Performance Ratings and audio/visual recording of all procedures. Inter-evaluator reliability will be assessed with video review and blinding to refresher method using intra-class correlation coefficients (ICC) (ICC>0.7 = acceptable; >0.8 = good; >0.9 = excellent). Statistical tests for IPS differences include chi-squared for categorical data, t-tests, generalized estimating equations and analysis of covariance to adjust for confounds such as experience.

Relevance: Little data currently exist on methods to minimize surgical skills degradation. This work will provide objective measurement of the durability of combat-injury-relevant surgical skills and important cost/benefit data for maintaining combat care readiness. The skills refresher methods anticipated from these studies will be readily deployable, not require cadavers, and be suitable for both surgeons and combat medics.

Appendix 39: Pre-Proposal BA150808 – "Emergency Refreshing of Combat Surgical Skills"

ARMY Pre Proposal Sept 30th 2015

Project Title: Emergency Refreshing of Combat Surgical Skills.

Principal Investigator (PI): Sam Tisherman MD FACS.

Co-PI's: Adam Puche, PhD Maj Jason Pasley,FACS COL Stacy Shackelford FACS

Co-Investigators: Mark Bowyer FACS , Sharon Henry, FACS Valerie Shalin,PhD Shimimg Yang, PhD Hegang Chen,PhD Peter Hu PhD

Consultants: Colin F Mackenzie MD, Prof Nick Sevdalis PhD

Problem to Be Studied:

Commercial pilots must pass semiannual evaluations on full-mission flight simulators to maintain their licensure. Surgeons have no such operative skills re-evaluation requirement, and the causes and prevention of surgical skills degradation remain largely unexplored. Because civilian surgical practice provides limited opportunities for management of combat-like injuries, cadaveric courses have been developed to train military and civilian trauma surgeons in combat surgical skills. The Advanced Surgical Skills Exposures for Trauma (ASSET) training program, developed by the American College of Surgeons Committee on Trauma and adopted by military pre-deployment training platforms, teaches surgeons how to expose and control major vascular trauma. An ongoing aspect of the program is evaluation of skills deterioration over time. These evaluations include a need to find the best approach to refreshing ASSET skills.

Surgeons deploying to care for combat casualties must be proficient in the exposure and control of major vascular injuries and in fasciotomy. No current standards exist for assessing basic competency in or retention of these skills after training or the surgeon's competency in preparation to care for combat-associated injury. Likewise, there is no current mechanism for assessing the durability or factors in degradation of these skills, particularly after return to peacetime practice, where these skills are unlikely to be used with any frequency. We propose to test two approaches to refresh skills in a cohort of surgeons 3 years and more after ASSET Training when we know that the majority of surgeons have skill degradation as a result of standardized testing using unpreserved cadavers in a previously funded study.

Background: As a result of US Army funding (W81XWH-13-2-0028): Use of Performance Measures to Evaluate, Document Competence and Deterioration of Advanced Surgical Skills Exposure for Trauma (ASSET) Surgical Skills) we developed and validated surgeon performance metrics for evaluating technical and non-technical surgical skills including an individual procedure score (IPS) for performance of 4 ASSET procedures on unpreserved cadavers —exposure of axillary, brachial, and femoral arteries and fasciotomy[6]—included among the 57 procedures taught on the 1 day ASSET course. The IPS metrics include individual checklists as well as validated IPS Likert scales for surgical technical skills metrics and error

Appendix 40: Pre-Proposal BA150077 – "Refreshing Combat Surgical Skills"

Project Title: Refreshing Combat Surgical Skills for Vascular Control.

Principal Investigator (PI): Colin F Mackenzie.

Co-PI: Stacy Shackelford,

Co-Investigators: Mark Bowyer, Sharon Henry, Evan Garofalo, Valerie Shalin, Peter Hu, Shimimg Yang, Jason Pasley

Problem to Be Studied:

Commercial pilots must pass semiannual evaluations on full-mission flight simulators to maintain their licensure. Surgeons have no such operative skills re-evaluation requirement, and the causes and prevention of surgical skills degradation remain largely unexplored. Because civilian surgical practice provides limited opportunities for management of combat-like injuries, cadaveric courses have been developed to train military and civilian trauma surgeons in combat surgical skills. The Advanced Surgical Skills Exposures for Trauma (ASSET) training program, developed by the American College of Surgeons Committee on Trauma and adopted by military pre-deployment training platforms, teaches surgeons how to expose and control major vascular trauma. An ongoing aspect of the program is evaluation of skills retention over time. These evaluations including different approaches to refreshing ASSET skills versus no refreshing.

A range of professional, technical, and social factors have also decreased trauma surgery experience for residents including factors that affect inner city violence, non-surgical options for treatment of solid organ injuries, especially interventional radiological advances, and shortened residency training hours. All have about halved trauma surgery caseloads and experience for graduating chief residents in the last decade, from 60.4 cases in 1999, to 33.5 cases in 2012.[1] This diminished operative experience in trauma is especially true for those surgical skills most relevant to caring for vascular trauma. [2,3,4]. Over the last ten years the mean number of major vascular repairs for trauma (including repair of thoracic vessels abdominal aorta, peripheral and other vascular injuries) done over the course of a residency in general surgery reported by graduating chief residents to the American Board of Surgery decreased from average 5.0 in 2001-2002 to 2.1 in 2010-2011 [1,4]. Significant numbers of trainees have no experience with caring for major vascular trauma. The average number of fasciotomies reported was 1.2. The average number of exposures of the brachial artery reported by chief residents in 2010-2011 was 0.0. This training gap has significant consequences. Inexperience with lower extremity fasciotomy has contributed to loss of life and limb among casualties in the current conflicts due to incomplete or delayed fasciotomies.[5]

Surgeons deploying to care for combat casualties must be proficient in the exposure and control of major vascular injuries and in fasciotomy. No current standards exist for assessing basic competency in or retention of these skills after training or the surgeon's competency in preparation to care for combat-associated injury. Likewise, there is no current mechanism for

Appendix 41: Procedure Case Scripts Used During Surgeon Evaluations

Name of Evaluator: **Date:**

Name of Candidate: **(Circle timing): Pre Post**

1st Trial

Circle type of trial: Cadaver / Model

Case One: Axillary Artery

Case Presentation:

- You are called to the Emergency Department to see a 24 y/o male who was shot during an attempted robbery sustaining a single gunshot wound to the upper anterior lateral Right/Left Chest.
- He was reported to have a large amount of bright red blood at the scene, but is currently not bleeding.
- He is complaining of pain at the site of the wound and inability to move his arm.

[Advance slide to show image of wound]
[Advance slide to continue narrative]

- He is awake and talking with bilateral and equal breath sounds and a BP of 80/60 and a heart rate of 130 after 2 liters of lactated ringers
- There is a single wound as seen with no other obvious trauma and no "exit wound". His hand is cool and pale.

1

Appendix 42: RASP Evaluator Training Handbook & Video

RASP Evaluator Training Handbook
December 2013

Using only small portion of incision space and “Keyhole” Surgery

Appendix 43: ASSET Consent Form

UNIVERSITY of MARYLAND
THE FOUNDING CAMPUS

RESEARCH CONSENT FORM

Protocol Title: Use of performance measures to evaluate, document competence and deterioration of ASSET surgical skills: ASSET Study

Study No.: HP-00054443

Principal Investigator: Colin Mackenzie MD. 410-328-7488
Co Investigators: Mark Bowyer MD, Stacy Shackelford MD, Sharon Henry MD

Sponsor: Department of Defense / TATRC

You are being asked to participate in a research study. Your participation in this study is voluntary and you may ask questions at any time. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. You may keep a copy of this consent form to think about before making your decision

PURPOSE OF STUDY

The purpose of the study is to assess the Advanced Surgical Skills Exposures for Trauma (ASSET) course and ASSET skills retention for 1- 5 years after training.

You are being asked to participate in this ASSET Study either as an expert, a novice (never participated in ASSET training) or as a Senior surgeon who has previously taken a full ASSET course. If you choose not to participate, there will be no loss of benefits to which you are otherwise entitled.

You will be one of 100 total subjects participating in this study being conducted by Dr. Colin Mackenzie and colleagues at Anatomy Board, University of Maryland School of Medicine, Baltimore, in collaboration with the Uniform Services University of Health Sciences (USUHS) Bethesda, Maryland

PROCEDURES

Study staff will provide initial information about the study by e-mail, including copies of the consent form and descriptions of the data to be collected on each participant. If you express interest in participating in the study you will be provided with likely dates the ASSET Study will be conducted. On the day of ASSET Study participation, time will be set aside to discuss the study and the consent process during which all procedures, and alternatives, risks and benefits, associated with participation in ASSET Study will be discussed. You will be encouraged to ask questions at any time during this process and throughout the study.

HP-00054443 UM IRB Approval Date 11/17/2014
Do Not Sign this Form after this Date 11/16/2015

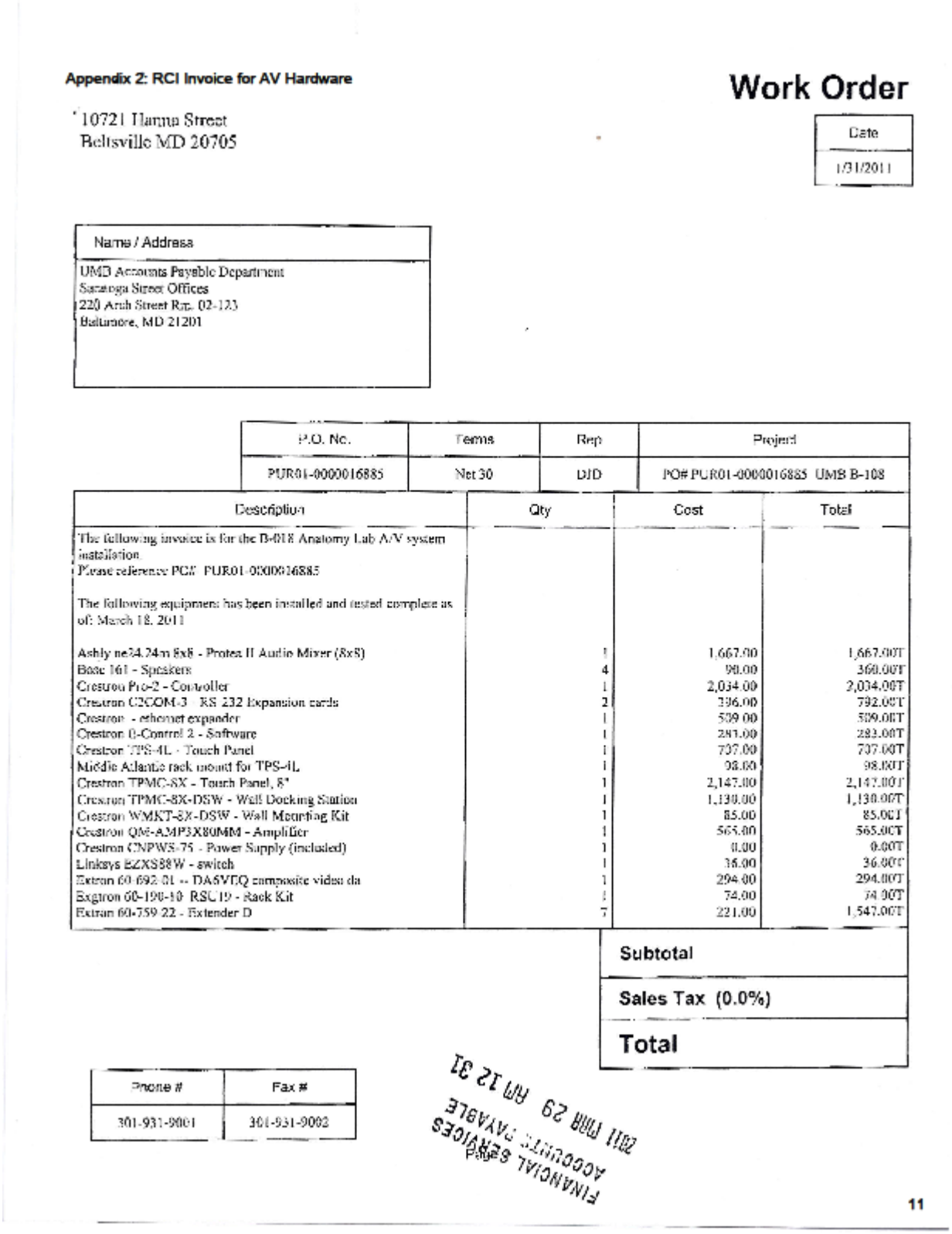
Appendix 44: Kick-Off Meeting Agenda February 14th, 2013

Kick-Off Meeting Agenda February 14th

ASSET Funding Kick-Off Meeting
Thursday, February 14, 2013, 12:30pm – 4:00pm; Executive Board Room HSF II
Final Agenda

12:30	*Check in and light Lunch*
1:00 – 1:15 pm	Introduction Bruce Jarrell, Chief Academic and Research Officer (CARO), Senior Vice President, and Dean of the Graduate School UM Baltimore Tom Scalea, Professor of Surgery, Director Shock Trauma Center
1:15 - 1:30 pm	Medical Simulation Mr Tony Story (via Teleconference) , Telemedicine & Advanced Technology Research Center (TATRC). Armed Forces Simulation Institute for Medicine
1:30 - 1:45 pm	ASSET Overview and Summary Statistics Col (Rtd) Mark Bowyer, MD FACS, Director of Surgical Simulation The Normal M Rich Dept of Surgery Uniformed Services University (USUHS)
1:45 – 2:00 pm	ASSET History at UMB Sharon Henry, MD FACS, UMB
2:00 - 2:15 pm	USAF Military Perspective on ASSET and Study Col Stacy Shackelford, MD FACS, Director C-STARS Baltimore
2:15 - 2:45 pm	Study overview and SOW Colin Mackenzie, PI, UMB / STAR ORC
2:45 – 3:00 pm	Cognitive Task Analysis(via Teleconference) Valerie Shalin, PhD, Wright State University
3:00 – 3:20 pm	*Break*
3:20 – 3:40 pm	Maryland State Anatomy Board

Appendix 45: RCI Invoice for AV Hardware



Appendix 2: RCI Invoice for AV Hardware

Work Order

10721 Hanna Street
Beltsville MD 20705

Date
1/31/2011

Name / Address
UMD Accounts Payable Department Saratoga Street Offices 220 Arch Street Rm. 02-123 Baltimore, MD 21201

P.O. No.	Terms	Rep	Project
PUR01-0000016885	Net 30	DJD	PO# PUR01-0000016885 UMB B-108

Description	Qty	Cost	Total
The following invoice is for the B-018 Anatomy Lab A/V system installation Please reference PO#: PUR01-0000016885 The following equipment has been installed and tested complete as of: March 18, 2011			
Ashly ne34.24m 8x8 - Protea II Audio Mixer (8x8)	1	1,667.00	1,667.00T
Bose 161 - Speakers	4	90.00	360.00T
Crestron Pro-2 - Controller	1	2,034.00	2,034.00T
Crestron C2COM-3 - RS 232 Expansion cards	2	396.00	792.00T
Crestron - ethernet expander	1	509.00	509.00T
Crestron G-Control 2 - Software	1	283.00	283.00T
Crestron TPS-4L - Touch Panel	1	707.00	707.00T
Middle Atlantic rack mount for TPS-4L	1	98.00	98.00T
Crestron TPMC-8X - Touch Panel, 8"	1	2,147.00	2,147.00T
Crestron TPMC-8X-DSW - Wall Docking Station	1	1,130.00	1,130.00T
Crestron WMKT-8X-DSW - Wall Mounting Kit	1	85.00	85.00T
Crestron QM-AMP3X80MM - Amplifier	1	565.00	565.00T
Crestron CNPWS-75 - Power Supply (included)	1	0.00	0.00T
Linksys SLXS88W - switch	1	36.00	36.00T
Extron 60-692-01 -- DA6VDQ composite video da	1	294.00	294.00T
Extron 60-190-10 RSC19 - Rack Kit	1	74.00	74.00T
Extron 60-759-22 - Extender D	7	221.00	1,547.00T
		Subtotal	
		Sales Tax (0.0%)	
		Total	

Phone #	Fax #
301-931-9001	301-931-9002

FINANCIAL SERVICES
ACCOUNTS PAYABLE
2011 MAR 29 AM 12 31

11

Appendix 46: UMB Invoice for TRR System

Appendix 3: UMB invoice for TRR system

Tax Invoice

AlfredHealth

ABN: 27 318 956 319
Alfred Health incorporates The Alfred, Caulfield Hospital and Sandringham Hospital.
Finance Department, The Alfred, PO Box 315, Prahran VIC 3181
Telephone : 03 9076 5442 Fax: 03 9076 2102

Page
1 of 1
Invoice Number
INV00138482
Invoice Date
3-Jul-2013
Reference

UMB Accounts Payable Department
Saratoga Street Offices
220 Arch Street
Rm. 02-123
Baltimore MD 21201
UNITED STATES OF AMERICA

email: accounts.receivable@alfred.org.au

Description	Qty	Rate	Pre GST Amt	GST Amt	Full Amount
sundry income	1	273,405.230	273,405.230	0.00	273,405.23

Purchase Order: PUR01-0000024662
Site & Subject Specific License TRR Software including TRR Algorithm
Designer Tool scripted for ASSET
Redesigned User Interface for TRR/ASSETT
TRR Algorithm Design Training Support
TRR Algorithm Testing
Simulation training and verification
Documentation, Version Control & User Manuals
Systems monitoring and technical support for 3 years
Payable in Australian Dollars $ 273,405.23
(USD$250,000=AUD$273,405.23 at July4th 2013,
USD$1=AUD$1.09362)

Total	**0.00**	**273,405.23**
Payment Received		0.00
Total Payable		273,405.23

To ensure the correct identification, please detach the slip below and return it with your payment.

Payment Terms: 14 Days

Payment From	Invoice Number	Invoice Date	Total Payable
UMB Accounts Payable Department UMB002	INV00138482	3-Jul-2013	273,405.23

Credit Card Number	Expiry Date	Signature	$

Type: Bank Card Master Card VISA Diners Amex

Name on card:

EFT Payment Details
Please ensure that invoice number is quoted and remittance advice is faxed or emailed to the above address
Westpac BSB: 033-079 Account No: 114772

13

Appendix 47: Assessing Surgical Training: a Utility Analysis of the Advanced Surgical Skills for Exposure in Trauma Course

[7]The Norman M. Rich Department of Surgery, Uniformed Services University of Health Sciences

Abstract

Background: Surgical experience with managing traumatic hemorrhage has declined in training programs and in practice. To address this, the American College of Surgeons launched the Advanced Surgical Skills for Exposure in Trauma (ASSET) course in 2010, a human cadaver-based course to review the anatomy, skills and techniques for rapid vascular exposures.

Study design: We compared self-reported confidence of participants (n=523) with surgical tasks (n=47) at baseline and directly after ASSET training to examine the effect of training. Median pre- and post-training self-reported confidence scores were assessed by Wilcoxon matched pairs test, directional change by Freeman-Halton contingency tests, and relative improvement for specific procedures using utility values assigned for each possible combination of pre- and post-training confidence levels.

Results: All surgeons recorded improved confidence in all five anatomic body regions after ASSET training ($p<0.0001$). Following the course, surgeons reported a high confidence level in 78% of the 47 procedures. The body region most improved by ASSET training was the upper limb, with 49% of surgeons improving from low to high confidence (Freeman-Halton 1x3 $p=0.017$). Residents/fellows achieved the greatest improvement in confidence levels. The highest utility value occurred with pelvic

Appendix 48: OEI Invoice for Physical Model Delivery

Appendix 5: OEI invoice for Physical models

Operative Experience, Inc.
500 Principio Parkway West
Suite 900
North East, MD 21901

Invoice

Date	Invoice #
4/1/2013	21

Bill To

University of Maryland
Accounts Payable Dept.
Building/Street Offices
220 Arch St, Rm 02123
Baltimore MD 21201

Ship To

655 W. Baltimore St
BRB Rm. 8-075
Baltimore, Maryland 21201
Attention: Sam T. Chinn

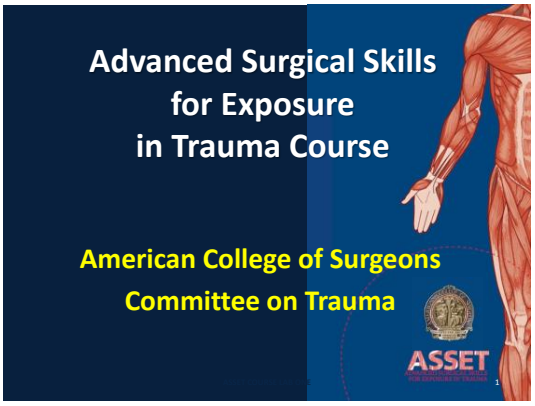
S.O. No.	P.O. No.	Terms	Project
8	[illegible]	[illegible]	

Item	Description	Ordered	Prev. Invoi...	Invoiced	Rate	Amount
Surgical Fasc...	Hyper Realistic Physical model of Human Anatomy: Lower Extremity Leg, as well as Upper Extremity Arm.	100	0	30	800.00	24,000.00
Surgical Arm	Hyper Realistic Physical Model of Human Anatomy: Upper Extremity Arm Due.	100	0	30	800.00	24,000.00
Shipping and ...		5	0	1	200.00	200.00
	Delivery Schedule - April 22, 2013 3 of the 2-part Fasciotomy Leg -May 15, 2013 3 of the 2-part Fasciotomy Leg May 24, 2013 2 of the 2-part Fasciotomy Leg -May 24, 2013 2 Surgical Arms -June 3, 2013 2 of the 2-part Fasciotomy Leg & 28 Surgical Arms.					

Total	$48,200.00
Payments/Credits	20.00
Balance Due	$48,200.00

33

Appendix 49: Evaluation Script Slides and Video Evaluation Sheet



Evaluation Sheet Examples

AXILLARY ARTERY EXPOSURE GLOBAL RATING (circle one):

Overall Understanding of the Evaluation and Treatment of a Patient with a Suspected Axillary Artery Injury:

1	2	3	4	5	UTA*
Core knowledge is poor and there is no evidence of understanding the nuances of evaluation and diagnosis.	Core knowledge is fair with some understanding of the nuances of evaluation and diagnosis.	Core knowledge is good with moderate understanding of the nuances of evaluation and diagnosis.	Core knowledge is very good with thorough understanding of the nuances of evaluation and diagnosis.	Core knowledge is excellent with a superior understanding of the nuances of evaluation and diagnosis.	

Overall Understanding of the Surgical Anatomy of the Axillary Region:

1	2	3	4	5	UTA*
Poor knowledge of the regional anatomy. Unable to identify major structures or their relationships.	Fair knowledge of regional anatomy. Can name some of the major structures and their relationships	Good understanding of the anatomy. Can name most of the major structures and their relationships.	Very good understanding of anatomy. Able to point out all of the major structures and their relationships.	Excellent understanding of the anatomy, including variants. Knows the minutia, Should be teaching anatomy class.	

Technical Skills for Exposing Axillary Artery:

1	2	3	4	5	UTA*
The participant's technical skills were poor with much wasted moves and very poor tissue handling.	The participant demonstrated fair technical skills with some wasted movements and errors in tissue handling	The participant demonstrated good technical skills with occasional wasted movements and errors in tissue handling.	The participant demonstrated very good technical skills with minimal wasted movements and errors in tissue handling.	The participant demonstrated excellent technical skills with no wasted movements and proper respect for tissues.	

This participant is ready to perform exposure and control the Axillary Artery:

1	2	3	4	5	UTA*
Take me to another hospital please!	This participant could do the exposure fine with experienced help, but will struggle if left alone.	The participant might need to look at a text to refresh their memory but will be able to perform the exposure.	This individual will be able to perform the exposure with minimal difficulty in an expeditious fashion.	Absolutely, I hope that this individual is on call if I am injured.	

Overall rating (1-100):

Body Habitus of cadaver (circle): Obese Average Thin

Cadaver Anatomy (circle): Normal Variant

≥ 90 Excellent I hope that this individual is on call if I am injured
80-89 This individual will be able to perform the exposure with minimal difficulty in an expeditious fashion.
70-79 The participant might need to look at a text to refresh their memory but will be able to perform the exposure
60-69 This participant could do the exposure with experienced help, but will struggle if left alone
<60 Take me to another hospital please!

***UTA** (Unable to Assess): The detail for this determination was not possible from the video

100

Appendix 50: Development of a Surgical Skills Assessment Method for Trauma

Stacy Shackelford, MD, FACS, Evan Garofalo, PhD, Megan Holmes, BS, Hegang Chen PhD, Mark Bowyer, MD, FACS , Sharon Henry, MD, FACS, Babak Sarani, MD, FACS, Jason Pasley, MD, Colin Mackenzie, MBChB

Background: With limits on residency training hours and decrease in penetrating trauma nationally, surgical experience with managing traumatic hemorrhage has declined. An objective assessment of surgical skills in trauma would be useful in many training situations, to include course development, residency training, board certification and preparation for military deployment. We hypothesized that performance metrics for trauma surgery can reliably distinguish expert from novice surgeons.

Study Design: We performed a video task-analysis of 10 attending trauma surgeons and 10 general surgery residents during performance of three vascular exposures (axillary, brachial, femoral arteries) and lower extremity fasciotomy. Performance characteristics of expert and novice surgeons were identified and used to develop a technical skills metric score. The score includes completion of specific surgical steps and assessment of surgical technique. Five evaluators scored blinded videos of the four procedures. Interrater reliability was assessed using intraclass correlation coefficient (ICC). Expert and novice scores were compared using Kruskal-Walis test.

Results: Discriminating characteristics with best evaluator ICC between expert and novice technical skills included obtains necessary exposure ($p<0.00001$), performing procedures without unnecessary dissection ($p<0.00001$), proceeds at appropriate pace ($p<0.00001$), and performs procedure with a logical sequence ($p=0.00001$). ICC displayed in table.

Conclusion: A surgical technical skills metric score can discriminate expert from novice performance required to complete four surgical procedures through the use of discriminating performance characteristics that may be useful for objective surgical skill assessment.

	Intraclass Correlation Coefficient			
Technical Skill	**Axillary artery exposure**	**Brachial artery exposure**	**Femoral artery exposure**	**Fasciotomy**
Obtains necessary exposure	0.98	0.92	0.79	0.97
No unnecessary dissection	0.96	0.91	0.96	0.94
Proceeds at appropriate pace	0.97	0.88	0.94	0.97

Performs with logical sequence	0.93	0.87	0.97	0.95

Appendix 51: Video of an Expert Performing the Axillary Artery Exposure

Appendix 51 - Expert Axillary Artery Exposure.wmv

Appendix 52: Updated Script and Powerpoint Slides Used for Evaluations

Name of Evaluator: **Date:**

Name of Candidate: **(Circle timing): Pre Post**

1st Trial

Circle type of trial: Cadaver / Model

Case One: Axillary Artery

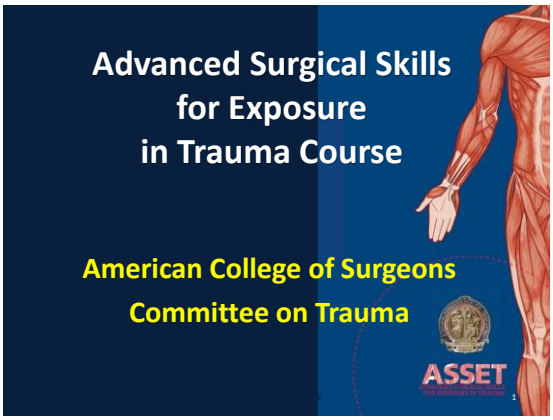
Case Presentation:

- You are called to the Emergency Department to see a 24 y/o male who was shot during an attempted robbery sustaining a single gunshot wound to the upper anterior lateral Right/Left Chest.
- He was reported to have a large amount of bright red blood at the scene, but is currently not bleeding.
- He is complaining of pain at the site of the wound and inability to move his arm.

[Advance slide to show image of wound]
[Advance slide to continue narrative]

- He is awake and talking with bilateral and equal breath sounds and a BP of 80/60 and a heart rate of 130 after 2 liters of lactated ringers
- There is a single wound as seen with no other obvious trauma and no "exit wound". His hand is cool and pale.

1



Appendix 53: Critical Errors in Rarely Performed Procedures 0.5-5 Years After Training Among 85 Surgeons

Colin F Mackenzie, Kristy Pugh, Guinevere Granite, Hegang Chen, Adam Puche, Samuel Tisherman. Shock Trauma Anesthesiology Research, Departments of Epidemiology, Anatomy and Neurobiology, Surgery, University of Maryland School of Medicine, Baltimore

Background: Technical failures in individual clinical skills occur during surgery and are known to increase post-operative morbidity and mortality (1). Graduating general surgery residents have little experience with many procedures needed for trauma, e.g., brachial artery exposures or lower extremity fasciotomy (2). The Advanced Surgical Skills for Exposure in Trauma (ASSET) course was developed to correct this deficit. We hypothesized that the occurrence of critical technical errors (e.g., vessel loop encircled wrong structure) and critical management errors (e.g., life-threatening delays) decrease with training and subsequently increase with post-training interval skill decay. Skill decay in complex procedures occurs widely, including for anesthesiologist's procedural skills (3).

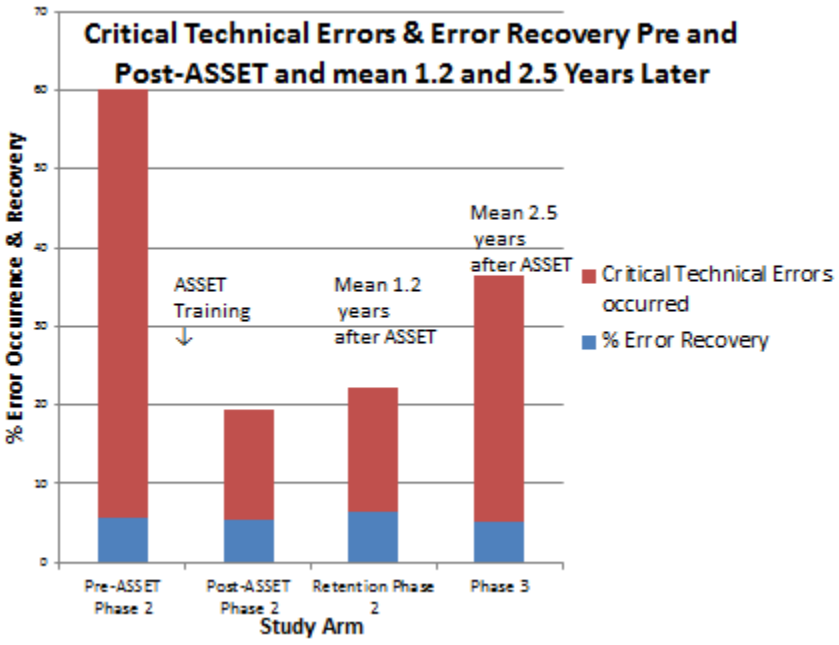
Methods: Surgeons 0.5-5 years after ASSET training were video recorded performing axillary, brachial, and femoral artery exposure and control (encircle with double vessel loop), and a 4 compartment lower extremity fasciotomy (FAS) on unpreserved cadavers. Skills were evaluated by two trained, co-located evaluators with a standardized script and a validated individual procedure score (IPS) metric (4). Linear mixed modelling included: anatomy skills, years and operative experience since training, and cadaver body habitus.

Results: All 4 procedures were performed by 85 surgeons, Group 2: forty 2^{nd} – 6^{th} year residents before and after training and 1-1.5 years later, Group 3: 35 practicing surgeons 2.5 years after training, and 10 Experts (practicing [mean 16 years] as trauma attending surgeons).For vascular procedures, among Group 2 surgeons, 60% critical error rate decreased to 19% ($P< 0.001$) immediately after training, a rate comparable to experts (15%). There was no difference in error rates post-training out to 1-1.5 years (22%). However, Group 3 surgeons error rates increased to 36,5% ($P<0.003$) and error recovery decreased compared to all other surgeons after training (Figure). A similar pattern was observed for FAS. Only 10% of Group 2 surgeons decompressed all four compartments before ASSET, which improved ($p< 0.02$) to 50% post-training comparable to 60% 4 compartment decompression among experts). However, only 35% of Group 3 surgeons decompressed all 4 compartments, fewer ($p <0.03$) than all other surgeons after training. Among Group 3 surgeons, error recovery was lowest ($p<0.05$) for the 3 vascular procedures and less FAS compartments were decompressed mean 2.5 years after training ($p < 0.03$). Four experts failed decompress =/> 1 compartment. Critical errors correlated with IPS measured lack of correct anatomic landmarks and procedural steps, suggesting mitigation efforts may be amenable to focussed training interventions (5).

Conclusion: Occurrence of critical errors improved with training, but skills decay was detectable mean 2.5 years later. Refresher strategies, concentrating on anatomy, are required to minimize skills decay in rarely used procedural skills, even among experts.

References ***(1)*** *N Engl J Med 2013;369:1434-42****.*** ***(2)****Accreditation Council for Graduate Medical Education. Available at:http://www.acgme.org/acgmeweb/Portals/0/PDFs/GSNatData1011.pdf.;* ***(3)*** *J Cont. Educ Health Prof. 32:269–278, 2012;* ***(4)*** *J Surg Educ 2015: 72: 178-1289;* ***(5)*** *Ann Emerg Med. 2003;41:110-120.*

Supported by U.S. Army Medical Research & Materiel Command W81XWH-13-2-0028.



Supporting Data

Table 1: Median Confidence with Surgical Anatomy (Phase II)

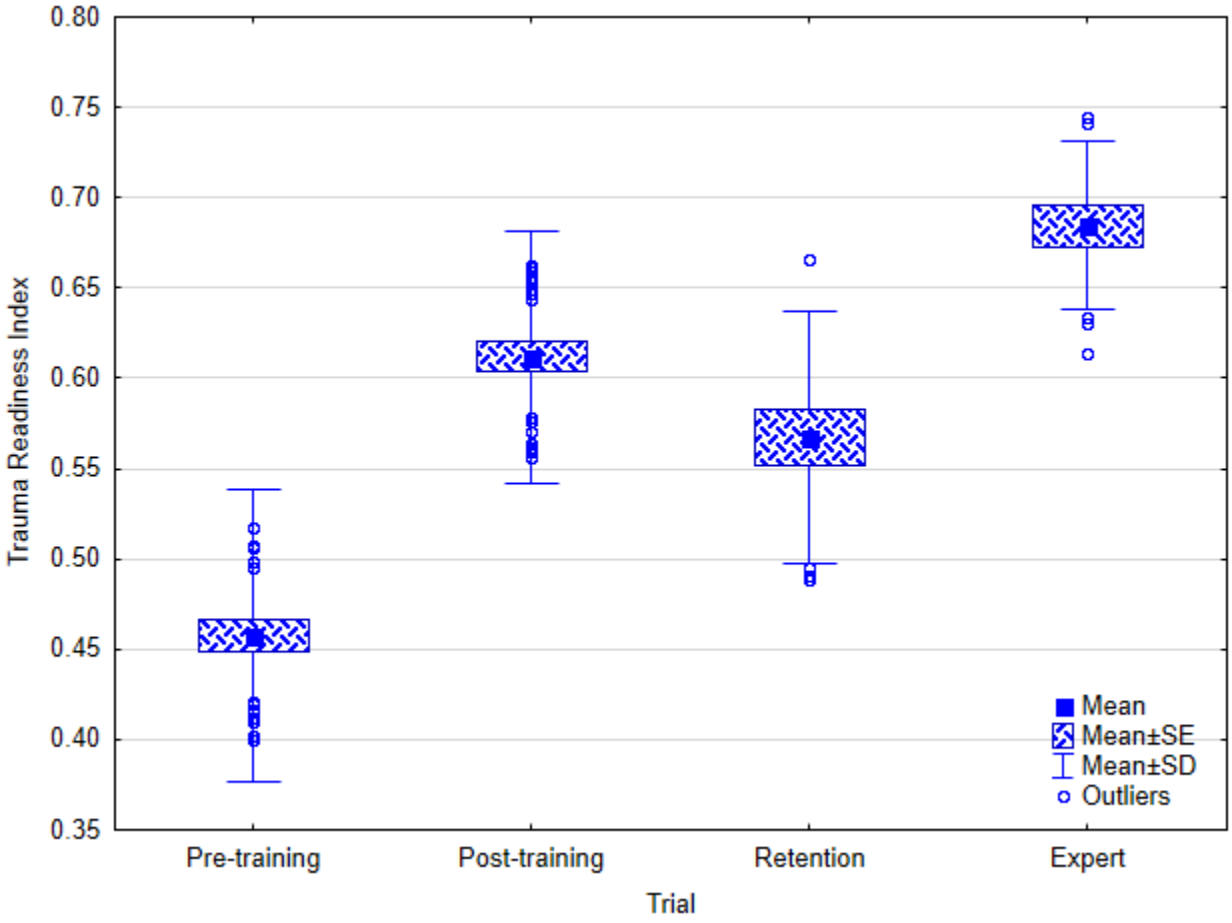
Median reported levels of confidence with the surgical anatomy and comfort to performance surgical procedures independently before and after ASSET training (n=23)

		Pre-Training		Post-Training	
		Pre-evaluation	Post-evaluation	Pre-evaluation	Post-evaluation
Understanding of the surgical anatomy:	**Shoulder/ axillary region**	2.5	2	4	4
	Arm	3	3	3.5	4
	Forearm	3	3	3	4
	Ingunal region	4	4	4	4
	Lower extremity	3	4	4	4
Performing surgical procedures for traumatic injury independently:	**Shoulder region for traumatic injury**	2	2	3	4
	Arm for traumatic injury	2	3	4	4
	Forearm for traumatic injury	2	3	4	4
	Inguinal region for traumatic injury	3	4	4	4
	Lower extremity fasciotomy for traumatic injury	3	3	4	4

These data indicate that surgeons have moderate confidence in their understanding of the relevant anatomy before beginning ever performing the procedures. Their confidence increases after the initial procedure performance and continues to increase following their post-training evaluation.

Phase 2 surgeons have low to moderate confidence initially in their ability to perform procedures independently but they gain higher levels of confidence after deliberate practice performing the procedures.

Figure 1: Mean Trauma Readiness Index by Experimental Trial



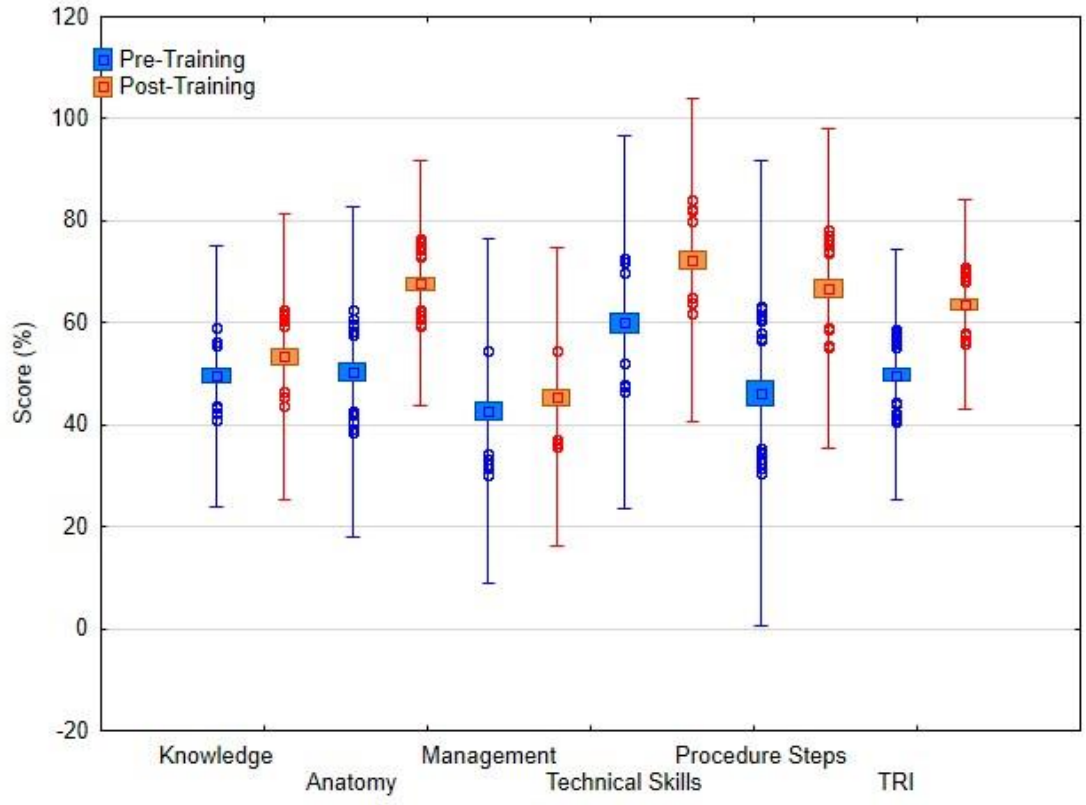
These data indicate a significant improvement after training, a lower score for surgeons 2 to 5 years after training and a significantly higher score for Expert surgeons.

Table 2: Pair Wise Comparisons of TRI between Surgeon Types
(Tukey unequal n, α=0.05, red indicates significant comparisons)

		Pair-wise Trial		
Trial	Mean TRI	Pre-training	Post-training	Retention
Pre-training	0.46			
Post-training	0.61	*0.000008*		
Retention	0.57	*0.00004*	0.2	
Expert	0.68	*0.000008*	*0.02*	*0.00004*

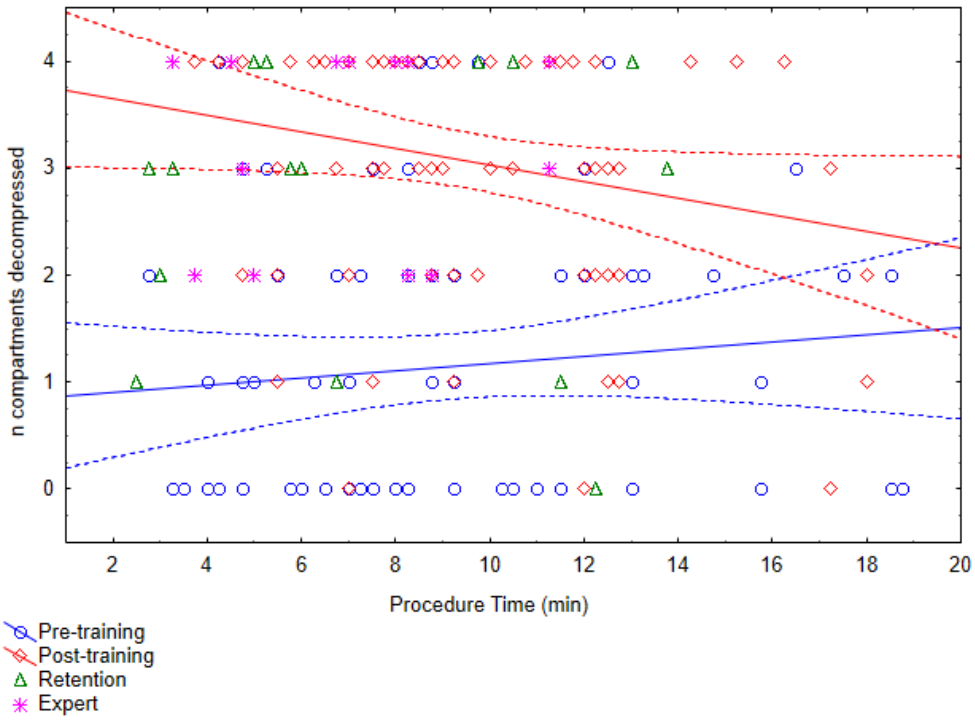
Figure 2: Score (%) for Individual Components of TRI before and after Training

(box plot: mean, 1 SE, and whiskers=2 SD)



These data indicate that the greatest improvement after training is seen for anatomical knowledge, technical skills, and procedural steps.

Figure 3: Successful Compartment Decompressions among Surgeon Types



This figure indicates the number of successfully decompressed compartments during a 2 incision 4 compartment lower extremity fasciotomy by time performed by surgeons in each experimental group. Fit lines with 95% CI are shown for Pre and Post-training residents only. Post-training surgeons and experts tend to decompress more compartments in about the same amount of time as Pre-trained surgeons decompress fewer compartments (fail to decompress the compartments).

Figure 4: Individual Procedure Score (IPS) and TRI for all Four Procedures

(box plot: mean, 1 SE, and whiskers=1 SD)

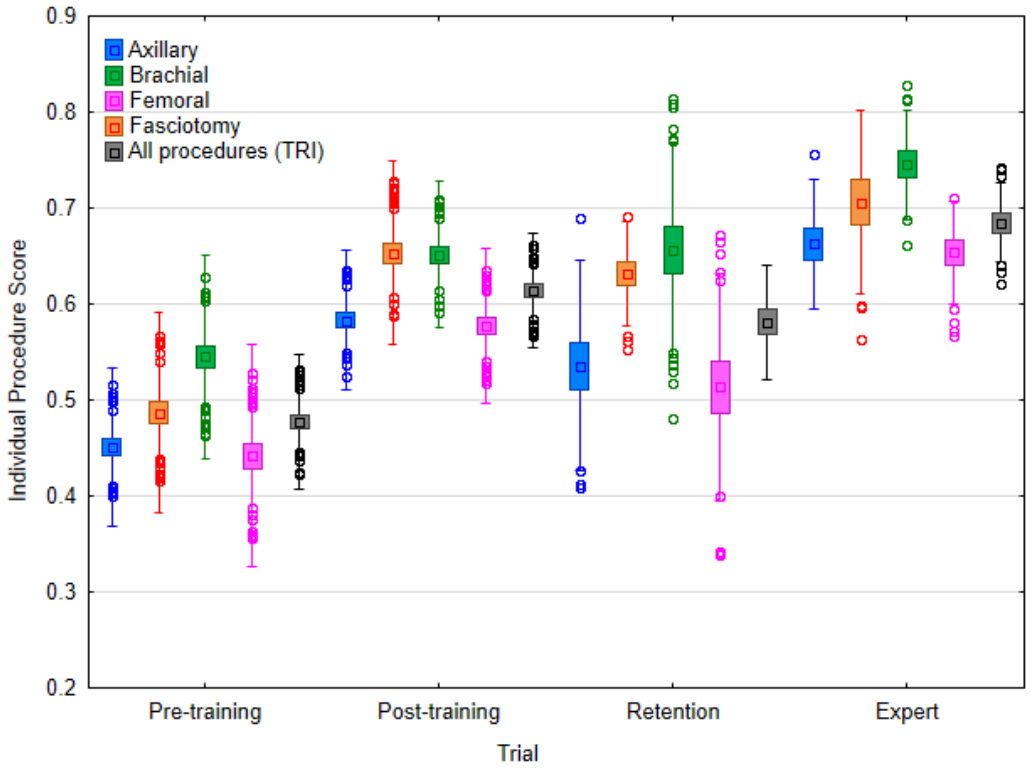


Table 3 A : Completed SF 425 form

FEDERAL FINANCIAL REPORT

1. Federal Agency and Organizational Element to Which Report is Submitted	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment	Page	of
US Army Medical Research	W81XWH-13-2-0028	1	1 pages

3. Recipient Organization (Name and complete address, including ZIP code)

University of Maryland, Baltimore, Sponsored Projec ts Accounting and Complianc e, 220 Arch Street, Baltimore MD, 21201

4a. DUNS number	4b. EIN	5. Recipient Account Number or Identifying Number	6. Report Type	7. Basis of Accounting
188435911	52-6002033	10011190	Quarterly ☐ Semi-Annual ☐ Annual ☐ Final ☒	Cash ☒ Accrual ☐

8. Project/Grant Period From: (Month, Day, Year)	To: (Month, Day, Year)	9. Reporting Period End Date (Month, Day, Year)
02/15/13	02/14/16	02/14/16

10. Transactions	Cumulative
(Use lin a-c for single or multiple grant reporting)	
Federal Cash (To report multiple grants, also use the FFR Attachment)	
a. Cash Receipts	1,862,757.25
b. Cash Disbursements	2,068,387.82
c. Cash on Hand (line a minus b)	(205,630.57)
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	2,068,387.82
e. Federal share of expenditures	2,068,387.82
f. Federal share of unliquidated obligations	
g. Total Federal share (sum of lines e and f)	2,068,387.82
h. Unobligated Balance of Federal funds	0.00
Recipient Share:	
i. Total recipient share required	
j. Recipient share of expenditures	
k. Remaining recipient share to be provided (line i minus j)	0.00
Program Income:	
l. Total Federal program income earned	
m. Program income expended in accordance with the deduction alternative	
n. Program income expended in accordance with the addition alternative	0.00
o. Unexpended program income (line l minus line m or line n)	0.00

11. Indirect Expense	a. Type	b. Rate	c. Period From To	d. Base	e. Amount charged	f. Federal Share
	Pre-Determined	26.00%	02/15/13 - 02/14/16	1,528,293.78	397,356.40	397,356.40
	Pre-Determined	0.00%		0.00	0.00	0.00

12. *Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with the governing legislation*

Prepared by: Andrew Rice Email: andrew.rice@umaryland.edu

13.Certification: **By signing this report, I certify to the best of my knowledge and belief that the report is true, complete and accurate, and the expenditures, disbursements and cash receipts are for the purposes and intent set forth in the award documents. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil or administrative penalties. (U.S> Code, Title 18, Section 1001)**

Typed or Printed Name and Title	Telephone (Area code, number and extension
Krista Salsberg, Manager Sponsored Projects Accounting and Compliance	410-706-6786 Email address ksalsberg@umaryland.edu
Signature of Authorized Certifying Official: Krista Salsberg	Date Report submitted: 04/07/2016

Standard Form 425 OMB Approval Number: 0348-0061 Expiration Date: 10/31/2011

Table 3 B: Expenditures for the Quarter Ending 02/15/16

NEW QUARTER (12/01/2014 - 02/28/2015)	
Cost Elements	**Quarter Total**
Personnel	$93,198.37
Fringe Benefits	$19,085.25
Supplies	$776.00
Equipment	-$11,400.00
Travel	$3,238.84
Other Direct Costs	$37,089.89
Subtotal	$141,988.35
Indirect Costs	$39,880.96
Fee	$0.00
Total Expenditures	$181,869.31

Table 4: Current Personnel Effort

Personnel	Role	Percent Effort
Mackenzie, Colin	Principal Investigator	60%
Hu, Peter	Co-Investigator	5%
Hagegeorge, George	Senior Technician	60%
Chen, Hegang	Statistician	21%
Granite, Guinevere	Research Coordinator	60%
Pugh, Kristy	Research Assistant	100%
Teeter, William	Surgical Resident	25%
Stansbury, Lynn	Research Assistant	8%
Yang, Shiming	Research Associate	35%

Figure 5: Prediction Fit Plots: a) BA adj IPS using AA adj IPS; b) BA reg IPS using FA and AA adj IPS; c) FA reg IPS using AA reg IPS

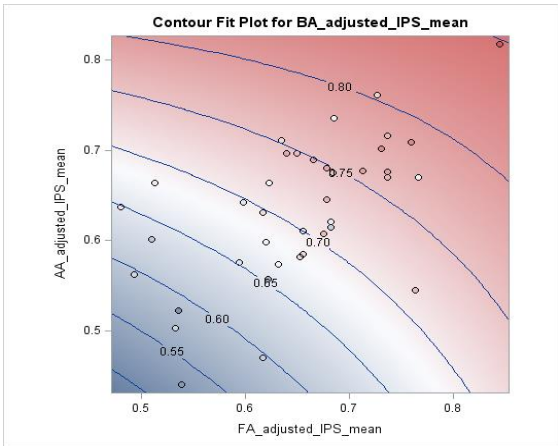


Figure 5a. Predicting Brachial Artery (BA) adjusted Individual Procedure Score (IPS) using Axillary Artery (AA) and Femoral Artery (FA) adjusted IPS

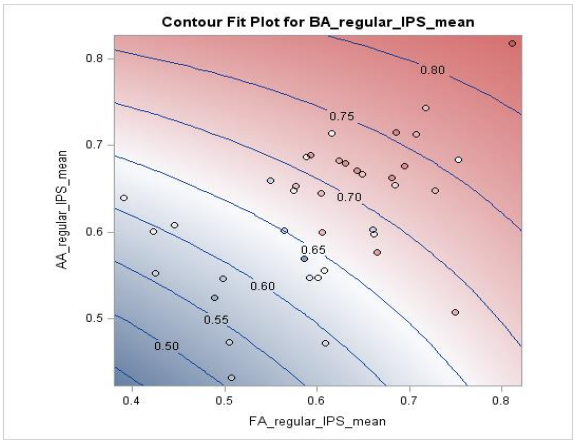


Figure 5b. Predicting BA regular IPS using AA and FA regular IPS

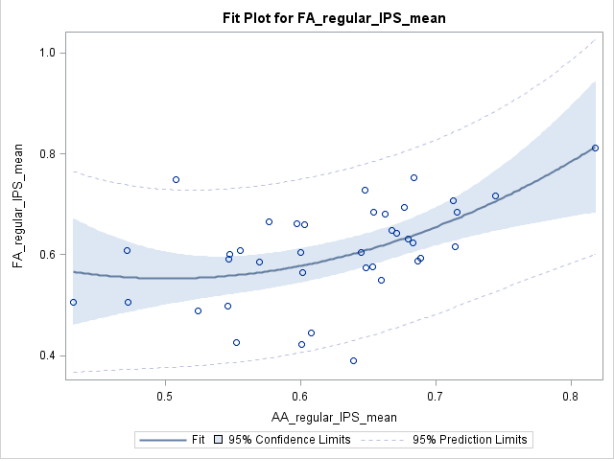
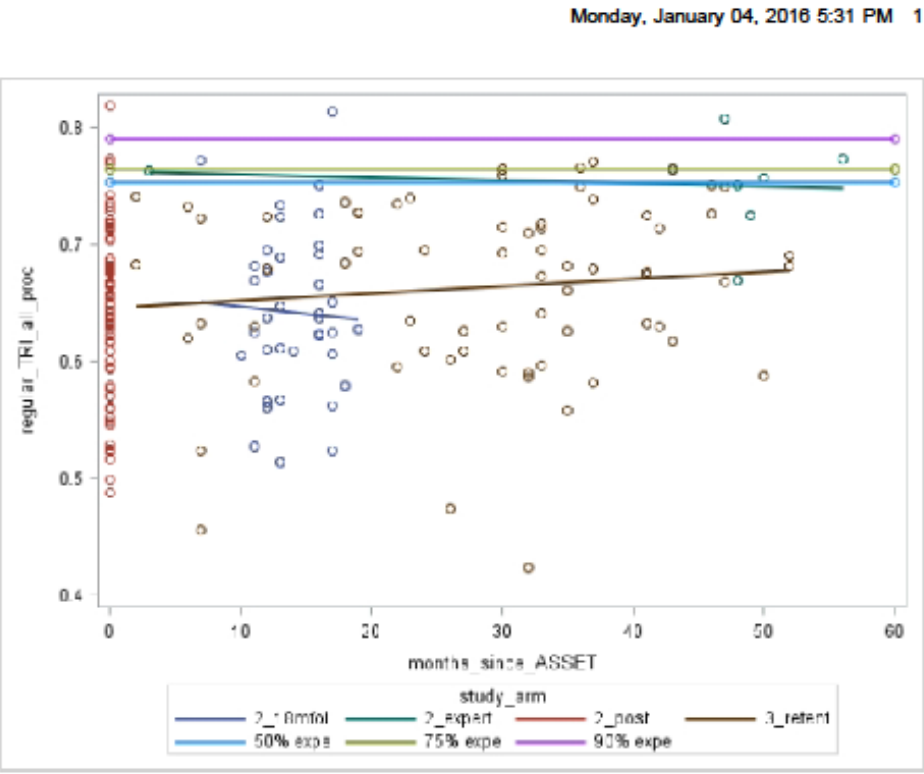


Figure 5c. Predicting FA regular IPS using AA regular IPS

Figure 6: Regular IPS and TRI Retention Plots



Page 1: Regular Trauma Readiness Index (TRI) scores and regression lines for all 4 procedures (Axillary Artery, Brachial Artery, Femoral Artery, and Lower Leg Fasciotomy) for Phase 2 participants after the ASSET course (2_post) and 12 to 18 months after ASSET (2_18mfol), Phase 3 participants 2 to 5 years after ASSET (3_retent), and Experts (2_expert), and how they correlate with 50, 75, and 90% expert tertiles. This longitudinal graph demonstrates the performance retention of all surgeons evaluated on the 4 procedures at specific time intervals since taking the ASSET course.

Page 2: Regular Trauma Readiness Index (TRI) scores and regression lines for all 4 procedures (Axillary Artery, Brachial Artery, Femoral Artery, and Lower Leg Fasciotomy) of the Phase 2 participants 12 to 18 months after ASSET, Phase 3 participants 2 to 5 years after ASSET, and Experts (labeled as all), and how they correlate with the 50, 75, and 90% expert tertiles. This graph demonstrates surgical performance retention for these 3 participant groups evaluated longitudinally on all 4 procedures.

Page 3: Regular Trauma Readiness Index (TRI) scores and regression lines for all vascular procedures (Axillary Artery, Brachial Artery, and Femoral Artery) for Phase 2 participants after the ASSET course (2_post) and 12 to 18 months after ASSET (2_18mfol), Phase 3 participants 2 to 5 years after ASSET (3_retent), and Experts (2_expert), and how they correlate with 50, 75, and 90% expert tertiles. This longitudinal graph demonstrates the performance retention of all surgeons evaluated on the 3 vascular procedures at specific time intervals since taking the ASSET course.

Page 4: Regular Trauma Readiness Index (TRI) scores and regression lines for all vascular procedures (Axillary Artery, Brachial Artery, and Femoral Artery) of the Phase 2 participants 12 to 18 months after ASSET, Phase 3 participants 2 to 5 years after ASSET, and Experts (labeled as all), and how they correlate with the 50, 75, and 90% expert tertiles. This graph demonstrates surgical performance retention for these 3 participant groups evaluated longitudinally on the 3 vascular procedures.

Page 5: Regular Axillary Artery (AA) procedure mean Individual Procedure Score (IPS) scores and regression lines for Phase 2 participants after the ASSET course (2_post) and 12 to 18 months after ASSET (2_18mfol), Phase 3 participants 2 to 5 years after ASSET (3_retent), and Experts (2_expert), and how they correlate with 50, 75, and 90% expert tertiles. This longitudinal graph demonstrates the AA procedure performance retention of all surgeons evaluated at specific time intervals since taking the ASSET course.

Page 6: Regular Axillary Artery (AA) procedure mean Individual Procedure Score (IPS) scores and regression lines for the Phase 2 participants 12 to 18 months after ASSET, Phase 3 participants 2 to 5 years after ASSET, and Experts (labeled as all), and how they correlate with the 50, 75, and 90% expert tertiles. This graph demonstrates surgical performance retention for these 3 participant groups evaluated longitudinally on the AA procedure.

Page 7: Regular Brachial Artery (BA) procedure mean Individual Procedure Score (IPS) scores and regression lines for Phase 2 participants after the ASSET course (2_post) and 12 to 18 months after ASSET (2_18mfol), Phase 3 participants 2 to 5 years after ASSET (3_retent), and Experts (2_expert), and how they correlate with 50, 75, and 90% expert tertiles. This longitudinal graph demonstrates the BA

procedure performance retention of all surgeons evaluated at specific time intervals since taking the ASSET course.

Page 8: Regular Brachial Artery (BA) procedure mean Individual Procedure Score (IPS) scores and regression lines for the Phase 2 participants 12 to 18 months after ASSET, Phase 3 participants 2 to 5 years after ASSET, and Experts (labeled as all), and how they correlate with the 50, 75, and 90% expert tertiles. This graph demonstrates surgical performance retention for these 3 participant groups evaluated longitudinally on the BA procedure.

Page 9: Regular Femoral Artery (FA) procedure mean Individual Procedure Score (IPS) scores and regression lines for Phase 2 participants after the ASSET course (2_post) and 12 to 18 months after ASSET (2_18mfol), Phase 3 participants 2 to 5 years after ASSET (3_retent), and Experts (2_expert), and how they correlate with 50, 75, and 90% expert tertiles. This longitudinal graph demonstrates the FA procedure performance retention of all surgeons evaluated at specific time intervals since taking the ASSET course.

Page 10: Regular Femoral Artery (FA) procedure mean Individual Procedure Score (IPS) scores and regression lines for the Phase 2 participants 12 to 18 months after ASSET, Phase 3 participants 2 to 5 years after ASSET, and Experts (labeled as all), and how they correlate with the 50, 75, and 90% expert tertiles. This graph demonstrates surgical performance retention for these 3 participant groups evaluated longitudinally on the FA procedure.

Page 11: Regular Lower Leg Fasciotomy (FAS) procedure mean Individual Procedure Score (IPS) scores and regression lines for Phase 2 participants after the ASSET course (2_post) and 12 to 18 months after ASSET (2_18mfol), Phase 3 participants 2 to 5 years after ASSET (3_retent), and Experts (2_expert), and how they correlate with 50, 75, and 90% expert tertiles. This longitudinal graph demonstrates the FAS procedure performance retention of all surgeons evaluated at specific time intervals since taking the ASSET course.

Page 12: Regular Lower Leg Fasciotomy (FAS) procedure mean Individual Procedure Score (IPS) scores and regression lines for the Phase 2 participants 12 to 18 months after ASSET, Phase 3 participants 2 to 5 years after ASSET, and Experts (labeled as all), and how they correlate with the 50, 75, and 90% expert tertiles. This graph demonstrates surgical performance retention for these 3 participant groups evaluated longitudinally on the FAS procedure.

Figure 7 (a-d): IPS Longitudinal Data Graphs

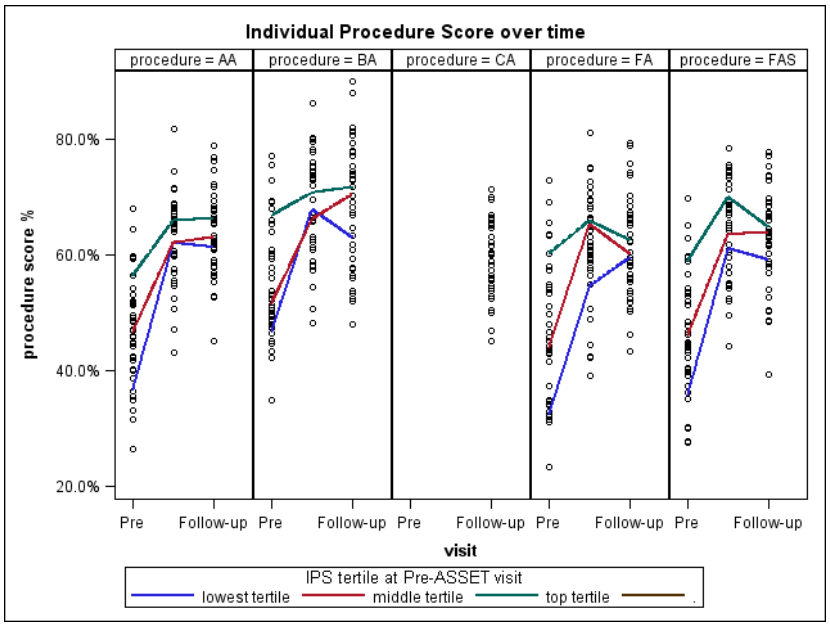


Figure 7a. Longitudinal Data Graphs of Phase 2 Pre, Post, and Follow-up Individual Procedure Score (IPS or procedure score %) scores for 4 of the 5 evaluated procedures (Axillary Artery (AA), Brachial Artery (BA), Femoral Artery (FA), and Lower Leg Fasciotomy (FAS)), and Phase 2 follow-up IPS scores for Carotid Artery (CA), and how these IPS scores correlate to the 3 tertile rankings (lowest, middle, and top) for each evaluation time interval.

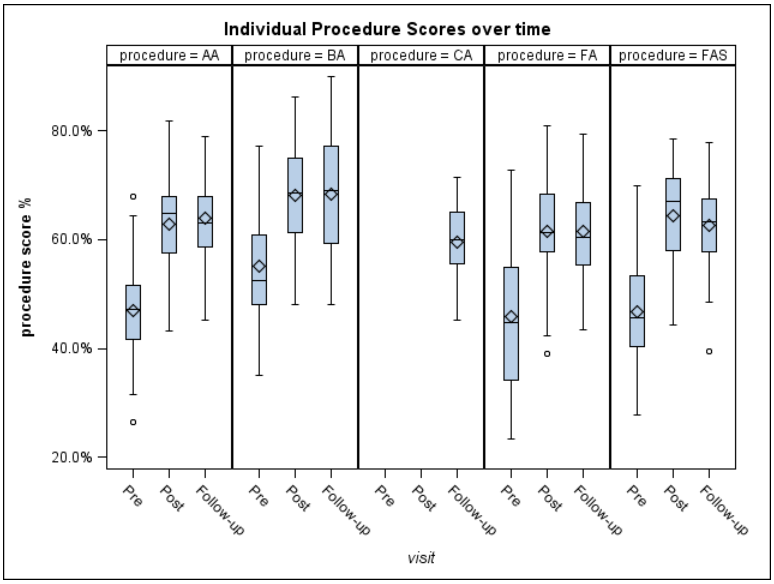


Figure 7b.

Figure 8: Benefits of ASSET Training on Surgical Skills

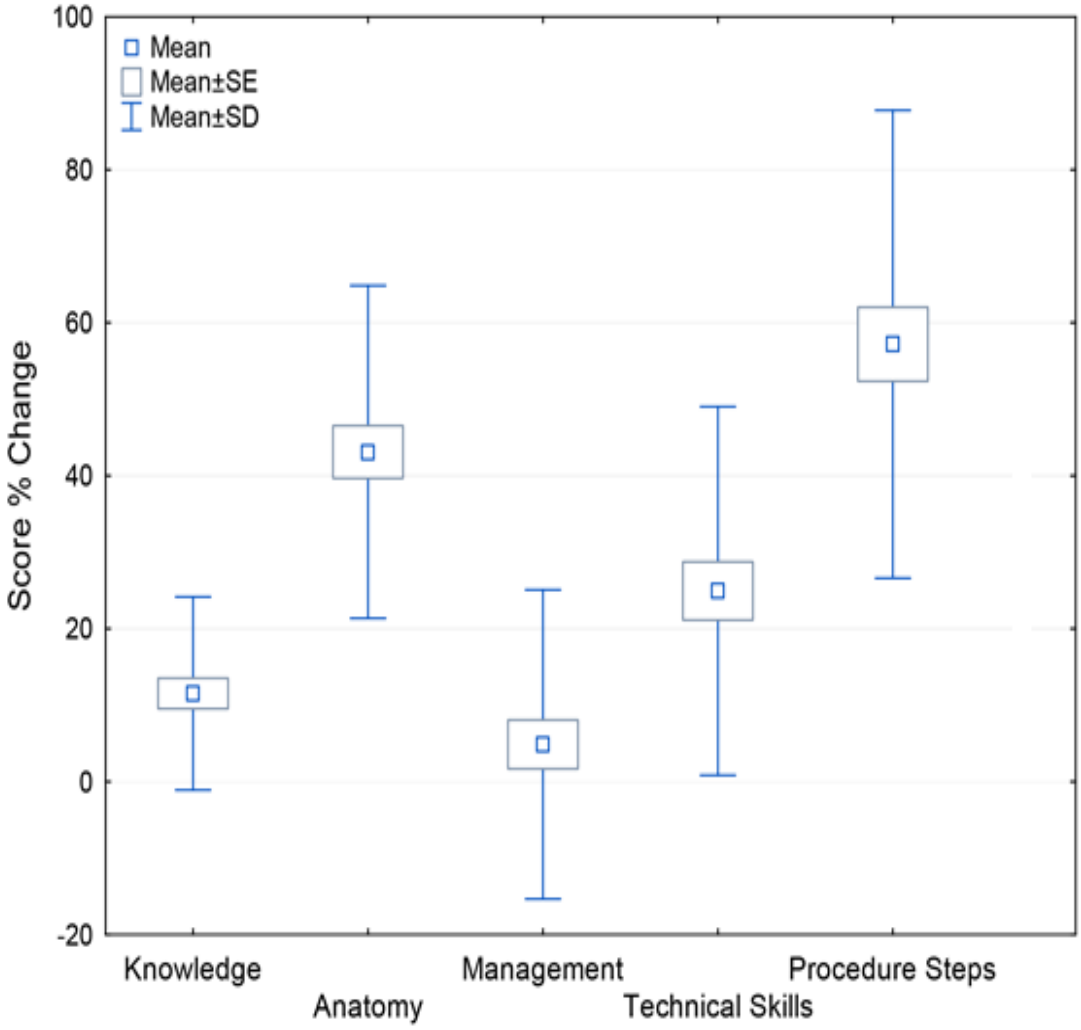


Figure 8. Surgical Skills Score Changes Post-ASSET: Procedural Steps Skills Increased 57%; Anatomic Skills (i.e. Correct Landmarks, Skin Incision, etc.) Increased 43%; Technical Skills Increased 25%; Vascular Procedures Trauma Readiness Index Increased 28%; 1.9 to 3 minutes Decrease (mean 2.5 minutes) in Vascular Procedure Time

Figure 9 (a & b): Individual Procedure Scores (IPS) Pre- and Post-ASSET Training vs. Experts

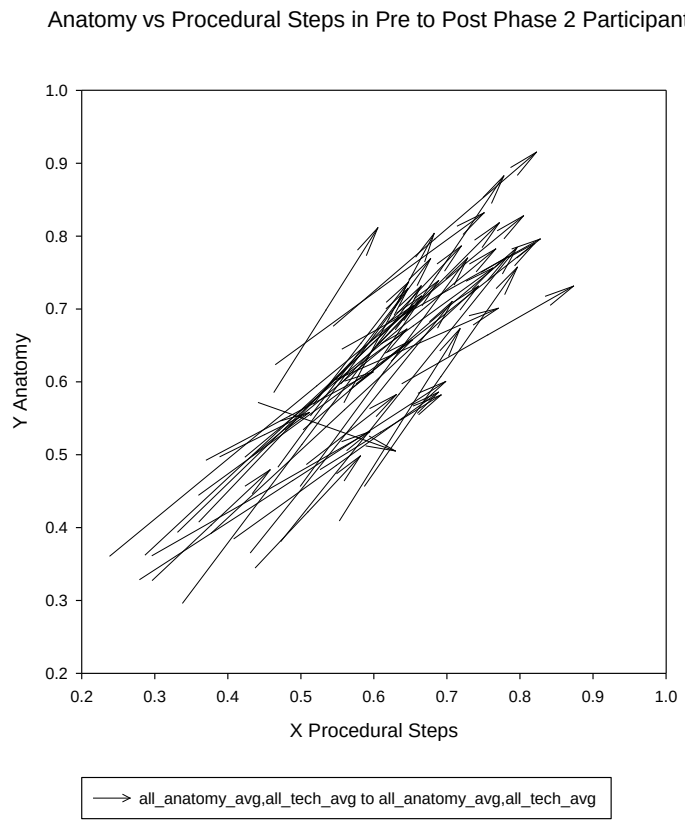


Figure 9a. Vectors showing IPS change Pre to Post ASSET for the 40 Phase 2 surgeons

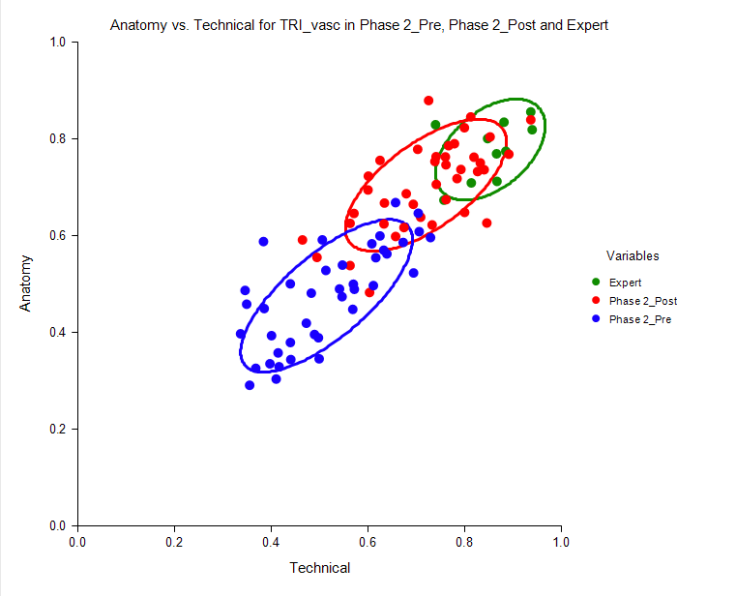


Figure 9b. Nearest Neighbor Pre- and Post-ASSET (n=40) vs. Expert (n=10) Anatomy vs. Technical Skill

Figure 10 (a-c): Skill Degradation with Time – Error Occurrence and Recovery Since ASSET

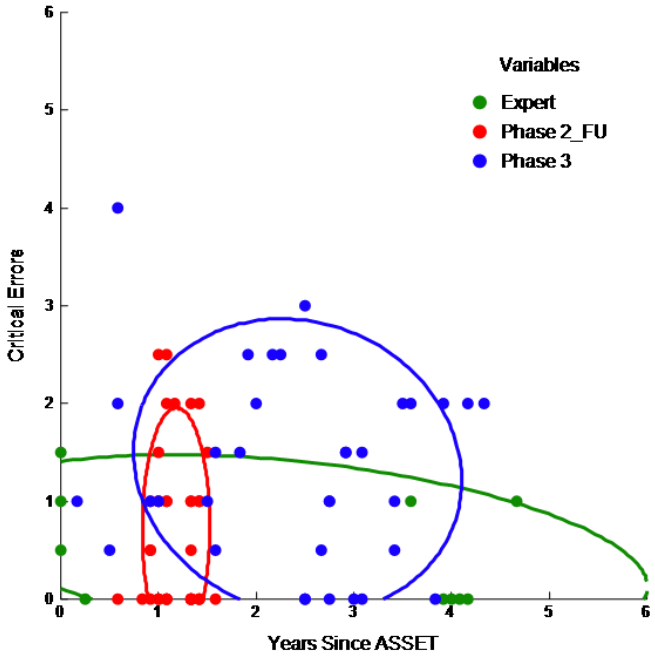


Figure 10a. Critical Errors vs. Surgeon Study Arm +/- 1 s.d. suggesting a refresher ASSET Course every ~ 2.5 years could be beneficial to surgeons

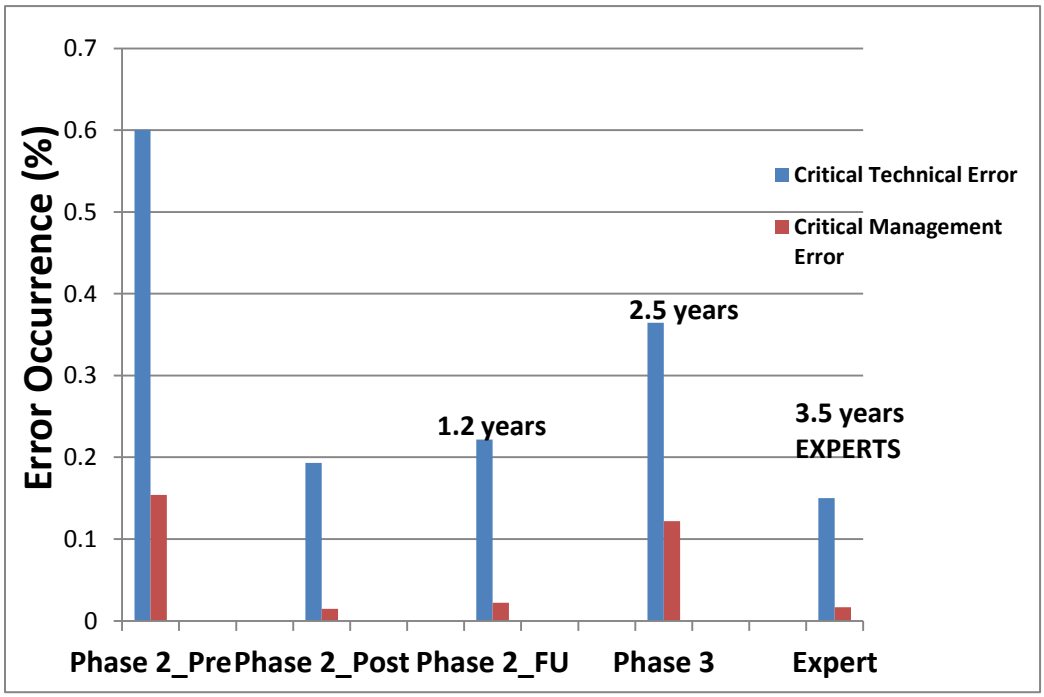


Figure 10b. % Critical Technical & Management Errors for all vascular procedures by study arm with mean number of years since ASSET Training

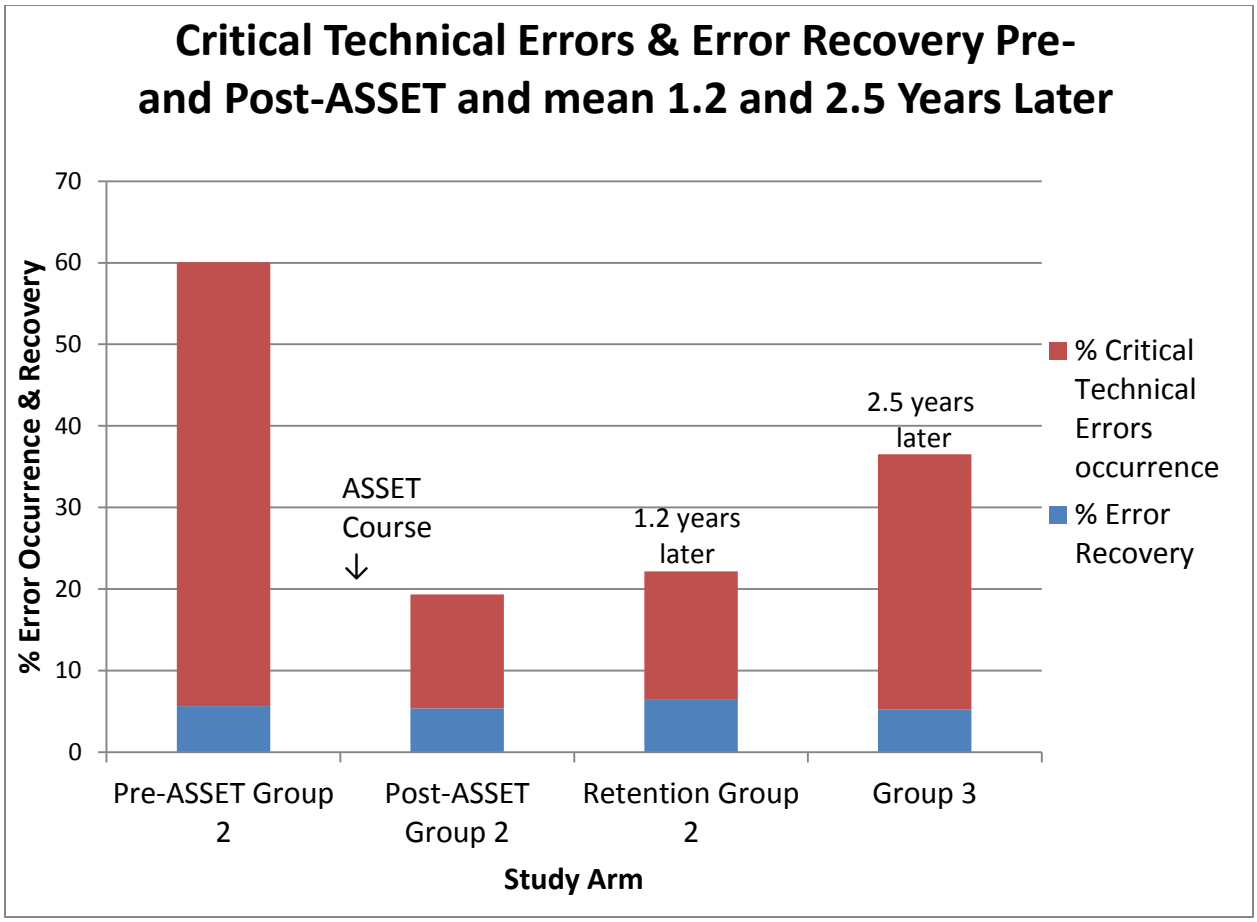


Figure 10c. Demonstrates the substantial decrease in Critical Technical Errors after ASSET but the increase in such errors 1.2 to 2.5 years later.

MHSRS 2016 Abstract Submissions

How competent in vascular exposure and fasciotomy are residents after training?

Colin Mackenzie[1,2], Adam Puche[2], Hegang Chen[2], Kristy Pugh[3], Stacy Shackelford[4], Sharon Henry[2], Samuel Tisherman[2], Mark Bowyer[3] and the RASP Group of Investigators*.

Shock Trauma Anesthesiology Research Center[1], University of Maryland School of Medicine[2], Baltimore, Uniformed Services University of Health Sciences, Bethesda[3], US Army Institute Surgical Research, San Antonio[4]. .

**Amechi Anazodo, Brandon Bonds, Mark Bowyer, Hegang Chen, Evan Garofalo, Guinevere Granite, George Hagegeorge, Sharon Henry, Megan Holmes, Peter Hu, Elliot Jessie, Nyaradzo Longinaker, Colin Mackenzie (Chair), Alexys Monoson, Mayur Narayan, Jason Pasley, Joseph Pielago, Adam Puche, Kristy Pugh, Eric Robinson, Anna Romagnoli, Babak Sarani, Stacy Shackelford, Valerie Shalin, Niki Squires, William Teeter, Sam Tisherman, Shiming Yang.*

Background: Peripheral vessel exposure and fasciotomy are core trauma procedural competencies. Because of endovascular hemorrhage control, diminished vehicle-occupant injuries and lower incidence of penetrating trauma, fewer open surgical procedures are needed for trauma. Advanced Surgical Skills for Exposure in Trauma (ASSET) training is one way to fill this gap. We tested resident competence before, immediately after and on re-evaluation up to 1.5 years following ASSET training, and compared resident performance after training and re-evaluation to that of experts.

Methods: Forty (PGY 2-6) residents from 13 different training programs were assessed by trained evaluators using a validated procedure-based trauma readiness index (TRI) checklist scoring system (including knowledge, anatomy, management, procedural steps, technical points), Global Ratings Scale score (GRS), errors and time to complete the procedure[1]. The residents were compared to 10 expert traumatologists (mean 14 years attending-level experience from 6 different level 1 trauma centers). In response to standardized scripts, residents and experts performed three vascular exposures (axillary [AA], brachial [BA], femoral arteries [FA]) and a lower extremity fasciotomy [FAS] in fresh cadavers. Cluster analysis, general linear modeling (GLM), univariate and MANOVA analysis were used for TRI, GRS and error comparisons between residents and experts. *A priori* sample size calculation required 36/40 (90%) residents to be followed up for up to 1.5 years to detect skill degradation

Results: TRI improved ($P < 0.001$) after training in 40 residents. Specifically, comparing post-training performance to pre-training, they demonstrated a 43% increase in anatomy knowledge, a 57% increase in procedural steps, a decrease in frequency of errors from 60% to 20%, and decreased time to complete the procedures by 2.5 minutes. Five residents did not improve their TRIs after training. 38/40 (95%) residents returned for re-evaluation at a mean of 1.2 years later. There were no differences in resident performance judged by TRI 1.2 years later versus immediately post-training. TRI in 21/38 (55%) residents was within one nearest neighbor classifier of the experts, who were significantly ($p < 0.05$) better performers as a cohort judged by TRI and GRS. Number of errors and error recovery rate were not different between the residents on re-evaluation and the expert cohort. Members of both expert and resident cohorts failed to decompress at least one FAS compartment, often the anterior and/or deep/posterior.

Conclusion: Anatomy and procedural steps were key skills learned with ASSET. The performance of peripheral vessel exposure by most residents upon follow-up was within one nearest neighbor classifier of expert performance. However, both experts and residents made errors, especially failure to decompress all FAS compartments. In the cohort of 38 residents

evaluated, no skill degradation was detected mean 1.2 years after ASSET training. Five residents did not improve with training.

[1] J Surg Educ 2015; 72: 1278-128

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Evaluating the Elemental Components of Surgical Skill

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Background: The military needs a method to assess trauma surgical readiness for deployment. We utilized a validated evaluation tool to assess trauma surgical skills following the Advanced Surgical Skills for Exposure in Trauma (ASSET) course.

Methods: 83 surgeons were evaluated performing axillary (AA), brachial (BA), femoral (FA) artery exposures and lower-extremity fasciotomy (FAS) on unpreserved cadavers. Previously validated performance metrics[1], standardized script, two co-located evaluators, and a tablet application score sheet were used for evaluation with checklists (Trauma Readiness Index—TRI), global rating scale (GRS), total time, and errors. Group 1: 38 PGY 2-6 residents evaluated 12-18 months after ASSET training; Group 2: 35 practicing surgeons (pediatric, plastic, orthopedic, general or critical care surgeons) evaluated 2-4 years after ASSET training; Group 3: 10 experts (mean 14 years as attending traumatologists). Kruskal-Wallis test and general linear modeling (GLM) compared Groups to identify effects of months since ASSET training and interval experience since training including: numbers of trauma patient evaluations,

numbers of upper extremity (UE) and lower extremity (LE) procedures determined by survey and case logs as high, medium, low, and relationship to components of TRI including: anatomy, procedural steps, knowledge and overall GRS readiness to perform.

Results: Group 3 surgeons scored significantly higher in overall TRI and each of the skill components compared to Group 1 and 2, ($p<0.05$). Group 2 TRI was less than Group 1 in the skill components "procedural steps" (Group 1 = 71±21, Group 2 = 64±25, Group 3 = 80±18 percent, $p<0.05$) and Group 2 made more "errors" (Group 1 = 2.4±0.66, Group 2 = 4.1±1.01, Group 3 = 2.2±0.7 errors/surgeon, $p<0.05$), indicating that fewer procedures were correctly completed and errors increased with longer time since ASSET training. Low interval experience with UE, FAS and number of trauma patients evaluated were significantly ($p <0.04$) related to TRI. GLM showed interval experience of number procedures performed, trauma patients evaluated, anatomy, knowledge, procedural steps were significant factors ($p < 0.03$) in Group 2 surgeon skill degradation. Time since ASSET was a factor for FAS.

Conclusions: Group 2 practicing surgeons had more errors, lower TRI and were considered less ready to perform UE and FAS procedures on average 28 months after ASSET training. The key factors associated with interval skill degradation included number of trauma patients evaluated and number of UE and FAS procedures performed. Anatomy, procedural steps, and knowledge were features of performance evaluated by TRI showing degradation in Group 2 surgeons; all such features are amenable to re-training. In the Group 2 cohort studied, interval experience since ASSET training, not time, generally determined skill degradation, reduced readiness and increased procedural errors.

[1]J Surg Educ 2015; 72: 1278-1289

Supported by W81XWH-13-2-0028

Title: General longitudinal misperception of surgeons' surgical anatomic knowledge and vascular trauma skills

Authors: Guinevere Granite [1,2] Kristy Pugh[3] Hegang Chen [2], Nyaradzo Longinaker [1] Evan Garofalo [4] Stacy Shackelford [5] Valerie Shalin[6], Adam Puche [2] Jason Pasley[7] Babak Sarani[8] Sharon Henry[2] Mark Bowyer [3] Colin Mackenzie[1,2], and RASP Group Investigators*

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University of Arizona, Phoenix[4], US Army Institute of Surgical Research[5], Wright State University[6], US Airforce Center for the Sustainment of Trauma and Readiness Skills, Baltimore[7], George Washington University School of Medicine[8]
**Amechi Anazodo, Brandon Bonds, Mark Bowyer, Hegang Chen, Evan Garofalo, Guinevere Granite, George Hagegeorge, Sharon Henry, Megan Holmes, Peter Hu, Elliot Jessie, Nyaradzo Longinaker, Colin Mackenzie (Chair), Alexys Monoson, Mayur Narayan, Jason Pasley, Joseph*

Pielago, Adam Puche, Kristy Pugh, Eric Robinson, Anna Romagnoli, Babak Sarani, Stacy Shackelford, Valerie Shalin, Niki Squires, William Teeter, Sam Tisherman, Shiming Yang

Background: Surgical residents have increasingly limited exposure to vascular trauma management due to reduced on-call hours, replacement of open hemorrhage control with non-surgical radiological balloon occlusion and embolization, fewer vascular trauma cases nationwide, and new blood-use protocols reducing the need for open surgical interventions to control bleeding. We previously showed residents express a moderately high level of confidence in their ability to perform specific vascular exposures[1]. This self-reported confidence did not match that of co-located evaluators who assessed the residents as they performed procedures during their evaluations. This study reports self-confidence of a cohort evaluated before and after ASSET training and 12 to 18 months later. We hypothesize that residents will better judge their own skill after the ASSET course than before when compared to evaluator performance ratings, resulting in self-perceptions that more accurately reflect reality.

Methods: Forty PGY2-7 surgical residents were recruited to participate in a validation study of the Advanced Surgical Skills for Exposures in Trauma (ASSET) course. Each surgeon performed four procedures: axillary artery, brachial artery, and femoral artery exposure and control, and lower extremity fasciotomy on unpreserved cadavers at three separate evaluations. These evaluations occurred prior to taking the ASSET course (Pre-evaluation), within four weeks after taking ASSET (Post-evaluation), and 38 out of the 40 surgeons returned to be evaluated again 12 to 18 months later (mean ~1.2 years) (Retention-evaluation). Before and after each evaluation, the surgeons self-assessed their baseline confidence in anatomical understanding and procedure performance using a 5-point Likert scale. During the three evaluations, different pairs of trained co-located evaluators assessed each surgeon's anatomical knowledge and surgical performance for each procedure using global ratings on a 5-point Likert scale. Each before and after self-assessment score was then compared to these corresponding global ratings using the Student t-test with α set at $p<0.05$.

Results: For all three evaluations, residents consistently rated their understanding of anatomy ($p<0.04$) and surgical performance ($p<0.03$) higher than evaluators for both the femoral artery and fasciotomy procedures. The greatest difference occurred after the Pre-Evaluation for femoral artery anatomical understanding (Surgeon: 3.05 +/- 1.19, Evaluator: 1.96 +/- 0.76) and fasciotomy surgical performance (Surgeon: 3.55 +/- 0.89, Evaluator: 2.35 +/- 1.01). Residents rated their anatomical knowledge higher ($p<0.005$) than evaluators for the brachial artery procedure after their Post-evaluation and before and after their Retention-evaluations. Surgical performance was self-reported higher ($p<0.03$) than evaluators before and after their brachial artery Post- and Retention-evaluations. The greatest difference for both surgical performance and

anatomical understanding of the brachial artery procedure occurred after the Retention-Evaluation (Anatomy Surgeon: 4.11 +/- 0.61, Evaluator: 2.24 +/-0.80; Performance Surgeon: 3.97 +/- 0.72, Evaluator: 2.26 +/- 0.81).
Conclusion: Residents overrate their anatomical understanding and performance abilities even after their Retention-evaluation 12 to 18 months later. Although evaluator ratings increase overall with ASSET demonstrating training benefits, resident surgeon self-perception does not reflect their trauma surgical competency. Such operative skills are best judged with evaluations performed by independent observers using validated measurements.

Reference:
[1]J Surg Res. 2015 Oct;198(2):280-8.
Supported by W81XWH-13-2-0028

Autonomous Generalizable Performance Evaluation by Sensor-free Computer Vision Hand-Motion Entropy and Video Analysis of Technical Performance During Open Surgery: Proof of Concept

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Shock Trauma Anesthesiology Research Center [1], University of Maryland School of Medicine [2], Baltimore, University of Arizona, Phoenix[3] , Uniform Services of Health Sciences[4], Wright State University[5], Dayton, US Army Institute of Surgical Research, San Antonio [6].

**Amechi Anazodo, Brandon Bonds, Mark Bowyer, Hegang Chen, Evan Garofalo, Guinevere Granite, George Hagegeorge, Sharon Henry, Megan Holmes, Peter Hu, Elliot Jessie, Nyaradzo Longinaker, Colin Mackenzie (Chair), Alexys Monoson, Mayur Narayan, Jason Pasley, Joseph Pielago, Adam Puche, Kristy Pugh, Eric Robinson, Anna Romagnoli, Babak Sarani, Stacy Shackelford, Valerie Shalin, Niki Squires, William Teeter, Sam Tisherman, Shiming Yang.*

Background: Domains such as piloting, driving or laparoscopic surgery support the collection and analysis of motor control data because human action is executed through instruments with

restricted range of motion. However, domains using instrumentation with unlimited motion, such as open surgery, cannot exploit instrument-dependent data collection methods. Compensatory approaches employing hand-motion sensors risk task interference and complicate performance analysis. Standard observational judgment is costly and logistically challenging. We tested color coded gloves and identification of surgical hand-tools, as a proof-of-concept video-based approach to sensor-free automated surgeon performance evaluation

Methods: We employed computer vision algorithms (CV) to detect hand motion change, with video and Shannon Joint Entropy (speed, acceleration direction, (SAD) change) analysis to demonstrate the potential for a partially autonomous evaluation of surgical technical performance evaluation. Hand-motion SAD obtained by entropy was correlated with an independently validated observational performance metric (Individual Procedure Score[1] (IPS)). We evaluated surgical technical skill for open surgery vascular exposure and control for trauma using axillary artery exposure and control (AA) among experts surgeons, residents (both before and after training) and anatomy demonstrators, all performing AA on fresh cadavers.

Results: Time to pectoralis major, number of instrument changes, SAD and IPS for 3 types of operators differed among resident surgeons, anatomists and experts. Resident's SAD and IPS differed between post-training and a skill retention evaluation 1 year after training. SAD data showed changes convergent with those of IPS. SAD for 2 experts was 7.29/7.31/3.25, had less hand motion change than 2 surgical residents SAD of 8.55/8.62/3.25 and same resident SAD 1 year later of 8.47/8.63/3.4 . Both expert and resident surgeons had lower SAD than 2 anatomists of 9.15/9.17/3.29. IPS were 79% (experts), 75%/62% (residents immediately after and 1 year after training). Anatomist's IPS was not applicable as both were trained IPS evaluators. Procedure instrument changes were anatomists 45, experts 23, residents before/after training and 1 year later were 97/35/50 instrument changes respectively . Time (in seconds) to pectoralis minor was anatomist 99, experts 64, residents before/after training and 1 year later 842/ 100/120. The CV algorithm is robust and locks onto only hands with colored gloves and is not distracted by other colored surgeon-assistant gloves (video available)

Conclusions: These preliminary findings using surgeon hand-motion SAD have potential for a generalizable, semi-automated, open vascular surgery performance evaluation tool. Addition of miniature sensors on instruments and machine-learning driven surgical gesture recognition (incision, scissors, vessel loop, suturing etc) could enhance automation and even avoid labor-

intensive video analysis of procedural steps. Hand motion SAD entropy from CV analyses were congruent with the resource-intensive IPS evaluations. SAD without sensors can discriminate levels of surgical skill, operators and training, showing reduction in experts compared to anatomists and resident surgeons.

1) J Surg Educ 2015; 72: 1278-1289

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Assessments by blinded trained evaluators using video recordings of open surgical procedures on cadavers can evaluate performance as well as co-located evaluators.

Colin Mackenzie, Hegang Chen, Kristy Pugh, Nyaradzo Longinaker, Stacy Shackelford, Jason Pasley, Evan Garofalo, Samuel Tisherman and RASP Group of Investigators*.

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**Amechi Anazodo, Brandon Bonds, Mark Bowyer, Hegang Chen, Evan Garofalo, Guinevere Granite, George Hagegeorge, Sharon Henry, Megan Holmes, Peter Hu, Elliot Jessie, Nyaradzo Longinaker, Colin Mackenzie (Chair), Alexys Monoson, Mayur Narayan, Jason Pasley, Joseph Pielago, Adam Puche, Kristy Pugh, Eric Robinson, Anna Romagnoli, Babak Sarani, Stacy Shackelford, Valerie Shalin, Niki Squires, William Teeter, Sam Tisherman, Shiming Yang.*

Background: An efficient method of trauma core procedural competency evaluation is needed to assess progress in training and readiness for surgeon deployment. Because on-call hours were restricted in 2003 and endovascular control of hemorrhage has reduced use of open vascular control in civilian practice, open trauma surgical procedural training has declined. We assessed the validity of a Trauma Readiness Index (TRI) performance metric for three vascular exposures and lower-extremity fasciotomy (FAS) assesing TRI with blind video evaluations compared to co-located evaluators. Such blind video evaluations would greatly simplify logistics and reduce inherent biases of assessing surgeon performance of trauma core surgical competencies.

Methods: We video recorded performance of axillary (AA), brachial (BA) and femoral artery (FA) vascular exposure and lower extremity FAS on fresh cadavers by 40 PGY 2-6 residents from 13 different training programs using head-mounted cameras. Two co-located trained evaluators assessed residents with a standardized script, checklists (TRI), Global Rating Scales

(GRS), time required to complete the procedures and number of errors[1], before and after training. One surgeon in each pre-training tertile of TRI for each of the four procedures was randomly identified for blind video review. The same 12 surgeons were video-recorded repeating the same procedures within 1 month after training. Five trained evaluators independently reviewed all 96 randomly-arranged blinded videos. Inter-rater reliability/consistency and intra-class correlation coefficient (ICC) were compared by co-located versus video review of TRI and errors. Study methodology and bias were judged by Medical Education Research Study Quality Instrument (MERSQI) and the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) criteria.

Results: All 40 residents returned and were re-evaluated after training performing the same procedures. TRI was significantly increased, time to complete the procedures and errors were reduced (all $p < 0.001$) with training. There were no differences ($p \geq 0.5$) in TRI for the 12 surgeons whose videos were reviewed, whether evaluators were co-located or reviewed video recordings. Video evaluator consistency was good (0.3-0.8). Video and co-located evaluators were in total agreement ($p = 1.0$) for error recognition. ICC was 0.73-0.92 for video-rater agreement. Correlation of video vs co-located evaluations was 0.5-0.9. Except for BA, blinded video evaluators could discriminate ($p < 0.002$) between procedures performed pre- versus post-training. Video views of BA were confounded by upper arm obesity and difficulty obtaining adequate images to discriminate structures that could be visualized by co-located reviewers. Study methodology by MERSQI criteria scored 15.5/ 18, QUADAS-2 showed low bias risk in blind video review.

Conclusion: Evaluation of performance by video review rather than requiring co-located evaluators would simplify the logistics of competency evaluations and assessing surgeon readiness for deployment. Video evaluations of trauma core procedural competencies for AA, FA and FAS with TRI are un-biased, valid and have potential for formative assessments of competency.

[1]J Surg Educ 2015; 72: 1278-1289

Supported by W81XWH-13-2-0028

Title: General longitudinal misperception of surgeons' surgical anatomic knowledge and vascular trauma skills

Authors: Guinevere Granite [1,2] Kristy Pugh[3] Hegang Chen [2], Nyaradzo Longinaker [1] Evan Garofalo [4] Stacy Shackelford [5] Valerie Shalin[6], Adam Puche [2] Jason Pasley[7] Babak Sarani[8] Sharon Henry[2] Mark Bowyer [3] Colin Mackenzie[1,2], and RASP Group Investigators*

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**Amechi Anazodo, Brandon Bonds, Mark Bowyer, Hegang Chen, Evan Garofalo, Guinevere Granite, George Hagegeorge, Sharon Henry, Megan Holmes, Peter Hu, Elliot Jessie, Nyaradzo Longinaker, Colin Mackenzie (Chair), Alexys Monoson, Mayur Narayan, Jason Pasley, Joseph Pielago, Adam Puche, Kristy Pugh, Eric Robinson, Anna Romagnoli, Babak Sarani, Stacy Shackelford, Valerie Shalin, Niki Squires, William Teeter, Sam Tisherman, Shiming Yang*

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Methods: Forty PGY2-7 surgical residents were recruited to participate in a validation study of the Advanced Surgical Skills for Exposures in Trauma (ASSET) course. Each surgeon performed four procedures: axillary artery, brachial artery, and femoral artery exposure and control, and lower extremity fasciotomy on unpreserved cadavers at three separate evaluations. These evaluations occurred prior to taking the ASSET course (Pre-evaluation), within four weeks after taking ASSET (Post-evaluation), and 38 out of the 40 surgeons returned to be evaluated again 12 to 18 months later (mean ~1.2 years) (Retention-evaluation). Before and after each evaluation, the surgeons self-assessed their baseline confidence in anatomical understanding and procedure performance using a 5-point Likert scale. During the three evaluations, different pairs of trained co-located evaluators assessed each surgeon's anatomical knowledge and surgical performance for each procedure using global ratings on a 5-point Likert scale. Each before and after self-assessment score was then compared to these corresponding global ratings using the Student t-test with α set at $p<0.05$.

Results: For all three evaluations, residents consistently rated their understanding of anatomy ($p<0.04$) and surgical performance ($p<0.03$) higher than evaluators for both the femoral artery

and fasciotomy procedures. The greatest difference occurred after the Pre-Evaluation for femoral artery anatomical understanding (Surgeon: 3.05 +/- 1.19, Evaluator: 1.96 +/- 0.76) and fasciotomy surgical performance (Surgeon: 3.55 +/- 0.89, Evaluator: 2.35 +/- 1.01). Residents rated their anatomical knowledge higher ($p<0.005$) than evaluators for the brachial artery procedure after their Post-evaluation and before and after their Retention-evaluations. Surgical performance was self-reported higher ($p<0.03$) than evaluators before and after their brachial artery Post- and Retention-evaluations. The greatest difference for both surgical performance and anatomical understanding of the brachial artery procedure occurred after the Retention-Evaluation (Anatomy Surgeon: 4.11 +/- 0.61, Evaluator: 2.24 +/-0.80; Performance Surgeon: 3.97 +/- 0.72, Evaluator: 2.26 +/- 0.81).
Conclusion: Residents overrate their anatomical understanding and performance abilities even after their Retention-evaluation 12 to 18 months later. Although evaluator ratings increase overall with ASSET demonstrating training benefits, resident surgeon self-perception does not reflect their trauma surgical competency. Such operative skills are best judged with evaluations performed by independent observers using validated measurements.

Reference:
[1]J Surg Res. 2015 Oct;198(2):280-8.
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Can hyper-realistic physical models of peripheral vessel exposure and fasciotomy replace cadavers for performance assessment?

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Background:

Limits in on-call hours have reduced operative experience for residents. The cadaver-based Advanced Surgical Skills for Exposure in Trauma (ASSET) course fills this training gap. Cadaver use has limitations including cost, availability, and staffing demands. Hyper-realistic synthetic models may provide an alternative to cadaver training. We compared same surgeon

performance on synthetic models and cadavers to determine inter-changeability for formative evaluation.

Methods:

75 surgeons (n = 40 PGY 2-7 residents < 4 weeks after ASSET; n = 35 surgeons including faculty mean 2.5 years after ASSET) exposed and controlled axillary (AA), brachial (BA), and femoral arteries (FA), and performed lower extremity fasciotomy (FAS). Starting order was randomized to cadavers or models (Operative Experience Inc.). Participants were evaluated using individual procedure scores (IPS) and aggregate IPS for 4 procedures, a trauma readiness index (TRI). Statistical analysis used student t-tests. P-values ≤ 0.05 were considered significant.

Results

For the same surgeon, TRI was significantly higher on the model compared to the cadaver in both residents and faculty groups (0.67 ± 0.01 vs 0.64 ± 0.01, $p=0.01$; 0.7 ± 0.01 vs 0.66 ± 0.01, $p<0.01$, respectively). For both residents and faculty average error rates for all procedures were lower for the model (19 vs 29.5, $p<0.01$; 12.7 vs 28, $p<0.01$, respectively). Completion times were also lower on the models (6.2 ± 1.59 vs 9.9 ± 2.47, $p<0.01$; 4.9 ± 1.75 vs 9.9 ± 2.82, $p<0.01$, respectively). Faculty group had higher IPS on the model compared to the cadaver (AA 0.67 ± 0.07 vs 0.61 ± 0.1, $p<0.01$; BA 0.79 ± 0.05 vs 0.68 ± 0.12, $p<0.01$; FA 0.65 ± 0.08 vs 0.59 ± 0.11, $p<0.01$; and FAS 0.69 ± 0.08 vs 0.64 ± 0.1, $p<0.01$). For residents IPS was only higher for the BA procedure (0.75 ± 0.07 vs 0.67 ± 0.09, $p<0.01$).

Conclusion

Same surgeons completed all four procedures almost twice as quickly with fewer errors and a higher TRI performance score on model than cadaver, indicating the relative ease of the model. The model, with easily discernable and standardized anatomic structures, fails to capture the complexity and variability of the cadaver. For residents, the models may be useful in the early stages of training to understand critical steps of complex procedures. Residents with multiple procedural practices on cadavers before model may account for why the model-IPS was only different on the particularly easy BA procedure. Because the same surgeon makes fewer errors in the models than the cadavers and because of higher TRI and ease compared to cadavers, models are insufficient to assess competency or skill degradation.

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